Use of surveys and agent-based modelling to assess the management implications of the behaviours of specialised recreational boat fishers

Image supplied by my very talented god daughter Trinity Barrett, age 6.

by

Calais Jaye Tink

This thesis is presented for the degree of Doctor of Philosophy of Murdoch University

2015

B.Sc. (Hons)

Murdoch University, Western Australia

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any university.

Calais Jaye Tink

Abstract

This PhD study employed two fisheries surveys and an agent-based model to characterise, in the context of specialisation theory, the behaviours and motivations of non-avid and avid fishers among a diverse group of recreational boat fishers. Broadly, specialisation theory, which relates to the field of human dimensions research, dictates that groups of recreational fishers fit along a continuum of behaviour or 'specialisation', from occasional, novice fishers to avid and highly-experienced fishing specialists. Furthermore, this theory considers that fishers may be characterised according to such attributes as frequency of participation, species targeted, fishing locations and fishing gears, motivations for going fishing, preferences for resource management, as well as various other attributes.

In one survey, a sample of recreational fishers living near Perth, in Western Australia, was randomly-selected from a database containing details of recreational fishing boat licence holders in that state. Selected anglers were interviewed by phone using the Computer Assisted Telephone Interviewing (CATI) technique. Fishers were chracterised as either non-avid or avid, based on levels of participation rates, an approach consistent with many fisheries surveys. The phone survey demonstrated that Perth boat fishers are typically male, often 45-59 y and mainly target inshore, easy-to-catch 'bread and butter' species, such as whiting species and Australian herring. Anglers typically use rod and lines for fishing and often revisit areas in which they have experienced previous fishing success. Ownership of Global Positioning Satellite (GPS) systems was high among all surveyed boat fishers. However, compared with non-avid fishers, avid fishers were, as hypothesised according to specialisation theory, more likely to use these devices for storing fishing locations (and also for storing a greater number of locations compared to non-avid fishers). Moreover, as hypothesised, avid fishers were more likely than non-avid fishers to go fishing on a normal weekday rather than on a weekend or public holiday, presumably to avoid periods of congestion at boat ramps.

Unlike most fisheries surveys, those undertaken for this study asked a range of questions relating to movements of boat fishers when fishing. Surveyed fishers generally travelled small distances offshore (< 5 km), visited few fishing locations (≤ 4), and typically moved ≤ 3 km between their first and second fishing location, usually moving because they were not catching any fish. The hypothesis that avid fishers would be more likely than non-avid fishers to move more frequently between fishing locations when catch rates were low was not supported by the available data, however, as the durations of fishing trips were relatively short (~3.5 h) and fishers only moved a few times during each trip. It was able to be shown, however, that avid fishers are more likely to move when they receive a low fish 'bite rate'.

A second survey, in the form of a written questionnaire, was developed to obtain data with which to characterise fishers who are members of angling clubs located in the same region as the fishers interviewed by the above phone survey. Comparisons were made between the data from the two surveys to test the hypothesis that the club members are more avid and specialised than the general population of boat fishers interviewed in the phone survey.

The surveyed club members were predominantly male, between the age of 45-59 y and almost all had more than 10 y fishing experience. These fishers were more likely than the fishers interviewed in the phone survey to own their own boat and GPS, and generally targeted a 'mix' of demersal reef fish species including West Australian dhufish, *Glaucosoma hebraicum,* and pink snapper, *Chrysophrys auratus.* As hypothesised, compared with non-members, club members were more avid, tended to travel further to fishing locations, typically fished in deeper waters, made greater investments in fishing technology and greater use of this (more fishing locations stored in their GPS systems), and moved more frequently between fishing locations when not receiving good fish bite rates. These findings were thus consistent with the hypothesis that club members are more specialised than avid, non-club affiliated fishers.

In the next phase of the project, an agent-based model (ABM) was employed to simulate the dynamics of the multi-species demersal, boat-based recreational fishery near Perth, in Western Australia. The model considered three fish species, West Australian dhufish and pink snapper, and a non-target species (with biological characteristics based on those of silver trevally, *Pseudocaranx georgianus*), and a 'fleet' of avid, recreational boat fishers, with characteristics similar to those of the fishers surveyed at angling clubs. The model simulated the fishing activities of this group of boat anglers in a reef fishing area (*i.e.* an artificial computer landscape) and subject to an established fisheries management regime (size and boat limits), and tracked their catches (released and retained) and impacts of these on fish populations. The characteristics of the individual fishers, individual fish and certain characteristics of the computer landscape were informed by a combination of biological information from existing literature and results obtained from the survey of angling club members.

Several hypotheses were explored in simulations. For example, it was demonstrated that, in simulations, fishers are able to maintain similar catch rates despite declining abundances of fish by moving more rapidly between fishing locations and by finding new locations with relatively high fish abundances. This ability of fishers to maintain catch rates was also linked to fishers updating their 'knowledge' of the quality of their fishing locations (*i.e.* as stored in a GPS) based on previous fishing experiences. Thus, it was concluded that, for this recreational demersal fishery, such 'learning' behaviours of fishers, and particularly their ability to improve their knowledge of good fishing locations, are key to making them highly specialised, successful fishers. It was also demonstrated that the behaviours of fishers, in response to a change in abundance of one species, can impact on the abundances of another fish species, which thus has implications for managing multi-species fisheries.

Model simulations provided a range of other results across different scenarios of initial abundance of *G. hebraicum* and different management regulations, some of which were not expected (*i.e*. not immediately intuitive), which thereby provided some useful insights regarding the dynamics of the system. For example, as initial fish abundance increased, catch per hour fishing did not always increase, a result that was attributed to management regulations limiting the number of fish that anglers may retain, reduced movements by anglers from fishing locations and reduced time spent searching by anglers. The study results also suggested that catch per unit of 'time spent searching' by anglers could be a useful indicator of stock abundance. The ability of anglers to maintain their catches when fish abundances were declining, through searching for new fishing locations and moving between locations more often, highlights the fact that catch rate data, as typically obtained in many surveys, do not necessarily provide a reliable index of fish abundance.

Unlike many studies relating to human dimensions research, this study focussed on understanding the key characteristics and behaviours of avid and specialised boat-based anglers in a multi-species fishery. In such an environment, different anglers are likely to adjust their behaviours in different ways to balance their fishing skills and the values they place on the mixture of species that they are likely to catch. That is, in a multi-species fishery, anglers act in a 'multiple objective decision making framework', and individuals respond to their own motivations and assessments of the values that they accord to the fishing experience. Although it is unlikely that the knowledge gained in one fishery will be totally applicable to the next, research methods are, however, likely to be transferable among fisheries. In this context, this study benefited from the integration of fishery surveys and simulation modelling, and consideration of the combined results in the context of specialisation theory.

Contents

List of Tables

List of Figures

List of Appendices

Acknowledgements

I wish to express my upmost gratitude to Professor Norman Hall and Dr Alex Hesp for the opportunity to undertake my PhD under their supervision. My thanks for their continued support and encouragement, for our many enthralling discussions, which led to a much improved understanding of various aspects of the project, and for the large amount of time spent helping with the editing of my thesis.

I am most grateful for the advice that was offered by Drs David Die, Steve Sutton and Jeremy Lyle, who examined an earlier version of this thesis, and who offered many invaluable suggestions as to how it might be improved.

I thank Rowena Burch (Honours student) for her assistance in the initial stages of creating some of the questions and the designing and trialling of the first recreational fisher questionnaire at Marmion Angling Club. Rowena was also involved in the early stages of development of the agent-based model. I am very grateful that she shared the ride with me in the first year and helped solve some of the early problems encountered.

I am thankful to RecFishWest for its support, especially Kane Moyle for his assistance in helping to organise the very first angling survey, and Kane, Richard Stevens and Felicity Horn (WAFIC), and Brent Wise and Brett Molony (DoF) for their feedback during the study. I also thank Corey Wakefield (DoF) for providing unpublished data to estimate the size-selectivity of pink snapper. I am grateful to the Western Australian Department of Fisheries for providing access to, and drawing a random sample from, their Recreational Fishing Boat Licence database, for use in the telephone survey that I conducted.

Thank you to all of the many recreational fishers that took time out of their busy schedules to participate in the two angler surveys. In particular, I would like to thank the specialised and enthusiastic anglers at Marmion Angling Club, Ocean Reef Angling Club and Quinns Rock Angling Club and also fishers from the Bunbury Angling Club and Naturaliste Game and Sport Fishing Club, for their time in completing our survey and also for their feedback and sharing their local knowledge and insights.

My sincere thanks to Professor Ken Pollock and Karina Ryan for their interest and involvement in helping to improve the design of my survey questions and overall survey structure for the recreational fishers phone survey. I also wish to acknowledge Dr Steve Sutton (James Cook University, Queensland) for the early advice that he provided to one of my supervisors (Dr Alex Hesp) on improving the wording of questions in the written survey described in Chapter 3. That survey was initially developed as part of FRDC project 2008/033, undertaken by my supervisors, Ms Rowena Burch and myself).

My thanks to the Edith Cowan University (ECU) Survey Research Centre staff, and especially to Theresa Wilkes and Vicki Graham. Their advice and feedback in formatting the survey questions for the CATI system was invaluable. The research centre carried out the survey in a completely professional manner, and also did their very best to maximise the data from the survey through follow-up interviews.

My thanks also go to Dr Eric von Dietze (Murdoch University, Human Ethics Committee) for his advice and assistance on effective and ethical human survey research.

I gratefully acknowledge the Australian Fisheries Research Development Corporation (FRDC) for funding initial research relating to the agent-based modelling component of my study (FRDC 2008/033). I also thank Murdoch University for providing funds to enable the recreational fisher phone survey to be undertaken.

I am also very appreciative of my Australian Postgraduate Awards (APA) scholarship which enabled me to further my education in the field of my choice.

Thanks to many colleagues at the Centre for Fish and Fisheries and Aquatic Ecosystems for their friendship, and their help. Thanks to Emily Fisher for her enduring efforts in drinking cheap beer and listening to angler’s fish tales at the various angling clubs, while helping to collect survey responses from recreational fishers. Thanks to my awesome lab buddy Lauren Veale for her continued support and encouragement throughout the entire PhD journey. I couldn’t have done it without you. Thanks heaps, mate. Let’s have a cider! Thanks also to Amanda Buckland and Alan Cottingham next door, for their huge support, ideas and inspiration, friendship and also company on the many coffee trips taken.

Thanks to my family and friends who have supported me throughout my PhD, I don’t want to name too many names, you know who you are and I am so very grateful to have you in my life. A PhD truly is an emotional marathon, and having so many wonderful supportive people around you really is important, so thank you.

Finally, a very special thanks to my Nanna and Pappa for their endless love and support, and in particular to my Pappa, you were the one who taught me strength, courage, determination and, most importantly, the value of patience.

1. General Introduction

1.1. Overview

Recreational fishing is today the principal form of exploitation of fishes in most freshwater habitats and in many coastal waters across the western world (McPhee *et al*., 2002; Lewin *et al*., 2006; Greiner and Gregg, 2010; Fenichel *et al*., 2013). Furthermore, participation rates are typically increasing, with estimates of marine recreational fishing effort having risen by more than 20% in the past couple of decades (Coleman *et al*., 2004; Cooke and Cowx, 2006). Consequently, there is a growing awareness among fisheries managers that recreational fishing can have major impacts on fish stocks (Henry and Lyle, 2003; Coleman *et al.*, 2004; Granek *et al.,* 2008; Gao and Hailu, 2012). In 2000, recreational catches amounted to 47.10 billion fish, but many of these were subsequently released, with only 36.3% (17.09 billion fish) being retained (Cooke and Cowx, 2004). A similar number of fish (47 billion) was estimated to have been caught by recreational fishers in 2004, with the number of participants in this activity equating to more than 140 million fishers (FAO, 2012). Thus, recreational fishing has become an issue of key importance for fisheries managers (McPhee *et al.*, 2002; Cooke and Cowx, 2004; Granek *et al.*, 2008), and it is now widely acknowledged that accounting for impacts of recreational fishing is vital for ensuring the future sustainability of many fishery resources throughout the world (Henry and Lyle, 2003; Cooke and Cowx, 2004).

The shift in focus from commercial to recreational fishing has been accompanied by recognition that management objectives are no longer confined to maximising economic benefit while maintaining ecosystem structure and function. The broader, more diffuse set of objectives of the recreational fishing sector and community must now also be considered, noting that these objectives will vary not only between fishers within different fisheries, but also among fishers within even a single fishery. If fishery managers are to confront the challenges of addressing the objectives of recreational fishers, while achieving an appropriate balance with economic and conservation objectives, they will need to identify the various objectives of the different recreational fishers and obtain an understanding of the values of those objectives to different groups of recreational fishers. Until recently, there have been relatively few human dimension studies of recreational fisheries from which to develop an understanding of the motivations, characteristics, and behaviours of different recreational fishers and the values that they place on different aspects of the fishery experience. There has been growing recognition, however, of the need for such studies (*e.g.* Hunt *et al*., 2013). To fill a gap in human dimensions knowledge for one of the key recreational fisheries in Western Australia, *i.e.* the demersal fishery in the West Coast Bioregion, this study has collected data from anglers such that the characteristics of those fishers, and their behaviour in response to factors such as changes in abundance of a key species, can be determined. Such data will assist managers of this fishery to assess how recreational fishers are likely to respond to different management controls.

As noted by Henry and Lyle (2003), the primary responsibility of government is to "ensure the long term sustainable utilisation of fisheries resources for the prosperity and well-being of the community". However, this is by no means an easy feat as recreational fisheries worldwide are underpinned by a set of complex interactions between agents (*i.e.* fish, fishers, fishery managers) and their environment, with management often seen as a balancing act between the competing ecological, economic and social objectives of these components (Arlinghaus *et al*., 2002; Cowx, 2002; Little *et al*., 2009). The need to consider these holistically in the context of the total system has also been recognised (Hickley, 1998; Salas and Gaertner, 2004; FAO, 2012). Management is often hindered by a lack of information regarding fundamental questions about recreational fishing. For example, how much do recreational fishers catch? How much is sport fishing worth to the economy? Why do recreational fishers fish? Before the ecological, economic and social impacts of recreational fisheries can be evaluated, many questions such as these need to be considered carefully (McPhee *et al*., 2002; Pitcher and Hollingworth, 2002). Understanding how recreational fishers operate in a fishery is by no means a new concept, yet it is one that is often over-looked (Salas and Gaertner, 2004; Arlinghaus, 2006; Johnston *et al*., 2010; Hunt *et al*., 2011). Metcalf *et al.* (2010) further noted that the behavioural responses of recreational fishers to changes in fisheries management are rarely investigated and as a result, often poorly understood.

In general, fisheries management policies and regulations are focussed on regulating fishing mortality to ensure the long-term sustainability and productivity of fish stocks which, for recreational fishers, also means maintaining the quality of the fishing experience (Gentner and Sutton, 2008; Greiner and Gregg, 2010). Fishers, however, have the ability to modify their behaviours, *e.g.* travel further to catch fish, target different species and/or use different gear types, and thereby potentially maintain catch rates at their previous levels reducing the effectiveness of changes to fisheries regulations (Salas and Gaertner, 2004; Sutton and Ditton, 2005; Gentner and Sutton, 2008; Metcalf *et al.,* 2010). Furthermore, management restrictions imposed to protect one species may result in fishing effort being re-directed towards another species. This, ultimately, may result in a regulatory domino effect in which harvest restrictions placed on one species lead to increased exploitation of other species, creating the need for harvest restrictions on the substitute species, and so on (Thunberg *et al.*, 1995). Thus, fisheries management would benefit from prior investigations of the likely behavioural responses of recreational fishers to alternative regulatory changes as these would facilitate assessment of the potential effectiveness of the various proposed changes (Salas and Gaertner, 2004; Arlinghaus, 2005; Metcalf *et al.,* 2010). To obtain such information, researchers and managers typically employ surveys to identify characteristic behaviours and key motivations of recreational fishers (*e.g.* Wilde *et al.,* 1998; Hunt, 2001; Hunt *et al*., 2002; Arlinghaus and Mehner, 2003; Sutton, 2006; Prior and Beckley, 2007; Arlinghaus *et al*., 2008).

1.2. Recreational fishing

Recreational fishing is an activity that provides considerable social and economic benefits to many communities (Weithman, 1999; Sutinen and Johnston, 2003; Greiner and Gregg, 2010; Fenichel *et al.,* 2013). Recreational fishers fish for a variety of reasons besides just catching fish, with non-catch motives, including relaxation, often being more important to anglers than motives associated with catching fish (Graefe and Fedler, 1986; Fedler and Ditton, 1994; Danylchuk and Cooke, 2010; Smith *et al.,* 2012).

1.2.1. What is recreational fishing?

Recreational fishing is a very popular pastime and has origins dating back to the early Egyptians in 2000 BC (Hickley, 1998). Defining recreational fishing, at first glance, would seem relatively simple and straightforward. However, many nations with recreational fisheries have developed or are developing their own definitions for recreational fishing that are socially and culturally defined by participants in the activity (Ditton, 2008). In this thesis (as adapted from the definitions provided by McPhee *et al*. (2002), Cooke and Cowx (2004), Arlinghaus (2005), Ditton (2008) and FAO (2012)), I define recreational fishing as a leisure-based activity that involves the capture or attempted capture of aquatic living resources. Recreational fishing may be conducted by various fishing methods including angling, *i.e.* line fishing, using a hooking method, gathering (*i.e.* the collection of shellfish), spearing, trapping, netting and using other gears. Note that this definition does not include the subsistence fishing activities of various indigenous people, such as Australians living in traditional indigenous communities (Reid, 2008), nor does it include fishing activity by commercial fishers where some portion of the catch is retained by those fishers for their own use rather than sold. It does, however, include catch and release fishing, which has evolved and has also become an increasingly important component of many recreational fisheries, and which is practised voluntarily by many recreational fishers all over the world (Sutton and Ditton, 2001; Polinsky, 2002; Polinsky, 2008).

1.2.2. **Recreational fishing in Western Australia**

Recreational fishing in Western Australia is legislated by the *Fish Resources Management Act* 1994 (WA) and managed in accordance with this Act by the Department of Fisheries, Western Australia (WA). The objectives of the Act reflect the principles of Ecologically Sustainable Development (ESD), as outlined in Australia's *National Strategy for Ecologically Sustainable Development* (Anonymous, 1992).

Recreational fishing in Western Australia is concentrated in waters adjacent to the state's major population centres of Perth, Bunbury (180 km south of Perth) and Geraldton (420 km north of Perth), which fall within the area identified by the Department of Fisheries, Western Australia, as the 'West Coast Bioregion' management zone, extending northwards from Augusta to just north of Kalbarri (all land and waters south of 27° South latitude and west of 115° 30' East longitude) (Fig. 1.0). This management area accounts for 81% of Western Australia's population (Sumner *et al.*, 2008). As such, the West Coast Bioregion is a focal point for recreational fishing in this State.

The principal method used by recreational fishers in Western Australia is angling, *i.e.* use of hook and line. While other fishing methods, such as trapping, spearing and gathering, are also used by recreational fishers (including some anglers) in Western Australia, the focus of this study is on recreational angling. Thus, in the remainder of this thesis, because of the dominance of this method, the terms 'angling' and 'recreational fishing' (and 'anglers' and 'recreational fishers') have been used interchangeably.

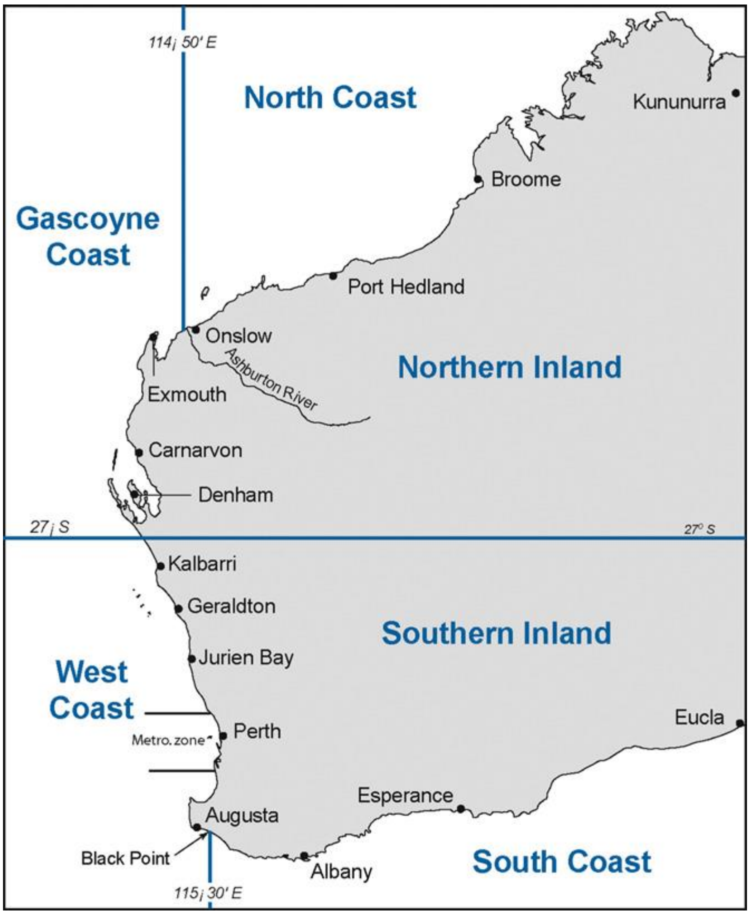


Figure 1.0 **Map of Western Australia showing the bioregional boundaries into which the Western Australian Department of Fisheries has divided the state's marine waters, and the location of the metropolitan (metro.) zone. (Image from Metcalf *et al.,* 2010).**

1.2.3. **Survey information on recreational fishing in the West Coast Bioregion**

The most recently published survey on recreational boat-based fishing in the West Coast Bioregion integrated (1) off-site phone surveys, (2) on-site boat-ramp surveys, and (3) a remote camera survey, making it the most comprehensive survey conducted in Western Australia to date (Ryan *et al*., 2013). The results from this survey showed that the majority of boat-based recreational fishing effort occurred in the West Coast (67%) of the state, with most of the fishing effort occurring in nearshore (51%) and inshore (25%) habitats, with line fishing (68%) being the preferred method used by recreational fishers (Ryan *et al*., 2013).

Although the *National Recreational and Indigenous Fishing Survey* (Henry and Lyle, 2003) and various creel surveys of the West Coast Bioregion (Sumner and Williamson, 1999; Sumner *et al*., 2008; Ryan *et al*., 2013) provide good information relating to recreational fishing effort, very few studies have focussed strongly on behavioural patterns of recreational fishers in Western Australia. One exception is the study of Prior and Beckley (2007), who conducted a survey to characterise recreational anglers in the Blackwood River Estuary (34°19'S, 115°11'E), south of Perth. Prior and Beckley (2007) gathered information on the demographics of anglers, their spatial and temporal patterns of fishing, and their expenditure and attitudes to conservation and management of fish resources. Almost half of the angling groups encountered during the survey were tourist families, visiting the Blackwood River Estuary from cities and towns in south-western Australia, many originating from Bunbury. Most anglers were also male and between the ages of 31-45 y old, who stated that their main motivation for angling was for relaxation. Furthermore, it was found that, on average, boat-based anglers fished more frequently than shore-based anglers and locals fished more frequently in the Blackwood River Estuary than tourists, with considerable expenditure on bait, tackle, and capital equipment (Prior and Beckley, 2007).

A similar survey that also explored behavioural aspects of recreational fishing was conducted for shore-based anglers on Rottnest Island (32°00'S, 115°30'E), located off the south-west coast of Western Australia (Latitude 32°00'S, Longitude 115°30'E) (Smallwood *et al.*, 2006). The majority of anglers on Rottnest Island during the survey were from the Perth Metropolitan Region, with just over one-third of anglers being children, most of whom were observed fishing from jetties. The results of the survey also showed that shore-based anglers' often targeted Australian herring (*Arripis georgiana*) with the highest number of anglers observed coinciding with the autumn/winter migration of Australian herring. Avid anglers, however, were more likely to target larger and more valued fish species, such as yellowtail kingfish (*Seriola lalandi*) and tailor (*Pomatomus saltatrix*). The study also revealed that 36% of fish caught on Rottnest Island were subsequently released (Smallwood *et al*., 2006).

In summary, most surveys of recreational fishing in Western Australia have focussed on producing estimates of catch and effort, assessing knowledge of fishing regulations, and obtaining information on attitudes towards management initiatives and broad demographic data. With the exception of the surveys by Smallwood *et al*. (2006) and Prior and Beckley (2007), there has been minimal attention given in published reports to the motivations and behaviours of anglers in Western Australia, and their likely responses to factors such as changes in fish abundance or fishery regulations.

1.3. **Survey methods**

Angler surveys are used by fisheries agencies in many parts of the world to obtain a variety of information for management purposes (Henry and Lyle, 2003; Dempson *et al*., 2012). As described by Pollock *et al*. (1994), there are seven basic survey methods used to estimate and record angler characteristics and activities. These are mail, telephone and door-to-door surveys, fishing logbooks or diary surveys, access point surveys, roving surveys and aerial surveys. All but the last of these methods allow the collection of data from recreational fishers relating to their demographic characteristics, motivations, and behaviours. The first four of Pollock *et al*.'s (1994) methods are regarded as off-site approaches (surveys conducted away from fishing sites), with individuals or households selected from a sampling frame, and these individuals or representatives of selected households then being contacted and asked to respond to a survey or interview. The other approaches are regarded as on-site methods (surveys conducted at the fishing site). On-site surveys employ a 'spatio-temporal' sampling frame where certain sites are visited at selected times, and randomly-selected fishers encountered at those sites are contacted and asked to respond to a survey or interview (Pollock *et al*., 1994; Henry and Lyle, 2003).

A common method that is employed to obtain data from recreational fishers is through use of an on-site creel survey (Pollock *et al*., 1994). Such surveys typically focus on collecting information about the fish that are caught (and related fishing effort) rather than on the fishers themselves. Offsite surveys (telephone, mail, etc.), in contrast, are primarily used to sample angler opinions and collect socio-economic data (Pollock *et al*., 1994) and have often been used to collect fishery-wide data. Thus, for example, a phone survey is a major component of the methods used by the National Marine Fisheries Service (NMFS) to collect effort data for recreational fisheries in the U.S.A., *i.e.* the Marine Recreational Fisheries Statistics Survey (MRFSS) and its successor, the Marine Recreational Information Program (MRIP) (Sullivan *et al*., 2006). In recent years, there has been an increased tendency for researchers to use mixed mode surveys, *i.e.* data collected by two or more methods for a single survey purpose (Dillman, 1991). For example, researchers may use telephone-diary surveys in conjunction with on-site creel surveys or follow-up mail surveys after an on-site creel survey, or online surveys in conjunction with a telephone follow-up, thus increasing data quality and overcoming the shortcomings of certain biases inherent in each of the techniques (Brown, 1991; Ditton and Hunt, 2001; Lyle, 2008; Crosson, 2010). For example, data from follow up surveys are used when attempting to adjust for non-response.

So which survey method(s) should one use? Answering this question is not always straightforward, as each method has its own strengths and weaknesses. Costs and complexities also increase as one moves from diary surveys to mail surveys and, in turn, to telephone surveys and, finally, to surveys involving direct contact with anglers (Pollock *et al*., 1994). The survey methods chosen to collect recreational fishing data are usually determined by: (1) the type of information required, (2) the temporal and spatial scale of the study, (3) the characteristics of the fishery, and ultimately (4) the resources (personal, funds, gear, etc.) available to the researcher (Henry and Lyle, 2003). Large scale surveys (national or state-wide level), for example, commonly use off-site techniques because of their lower associated costs and greater ability to deal with large numbers of fishers dispersed over large geographical areas (Henry and Lyle, 2003). The following sections look more closely at the use of mail and phone survey techniques in fisheries and their inherent merits and deficiencies. These techniques were identified as the most suitable methods for collecting data from recreational fishers in the studies undertaken for this thesis.

1.3.1. **Mail surveys**

Mail surveys are the most common survey method used among many fisheries agencies for angler-related research, due to their relatively low cost and simplicity of operation (Pollock *et al*., 1994; Fisher, 1997). These types of surveys are also highly flexible and able to reach a widely dispersed sample without the problems of interviewer access (Fisher, 1997). Survey questionnaires may be mailed or handed directly to potential participants, with completed forms being returned by post (or other collection system) by those individuals who choose to respond. Mail surveys are often used for socio-economic studies and for characterising anglers or communities affected by fisheries according to socio-economics or other attributes (Pollock *et al*., 1994).

As described by Pollock *et al*. (1994), a common weakness of mail surveys is the adequacy of the sampling frames that are used, *i.e.* angler licence or permit databases, which are often incomplete and hence do not provide an accurate representation of the angler population. Another weakness of mail surveys is related to variations in response rates among different groups of fishers, with avid and more specialised angler groups often being more likely to participate in recreational fishing surveys than other groups, thus biasing the data (Pollock *et al*., 1994; Arlinghaus, 2004). It is also important to recognise that mail surveys are limited in that that they ask anglers to report on past fishing events, and thus the accuracy of responses is likely to vary depending on how far in the past the fishers are being asked to recall fishing experiences and how memorable those experiences were. Therefore, mail surveys typically suffer from 'memory or recall biases' (Pollock *et al*., 1994; Connelly and Brown, 2011). Furthermore, anglers may exaggerate their catches to enhance their image ('prestige bias') (Pollock *et al*., 1994) with the result that estimates of catch and harvest rates can often be up to 20% higher than those reported from on-site survey methods (Roach *et al*., 1999).

Several algorithms have been developed to allow 'adjustments' for non-responses by anglers. Achieving a high response rate, however, is the best way to reduce the effects of non-response bias (Fisher, 1996). Dillman (1978), showed that non-response rates can be reduced through making a concerted effort towards minimising the length of individual written surveys to minimise the time required for the respondent to complete the questionnaire. The effects of other biases, *i.e*. recall and prestige, can be minimised through consideration of responses during the development of the questionnaire and limiting the number and type of questions (Larkin *et al*., 2010).

In summary, mail surveys sacrifice quality but benefit by being of lower cost (Pollock *et al*., 1994). Maximising the usefulness of mail surveys involves carefully structuring and designing surveys so that they are 'respondent-friendly' (Pollock *et al*., 1994; Dillman, 2000) and so that non-response rates (and hence, non-response biases) are minimised.

1.3.2. **Telephone surveys**

The use of telephone surveys to gather angler catch and attitudinal data has been shown to be an effective and consistent means of obtaining reliable information about the recreational fishing sector (Cockcroft *et al*., 1999). Telephone surveys are used by fisheries agencies to determine participation rates and angler profiles, *i.e.* profiles are created for each angler segment based on the interview data, their demographic characteristics, catches and level of fishing effort, expenditure associated with fishing activities, perceptions of fishery regulations, conflicts between fishers and understanding of issues relevant to fishers, including the future of their fisheries (Henry and Lyle, 2003; Beck *et al.,* 2009; Crosson, 2010).

The main advantages of using telephone surveys are that these surveys often have high response rates and short turn-around times. Of further advantage is that the resultant data can also be entered directly into a computer by the telephone interviewer and that, in comparison with face-to-face surveys and on-site surveys, they are relatively inexpensive. The ability for questionnaires and responses to be computerised, such as through the use of a Computer Assisted Telephone Interview (CATI) survey method, represents a huge advantage, as it can facilitate improved quality control and speed up the provision of data for analysis (Pollock *et al.,* 1994).

While telephone surveys, in comparison with surveys conducted at boat ramps, enable data to be collected from a larger number of people and, for the same expense, from a wider area, this sampling technique does not necessarily cover all 'types' of fishers (Pollock *et al.,* 1994; McCluskey and Lewison, 2008). In some instances, *i.e.* when anglers are not required to have fishing licences, it is necessary to sample from a phone directory. Telephone directory sampling frames, however, only include members of the population who have listed numbers, with only a proportion of these likely to be fishers (Pollock *et al.,* 1994; Cowx, 2002). This method also does not account for the fishers who do not have a telephone, or the increasing number of individuals who use mobile (cell) phones which are not listed in such directories (Pollock *et al.,* 1994; Kempf and Remington, 2007). Thus, inherent errors associated with under-coverage and sampling bias can be introduced. Therefore, a sample drawn from an appropriate sampling frame of fishers, such as those who hold fishing licences, is better than one drawn from a phone directory frame alone (Pollock *et al.,* 1994).

Telephone surveys also suffer from many of the same weaknesses as mail surveys, as they ask anglers to report on past fishing events, thus providing reliable data only for those experiences that can be easily remembered. In this regard, it has been pointed out that the ability for people to accurately recall events and details of fish catches reduces rapidly after about two months, which can lead to substantial biases, with a general trend towards overestimation of catch (Pollock *et al*., 1994; Connelly and Brown, 2011). As long as the potential for overestimates and biases in the reported catch and effort from participants is recognised, however, this survey method can still provide good angler data (Roach *et al*., 1999). In summary, telephone surveys provide reliable data for experiences that can easily be remembered by an angler, and can thus provide good information on current attitudes, as well as good demographic and sociological data (Pollock *et al*., 1994).

1.4. The human dimension

One of the shifts in thinking that has emerged within the framework of natural resource management in recent years is the growing awareness and importance being placed on the understanding of the behaviours, attitudes and needs of people, more commonly known as human dimensions (HD) research (Ewert, 1996; Ditton and Hunt, 2001; Johnston *et al*., 2010). Human dimensions of recreational fisheries management is the area of research dedicated to the study of recreational fishing and anglers (Hunt, 2001). This type of research is about identifying who anglers are, where they live, how far they travel to go fishing, the fish species they target and catch, and their experience preferences, together with their views, values and attitudes towards fisheries resources and management (Hunt, 2001; Arlinghaus, 2004). Understanding how anglers operate in a fishery can ultimately assist managers in understanding how that system works, inform stock assessment models, focus management and conservation priorities and set management objectives in light of knowledge of the overall 'public interest' (Aas and Ditton, 1998; McPhee *et al*., 2002; Johnston *et al*., 2010). Human dimensions research can also provide insight and information to define what constitutes a satisfying fishing experience. Such information can also be used by governments to provide an environment that facilitates the delivery of the best possible services, facilities, fishing opportunities and educational programs for anglers and the general public (Hunt, 2001; Arlinghaus *et al.,* 2008).

1.4.1. Recreational fisher specialisation

Recreational fishers display wide variation across many fishing-related attributes including their catch preferences (size, species, and number), levels of avidity (*i.e.*

keen interest or enthusiasm), consumptive orientation (*i.e.* the degree to which anglers value the catch-related outcomes of the angling experience), fishing methods and gear usage and their expectations, commitment, economic expenditures and social interactions (Sutton and Ditton, 2001; Salz and Loomis, 2005; Kyle *et al*., 2007).

Bryan (1977) was the first to conceptualise 'recreation specialisation' as a means of identifying particular groups of anglers from within diverse groups of fishers, according to a single recreational activity, *e.g.* boat-based, saltwater anglers (Bryan, 1977; Salz and Loomis, 2005; Oh and Ditton, 2008). Groups of recreational participants (anglers) are considered to fit along a continuum of behaviour or specialisation, from the occasional or novice angler at one end of the spectrum to the technique-setting specialist or highly experienced angler at the other (Bryan, 1977; Ditton *et al.*, 1992; Calvert, 2002; Salz and Loomis 2005; Oh and Ditton, 2008). The types and locations of anglers on the continuum are reflected in such phenomena as their frequency of participation, fishing locations and technique preferences, choice of equipment, importance of catch, social setting of activity and preferences for resource management (Bryan, 1977; Ditton *et al.*, 1992). As the level of angler specialisation increases, there is often a shift in focus from fish harvest and consumption towards resource conservation, and an increased emphasis on enjoying the activity itself and the natural environmental setting (Oh and Ditton, 2006a; 2008), however, this premise doesn't always hold true (Dorow *et al*., 2010).

1.4.2. **The specialised angler**

In the overall context of recreational fisheries management, specialised anglers are very important stakeholders (Hilborn, 1985). In terms of management, important attributes of specialised anglers (*i.e.* relative to novice anglers) are their higher levels of activity and involvement, ecological understanding and success in catching fish (Hilborn, 1985; Dorow *et al.,* 2010). Specialised anglers also often place greater importance on the size and quality of fish caught than on quantity, and have been found to show greater support for catch and release methods than their counterparts (Sutton and Ditton, 2001; Salz and Loomis, 2005; Hutt and Bettoli, 2007; Danylchuk and Cooke, 2010). Distributions of overall catch (and effort), particularly for higher value fish species, are usually skewed, however, with small numbers of more specialised and avid anglers taking a large proportion of the overall catch (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). Specialised anglers are also more likely to be actively involved with local fishing clubs, participate in fishing tournaments and be members of national fishing organisations (Salz and Loomis, 2005). They often have large social and financial investments in fishing and often voice the strongest opinions in response to management actions (Wilde *et al*., 1998; Arlinghaus and Mehner, 2003; Margenau and Petchenik, 2004; Salz and Loomis, 2005).

1.4.3. **Research questions arising from human dimensions**

Since Bryan's early work (Bryan, 1977), many researchers have explored the notion of recreation specialisation in many different types of outdoor leisure-based activities, *e.g.* fishing (Ditton *et al*., 1992), hunting (Kuentzel and Heberlein, 1992), camping (McIntyre, 1989; McIntyre and Pigram, 1992), canoeing/boating (Wellman *et al*.,1982; Donnelly *et al*., 1986; Kuentzel and McDonald, 1992; Bricker and Kerstetter, 2000), bird-watching (Lee and Scott, 2004; McFarlane, 1994; 1996), hiking (Virden and Schreyer, 1988), and scuba diving (Thapa *et al*., 2005; 2006). In recent years, the concept has also been extended to such activities as heritage tourism (Kerstetter *et al*., 2001), golf tourism (Kim *et al*., 2008) and indoor recreational activities such as bridge (Scott and Godbey, 1994).

Some key points emerge from an examination of the literature on human dimensions and the use of specialisation theory in leisure-based systems, particularly in its application in fisheries science. Firstly, the characteristics of anglers will differ slightly from fishery to fishery (Schramm *et al*. 1998; Aterburn *et al*., 2001; 2002; Anderson *et al*., 2007; Zichke *et al*., 2012). Certainly, there may be some similarities in the characteristics of recreational anglers in different fisheries, *e.g.* anglers in a trout fishery and a tuna sport fishery will have a target species, employ specialised gear types, etc. For anglers within a specific fishery, however, those characteristics, behaviours, attitudes and needs are likely to be influenced strongly and ultimately shaped by the nature of the fishery, the abundance of the stocks, the management context, and the socio-economic environment in which the fishery operates, thus highlighting the importance of not generalising findings too broadly from one specialisation study, to the next (Beardmore *et al*., 2013).

Secondly, as with the first point, it is likely that the factors that relate to recreational fishing specialisation will be determined by the biology and abundance of the targeted species and the management context of the fishery. For example, if a species is abundant and easily caught, there would be little advantage in angler specialisation to increase catch success, but the opposite would hold true when the species is highly prized and difficult to catch, with increased knowledge and skill giving an angler a considerable advantage (Scott and Godbey 1994; Sutton, 2001; Salz and Loomis, 2005; Zichke *et al*., 2012; Beardmore *et al*., 2013). Further, it has been noted that a casual (*i.e.* less specialised and committed) angler is happy to catch 'something' whilst out fishing for the day (Graefe, 1980; Dorow *et al*., 2010; Beardmore *et al*., 2013), usually the bigger the better. A specialist or more avid angler, however, will likely have a specific target species (Dorow *et al*., 2010), and use high-quality species specific fishing tackle and is more likely to select fishing waters based on their premium fishing quality. These specialist anglers, who are likely to use many sources of information about fishing and may subscribe to angling magazines devoted to a certain species or fishing styles, will also have certain expectations regarding the fishing trip (Beardmore *et al*., 2013). It should be noted, however, that these assumptions do not always hold true as several studies have noted the use of more high quality angling gear by the less specialised anglers (Beardmore *et al*., 2013), with some specialised and avid anglers preferring more traditional and/or challenging fishing methods such as fly fishing (Hutt and Bettoli, 2007; Wilde *et al*., 1998; Zichke *et al*., 2012). It should also be recognised that the defining characteristics of an avid and specialised angler in one fishery may not be identical to the characteristics of specialised anglers in another.

The recreational fishery for demersal fish in the West Coast Bioregion of Western Australia is a multispecies fishery with two iconic fish species, each of which is highly prized by anglers but which, because of its low abundance, is difficult to catch. Other 'bread and butter' fish are more abundant and easier to catch. This study explores whether, in accordance with human dimensions and specialisation theory and within the context of the multispecies nature of this demersal fishery, the characteristics of the boat-based recreational anglers who are content to catch a mixture of 'bread and butter' species differ from those of the more specialised fishers who seek to catch the two iconic species, and whether the characteristics of the latter group of fishers reflect specialisation to improve potential catches of those prized species.

1.5. Assessing the implications of behavioural responses by anglers

In addition to the collection of angler data, tools are required to facilitate the determination of the likely behavioural responses of anglers to environmental change or changes in fisheries regulations and their implications for management. For example, qualitative models, such as that of Metcalf *et al.* (2010), have proven to be useful for exploring the ways in which the behaviour of fishers might influence the effectiveness of fisheries regulations (Justus, 2005; Bakus, 2007; Dambacher *et al.,* 2009). Such models, however, while possibly providing a semi-quantitative assessment of the consequences of behavioural responses, are largely unable to quantify the impacts of those responses (Whipple *et al.,* 2000). Quantitative models that have been used for fishery assessment include those that range from single-to multi-species models, through to whole-of-ecosystem models. The last of these model types has proven to be particularly useful for the holistic exploration of fishery systems, including the ability to explore the interactions between fish, fishers, and managers (Latour *et al*., 2003; Pikitch *et al*., 2004; Plagányi, 2007; FAO, 2008; Koen-Alonso, 2009; Schlüter *et al*., 2012).

Agent-based models such as OSMOSE (Shin and Cury, 2001; Shin *et al.,* 2004) and INVITRO (Gray *et al.,* 2006) have provided modelling platforms that are well suited to exploring the implications of the behavioural responses of fishers to changes in fish abundance and management regulations. Such approaches have been shown to be particularly useful in understanding the 'emergent' behaviour of multiple agents, which can adapt to ecological and economic constraints through learning and negotiation processes (Billari *et al*., 2006). Moreover, agent-based modelling techniques are also valuable for explaining how individual agents make strategic decisions and interact on multiple levels (Kaitala and Munro, 1995; Dockner *et al*., 2000; BenDor *et al.,* 2009).

This study employed agent-based modelling (ABM) to explore the implications, for fisheries management, of a range of recreational fisher behaviours and also focussed on changes in model output in response to changes in certain parameters such as the abundance of a key fish species.

1.6. **Agent-based modelling**

Agent-based models (ABMs), sometimes referred to as individual-based models (IBMs), are computer models which simulate the behaviours of, and interactions between, collections of 'agents' (*i.e.* individuals, such as individual anglers) with each other and/or their environment (see Lomnicki, 1992; Grimm, 1999; Grimm *et al*., 2005; Breckling *et al*., 2006). Unlike more traditional (state-variable) models, that are based on differential and difference equations, and classical models such as the logistic model of population growth, which describe the (mean) dynamics of a pool of individuals, ABMs focus on the lowest entities of a system, *i.e.* the individual (Grimm, 1999). Agent-based models have been used for a wide variety of purposes across a range of disciplines (Van Dyke Parunak *et al*., 1998), including fisheries science (*e.g.* Rose and Cowan, 1993; Dreyfus-Leon, 1999; Rothschild, 2000; Little *et al.,* 2004; Yu *et al*., 2009; Hesp *et al*., 2012; Saul *et al*., 2012). For example, Saul *et al*. (2012) employed an individual-based model to explore the migration patterns of red grouper (*Epinephelus morio*) on the West Florida Shelf. Their results from the biased random walk model used to simulate the directional movement of fish from inshore nursery habitats to the offshore reef habitat inhabited by adults, were comparable to empirical results and to observed catches at age.

The rules describing the behaviours of the agents may be based on random choices among alternative decisions (according to relative probabilities), or may be modelled in more sophisticated ways. Thus, for example, Dreyfus-León (1999) and Dreyfus-León and Kleiber (2001) used neural networks (*i.e.* a computing method based on the way the human brain performs computations) to model the decision-making processes and search behaviours of fishers, while Little *et al.* (2004) simulated fisher behaviours using Bayesian networks. However, due to the computational demands of modelling the behaviours of each of the individual agents that need to be considered in agent-based models, simpler and more easily-computed rules are frequently used. Coincident with increases in computer technology, studies employing this computer-intensive simulation approach (*i.e.* agent-based modelling) are becoming increasingly reported in the literature (see Schlüter *et al*., 2012).

1.6.1. **Characteristics of agent-based models**

There are several characteristics that distinguish ABMs from other modelling approaches. In this regard, Grimm and Railsback (2005) provide a set of characteristics for what they refer to as 'individual-based ecology' - the field of ecology concerned with the use of IBMs (or ABMs). Although specific to ecological applications, these characteristics can be used to illustrate the key attributes of ABMs in general.

The purpose of an ABM is to understand system properties and the impacts of agent behaviour on the emergence of such properties (Lomnicki, 1992; O'Sullivan, 2008). Agents do not exist in isolation, but interact with other agents of the same and different types and their environment (Bosquet and Le Page, 2004). Hence, to properly model a system using agent representations of the system's actors, it is crucial that the system is modelled as a collection of unique agents (Breckling *et al.*, 2006).

Unlike traditional modelling approaches, ABMs are not formed from differential equations, but from concepts derived from complexity science, *i.e.* the science of complex, adaptive systems (Railsback, 2001). These concepts include emergence and adaptability (Railsback, 2001; Grimm and Railsback, 2005). Emergence refers to the way in which system-level properties arise from the characteristics of the system's component parts, namely the agents and the environment (Railsback, 2001). Adaptability refers to the way in which agents in a model increase their own 'fitness', through 'making decisions' by means of procedural rules in the model (Grimm and Railsback, 2005).

As described above, a key element of agent-based models is that they involve simulation. Important properties of simulation are that the agents in the system must be separately accessible and have at least one property that distinguishes them from each other. For this reason, agent-based modelling lends itself well to object-oriented programming (Grimm and Railsback, 2005; Grimm *et al*., 2010).

As the purpose of an ABM is to explore some aspect of a real world scenario, it is crucial that the researchers have some knowledge of the agents and system they are modelling. In this regard, field or laboratory studies can be useful in constructing models of agent behaviour, and organising and testing the model (DeAngelis *et al*., 1980; Grimm and Railsback, 2005; Benenson *et al*., 2008).

1.6.2. **Advantages of using agent-based modelling**

Agent-based models can be useful both for developing ecological theory and for practical management, as they allow researchers to consider aspects usually ignored in analytical models, such as variability among individuals, local interactions in the system, differences in how an organism behaves/interacts at different stages in its lifecycle, and how individuals might 'adapt' to changes in their environment (Grimm *et al.,* 2006; Mathews *et al*., 2007). ABMs are also ideally suited for scenario-testing, and thereby allow managers and users an opportunity to investigate the likely consequences of many different management scenarios before any management decisions are implemented (Hunt *et al*., 2007; Cabral *et al*., 2010). ABMs also have the advantage of being able to incorporate real habitat (GIS) data (Kennedy *et al*., 2009).

There are also several key advantages of ABMs compared with other modelling techniques: (1) the simulation model is able to capture emergent phenomena (Bonabeau, 2002), (2) the model provides a natural description of a system and its processes (Van Winkle *et al*., 1993; Bonabeau, 2002), and (3) this type of model is flexible in nature (Bonabeau, 2002). ABMs can allow for individuals (agents) represented in the model to be equipped with the adaptive behaviours of memory and learning, and thus, throughout a model simulation, an agent can learn and modify its behaviours to improve its outcomes (McLane *et al.*, 2011). In this regard, ABMs can more accurately represent reality, *e.g.* as in real life, fishers are able to 'make decisions' (Dreyfus-Leon and Kleiber, 2001).

1.6.3. **Agent-based models in fisheries science**

As noted above, agent based models such as OSMOSE (Object-oriented Simulator of Marine Ecosystem Exploitation) (Shin and Cury, 2001; Shin *et al.,* 2004) and INVITRO (Gray *et al.,* 2006) have been used in fisheries studies to explore ecosystem and associated socio-economic processes. Two other key areas in which ABMs have been applied in fisheries science include investigations into fish displacement (distribution and migration patterns), and as a tool to explore the mechanisms responsible for recruitment success or failure in commercially important marine fish stocks (see Miller, 2007 for a more in depth review) (Bastardie *et al*., 2010).

Although there is increasing interest in modelling angler behaviours to improve management in fisheries (Fenichel *et al*., 2013), agent-based models have thus far typically been used to model the behaviours of fishers in commercial fisheries, with the exception of an ABM for a recreational fishery in Ontario, as briefly described by Hunt *et al.* (2006) and an ABM to simulate recreational fishing activities and their interactions with the environment in the Ningaloo Marine Park, Western Australia (Gao and Hailu, 2010; 2011; 2012; 2013).

With fisheries managers becoming increasingly aware of the growing impacts of recreational fishing (*e.g.* McPhee *et al.*, 2002; Cooke and Cowx, 2004; Granek *et al.*, 2008; Gao and Hailu, 2011), the modelling of the behaviours of recreational fishers represents an area where future research is likely to be beneficial. In the context of this thesis, an agent-based model was adopted as the tool to explore the process through which the behaviour of recreational fishers was likely to affect the catches that were made by those fishers in response to changes in fish abundance. Understanding such processes is necessary if fisheries managers are to assess how fishers might respond to changes in fisheries regulations.

1.7. **Objectives and thesis chapter outline**

The overall objective of this project was to explore the research questions identified above (Section 1.4.3) by describing the characteristics, *i.e.* motivations, behaviours and fine-scale movements when boat fishing, of recreational boat fishers in the Perth Metropolitan Region and testing hypotheses to determine whether survey results relating to non-avid and avid anglers were consistent with the differences expected on the basis of published results of other recreational fishing studies. The characteristics of members of recreational fishing clubs were also compared with those of more avid fishers from the general population of boat-based, recreational anglers to assess whether the results of such comparisons were consistent with the hypothesis that club members represent a group of more specialised anglers who target the more iconic demersal fish species within the West Coast Bioregion of Western Australia. A profile of the characteristics of these club members was then constructed with the ultimate purpose of developing an agent-based model to simulate the targeting behaviours of these fishers for two iconic marine fish species, West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Chrysophrys auratus*) that occupy the waters off the south-western coast of Australia. The aim of this latter component of the study was to demonstrate how fishers' behaviour, such as, for example, fine scale movements between fishing locations in response to changes in abundance of a targeted species, would be likely to affect the catches of not only the target species but also those of other species.

The specific objectives and/or hypotheses relating to the survey studies and agent-based modelling study are outlined in the relevant chapters. To facilitate the presentation of each chapter as an essentially stand-alone unit, some material contained in this introduction is also presented within the introductory text of these chapters.

Chapter 2 explores, describes and compares the behaviours and motivations of non-avid and avid recreational boat fishers near the Western Australian capital city of Perth. The Recreational Fishing Boat Licence (RFBL) database provided a frame from which a random sample of licence holders (aged 18 years or older) was selected and surveyed by telephone in the Perth Metropolitan Region. In order to gain a better understanding of the characteristics of non-avid and avid anglers in this region, *i.e.* differences in anglers' participation and motives for fishing, the gear and methods they use, their movements during a fishing trip, and the fish species that they target and land were examined.

Chapter 3 examines and describes the characteristics, catch preferences, behaviours, movement patterns, gear and angling methods of members of fishing clubs in the Perth Metropolitan Region. These recreational fishers represent a group of highly specialised boat anglers (SBAs), who typically target and catch marine, demersal fish species (*i.e.* West Australian dhufish and pink snapper). The characteristics of these anglers were compared with those obtained from the more avid recreational fishers who participated in the phone survey described in Chapter 2. Club members were also asked to provide data on their targeting methods for catching the iconic West Australian dhufish and pink snapper in the region, such that these results might be used to inform an agent-based model of the recreational fishery for these species.

Chapter 4 describes an agent-based model for simulating the dynamics of the recreational fishery for West Australian dhufish and pink snapper. Simulations using this model were undertaken for a range of scenarios of differing fish abundance and management regulations to explore how certain behavioural responses by fishers to differences in these factors affect catches of West Australian dhufish and pink snapper and were thus also likely to affect the sustainability of these species.

Lastly, Chapter 5 discusses the broader perspectives and conclusions of the surveys and agent-based modelling results. The surveys undertaken in this study have attempted to provide insight into the characteristics of anglers in the Perth Metropolitan Region in terms of their catch preferences, behaviours, movement patterns, gear and angling methods with the hope of aiding human dimensions (HD) research in the Region. The notion of using specialisation theory to assist in discerning why different anglers seek different types of fishing opportunities and experiences was also explored. Further, the identification of such angler segments represents the first step in understanding the objectives and requirements of those different groups. It is recognised, however, that on-going research and inclusion of human dimensions research is required. The integrated-modelling approach presented in this study could potentially be of benefit in helping to predict how boat fishers operating in multi-species line fisheries may respond to changes in management and fish abundance, and the implications of this for the success of fisheries management.

2. Comparisons of the motivations, behaviours and movements of non-avid and avid recreational boat anglers in south-western Australia

2.1. Introduction

Many major fisheries problems around the world can be attributed to a failure to understand and manage fishers, rather than a lack of knowledge of fishery resources (Hilborn, 1985; Hilborn *et al.,* 2003; Beddington *et al*., 2007; Worm *et al*., 2009; Fenichel *et al*., 2013). Traditionally, most research has focussed on the collection of ecological and biological data and assessment of the direct effects of fishing on fish stocks. There is increasing recognition by fisheries managers, however, of the need to better understand the human component of fisheries and to allow for this when developing management strategies (Wilde *et al*., 1996; Arlinghaus, 2004; Little *et al*., 2004). This is particularly the case with recreational fisheries as the fishing-related attributes of anglers vary widely in relation to catch preferences (size, species, and number), avidity (*i.e.* frequency of fishing), fishing behaviours and motivations, gear, economic investment, and social interactions (Salz and Loomis, 2005). Although an understanding of the behaviours of recreational anglers is considered important to ensuring sustainability of the fish stocks targeted by recreational fishers, information regarding their behaviours is too often under-represented in modern recreational fisheries science and management (Arlinghaus, 2006; Schlüter *et al*., 2012).

To better account for the behaviours of recreational anglers in fisheries management, studies are required to elucidate, in detail, the full diversity of behaviours and associated attributes of recreational fishers. Such studies fall within the discipline of human dimensions (HD) research, which, in the context of fisheries, is the field of science that attempts to describe, predict, understand, and also affect human thoughts and actions towards fishery resources (Aas and Ditton, 1998).

Recreational fishers can be classified broadly as avid and non-avid anglers. Graefe (1980) first proposed the use of frequency of participation as a useful measure for characterising anglers as avid or non-avid fishers (Ditton, 1996; Fisher, 1997; Salz *et al*., 2001) as, in general, in comparison with non-avid fishers, avid fishers tend to fish more frequently, invest more in fishing gear and technology, target particular fish species, possess better fishing skills and knowledge and are more successful in catching fish (Hahn, 1991; Ditton *et al*., 1992; Salz *et al*., 2001; Johnston *et al*., 2010). In the case of marine anglers, avid anglers are likely to own larger boats with specialist fish-finding equipment, *e.g.* global positioning system (GPS) systems and echo sounders. They are also likely to fish further offshore to target larger fish species and/or fish in areas that are less accessible to other, less avid fishers, which may thus harbour greater fish abundances due to reduced exploitation pressure. It might also be expected that, in comparison with non-avid fishers, avid anglers will more readily modify their fish-targeting behaviours if they encounter a low catch rate at a particular fishing location, *e.g.* respond rapidly by moving to a potentially better fishing location to increase the chances of catching a fish.

Because avid anglers are typically very successful in catching fish, they can exert major impacts on fishery resources (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). Moreover, due to their level of interest and investment in fishing, they are likely to voice strong opinions in response to proposed management actions. Thus, there is a particular need for fishery managers to understand the motivations and behaviours of this group of recreational fishers (Wilde *et al*., 1998; Salz and Loomis, 2005; Dorow *et al*., 2010).

In addition to providing broad support for the above generalisations regarding non-avid vs avid fishers, analyses of data from fishery surveys have yielded many insights into HD aspects of certain recreational fisheries. For example, avid anglers are more likely to be young, unmarried males (Arlinghaus and Mehner, 2003), and be motivated by the sporting aspects of fishing (Frijlink and Lyle, 2010b). These more avid anglers are also more likely to be actively involved with local fishing clubs and national fishing organisations and seek information related to fishing techniques and locations from media sources such as magazines, internet sites, and television (Bryan, 1977; Salz and Loomis, 2005).

In recent decades, an increasing number of fisheries and natural resource management agencies have conducted angler surveys to gather HD information on recreational fishers (Wilde *et al*., 1996; Connelly *et al*., 2000a; Dempson *et al*., 2012). Whilst a variety of different survey approaches can be used (*e.g.* telephone, mail, internet, aerial and on-site (creel) surveys), telephone surveys have been recognised for their ability to obtain good demographic and sociological data, *i.e.* on angler preferences, trends in participation rates, fisher profiles, values and attitudes and angler motivations (Pollock *et al*., 1994; Arlinghaus, 2004). For the above reasons, and because of their cost-effectiveness, telephone methods have been used extensively to estimate levels of harvest and effort in recreational fisheries around the world, as well as to gather HD information (Jennings, 1992; Lyle *et al*., 2002; Henry and Lyle, 2003; Lyle *et al*., 2005; Pollock, 2010).

In Australia, including Western Australia (W.A.), the angler information that has typically been collected in fisheries surveys consists mainly of catch and fishing effort data coupled with general demographic data (*e.g.* age, gender, motivations) and economic statistics (*e.g.* Lyle and Smith, 1998; Sumner and Williamson, 1999; Malseed *et al*., 2000; Malseed and Sumner, 2001; Sumner *et al*., 2002; Henry and Lyle, 2003; Campbell and Murphy, 2005; Coleman, 2004; Williamson *et al*., 2006; Sumner *et al*., 2008). Boat ownership has typically been found to be high (Lyle and Smith, 1998; Malseed and Sumner, 2001; Henry and Lyle, 2003) with large percentages of fishers using modern technology, including the use echo sounders (>70%) (Sumner *et al*., 2002; Williamson *et al*., 2006). The main motivations have been for relaxation and sport or to spend time with family (Henry and Lyle, 2003), with low percentages of fishers having club memberships (4-10%) (Lyle and Smith, 1998; Henry and Lyle, 2003; Coleman, 2004). Target species have typically been iconic species within the area, with crabbing popular around estuaries and waterways (Malseed *et al*., 2000; Malseed and Sumner, 2001). High levels of fishing and species knowledge coupled with compliance with existing regulations by anglers were also reported (Williamson *et al*., 2006).

The aim of this study was to characterise and then compare, using the results of a phone survey, the behaviours and motivations of non-avid and avid recreational boat fishers near the Western Australian capital city of Perth (*i.e.* the state's major population centre). Knowledge of the motivations and behaviours that characterise the different groups of fishers is likely to assist fishery managers in meeting the diverse needs of those recreational fishers. More specifically, the study focussed on testing the following hypotheses:

1. The primary motivations of avid boat-based anglers in the Perth Metropolitan Region for going fishing are to catch fish for sport, food and competitions, whereas those of less avid fishers in these regions are recreational, leisure and family interests.
2. Compared with less avid boat fishers, avid fishers in the Perth Metropolitan and Peel regions are typically younger and more likely to live close to the coast, fish on weekdays, own larger boats, travel further offshore to fish, and use specialised fishing gears and technologies.
3. Compared with less avid boat fishers, avid fishers move more frequently between fishing locations in search of fish when catch rates are low.

2.2. **Methods**

2.2.1. **Design of questionnaire**

A questionnaire was developed to obtain information about the characteristics of boat-based recreational anglers, aged 18 years of age or older, in the 'Perth Metropolitan Region' of Western Australia (Appendix A). Broadly, the data collected from the questionnaire included details pertaining to each fisher's frequency of participation, motivations, value attributed to the fishing experience, gear and fishing technology used, distance travelled offshore, factors influencing movement among fishing locations, targeted and retained species and general demographic information (*e.g.* gender, age, area of residence).

The questionnaire was designed to be employed in a phone survey carried out by the experienced and professionally-trained survey team at Edith Cowan University (ECU) Survey Research Centre, Joondalup W.A., thereby ensuring interviewer reliability and integrity and avoiding direct contact between the researcher and the interviewed subjects (Appendix B). Note that the overall final design and layout of the questionnaire was refined in consultation with Vicki Graham and Theresa Wilkes at the ECU Survey Research Centre. After finalising the design, the survey questions were loaded into the Research Centre's computer-assisted telephone interviewing (CATI) system for use by the interviewers at the Centre.

2.2.2. **Sampling design**

Six hundred fishers, with residences located within the Perth Metropolitan and Peel Regions (75 km south of Perth), were randomly-selected (using simple random sampling) for inclusion in the telephone survey for this study by the Department of Fisheries, Western Australia, from its 'Recreational Fishing from Boat Licence' (RFBL) database. Based on its address details, each record within this database had been assigned by the Department of Fisheries to an associated region, where the boundaries of the different regions were those described in the Regional Development Commissions Act (RDCA) of Western Australia. The total number of

RFBL records held within the database for the Perth Metropolitan and Peel Regions at this time were 46,007 and 9,143, respectively. In Western Australia, an RFBL must be held by an angler if he/she fishes from a powered boat, but unlicenced fishers may also fish from that boat provided there is an RFBL holder on board the vessel.

To ensure that the survey was conducted in strict accordance with confidentiality requirements, details of the names of the selected RFBL holders and their phone numbers were passed by the Department of Fisheries directly to the Edith Cowan University (ECU) Survey Research Centre, Joondalup W.A., which was contracted to undertake all telephone contact and interviews with the randomly selected fishers for this study. Information relating to the identities of those RFBL holders, who had been selected to be contacted for the survey, was thus available only to the Department of Fisheries and the ECU Survey Research Centre (SRC).

Note that the sample size of 600 RFBL licence holders was constrained by the funds available for this postgraduate study and by the expense of contracting the ECU Survey Research Centre to conduct the CATI telephone survey method.

2.2.3. Telephone survey

The telephone numbers of the randomly-selected RFBL holders were entered into a database at the SRC and were distributed to that Centre's interview staff. Attempts were made between 16 August 2011 and 19 September 2011 by interviewers at the SRC to contact each of the randomly-selected anglers and thereby recruit participants for the one-off-telephone survey. When a telephone call resulted in an answer, the survey questionnaire was displayed on a computer screen by the Computer Assisted Telephone Interviewing (CATI) system for use by the interviewer and communication was initiated with the respondent. An introductory script was first read by the interviewer to inform the RFBL holder of the aims and procedures of the study and advise of its voluntary nature. If the angler agreed to participate, the interview was then undertaken. Using the CATI system, interviewers at the Survey Research Centre were able to present the questions in the same manner and sequence. The survey questions to be completed were displayed one question at a time on the computer screen and the next question was not displayed until a valid response to the proceeding question had been recorded. Responses were entered directly into the computer, thereby eliminating the potential for biases based on data omissions as a result of question completion by the interviewer or question sequencing errors. The initial questions in the survey were used to screen the interviewees and determine whether or not they were in scope and should be presented with the full set of interview questions. In particular, in-scope interviewees were required to have undertaken boat-based fishing in marine waters within the previous twelve months. Systematic, clerical and computer-based editing checks were applied to all completed data forms to ensure that all data required was present.

The study was approved by the Human Ethics Committee of Murdoch University, W.A. (Project Number 2009/114, Appendix C).

2.2.4. **Data analysis**

All responses collected from participants in this one-off recreational angler phone survey were stored and provided to the researcher by the ECU SRC in a Statistical Package for the Social Sciences (SPSS) data format. Survey responses were summarised and subjected to statistical analysis using IBM SPSS Statistics version 20.0 software (IBM Corporation, 2011), EXCEL (www.microsoft.com, verified September 2010) and the R software package (R Development Core Team, 2013).

Postcode data were used to classify the residential addresses of participating anglers among six separate sub-regions of the Perth Metropolitan Region, *i.e.* the Central Metropolitan, East Metropolitan, North West Metropolitan, South East Metropolitan, South Metropolitan, the West Metropolitan Region, or the Peel Region (which lies just to the south of the Perth Metropolitan Region), and thereby to determine the proximity of those residences to the coast (Fig. 2.0). Details of the postcodes and corresponding sub-regions were obtained online from the Australian demographic and population analysts (ID Consulting Pty Limited., n.d. 'Community profiles'). This website uses current Census data to present population and community statistics to the public, with more than 250 councils across Australia and New Zealand subscribing to this resource and making the information available via their own council websites. Information on the population size in each of those sub-regions was also drawn from the same source. It is important to note that flaws within the existing database of RFBL holders do exist, as the data collected are not necessarily scrutinised to the same level of detail that has been performed in this study. Thus, some (negligible) data have been excluded from figures presented in the results section if they have fallen out of the re-allocated postcode sub-regions used for further analyses. Furthermore, any fisher within the existing database of RFBL holders with an age ≥ 100 y was excluded from analyses.

Based on the Department's ecosystem based fisheries management (EBFM) policy, each of the bioregions is also divided into broad ecological depth based habitats (Department of Fisheries, 2011; Fletcher and Santoro, 2012): pelagic (across all depths), offshore (demersal greater than 250 m), inshore (demersal 20–250 m), near shore (to 20 m deep), estuarine (saltwater and 'brackish' to river mouth), and freshwater (river, stream, dams) (Ryan *et al*., 2013) (Fig. 2.1).

Details of the particular species targeted by the 105 anglers who had reported they were mainly aiming to catch a fish species other than West Australian dhufish (*Glaucosoma hebraicum*) or pink snapper (*Chrysophrys auratus*) during their last boat fishing trip (see Appendix D for a full summary of the anglers' responses) were recorded by interviewers. The responses of anglers, who had reported that they were targeting more than one species, were placed in a 'mixed' category and this category was further separated into 'inshore' and 'offshore' species and then into 'pelagic' and 'demersal' species.

The response rate, R_R, in this study was calculated using the equation:

$$R_R = \frac{N_i}{N_e}$$

where N_i is the number of completed interviews from fully responding participants of the survey and N_e is the number of fishers from the eligible sample, *i.e.* the numbers of in-scope fishers remaining after the initial screening process (Ryan *et al*., 2013). Note that this method only takes account of respondents who had established eligibility (*i.e.* already partially responded to the survey and answered Q.1). Levels of 'avidity' of participants were assessed on the basis of participation rates, *i.e.* the number of separate days on which each fisher had undertaken any kind of recreational fishing (boat fishing, shore fishing, crabbing etc.) in W.A. during the past 12 months (*sensu* Graefe, 1980; Fisher, 1997; Henry and Lyle, 2003). Recreational fishers were classified as avid anglers if they had fished 15 or more days over the past 12 months, and as non-avid anglers, if they had fished less than 15 days. The classification criteria, *i.e.* relationship between frequency of fishing and avidity class, used in this study is the same as that used by the Western Australian Department of Fisheries (Ryan *et al*., 2013). Anglers were also classified into two groups based on the depth at which fishing had been undertaken during their last fishing trip, *i.e.* anglers who fished in waters < 15 m in depth were classed as inshore fishers and anglers who fished in waters > 15 m in depth were classed as offshore fishers.

Two-by-two contingency tables were constructed to compare the demographics, motivations, behaviours, and other characteristics of avid and non-avid fishers. The chi-square test was employed for these comparisons, with differences being considered statistically significant if the probability of the observed data, given the null hypothesis that no difference exists, was less than 0.05. Logistic regression analyses were also undertaken using R (R Development Core Team, 2013) to explore the above characteristics of the different groups of fishers, *i.e.* the non-avid/avid fishers, and the inshore/offshore fishers, and to test the various hypotheses, such as whether avid fishers who experience low catch rates are more likely to move than non-avid fishers. For all such logistic regression analyses, the dependent variable was first recast as a dichotomous factor. The glm procedure was then employed, with family set to 'binomial', to determine for each regression the extent to which the response variable was related to the various putative explanatory factors that had been hypothesised. The strength of each relationship was assessed on the basis of four levels of significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, and; $p < 0.001$. Note that, as the sample size of the survey was small, the significance level of 0.10 was employed to identify explanatory factors of borderline significance that, had a larger survey been undertaken, would have been likely to have been classified as statistically significant at the 0.05 level.

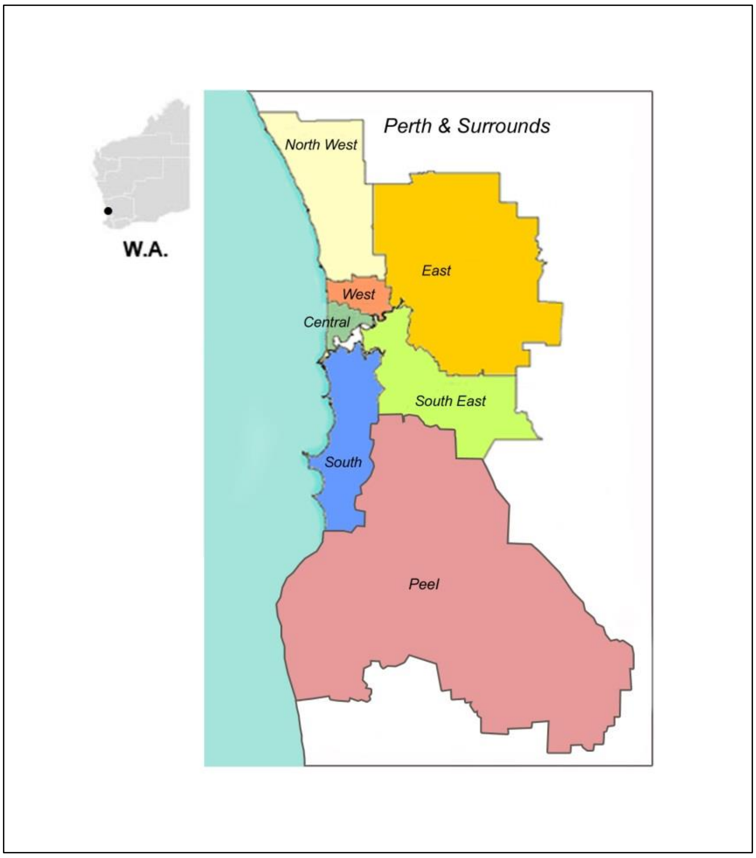


Figure 2.0 **The locations of the main regions (Central Metropolitan, East Metropolitan, North West Metropolitan, South East Metropolitan, South Metropolitan, and West Metropolitan) within the Perth Metropolitan Region, and also the Peel Region of Western Australia. The location of the Perth Metropolitan Region is marked on the smaller map of Western Australia with a black dot. The image has been redrawn from (Hejleh, 2014).**

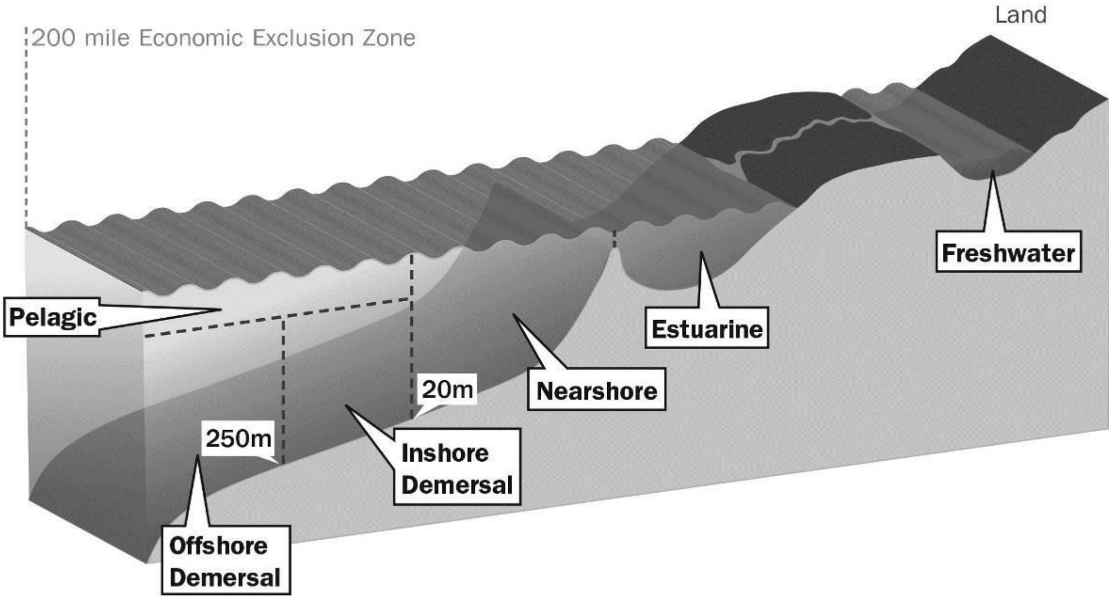


Figure 2.1 **Major habitat groups and depth regions for Western Australian fisheries (Image from Ryan *et al*., 2013).**

2.3. Results

2.3.1. Response profiles

Of the 600 randomly-selected RFBL holders, approximately 11% (64 fishers) could not be contacted during the survey period. This was due either to failure to answer the telephone call from the interviewer or because, on initial contact, a 'soft appointment' was made for a follow-up call but, despite repeated attempts by the SRC, no subsequent contact could be made before the end of the survey period. A further 3% (18 fishers) of the gross sample was lost as a result of failure to contact the specific RFBL holder in 15 successful calls to the phone number. The majority (44.7%, 268 fishers) of sample loss in the survey, however, was because the RFBL holders were considered to be 'out of scope'. These RFBL holders included those who had not undertaken any recreational fishing in marine waters in the past 12 months in W.A. (14.8%, 89 fishers) or where they had only undertaken shore-based recreational fishing in W.A. during that 12-month period (3.5%, 21 fishers). Further losses from the gross sample resulted from disconnected telephone numbers (5.2%, 31 fishers), or where RFBL holders were away for the survey period (2.3%, 14 fishers) or were not known at the number called (1.5%, 9 fishers) or, if known by the person who answered the phone, new contact details for the RFBL holder were not provided to the interviewer (1.3%, 8 fishers).

There were 332 (55.3%) fishers from the original (gross) sample of 600 RFBL holders from the Perth Metropolitan and Peel RDCA regions who, after taking into account the losses described above, were identified as eligible for the phone survey. Of these 332 individuals, 95% fully responded (*i.e.* completed all required interview questions), with 16 RFBL holders refusing to undertake the survey (4.8% of the net sample) (Table 2.0).

The average time of completion of the questionnaire was 15 min.

Table 2.0 **A summary of the sample size and response profile for the one-off recreational fishers' telephone questionnaire. Percentages in bold are calculated with respect to the number of eligible RFBL holders.**

	No.	Percent
Gross sample	600	
Unused numbers, *i.e.* no answer or 'soft appointments' but no contact before end of survey.	64	10.7%
Non-response, *i.e.* the phone number is definitely that of the fisher, but no contact with that fisher after 15 attempts to call.	18	3.0%
Sample loss, *i.e.* out of scope, or fax/modem, away for survey period, incapacitated, language barrier, or in concurrent Department of Fisheries survey.	186	31.0%
Eligible RFBL holders (net sample), *i.e.* those in scope who were invited to be interviewed.	332	55.3%
Refusals, *i.e.* number and percentage of 332 eligible RFBL holders.	16	**4.8%**
Full response	316	
Response rate, *i.e.* percentage of 332 eligible RFBL holders who fully responded.		**95.2%**

2.3.2. Comparisons between anglers in the RFBL database and interviewed recreational fishers

The age composition and mean age of the interviewed recreational fishers differed significantly from that of the fishers from the Perth Metropolitan and Peel Regions within the RFBL (Recreational Fishing from Boat Licence) database (chi-square test: $P < 0.01$; t-test: $P < 0.01$) (Fig. 2.2). The mean age of interviewed fishers was 53 y, while that of the fishers in the RFBL database was 51 y, *i.e.* the average age of the fishers in the survey exceeded that of the fishers in the RFBL database by 2 y.

The total numbers of RFBL holders held within the database for the Perth Metropolitan and Peel Regions were 46,007 and 9,143, respectively. The geographic distribution of the phone survey participants, who resided in the seven sub regions, did not differ significantly from that of fishers in the RFBL database (chi-square test: $P > 0.05$) (Table 2.1).

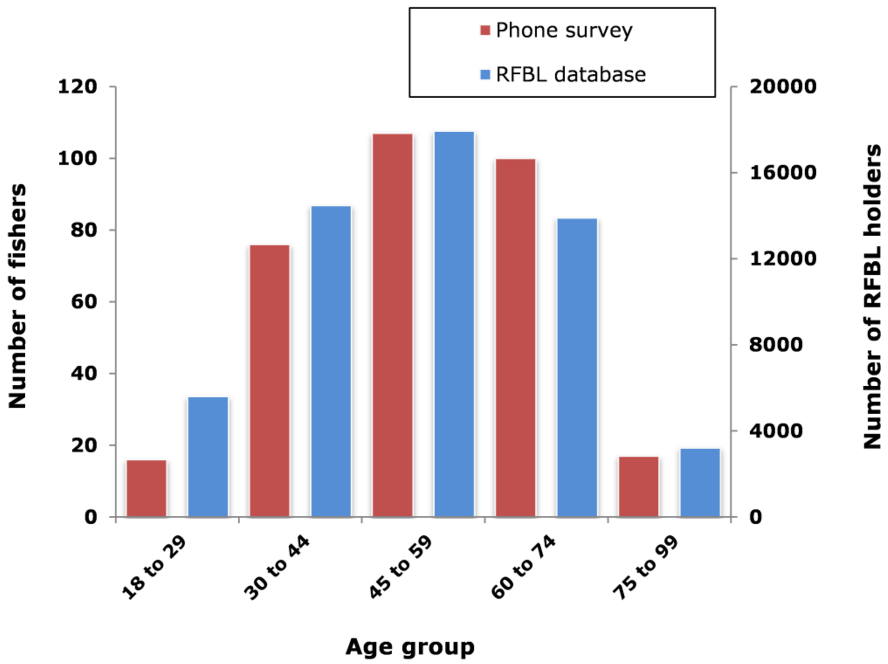


Figure 2.2 Age profiles of fishers from the Perth Metropolitan and Peel Regions in the RFBL database and interviewed recreational fishers.

Table 2.1 The population densities (and percentages), as reported in November 2011, in each of the seven major sub-regions of the Perth Metropolitan Region and also the Peel Region, in which the residences of those fishers undertaking the recreational boat angler survey were located, and the number of survey respondents from each sub-region. Population estimates and areas were courtesy of ID Consulting Pty Limited., n.d.

Zone	Population estimate (thousands)	Area (km^2)	Population density (persons per km^2)	RFBL database	Survey respondents
Central Metropolitan	143 (8%)	88	1,625	4,329 (8%)	35 (11%)
East Metropolitan	199 (11%)	2,101	95	4,835 (9%)	26 (8%)
North West Metropolitan	322 (18%)	785	410	9,508 (17%)	43 (14%)
Peel Region	114 (6%)	3,627	31	8,693 (16%)	57 (18%)
South East Metropolitan	382 (21%)	832	459	7,599 (14%)	38 (12%)
South Metropolitan	367 (20%)	619	592	13,702 (25%)	83 (26%)
West Metropolitan	284 (16%)	150	1,894	6,329 (11%)	33 (10%)
Total	**1,811,000**	**8,202**	**220**	**55,150**	**315**

2.3.3. **General demographics**

Age and gender

Of the 316 interviewed recreational fishers, most were males (88%, 277 fishers) (Fig. 2.3). The ratio of male to female recreational fishers in each age group did not differ significantly among those groups (chi-square test: $P > 0.05$). The age category that, for both sexes, contained the greatest number of recreational fishers (93 males and 14 females) was the 45-59 y old age group, followed closely by the 60-74 y old age group (87 males and 13 females) and the 30-44 y old age group (68 males and 8 females) (Fig. 2.3).

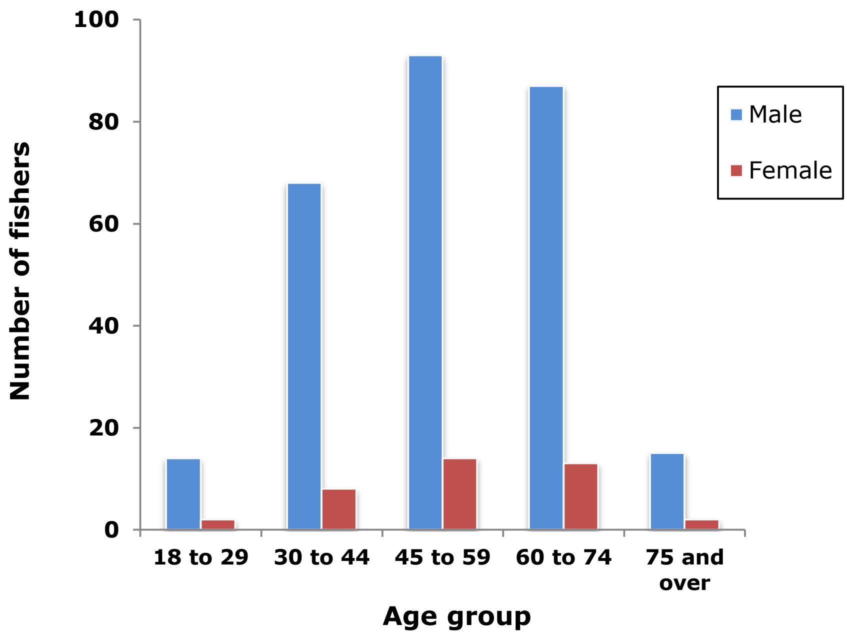


Figure 2.3 **Number of interviewed recreational fishers of different age categories and genders.**

Region

Of the seven regions sampled, the largest number of respondents were from the South Metropolitan Region (26%, 83 fishers), followed by the Peel Region (18%, 57 fishers) and then the North West Metropolitan Region (14%, 43 fishers) (Table 2.1). One anomalous interview record (not included in Table 2.1) was present in the sample, namely that of an angler who had a current postcode of 6530 (Geraldton) which is 420 km north of the Perth Metropolitan Region, *i.e.* in the Mid-West area of W.A. This fisher's responses have been included in other survey results based on the assumption that, although the postcode was inconsistent with the region code, the latter code was correct.

Avidity

Of the 316 recreational fishers interviewed, 134 individuals (42%) had fished for 15 or more days in the preceding 12 months and thus were considered to be avid fishers (Table 2.2). Avid fishers were also found to be significantly more likely to be ≥ 45 y old than non-avid recreational fishers in the Perth Metropolitan Region (chi-square test: $P < 0.05$). Furthermore, logistic regression analysis found no indication that avidity was related to the region in which the interviewed fisher resided. The more avid a fisher is, however, the more likely he/she would have gone fishing on a weekday rather than the weekend or a public holiday on their most recent fishing trip (logistic regression: $P < 0.10$) (Table 2.3).

Table 2.2 Number of interviewed recreational fishers in successive avidity classes.

	Avidity class categories					
	Non-avid			Avid		Total
	< 5 days	5-9 days	10-14 days	15–19 days	≥ 20 days	
Frequency	61	66	55	29	105	**316**
Percent	19.3%	20.9%	17.4%	9.2%	33.2%	**100%**

Table 2.3 Coefficients of explanatory variables of logistic regression model to determine factors influencing avidity. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.

	Region							Fishing days		
	Central Metro	East Metro	NW Metro	Peel	SE Metro	South Metro	West Metro	Public Holiday	Normal weekday	Normal weekend
Avidity									0.93	

Null dev.	429.03	on 314 degrees of freedom
Residual dev.	421.87	on 306 degrees of freedom
AIC	439.87	

2.3.4. Catch preference

Target species

While relatively few of the 316 anglers reported focussing on West Australian dhufish and/or pink snapper (3% and 7%, respectively) as their main target fish species, approximately one quarter (24%) reported that they sought to catch a mix of reef fish species including West Australian dhufish or pink snapper (‘mixed’) (Table 2.4). About one third of the boat-based fishers (33%) reported that they intended to catch a fish species 'other' than West Australian dhufish or pink snapper while the remaining 33% had no particular target species. The species targeted by non-avid and avid fishers did not differ significantly (chi-square test: $P > 0.05$). Furthermore, there was no significant difference between the percentages of non-avid and avid fishers targeting West Australian dhufish and pink snapper compared to the percentages not targeting those species (*i.e.,* the combination of 'other', 'mixed' and 'no target') (chi-square test: $P > 0.05$).

Table 2.4 Numbers (and percentages) of recreational non-avid and avid anglers, who reported that, in their last fishing trip, they had targeted the specified 'target species'.

Target species	Non-avid	Avid	Total (n)
West Australian dhufish	7 (4%)	3 (2%)	**10 (3%)**
Pink snapper	9 (5%)	12 (9%)	**21 (7%)**
Other	63 (35%)	42 (31%)	**105 (33%)**
Mixed	42 (23%)	35 (26%)	**77 (24%)**
No target	61 (34%)	42 (31%)	**103 (33%)**
Total	100%	100%	**316**

The top five ranked species, which accounted for 68% of the total species targeted by recreational fishers, who were mainly aiming to catch a fish species other than West Australian dhufish or pink snapper during their last boat fishing trip, were: (1) whiting (Sillaginidae) (18%), (2) crabs/lobsters (Scylla spp. including *Portunus pelagicus*, and Palinuridae spp.) (18%), (3) mixed – inshore pelagic and demersal species (several families) (17%), (4) squid (Teuthoidea) (8%), and (5) mixed - inshore pelagic species (several families) (8%) (Table 2.5). Overall, a substantial percentage (18%, 19 fishers) of these fishers targeted large crustaceans (*i.e.* crabs/lobsters), of which the majority (10%, 11 fishers) were focussed towards 'crabs – unspecified' (Scylla spp.) (see Appendix E). A significantly greater number of non-avid fishers targeted these large crustaceans (chi-square test: $P < 0.01$) (Fig. 2.4).

Table 2.5 The numbers (and percentages) of non-avid and avid recreational anglers, who reported that, rather than targeting West Australian dhufish or pink snapper on their last fishing trip prior to the survey, they had targeted the specified species or species group.

Species/ species group	Non-avid	Avid	Total
Whiting	9 (14%)	10 (24%)	**19 (18%)**
Crabs / lobsters	17 (27%)	2 (5%)	**19 (18%)**
Mixed - Inshore pelagic and inshore demersal	11 (17%)	7 (17%)	**18 (17%)**
Squid	4 (6%)	4 (10%)	**8 (8%)**
Mixed - Inshore pelagic	5 (8%)	3 (7%)	**8 (8%)**
King George whiting	4 (6%)	1 (2%)	**5 (5%)**
Mackerels	2 (3%)	3 (7%)	**5 (5%)**
Bream	2 (3%)	2 (5%)	**4 (4%)**
Mixed - Offshore pelagic	2 (3%)	2 (5%)	**4 (4%)**
Mixed - Estuarine / riverine	0 (0%)	4 (10%)	**4 (4%)**
Australian herring	2 (3%)	0 (0%)	**2 (2%)**
Emperors	1 (2%)	1 (2%)	**2 (2%)**
Mixed - Offshore demersal	1 (2%)	1 (2%)	**2 (2%)**
Barramundi	1 (2%)	0 (0%)	**1 (1%)**
Sea perch/snappers	0 (0%)	1 (2%)	**1 (1%)**
Tailor	0 (0%)	1 (2%)	**1 (1%)**
Kingfish / samson fish	1 (2%)	0 (0%)	**1 (1%)**
Other - Finfish	1 (2%)	0 (0%)	**1 (1%)**
Total	**63**	**42**	**105**

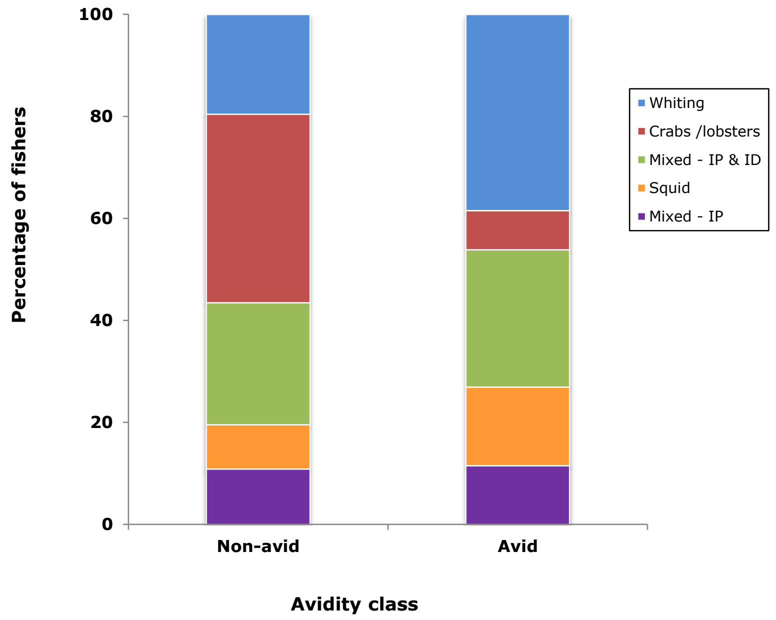


Figure 2.4 **The percentage of those non-avid and avid respondents, who had reported they were mainly aiming to catch a fish species 'other' than West Australian dhufish or pink snapper, who targeted each of the five principal taxa during the most recent boat fishing trip undertaken prior to the survey. 'Mixed – IP & ID' represents a mix of inshore pelagic and inshore demersal fish species, and 'Mixed IP' represents a mix of inshore pelagic species targeted.**

Species retained

Of the 316 recreational fishers interviewed, 282 (89%) reported that they were successful in catching fish on their last boat fishing trip. The most frequently retained taxa of marine finfish were: (1) whiting (including *Sillago* species and King George whiting *Sillaginodes punctata*), (2) trevally (Carangidae), (3) Australian herring (*Arripis georgianus*), (4) emperors (*Lethrinus spp.*), and (5) pink snapper. Substantial numbers (> 20 fish) of rock cods/gropers (Epinephelidae), West Australian dhufish, mackerels (Scombridae) and wrasse/tuskfish/gropers (Labridae) were also retained (Table 2.6). A wide diversity of other species was reported, including the estuarine species black bream (*Acanthopagrus butcheri*) and barramundi (*Lates calcarifer*), a native, freshwater/estuarine angling species of northern Australia (see Appendix F). Blue swimmer crabs, squid and cuttlefish

(Spirulidae) were also abundant in retained catches of interviewed boat fishers (Table 2.6, Appendix F).

Of the anglers interviewed, more than 70% retained finfish species on their last boat fishing trip (Fig. 2.5). Non-avid fishers were significantly more likely to have reported retained catches comprised of crabs/lobsters compared to the other taxa reported (*i.e.* finfish, small baitfish, prawns/yabbies and cephalopods), (chi-square test: $P < 0.01$).

Species released

The five most commonly released groups of marine finfish were: (1) emperors, (2) pink snapper, (3) wrasse/tuskfish/gropers, (4) rock-cod/gropers, and (5) trevally. Considerable numbers (> 10 fish), *i.e.* given the low survey sample size, of whiting, West Australian dhufish, sharks/rays and Australian herring were also released. Blue swimmer crabs was the most commonly-released non-fish species, followed by squid and cuttlefish (Table 2.7, Appendix G).

Of the anglers interviewed, more than 75% of recreational fishers released finfish species during their last boat fishing trip (Fig. 2.8). Similar to the trend for retained catch, non-avid fishers were significantly more likely to have released catches comprised of crabs/lobsters compared to the other taxa reported (chi-square test: $P < 0.01$) (Fig. 2.6).

Table 2.6 **Numbers of individual fish of each taxa retained by non-avid and avid recreational fishers from the catches made in the most recent boat fishing trip that was undertaken prior to the survey.**

Species/ species group	Non-avid	Avid	Total
Whiting	24	19	**43**
Trevally	23	13	**36**
Australian herring	23	11	**34**
Emperors	19	15	**34**
Pink snapper	15	16	**31**
Rock-cod/ gropers	13	15	**28**
West Australian dhufish	14	11	**25**
King George whiting	15	10	**25**
Mackerels	10	14	**24**
Wrasse/ tuskfish/gropers	12	9	**21**
Sea perch/ snappers	5	8	**13**
Tuna/ bonitos	3	7	**10**
Bream	2	6	**8**
Coral trout	5	3	**8**
Tailor	5	3	**8**
Garfish	3	1	**4**
Morwong	4	0	**4**
Sharks/ rays	0	4	**4**
Mulloway/ jewfish	0	3	**3**
Leatherjackets	2	0	**2**
Kingfish/ samson fish	0	2	**2**
Drummer	0	1	**1**
Mullet	1	0	**1**
Pike	0	1	**1**
Red mullet	0	1	**1**
Redfish	1	0	**1**
Sweep	1	0	**1**
Threadfin salmon	0	1	**1**
Barramundi	1	0	**1**
Other	4	3	**7**
Small herring/ pilchards	5	2	**7**
Small baitfish	0	1	**1**
Blue swimmer crab	26	4	**30**
Squid/ cuttlefish	16	11	**27**
Mud crab	1	1	**2**
Lobsters	1	0	**1**
Prawns	1	0	**1**
Total	**255**	**196**	**451**

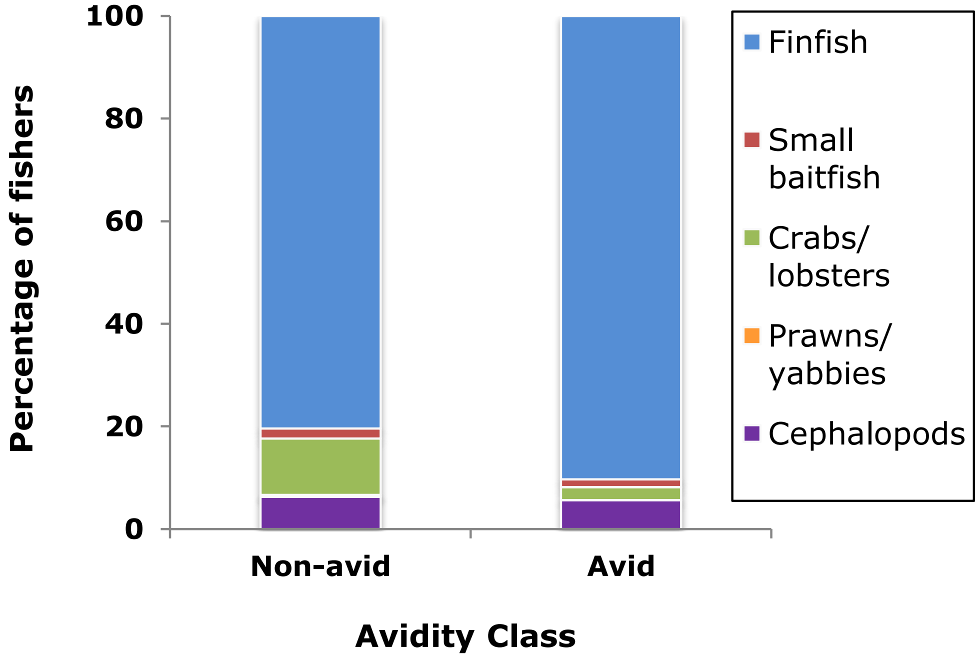


Figure 2.5 **Percentages of non-avid and avid recreational boat fishers who reported the following taxa in the retained catches from their last boat-based fishing trip.**

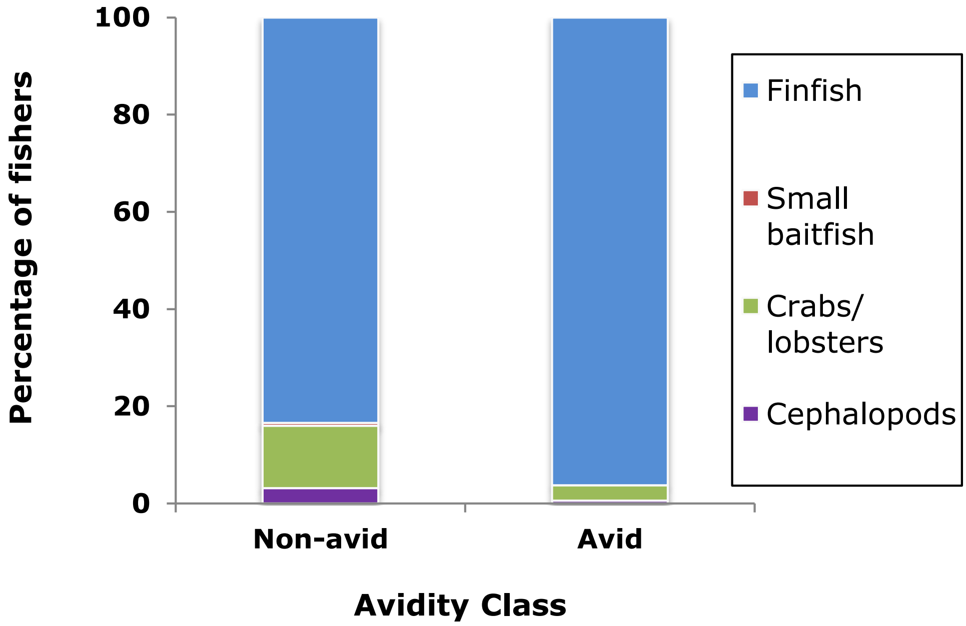


Figure 2.6 **Percentages of non-avid and avid recreational boat fishers who reported the following taxa in the released catches from their last boat-based fishing trip.**

Table 2.7 **The numbers of fish within the different taxa that were released by non-avid and avid recreational fishers from the catches made in the most recent boat fishing trip that was undertaken prior to the survey.**

Species/ species group	Non-avid	Avid	Total
Emperors	15	15	**30**
Pink snapper	16	14	**30**
Wrasse/ tuskfish/ gropers	17	11	**28**
Rock-cod/ gropers	9	14	**23**
Trevally	12	8	**20**
Whiting	8	11	**19**
West Australian dhufish	7	11	**18**
Sharks/ rays	8	7	**15**
Australian herring	9	5	**14**
King George whiting	13	1	**14**
Bream	3	8	**11**
Mackerels	5	6	**11**
Sea perch/ snappers	2	5	**7**
Coral trout	4	2	**6**
Butterfish	2	2	**4**
Flathead	3	1	**4**
Tuna/bonitos	2	2	**4**
Kingfish/ samson fish	0	4	**4**
Leatherjackets	2	1	**3**
Red mullet	0	2	**2**
Scorpionfish/ gurnard	0	2	**2**
Catfish	0	1	**1**
Drummer	0	1	**1**
Garfish	0	1	**1**
Pike	0	1	**1**
Redfish	1	0	**1**
Sweep	0	1	**1**
Tailor	1	0	**1**
Barramundi	1	0	**1**
Other	16	15	**31**
Small baitfish	1	0	**1**
Blue swimmer crab	23	4	**27**
Squid/ cuttlefish	6	1	**7**
Mud crab	0	1	**1**
Lobsters	1	0	**1**
Total	**187**	**158**	**345**

Reasons for release

The principal five reasons why the recreational boat anglers released fish from the different taxa were: (1) fish were undersized, *i.e.* below the minimum legal length for capture and retention (48%, 165 fishers), (2) too small due to a personal preference by the angler and not related to fishery regulations (17%, 59 fishers), (3) too many and thus not wanted (12%, 40 fishers), (4) 'other' - poor eating (10%, 36), and (5) catch and release fishing (5%, 17 fishers) (Table 2.8). The majority of fishers (95%) gave only a single response (from several alternatives) explaining why they had released fish that they had caught on their last boat fishing trip. Almost half of non-avid and avid anglers reported fish being "undersized (below legal limit)" as their primary reason for release. Avid anglers were also significantly more likely (chi-square test: $P < 0.01$) than non-avid anglers to have released a fish species due both to their greater ability to catch fish (thus exceeding the BL, *i.e.* daily allowable boat limit) and their greater use of catch-and-release fishing whilst on their last boat fishing trip. It should be noted that, as each fisher was able to enter more than one reason for releasing each (up to ten) species and the table reports only numbers (and percentages) of the top five reasons that were provided, the total numbers of fishers of each category reported in Table 2.8 do not match the number of fishers who were interviewed.

Table 2.8 **The numbers (and percentages) of interviewed non-avid and avid fishers who had reported that they had released fish because of one of the five principal reasons for release.**

Reasons for release	**Non-avid**	**Avid**	**Total**
Undersized (below legal limit)	92 (54%)	73 (50%)	**165**
Too small (personal preference)	37 (22%)	22 (15%)	**59**
Too many (didn't want/need)	15 (9%)	25 (17%)	**40**
Other - poor eating quality	22 (13%)	14 (10%)	**36**
Catch and release fishing	5 (3%)	12 (8%)	**17**
Total	**100%**	**100%**	**317**

Satisfaction

The majority (> 90%) of recreational fishers strongly agreed or agreed with the statement that their last boat fishing trip had been successful, with no significant difference between non-avid and avid anglers (chi-square test: $P > 0.05$) (Fig. 2.7).

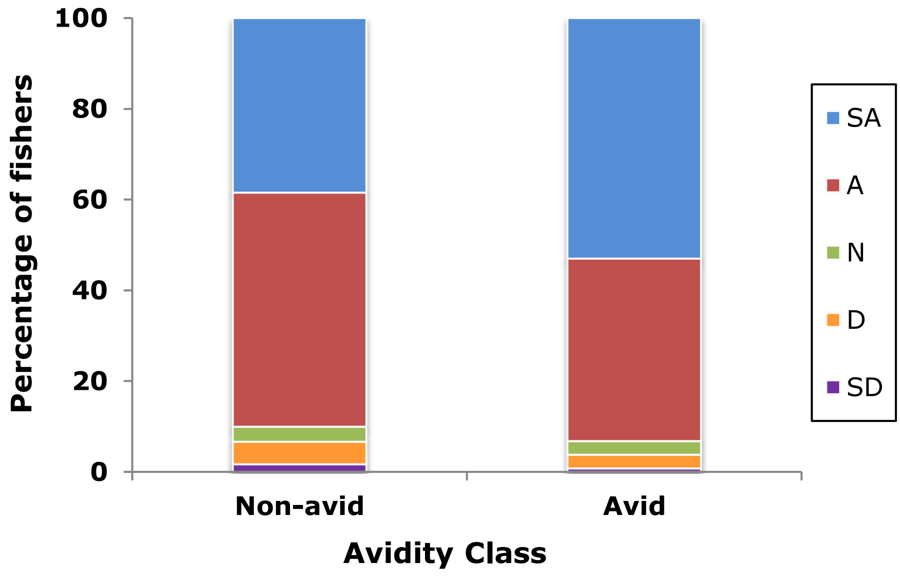


Figure 2.7 **Percentages of non-avid and avid interviewed recreational fishers, who strongly agreed (SA), agreed (A), were neutral (N), disagreed (D) or strongly disagreed (SD) that their last boat fishing trip was successful.**

2.3.5. Motives for fishing

The majority of both non-avid and avid recreational boat fishers reported the following factors as being important motivations (*i.e.* very important or quite important) for going fishing: "to be outdoors" (both 96%) and "to relax and unwind" (88% and 96%, respectively), "for the enjoyment or sport of catching fish" (86% and 91%, respectively), "to catch fresh fish for food" (83% and 85%, respectively) and "to spend time with friends" (84% and 88%, respectively) and "family" (79% and 78%, respectively) (Table 2.9). Less than a quarter of both non-avid and avid anglers (20% and 22%, respectively) identified the need to get away from people ("to be on your own") as important, and only a very small percentage of non-avid (3%) and avid (8%) fishers considered "competing in fishing tournaments" as an important motive for going fishing (Table 2.9). There was no significant difference between the percentages of non-avid vs avid anglers and the importance (*i.e.* very or quite important vs not very or not at all important) attributed to each motivation for going fishing, (chi-square test: $P > 0.05$).

The results of the logistic regression analyses suggest that relaxation and fishing for the enjoyment and the sport of catching fish were significantly more important (logistic regression: $P < 0.05$) for avid fishers than for non-avid fishers (Table 2.10). Anglers between the ages of 30-59 y were also more likely to go fishing for relaxation (logistic regression: $P < 0.05$) and to be outdoors (logistic regression: $P < 0.10$). Female anglers were also more likely to be motivated to go fishing to spend time with family (logistic regression: $P < 0.05$), whilst male anglers were more likely to go fishing to catch fresh fish for food (logistic regression: $P < 0.10$) (Table 2.10).

Table 2.9 **Importance of different factors to recreational boat anglers as motives for going fishing. Numbers outside of brackets refer to actual numbers of surveyed fishers.**

Motivation	Importance rating				
	Very	Quite	Not very	Not at all	Total
a. *Relax and unwind*					
Non-avid	99 (54%)	61 (34%)	19 (10%)	3 (2%)	**100%**
Avid	82 (61%)	46 (34%)	5 (4%)	1 (1%)	**100%**
b. *To be outdoors*					
Non-avid	105 (58%)	70 (38%)	4 (2%)	3 (2%)	**100%**
Avid	86 (64%)	42 (31%)	6 (4%)	0 (0%)	**100%**
c. *For solitude*					
Non-avid	16 (9%)	21 (12%)	70 (38%)	75 (41%)	**100%**
Avid	10 (7%)	19 (14%)	54 (40%)	51 (38%)	**100%**
d. *To be with family*					
Non-avid	78 (43%)	65 (36%)	27 (15%)	12 (7%)	**100%**
Avid	51 (38%)	54 (40%)	16 (12%)	13 (10%)	**100%**
e. *To be with friends*					
Non-avid	77 (42%)	75 (41%)	20 (11%)	10 (5%)	**100%**
Avid	63 (47%)	55 (41%)	12 (9%)	4 (3%)	**100%**
f. *Fishing competitions*					
Non-avid	1 (1%)	5 (3%)	37 (20%)	139 (76%)	**100%**
Avid	6 (4%)	5 (4%)	28 (21%)	95 (71%)	**100%**
g. *Fish for sport*					
Non-avid	90 (49%)	67 (37%)	15 (8%)	10 (5%)	**100%**
Avid	75 (56%)	47 (35%)	10 (7%)	2 (1%)	**100%**
h. *Fish for food*					
Non-avid	106 (58%)	45 (25%)	23 (13%)	8 (4%)	**100%**
Avid	77 (57%)	37 (28%)	18 (13%)	2 (1%)	**100%**

Table 2.10 **Coefficients of explanatory variables of logistic regression model to determine factors influencing importance values attributed to motivational items. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Gender		Region							Age					Waters fished			
	Male	Female	Central Metro	East Metro	NW Metro	Peel	SE Metro	South Metro	West Metro	18-29 y	30-44 y	45-59 y	60-74 y	75-99 y	Saltwater	Freshwater	Both	**Avidity**
To relax or unwind											**2.05**	**1.81**						**2.10**
To be outdoors											1.96	1.86						
To be on your own	**-2.20**																	
To spend time with family		**2.59**																
To spend time with friends					1.18			**1.16**										
To compete in competitions																		
For enjoyment or sport				1.46				**1.28**										**1.15**
To catch fish for food	1.54			**-1.59**													-0.70	

Null dev.	188.97	on 314 degrees of freedom
Residual dev.	159.00	on 298 degrees of freedom
AIC	193	

2.3.6. Gear and methods

Boat ownership

Of the 316 recreational fishers interviewed, the majority (71%) stated that they owned their own fishing boat. Note, a small sample of fishers (11%, 21 fishers), who were no longer fishing or did not own a boat, were deemed "out of scope" and had been excluded from the telephone survey. The level of boat ownership was significantly greater among avid fishers (78%) than non-avid fishers (66%) (chi-square test: $P < 0.05$) (Fig. 2.8).

Most non-avid and avid fishers (69%) reported that the size of their fishing boat was < 5 m in length, with no significant difference found between non-avid and avid fishers having a larger boat of more than 5 m in length (chi-square test: $P > 0.05$) (Fig. 2.9).

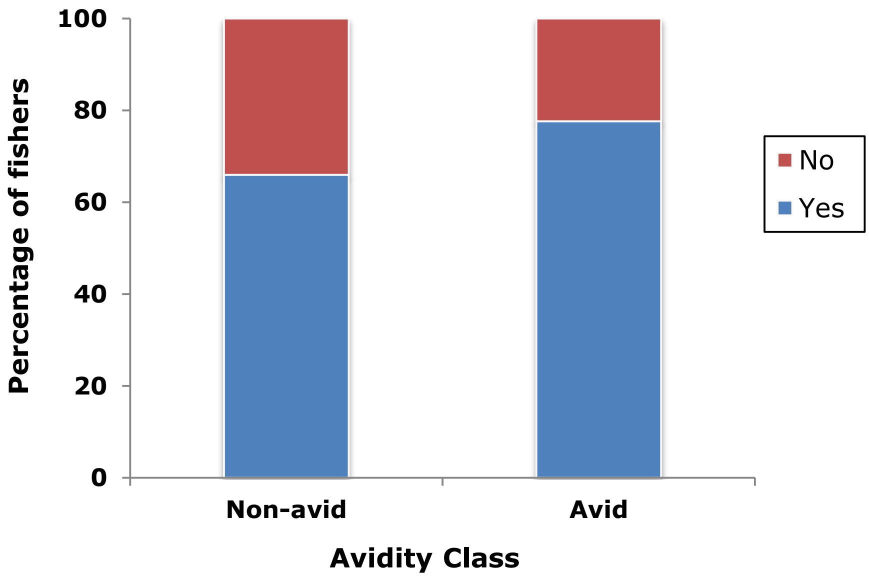


Figure 2.8 Percentages of non-avid and avid fishers who owned a boat for the purpose of fishing.

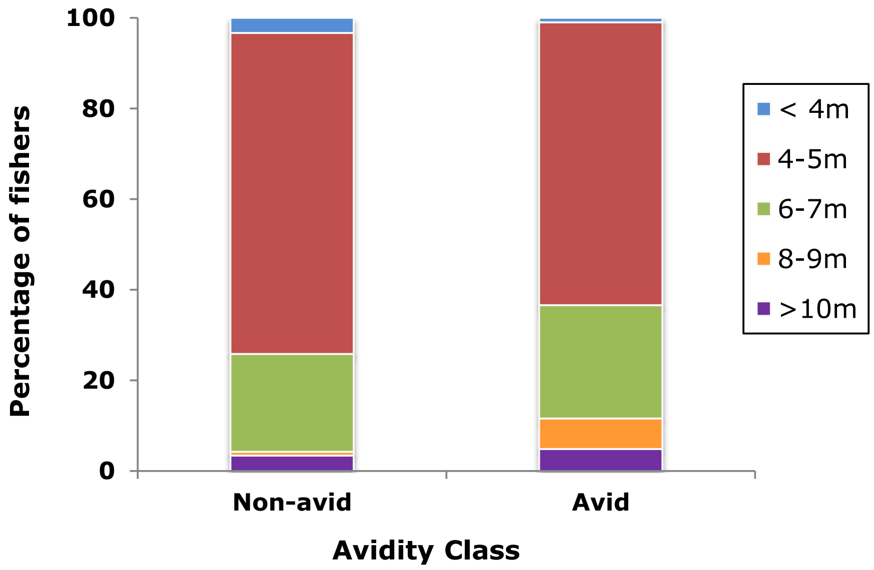


Figure 2.9 **Percentages of non-avid and avid fishers who reported that the boat they owned was < 4, 4-5, 6-7, 8-9 or > 10 m in length**

Use of technology

Of the 224 (71%) fishers who stated they owned a boat (see above, Fig. 2.8), just over half (58%) reported having a global positioning system (GPS). More than half of non-avid and avid boat fishers owned a GPS (66 (63%) and 63 (53%), respectively) and these GPS ownership levels did not differ significantly (chi-square test: $P > 0.05$).

The majority (72%) of fishers who owned a GPS answered "yes" to storing fishing locations in that device. A significantly greater percentage of avid fishers stored fishing locations in their GPS (83%) than did non avid fishers (60%) (chi-square test: $P < 0.01$). Of the fishers who had fishing locations stored in their GPS, most (41%) stored between 5-24 locations (Fig. 2.10). The percentage of non-avid vs avid fishers, who had stored ≥ 25 fishing locations in their global positioning system (GPS), also differed significantly (chi-square test: $P < 0.05$), with avid fishers more likely to store greater numbers of such fishing locations.

Most fishers reported visiting their best/favourite fishing locations either once or 3-4 times during the past 12 months (26% and 29%, respectively) (Fig. 2.11). The percentage of non-avid fishers who reported having visited their best/favourite fishing locations five or more times during the past 12 months differed significantly (chi-square test: $P < 0.05$) from that of avid fishers (Fig. 2.11). Note that, while avid fishers were found to have visited their favourite locations on a greater number of occasions, the use of frequency of fishing as a measure of avidity means that there were more opportunities for avid fishers to visit their favourite locations than for non-avid fishers, *i.e.* the variables are confounded.

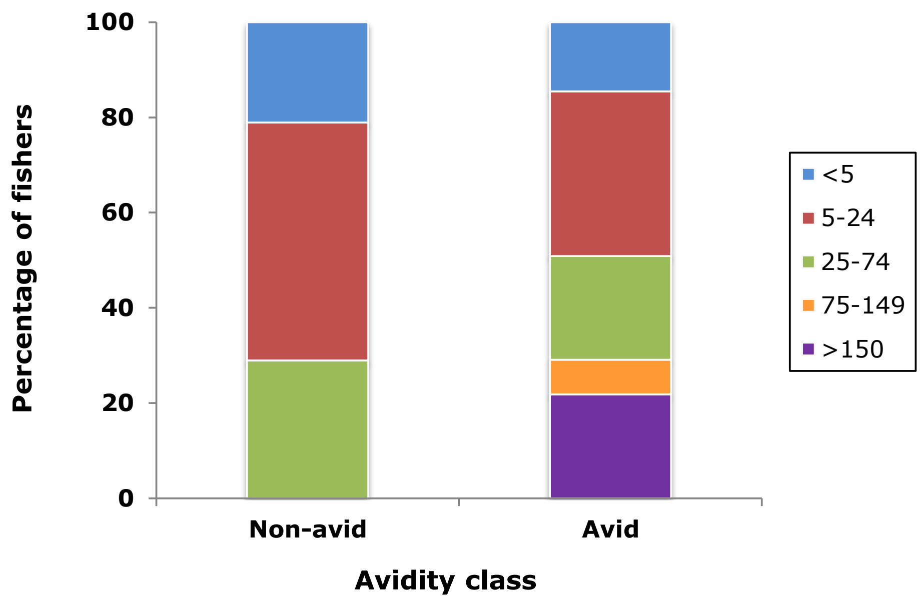


Figure 2.10 **Percentages of interviewed non-avid and avid recreational boat anglers, who owned a boat with a GPS, with different numbers of locations stored on their GPS system.**

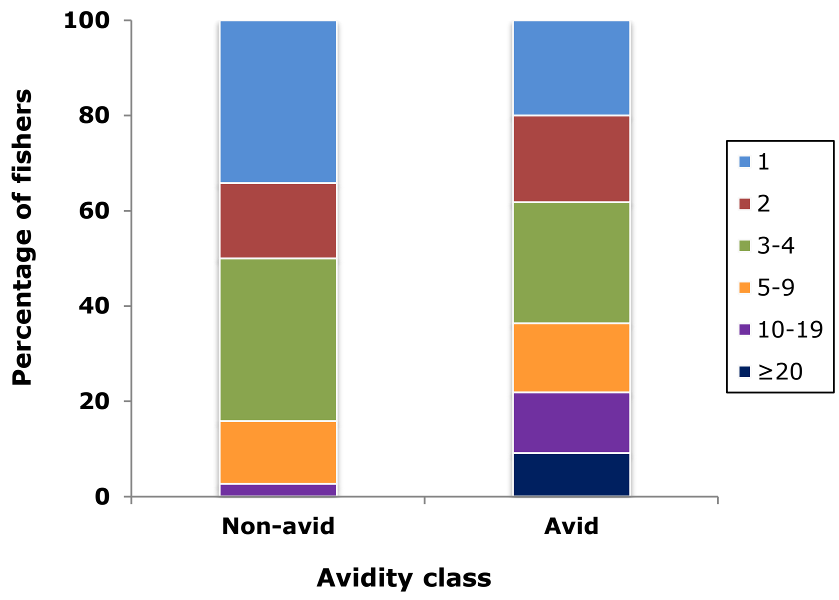


Figure 2.11 **Percentages of interviewed non-avid and avid recreational boat anglers, who reported having visited their best/favourite fishing locations 1, 2, 3-4, 5-9, 10-19, ≥ 20 times during the past 12 months.**

Fishing gear

In total, the 316 interviewed anglers reported having spent a total of 1165 h fishing on the last trip, with an average of 3.7 h per trip. The use of rods and lines accounted for 970 (83%) of the total number of fishing hours (Fig. 2.12). Significantly, crabbing was more popular among less avid fishers (chi-square test: $P < 0.01$). Note also, however, that as crabbing is seasonal, this result would likely differ depending on the timing of the survey.

Among those fishers who owned a boat and a GPS, it was found that those anglers who reported that they fish in deeper waters and place a high importance on fishing for the purposes of relaxation, and who reported targeting of estuarine species, are more likely to be avid (logistic regression: $P < 0.05$) (Table 2.11). Furthermore, those fishers who owned a boat and a GPS, and who have reported that they fish more frequently in the year, undertake fishing trips extending over durations of 4-5 or 6-7 h, and are less motivated to go fishing with family, are also more likely to fish further offshore (Table 2.12).

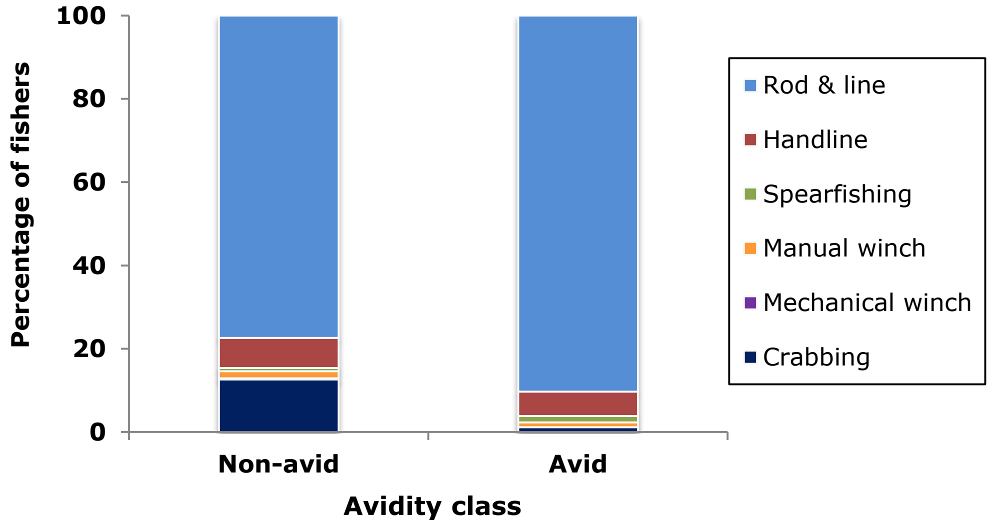


Figure 2.12 **Percentages of total fishing effort (hours) for non-avid and avid recreational boat anglers reported to have employed each of six different fishing methods.**

Table 2.11 **Coefficients of explanatory variables of logistic regression model to determine factors influencing avidity for fishers who owned a boat and GPS unit. ID, inshore demersal; OD, offshore demersal; IP & ID, a mix of inshore pelagic and inshore demersal; IP, inshore pelagic; and OP, offshore pelagic fish species. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Gender		Age					Depth fished	Motivations								Target											Fishing hours						
	Male	Female	18-29 y	30-44 y	45-59 y	60-74 y	75-99 y		Relaxation	Outdoors	Solitude	Family	Friends	Tournaments	Sport	Food	Dhufish	Snapper	Other	Mix Reef	No Target	Estuarine	ID	OD	IP&D	IP	OP	<2 h	2-3 h	4-5 h	6-7 h	8-9 h	10-11 h	>12 h
Avidity								0.65	1.38													3.08												

Null dev.	308.13	on 222 degrees of freedom
Residual dev.	259.79	on 185 degrees of freedom
AIC	335.79	

Table 2.12 **Coefficients of explanatory variables of logistic regression model to determine factors influencing the depth of fishing for fishers that owned a boat and GPS unit. ID, inshore demersal; OD, offshore demersal; IP & ID, a mix of inshore pelagic and inshore demersal; IP, inshore pelagic; and OP, offshore pelagic fish species. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Waters fished			Platform			Days fished					Duration best site							Duration new site							Fishing Hours							Motivations								Target										
	Saltwater	Freshwater	Both	Shore	Boat	Both	<5 d	5-9d	10-14 d	15-19 d	>20 d	<5 min	5-9 min	10-1 4min	15-19 min	20-29 min	30 min-1 h	Never	<5 min	5-9 min	10-1 4min	15-19 min	20-29 min	30 min-1 h	Never	<2 h	2-3 h	4-5 h	6-7 h	8-9 h	10-11 h	>12 h	Relaxation	Outdoors	Solitude	Family	Friends	Tournaments	Sport	Food	Dhufish	Snapper	Other	Mix Reef	No Target	Estuarine	ID	OD	IP&D	IP	OP
Depth of Fishing									**1.28**	1.31	1.10																	**1.62**	**2.91**							-0.99															

Null dev.	302.29	on 222 degrees of freedom
Residual dev.	200.95	on 180 degrees of freedom
AIC	286.95	

Fishing methods

During their most recent fishing trip, prior to the survey, the majority (68%) of boat anglers 'drift fished'. Thirty seven percent of those fishers who 'drift fished' reported using a sea anchor (also known as a drift anchor or drift sock) (Table 2.13). Nineteen (6%) fishers reported using 'other' fishing methods, including trawling and trolling, and using motor power. It should be noted that the terms "trawling" and "trolling" may have been confused in the telephone interview.

The method of drift fishing (with or without a sea anchor) was favoured by both non-avid and avid recreational fishers (Fig. 2.13).

Table 2.13 **Numbers and percentages of recreational boat fishers reported using five specified fishing methods during their last boat fishing trip. Note that each fisher may have reported the use of one or more fishing methods.**

	Sand anchor	Reef anchor/ reef pick	Drift fishing using a sea anchor	Drift fishing, no sea anchor	Other
Yes	89 (28%)	36 (11%)	79 (25%)	136 (43%)	19 (6%)
No	227 (72%)	280 (89%)	237 (75%)	180 (57%)	297 (94%)

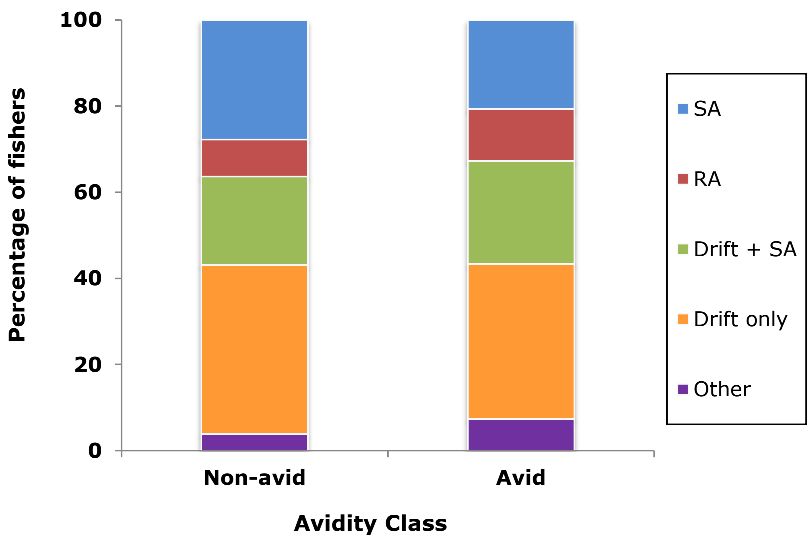


Figure 2.13 **Percentages of methods reported to have been used by non-avid and avid anglers during their most recent fishing trip. SA, sand anchor; RA, reef anchor or reef pick; Drift + SA, drift fishing using a sea anchor; Drift only, drift fishing without using a sea anchor.**

Fishing depths

More than half (55%) of the respondents had fished in < 15 m of water on their last fishing trip (Fig. 2.14). The percentages of non-avid vs avid fishers, who fished in water depths of ≥ 25 m, did not differ significantly (chi-square test: $P > 0.05$).

Anglers who fish more often in the year and undertake fishing trips that are 4-5 or 6-7 h in duration were more likely to fish in deeper, presumably offshore water (Table 2.14). Anglers who least targeted pink snapper, estuarine and inshore species (including demersal and pelagic species) but who had a target other than these species groups were also likely to fish in deeper water. Furthermore these anglers were more likely to fish in deeper water if they were motivated by sport and competing in fishing tournaments and place less importance on fishing to enjoy a family experience (Table 2.15).

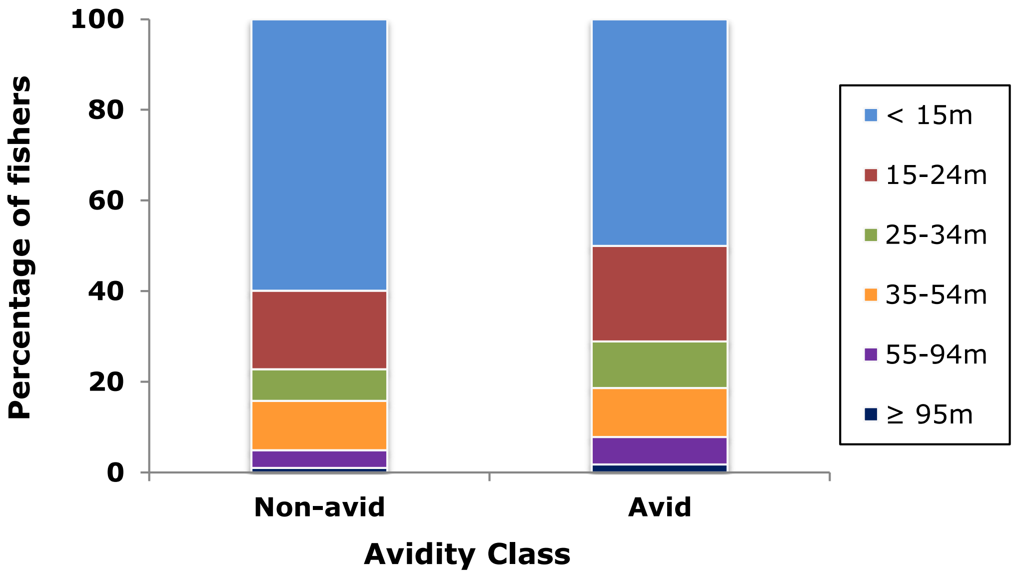


Figure 2.14 **Percentages of different depth ranges fished by interviewed anglers within each avidity class, during their last boat fishing trip.**

Table 2.14 **Coefficients of explanatory variables of logistic regression model to determine factors influencing depth of fishing. ID, inshore demersal; OD, offshore demersal; IP & ID, a mix of inshore pelagic and inshore demersal; IP, inshore pelagic; and OP, offshore pelagic fish species. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Waters fished			Platform				Days fished					Duration best site							Duration new site							Fishing hours							Motivations								Target										
	Saltwater	Freshwater	Both	Shore	Boat	Both	**Avidity**	<5 d	5-9 d	10-14 d	15-19 d	>20 d	<5 min	5-9 min	10-1 4min	15-19 min	20-29 min	30 min-1 h	Never	<5 min	5-9 min	10-1 4min	15-19 min	20-29 min	30 min-1 h	Never	<2 h	2-3 h	4-5 h	6-7 h	8-9 h	10-11h	>12 h	Relaxation	Outdoors	Solitude	Family	Friends	Tournaments	Sport	Food	Dhufish	Snapper	Other	Mix Reef	No Target	Estuarine	ID	OD	IP&D	IP	OP
Depth of Fishing										**1.22**	1.01	**0.96**																	**1.68**	**2.54**																						

Null dev.	427.93	on 313 degrees of freedom
Residual dev.	357.07	on 287 degrees of freedom
AIC	411.07	

Table 2.15 **Coefficients of explanatory variables of logistic regression model to determine factors influencing depth of fishing. ID, inshore demersal; OD, offshore demersal; IP & ID, a mix of inshore pelagic and inshore demersal; IP, inshore pelagic; and OP, offshore pelagic fish species. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Motivations								**Target**														
	Relaxation	Outdoors	Solitude	Family	Friends	Tournaments	Sport	Food	Dhufish	Snapper	Other	Mix Reef	No Target	Estuarine	ID	OD	IP&ID	IP	OP
Depth of Fishing				-0.53		1.07	0.79			**-2.48**			**-2.82**	**-4.28**	**-3.31**		**-2.81**	**-4.18**	

Null dev.	427.93	on 313 degrees of freedom
Residual dev.	357.41	on 295 degrees of freedom
AIC	395.41	

2.3.7. Commitment and movements

Movements between fishing locations

More than half (54%) of the interviewed anglers stated that they would not move from their best/favourite fishing location for 30 min – 1 h, while not getting any 'good' bites (*i.e.* bites from a fish likely to be big enough that anglers would be likely to keep the fish if it was caught) (Fig. 2.15). Of the remaining fishers, almost all would have moved after less time, usually sometime between 10 and 29 min.

The percentages of non-avid vs avid fishers who would stay at their best/favourite fishing location for ≥ 30 min differed significantly (chi-square test: $P < 0.05$), with avid fishers showing a greater willingness to stay for a longer period. Similar results were also reported for a newly-found fishing location as those described previously for a best/favourite fishing location (Fig. 2.16). The percentages of non-avid vs avid fishers, who would stay at a newly discovered fishing location for ≥ 30 min, did not differ significantly ($P = 0.76$), however.

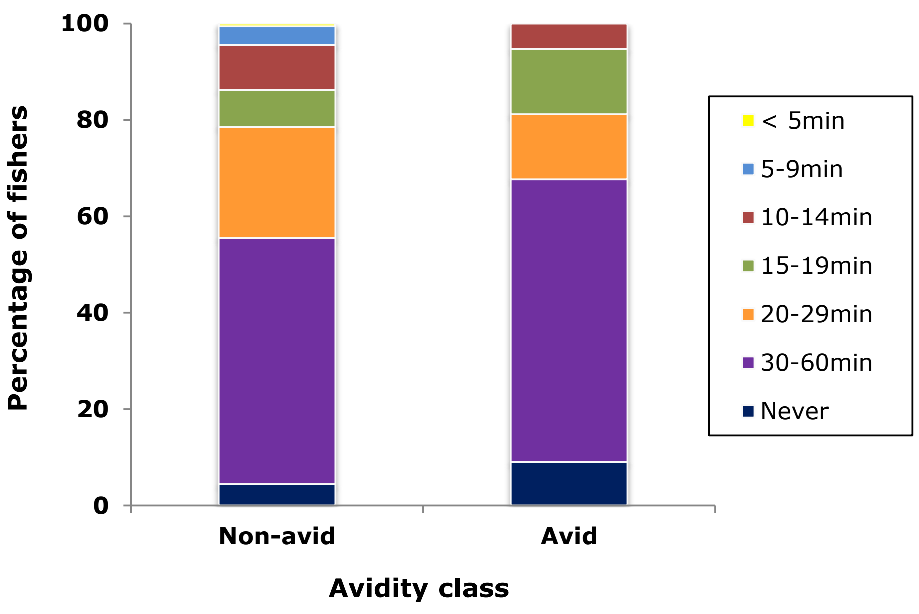


Figure 2.15 Percentage of non-avid and avid fishers, who would stay at their best/favourite fishing location for < 5, 5-9, 10-14, 15-19, 20-29, 30-60 min, or never move when not getting any 'good' fish bites.

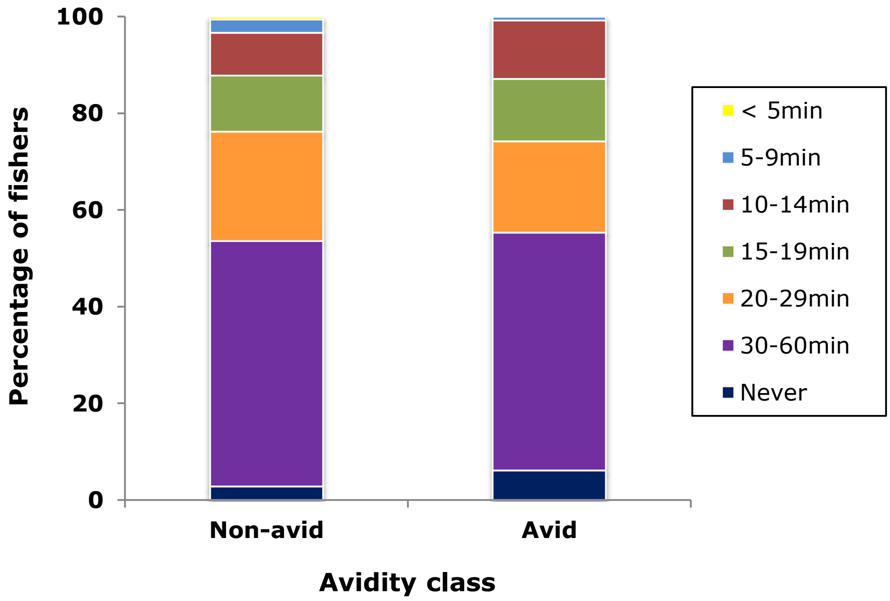


Figure 2.16 **Percentage of non-avid and avid fishers, who would stay at a newly discovered fishing location for < 5, 5-9, 10-14, 15-19, 20-29, 30-60 min, or never move when not getting any 'good' fish bites.**

Travel

More than half of the interviewed anglers (52%) reported travelling < 5 km from the boat ramp/pen (during their last boat fishing trip) (Fig. 2.17). The percentages of non-avid vs avid fishers, who travelled ≥ 20 km to their first fishing location during their last boat fishing trip, did not differ significantly (chi-square test: $P > 0.05$), however.

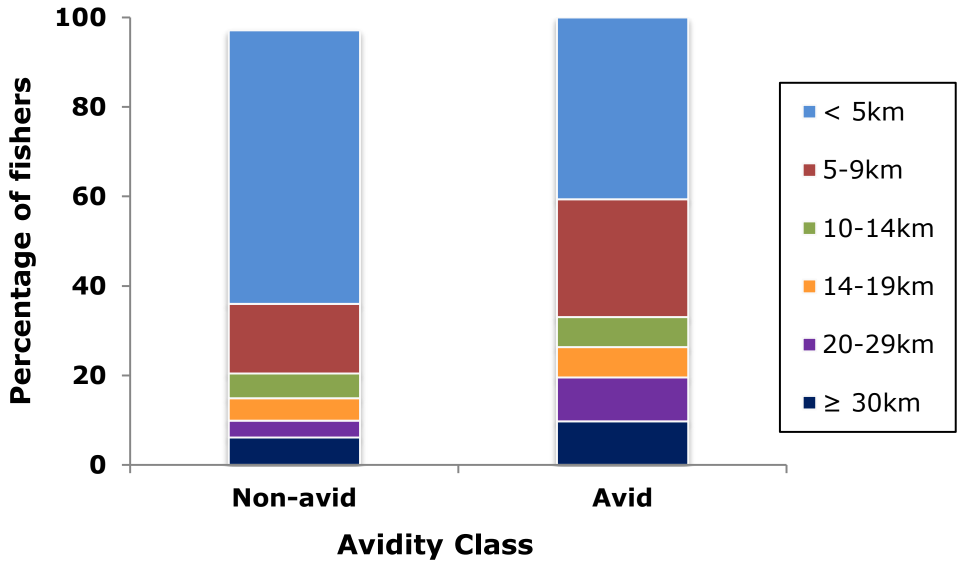


Figure 2.17 Percentage of non-avid and avid fishers, who travelled < 5, 5-9, 10-14, 14-19, 20-29 or ≥ 30 km to their first fishing location during their last boat fishing trip.

Fishing locations

Half of the anglers fished at only 1-2 fishing locations on their last boat-based fishing trip (Fig. 2.18) and a further 30% fished at 3-4 locations. Of the 207 anglers (66%) who reported that they had fished at more than one fishing location during their last boat-based fishing trip, about half (52%, 107 fishers) had moved between 1-3 km between their first and second fishing locations (Fig. 2.19). These distances travelled between the first and second fishing location did not differ significantly between non-avid and avid fishers (chi-square test: $P > 0.05$).

The greatest distance travelled between any one fishing location and the next (for those anglers who had fished at more than one location during their last trip) was 1-3 km for about half of such non-avid and avid anglers (53%, 110 fishers) (Fig. 2.20).

For all fishers, the main reason specified for their greatest move between fishing locations was "they weren't catching any fish" (66%, 137 fishers) (Table 2.16). Of the 12 (6%) fishers who responded that their furthest move between successive fishing locations was for 'other' reasons, responses included "just deciding to try a different spot" and 'they had been trolling and were exploring fishing locations'. A full list of the reasons provided by these 12 fishers is provided in Appendix H.

The primary reasons that anglers decided to head home at the end of their last boat fishing trip were: (1) because they had been out on the water all day and it was getting late (37%, 117 fishers), (2) had obtained their catch/bag limit (24%, 76 fishers), and (3) had commitments at home to which they had to return (13%, 42 fishers) (Table 2.17). The results did not differ significantly between avid and non-avid anglers for each of these primary reasons (as specified above) that anglers had specified as the basis of their decision to head home at the end of their last boat fishing trip (chi-square tests: $P > 0.05$). Of the 17 (5%) fishers who responded that they had returned home for 'other' reasons, those reasons included 'returning home for medical reasons', 'running out of fuel, bait or air in dive tanks' or 'had caught enough fish for a meal'. See Appendix I for a full summary.

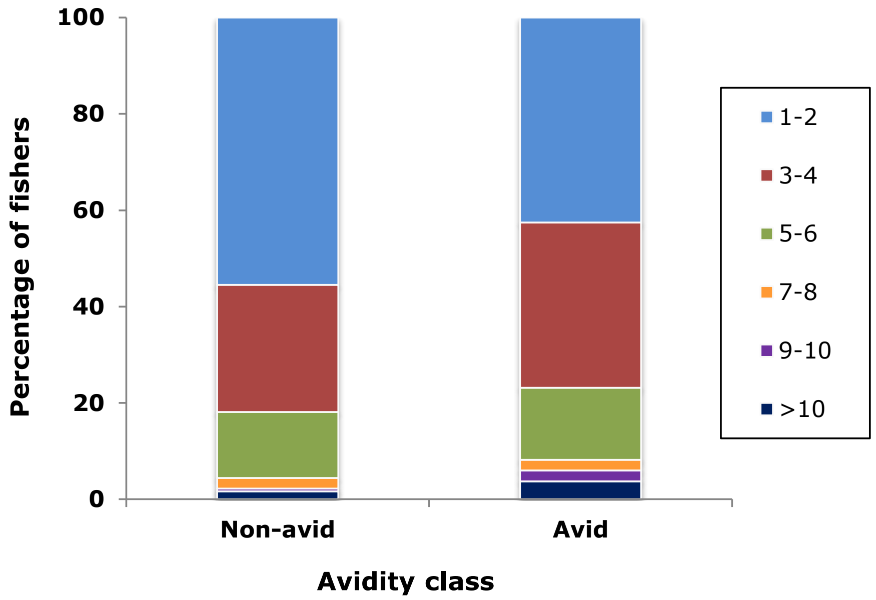


Figure 2.18 Percentages of non-avid and avid fishers, who fished 1-2, 3-4, 5-6, 7-8, 9-10 or > 10 fishing locations during their last boat fishing trip.

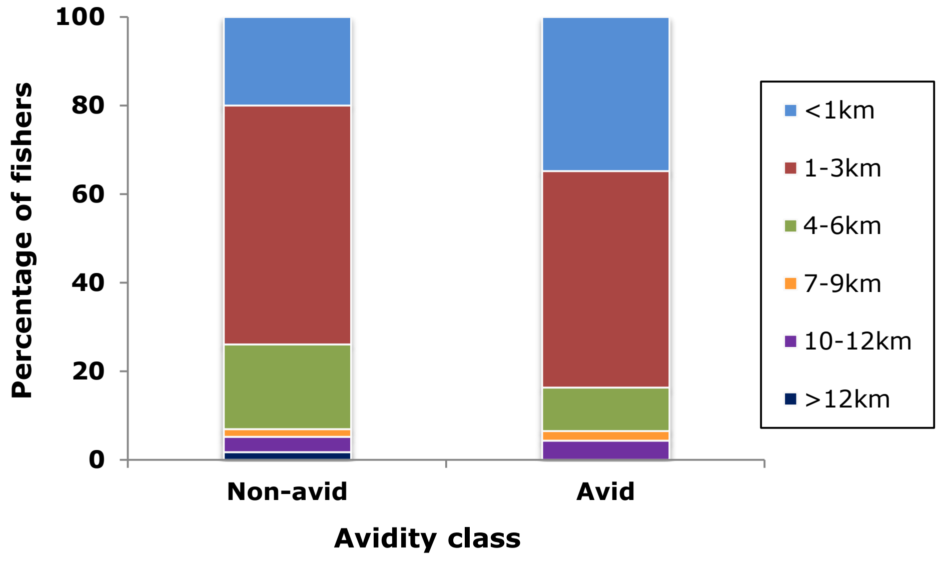


Figure 2.19 Percentage of non-avid and avid fishers, who travelled < 1, 1-3, 4-6, 7-9, 10-12 or > 12 km between their first and second fishing locations, during their last boat fishing trip.

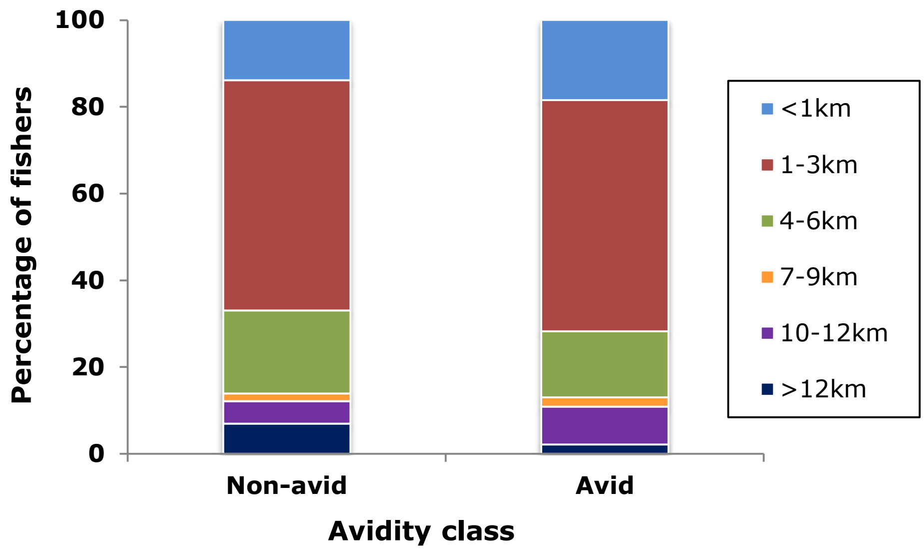


Figure 2.20 Percentage of fishers within each avidity class, for which the greatest travelled distance between any one fishing location and the next last during their last boat fishing trip was < 1, 1-3, 4-6, 7-9, 10-12 or > 12 km.

Table 2.16 Reasons why, during their last boat fishing trip, non-avid and avid recreational fishers undertook their greatest movement between successive fishing locations. Numbers outside brackets refer to actual numbers of surveyed fishers.

Reasons for travelling the furthest between fishing locations	Non-avid	Avid	Total
You weren't catching any fish.	79 (69%)	58 (63%)	**137**
You obtained your catch/bag limit for the fish species you were targeting and decided to target a different fish species somewhere else.	12 (10%)	10 (11%)	**22**
You decided to travel to one of your favourite fishing locations, which happened to be a long distance from where you had been fishing.	20 (17%)	14 (15%)	**34**
You were heading home and decided to stop to fish at a location along the way.	9 (8%)	10 (11%)	**19**
The weather turned rough, so you headed to a fishing spot in more sheltered locations/closer to shore.	11 (10%)	11 (12%)	**22**
The weather became calm, so you decided to try a fishing spot further offshore.	6 (5%)	3 (3%)	**9**
Other	4 (3%)	8 (9%)	**12**

Table 2.17 Reasons why non-avid and avid recreational fishers decided to head home at the end of their last boat fishing trip. Numbers outside brackets refer to actual numbers of surveyed fishers.

Reasons to head home	Non-avid	Avid	Total (n)
You obtained your catch/bag limit.	51 (28%)	25 (19%)	**76**
You weren't catching any fish.	117 (9%)	9 (7%)	**26**
You had been on the water all day/ getting late.	65 (36%)	52 (39%)	**117**
The weather turned bad.	19 (10%)	13 (10%)	**32**
You had commitments at home.	15 (8%)	27 (20%)	**42**
You weren't catching your target fish.	4 (2%)	2 (1%)	**6**
Other	11 (6%)	6 (4%)	**17**

Weather influences

Almost half of the interviewed fishers (41%, 129 fishers) reported that they would not travel more than 9 km offshore if the weather was fine and the water was flat calm (Fig. 2.21). A substantial number of anglers (26%, 83 fishers), however, reported that in such conditions they would travel > 30 km. A significantly greater proportion of avid vs non-avid fishers indicated that they would travel ≥ 20 km offshore if the weather was fine and the water was flat calm (chi-square test: $P < 0.01$).

Over half (52%) of respondents would cancel a boat fishing trip if the forecasted wind strength was moderate (11-16 knots or 20-29 km/h). Avid fishers were least likely (58%) to cancel a boat fishing trip if the forecast wind strength was moderate (Table 2.18). The majority of fishers (65%) responded that, given a moderate wind strength forecast, they would fish close to shore, *i.e.* < 5 km offshore. Of these fishers, however, 77% stated that they would not go fishing at all (Fig. 2.22). The percentages of non-avid vs avid fishers who would travel ≥ 20 km offshore if the weather was moderate (11-16 knots or 20-29 km/h) differed significantly (chi-square test: $P < 0.01$), with avid anglers willing to travel greater distances under such weather conditions.

Most fishers (86%) would cancel a boat fishing trip if the forecasted wind strength was fresh (17-21 knots or 30-39 km/h). Avid anglers would significantly be least likely to cancel a boat fishing trip in such weather conditions (chi-square test: $P < 0.01$) (Table 2.18).

Nearly all of the fishers (> 93%) interviewed would cancel a boat fishing trip if there were strong (22-27 knots or 40-50 km/h) or gale force (28-33 knots or 51-62 km/h) forecasted wind strengths (Table 2.18). The vast majority of anglers (96%) responded that if a strong (22-27 knots or 40-50 km/h) wind strength was forecast, they would not go fishing at all.

A large percentage of fishers (71%, 224 fishers) agreed that they would start a boat fishing trip earlier in the day if an early fresh or strong sea breeze was forecast, a result that was similar for non-avid and avid anglers (Fig. 2.23).

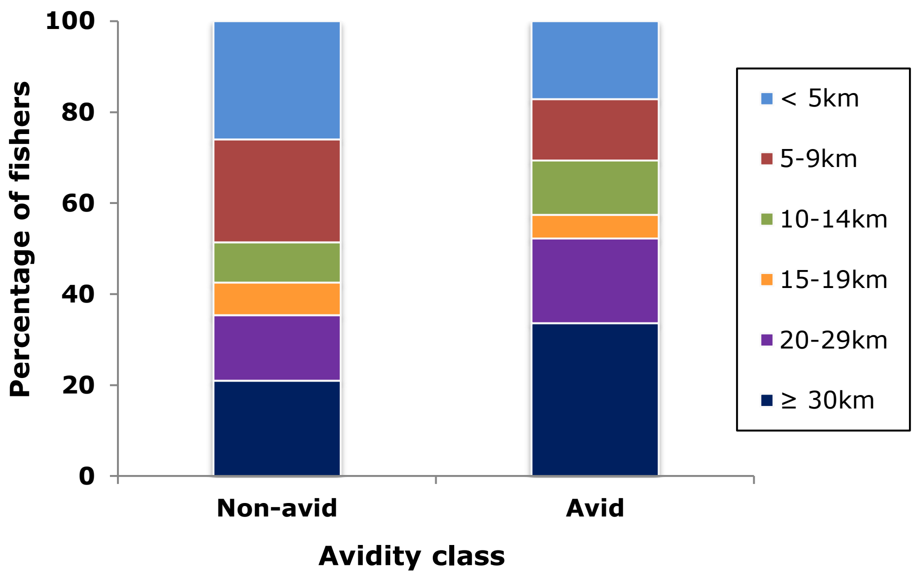


Figure 2.21 **Percentage of non-avid and avid anglers, who would travel < 5, 5-9, 10-14, 15-19, 20-29 or ≥ 30 km offshore if the weather was fine and the water was flat calm.**

Table 2.18 **Numbers and percentages of non-avid and avid fishers, who responded that they would or would not cancel a boat fishing trip if the weather forecasted was: a moderate wind strength (11-16 knots or 20-29 km/h), fresh wind strength (17-21 knots or 30-39 km/h), strong wind strength (22-27 knots or 40-50 km/h) and near gale wind strength (28-33 knots or 51-62 km).**

Wind strength	Cancel trip?	Avidity class	
		Non-avid	Avid
Moderate (11-16 knots or 20-29 km/h)	Yes	109 (60%)	56 (42%)
	No	73 (40%)	78 (58%)
Fresh (17-21 knots or 30-39 km/h)	Yes	167 (92%)	105 (78%)
	No	15 (8%)	29 (22%)
Strong (22-27 knots or 40-50 km/h)	Yes	172 (95%)	123 (92%)
	No	10 (5%)	11 (8%)
Near gale strength (28-33 knots or 51-62 km)	Yes	174 (96%)	127 (95%)
	No	8 (4%)	7 (5%)

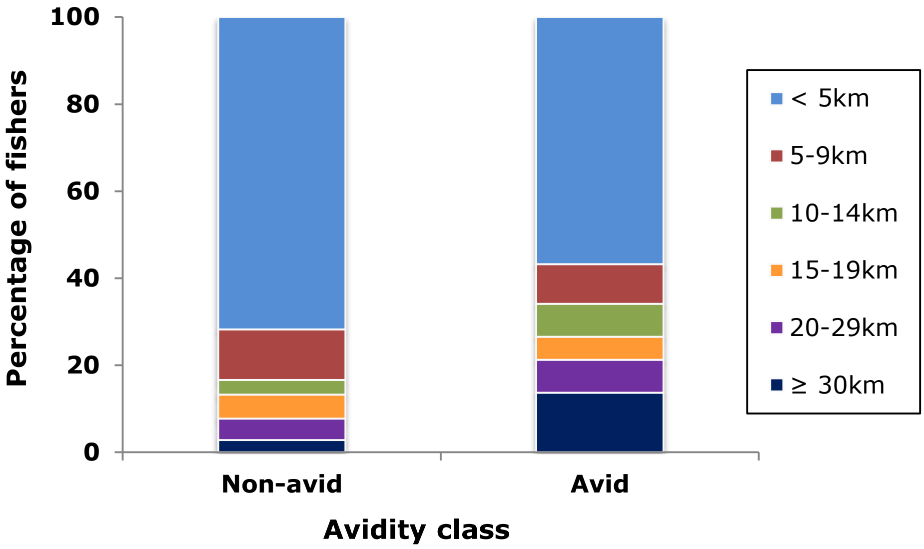


Figure 2.22 **Percentages of non-avid and avid anglers, who would travel < 5, 5-9, 10-14, 15-19, 20-29 and ≥ 30 km offshore, if the forecasted wind strength was moderate (11-16 knots or 20-29 km/h).**

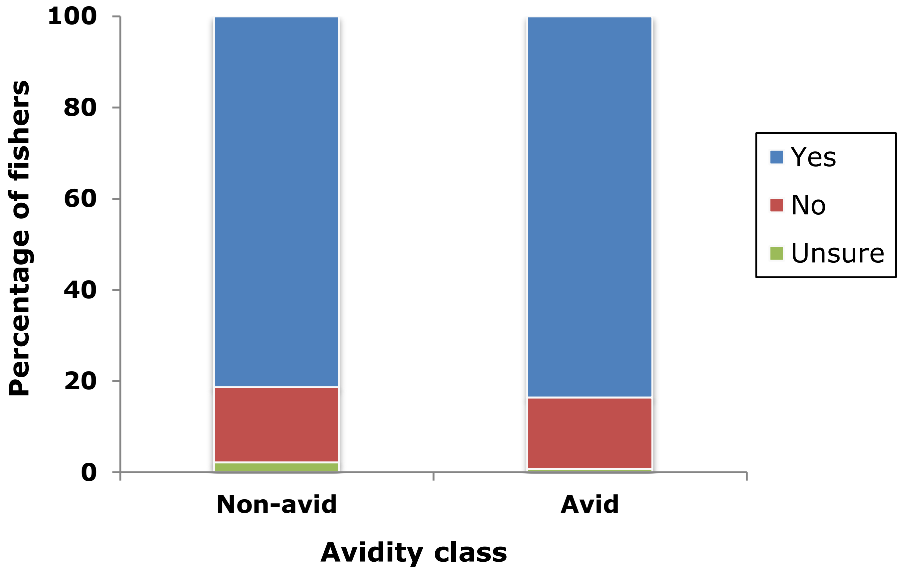


Figure 2.23 **Percentages of non-avid and avid anglers, who would, would not, or were unsure as to whether they would start a boat fishing trip earlier in the day if the weather forecast predicted a fresh or strong early afternoon sea breeze.**

Influence of holidays

Almost all of the interviewed recreational fishers (94%) in the Perth Metropolitan Region went fishing either on a normal weekday (55%) or a normal weekend (39%) during their last boat fishing trip (Fig. 2.24). Note, however, that responses to this question are likely to have been influenced by the timing of the survey (survey undertaken during August and September 2011). The date of the closest previous public holiday was June 6 and, before that, the Easter and ANZAC holidays on April 22, 25 and 26.

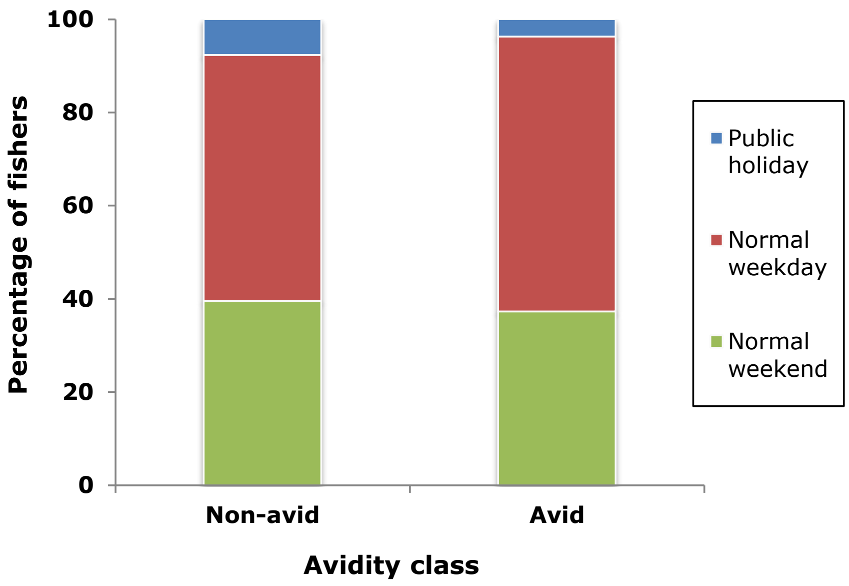


Figure 2.24 **Percentages of non-avid and avid anglers, who fished on a public holiday, a normal weekday or a weekend during their last boat fishing trip.**

Knowledge and behaviours

Nearly half (47%) of anglers replied that the statement "you have many fishing spots on your GPS, but of these, there are a few which you visit far more frequently than the others, because those few spots provide exceptional fishing" was not applicable (NA) to them, followed by 29% of anglers who agreed (*i.e.* strongly agree or agree) with the statement, and 18% of anglers, who disagreed (*i.e.* strongly disagree or disagree) (Table 2.19). Avid anglers were significantly more likely to disagree with this statement than non-avid fishers (chi-square test: $P < 0.001$) (Fig. 2.25).

The majority (86%) of fishers stated that they agreed (*i.e.* strongly agree or agree) with the statement that "the areas you tend to start fishing on a particular fishing trip are often those where, on your previous fishing trip, you had good success" (Table 2.19), with no obvious difference between the proportions of non-avid and avid fishers agreeing with the statement (thus, data not shown). Just over half (55%) of the anglers agreed (*i.e.* strongly agree or agree) that they "often fish in areas which friends have recommended" (Table 2.19), again with no obvious difference of opinion between non-avid and avid fishers. A similar number of anglers (54%) disagreed (*i.e.* strongly disagree or disagree) with the statement that they "use nautical charts, or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help them start searching for new fishing locations". Once again, there was no obvious difference between the proportions of non-avid and avid fishers who agreed with the statement (thus, data not shown). Most fishers (75%) also disagreed (*i.e.* strongly disagree or disagree) that they would "use information available from the internet to locate new fishing locations". In contrast, however, 48% of fishers agreed (*i.e.* strongly agree or agree) that they "often use depth contour and/or other inbuilt information in your GPS to locate new fishing spots" (Table 2.19), with no obvious difference between the proportions of non-avid and avid fishers who agreed with the statement (data not shown).

Approximately half (51%) of respondents disagreed (*i.e.* strongly disagree or disagree) with the statement that their "fishing trips tend to be shorter in duration" in the past 12 months, compared to previous years (Table 2.20). Avid anglers were significantly more likely to disagree with this statement than non-avid fishers (chi-square test: $P < 0.05$) (Fig. 2.26).

More than half (64%) of fishers disagreed (*i.e.* strongly disagree or disagree) that they tended to "go out fishing more regularly" in the last 12 months compared to previous years (Table 2.20), with non-avid fishers significantly more likely to disagree with this statement than avid fishers ($P < 0.01$) (Fig. 2.27). Similarly, 58% of anglers disagreed (*i.e.* strongly disagree or disagree) that they "now catch a wider range of fish species" (Table 2.20), with avid anglers significantly more likely to agree with this statement than non-avid anglers (chi-square test: $P < 0.05$) (Fig. 2.28).

Over half of anglers (57%) disagreed that they "now target a different fish species" in the last 12 months compared to previous years (Table 2.20), with no obvious difference between the proportions of non-avid and avid fishers expressing this opinion (data not shown). However, more than half (56%) of recreational fishers agreed (*i.e.* strongly agree or agree) that they now "tend to fish in areas outside the Perth Metropolitan Region" (Table 2.20), once again with no obvious difference in the opinions expressed by the non-avid and avid fishers (data not shown).

Table 2.19 The numbers and percentages of fishers who, when asked their opinion regarding each of the six listed statements, responded that they Strongly Disagreed (SD), Disagreed (D), were Neutral (N), Agreed (A), Strongly Agreed (SA) or were Unsure (U), or who considered the statement to be Not Applicable (NA) to them.

	SD	**D**	**N**	**A**	**SA**	**U**	**NA**	**Total**
You have many fishing spots on your GPS, but of these, there are a few which you visit far more frequently than the others, because those few spots provide exceptional fishing.	13 (4%)	45 (14%)	20 (6%)	65 (21%)	26 (8%)	0 (0%)	147 (47%)	**100%**
The areas you tend to start fishing on a particular fishing trip are often those where, on your previous fishing trip, you had good success.	2 (1%)	31 (10%)	10 (3%)	173 (55%)	99 (31%)	0 (0%)	1 (0%)	**100%**
You often fish in areas which friends have recommended.	18 (6%)	113 (36%)	10 (3%)	145 (46%)	28 (9%)	0 (0%)	2 (1%)	**100%**
You use nautical charts, or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help you start searching.	34 (11%)	138 (44%)	13 (4%)	94 (30%)	21 (7%)	0 (0%)	16 (5%)	**100%**
You use information available from the internet to locate new fishing locations.	48 (15%)	188 (59%)	4 (1%)	54 (17%)	10 (3%)	0 (0%)	12 (4%)	**100%**
You often use depth contour and/or other inbuilt information in your GPS to locate new fishing spots.	17 (5%)	31 (10%)	7 (2%)	101 (32%)	50 (16%)	1 (0%)	109 (34%)	**100%**

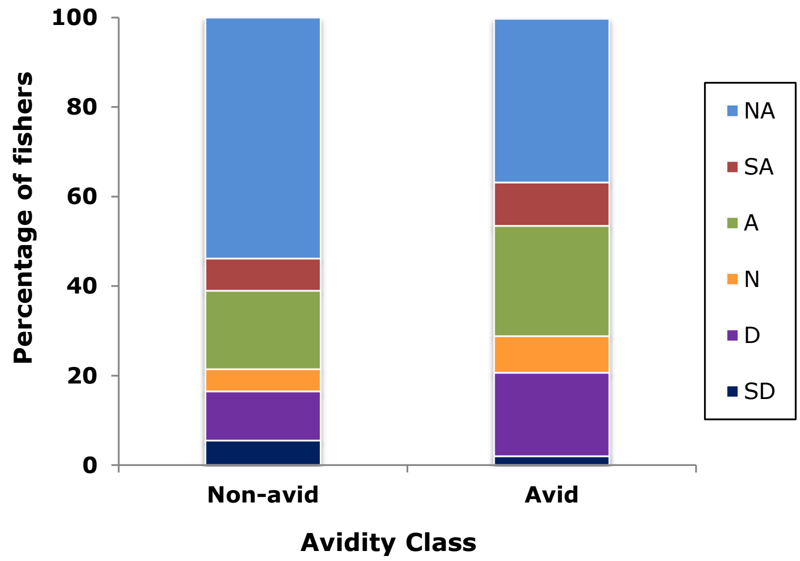


Figure 2.25 Percentages of non-avid and avid fishers who, when asked their opinion with respect to the statement "You have many fishing spots on your GPS, but of these, there are a few which you visit far more frequently than the others, because those few spots provide exceptional fishing", strongly agreed (SA), agreed (A), were neutral (N), disagreed (D) or strongly disagreed (SD), or who responded that the statement was Not Applicable (NA) to them.

Table 2.20 The numbers and percentages of fishers who, when asked their opinion with respect to each of the six listed statements, responded that they Strongly Disagreed (SD), Disagreed (D), were Neutral (N), Agreed (A), Strongly Agreed (SA) or were Unsure (U), or who considered the statement to be Not Applicable (NA) to them. Note that the statements related to the anglers' behaviours in the past 12 months and whether these had changed in the last year from those of previous years.

	SD	D	N	A	SA	U	NA	Total
Your fishing trips tend to be shorter in duration.	22 (7%)	138 (44%)	38 (12%)	98 (31%)	18 (6%)	0 (0%)	2 (1%)	**100%**
You go out fishing more regularly.	21 (7%)	182 (58%)	36 (11%)	66 (21%)	9 (3%)	0 (0%)	2 (1%)	**100%**
You now catch a wider range of fish species.	16 (5%)	168 (53%)	29 (9%)	91 29%	9 (3%)	0 (0%)	3 (1%)	**100%**
You target a different fish species.	10 (3%)	171 (54%)	29 (9%)	90 28%	12 (4%)	1 (0%)	3 (1%)	**100%**
You tend to fish in areas outside the Perth Metropolitan Region.	11 (3%)	111 35%	14 (4%)	127 (40%)	51 (16%)	0 (0%)	2 (1%)	**100%**

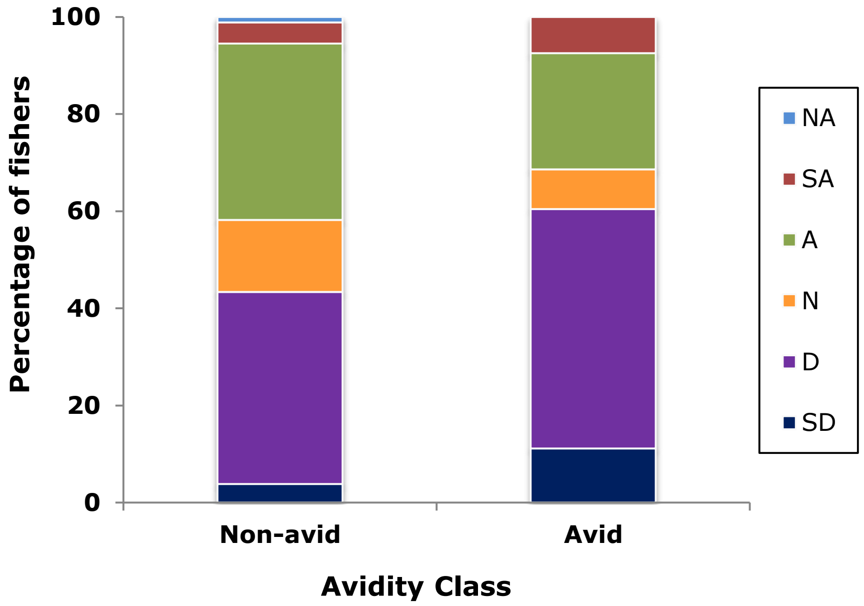


Figure 2.26 Percentage of non-avid and avid fishers, who, when asked to respond to the statement "Your fishing trips tend to be shorter in duration", strongly agreed (SA), agreed (A), were neutral (N), disagreed (D) or strongly disagreed (SD), or who responded that the statement was Not Applicable (NA) to them.

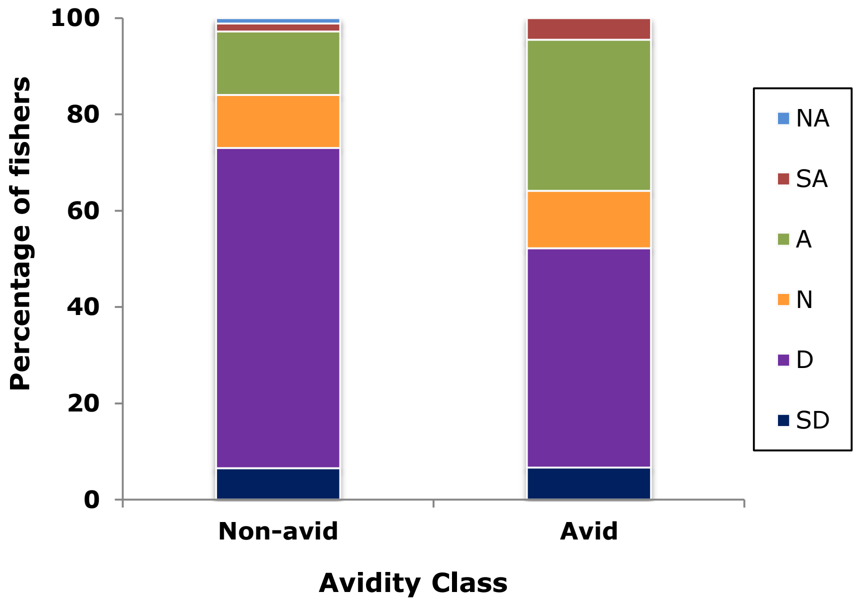


Figure 2.27 Percentages of non-avid and avid fishers who, when asked to respond to the statement; "You go out fishing more regularly", strongly agreed (SA), agreed (A), were neutral (N), disagreed (D), or strongly disagreed (SD), or who responded that the statement was not applicable (NA) to them.

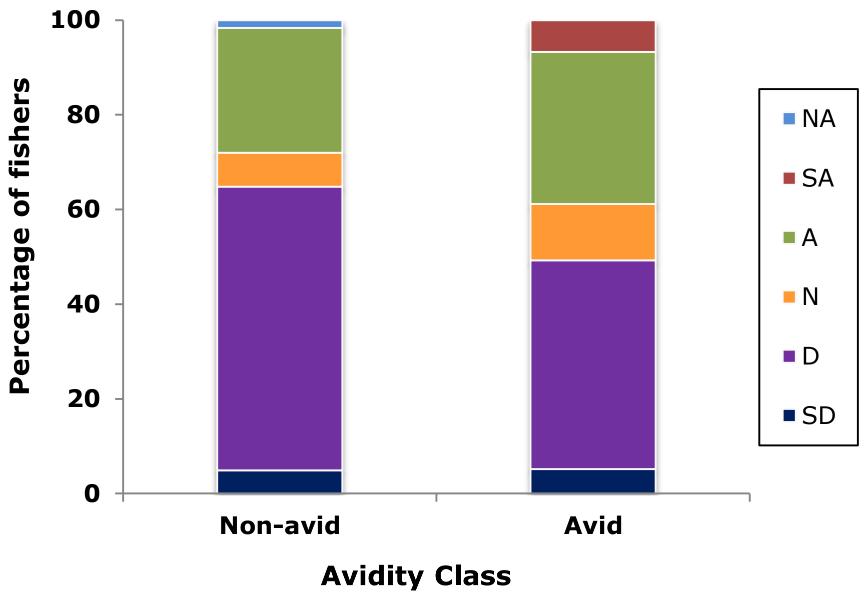


Figure 2.28 **Percentages of non-avid and avid fishers who, when asked their opinion of the statement "You now catch a wider range of fish species", strongly agreed (SA), agreed (A), were neutral (N), disagreed (D), or strongly disagreed (SD), or who responded that the statement was Not Applicable (NA) to them.**

2.3.8. **Social Interactions**

Nearly half (46%) of the recreational fishers reported that, in total, two people actively fished from their boat during their last fishing trip. A further 32% stated that three people had been actively fishing. Non-avid anglers were also significantly more likely to go fishing with other fishers on their boat (*e.g.* responding that they had two or more persons on their boat on their last fishing trip compared with only one person) compared to avid anglers (chi-square test: $P < 0.01$) (Fig. 2.29).

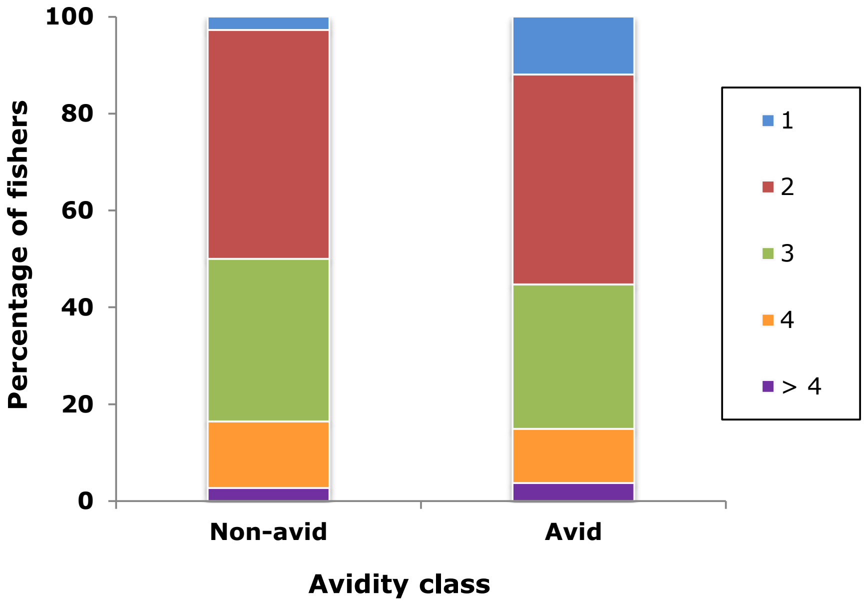


Figure 2.29 Percentage of non-avid and avid fishers, who reported that 1, 2, 3, 4, > 4 people were actively fishing on the boat that they fished from during their last fishing trip.

2.4. Discussion

2.4.1. Response rate

As stated by Pollock *et al.* (1994), off-site methods, such as the CATI telephone survey method used in this study, may suffer from several sources of non-sample error, including non-response bias. In this study, however, the response rate achieved was very high (~95%), and thereby, biases associated due to non-responses would have been minimal. Similarly high response rates (of 92-97%) were obtained, for example, by Ryan *et al*. (2013) in a survey of boat-based fishers in south-western Australia and by Frijlink and Lyle (2010b) (85%) in a survey of recreational fishing in Tasmania, Australia. Note, however, that several methods for calculating the response rate are available to researchers (see: Cochran, 1977), such that differences in the reported response rates can also be present between studies based on the method employed by the researcher for calculating such values.

Sample loss in this study was potentially higher than average as participants considered to be in-scope were required to have undertaken boat-based fishing activities in marine waters within the previous twelve months. It is also recognised that a greater proportion of avid than non-avid fishers may have been self-selected due to the inclusion of initial screening questions relating to their fishing activities (*e.g.* respondents purposely answered so as to be left out of scope of the survey, "soft refusal"). Thus, it is important to note that, while representative of interviewed RFBL holders, the high proportion of 'avid' anglers present in the resultant surveyed population may not necessarily be a true overall representation of all boat fishers within the Perth Metropolitan Region.

The slightly younger age composition seen in the fishers from the Perth Metropolitan and Peel Regions within the RFBL database compared to the surveyed recreational fishers in this study raises questions in regards to the possibility for potential biases created in the survey methods when contacting fishers, *i.e.* young people lost during the initial screening of the sample, and who were deemed "out of scope". For example, it is possible that a greater proportion of younger people are more difficult to contact during the working day. In future studies it would be worth comparing the age composition of the original random sample of 600 fishers drawn from the RFBL database to that of the fully responding fishers to see if biases do result from the screening of anglers, etc. Note, however, that there were twenty-seven instances when, based on the birthdate in the RFBL records, fishers were found to have ages in excess of 100 years. While the dates of birth for records with such extreme values of age can be classified as erroneous, it is not possible to determine the validity of ages that appear feasible. Thus, it is important to note that these fisher's ages in the RFBL database can only be broadly classified as representative of the fishers from the Perth Metropolitan Region and Peel Region, recognising that the dates of birth entered into the database were not subjected to rigorous validation at the time of data entry. Any fisher over the age of ≥ 100 y was excluded from the analyses.

The geographic distribution of fishers was comparable in the RFBL database to that of the phone survey participants, with larger proportions of recreational fishers reporting to reside in the South Metropolitan, Peel and North West Metropolitan Regions (more 'coastal' regions) of the Perth Metropolitan Region.

2.4.2. **Primary motivations for fishing**

Similar to the motivations of recreational shore-based and boat-based fishers reported in an Australian nationwide recreational fishing survey (Henry and Lyle, 2003), the results of the phone survey undertaken in this study revealed that fishers in the Perth Metropolitan and Peel Regions mainly go fishing for recreational purposes and for the enjoyment and sport of catching fish. Furthermore, the findings from this study that female anglers are more motivated to go fishing to spend time with family and male anglers attribute a greater importance to catching fresh fish for food is also consistent with those of Frijlink and Lyle (2010b), who found that males were also more likely to be motivated by the sporting dimensions of fishing, being outdoors and spending time with friends.

Previous studies have reported that only the more avid and highly specialised fishers are more likely to be affiliated with angling clubs and/or take part in fishing competitions (Bryan, 1977; Falk *et al*., 1989; Wilde *et al*., 1998; Anderson and Ditton, 2004; Margenau and Petchenik, 2004; Oh *et al*., 2007). Thus, the finding in this study that only a small percentage of non-avid fishers (3%) considered competing in fishing tournaments to be an important motive for fishing was to be expected. The finding that only 8% of avid fishers considered competing in fishing tournaments to be an important motive for fishing ran counter to the hypothesis that had been proposed in the introduction to this Chapter, however, indicating that, for this fishery, motivations other than competition were more important in determining frequency of fishing. Note, that no further comparisons or conclusions regarding fisher involvement, behaviours, characteristics etc. in either of these activities (*i.e.* being a member of an angling or taking part in fishing competitions) can be made due to the design of the questions. However, it recognised that question relating to *e.g*. club membership would be valuable for inclusion in future surveys to further help characterise recreational fishers and identify specialised angler groups

The finding that fishers reported having several anglers (2-3 people) aboard their vessel actively fishing on their last fishing trip was not unexpected as many of the fishers interviewed stated that spending time with friends and family on fishing trips was important, with very few fishers identifying the need for solitude or to get away from people as an important motive for fishing. Furthermore, past recreational fishing surveys have reported similar numbers (*e.g.* mean of 2.4 persons fishing per boat in the WCB (Sumner and Williamson, 1999), an average of 2 persons per boat in Western Australia (Raguragavan *et al*., 2010), and a mean of 2.34 anglers per party whilst recreational fishing in the Blackwood Estuary, W.A. (Prior and Beckley, 2007)). Knowledge on the number of persons fishing on a single boat on a fishing trip is important, as it not only gives insight into the social interactions of anglers but also helps researchers quantify effort (McCluskey and

Lewison, 2008) and the effectiveness of certain regulations, such as bag and boat limits (Fisher *et al*., 2011).

2.4.3. Characteristics of an avid fisher

General demographic information

The predominance of males is not an uncommon finding of angler surveys (Wilde *et al*., 1998; Henry and Lyle, 2003; Anderson and Ditton, 2004). However, the modal age of non-avid and avid fishers in this survey was slightly greater than those found in other angler surveys in Australia (Henry and Lyle, 2003; Prior and Beckley, 2007; Tracey *et al*., 2011). This in part, may potentially be due to some younger anglers being deemed “out of scope”, and therefore lost during the initial screening of the original random sample of 600 fishers drawn from the RFBL database (see above). Although in another study, Arlinghaus and Mehner (2003) described specialised carp anglers, *i.e*. more avid fishers, as younger than the general fishing population, in the current survey, more avid anglers were found likely to be older (*i.e.* 45 y or more). The iconic West Australian dhufish and pink snapper are highly prized for consumption. However, anglers who target these species also require more skill and knowledge, with access to larger boats and specialised gear types. Accordingly, these species are particularly likely to be targeted by fishers who have been involved in fishing for many years and have acquired the requisite skill, knowledge and gear. Further, this could also possibly be in part due to the large number of fishers interviewed residing in the South Metropolitan and Peel Regions (see below), areas which are known to be favoured locations for ‘retirees’ in the Perth Metropolitan Region. Census data for these regions, *i.e.* City of Mandurah located in the Peel Region and South Fremantle located in the South Metropolitan Region, have median ages of 42 y and 44 y, respectively, compared to a median age of 36 y in Perth, Central Metropolitan region (Australian Bureau of Statistics, 2013).

The largest numbers of survey respondents resided within the South and North Metropolitan and the Peel Regions, which are considered to contain coastal population “hot spots” (*e.g.* popular areas to reside and also contain high density populations), *i.e.* the cities of Fremantle, Rockingham, Hillarys, and Mandurah, respectively. Notably, these regions are in close proximity to a number of popular beaches, boat ramps and pens. As noted by Pradervand and Baird, (2002), the proximity to large urban areas undoubtedly plays a major role in the popularity of an angling venue, and estuaries (*e.g.* the Peel-Harvey and Swan estuaries in south-western Australia) that are situated closer to such areas generally experience higher levels of angling effort.

Fishing days

As hypothesised, the survey results demonstrated that the more avid anglers tend to go fishing more often on normal weekdays. It is also possible that the more avid fishers tend to avoid fishing on weekends and public holidays when boat ramps are likely to be busy and more congested, *e.g.* due to their ‘perceptions of recreational crowding’ (Vaske *et al.*, 1978; Salz and Loomis, 2005; Tseng *et al*., 2009; Hunt *et al*., 2011). These results differ slightly to those of past angling surveys in which angling effort for fishers in general has been found to be greater during the weekend period and also holiday seasons, *e.g.* Brouwer *et al*. (1997) and Pradervand and Baird (2002).

It is also possible that these results reflect ‘work-related’ factors, such as fishers participating in ‘fly-in fly-out’ work in mining activity in the north of Western Australia and thus having the ability to go fishing during the week on their ‘time-off’. Results of a 12-month creel survey undertaken in the West Coast Bioregion, including the Metropolitan Area, of Western Australia in 2005/06 showed changes in the level and distribution of recreational fishing effort when compared to the results of earlier recreational creel surveys conducted in 1996/97 and 2002/03 (Department of Fisheries, 2013). Fishers were travelling greater distances to catch fish and tended to go fishing further offshore and over a far wider area than in the earlier periods, a finding possibly relating to the growth in ownership of larger and faster boats (Department of Fisheries, 2013).

Over much of the last two decades, Western Australia has experienced an economic boom associated largely with an increase in mining activity. This has also resulted, for example, in a rapid increase in a 'fly-in fly-out' (FIFO) labour force, *i.e.* workers that commute from major metropolitan centres to relatively remote mining locations for periods of work, where food and lodging accommodation is provided for them, but not for their families. Schedules are thus established whereby employees spend a fixed number of days working at the site, followed by a fixed number of days at home (Storey, 2001; Joyce *et al*., 2013). These workers, who can earn very good incomes (Richardson and Denniss, 2011; Brueckner *et al*., 2013), are typically male and aged between 25-44 years (Joyce *et al*., 2013). These workers, who have extended periods of time available for recreation, often engage in fishing and it may thus be expected that the patterns evident in the data from the two surveys in the early to mid-2000s have continued, with many younger males now going fishing as well as investing substantially in fishing gear and technology (large boats) (Joyce *et al*., 2013). For future surveys in this state, it would therefore be beneficial to ask questions relating to fishers' current area of employment to understand the extent to which fishing patterns are being altered by changes in employment dynamics. Note also that the low numbers of fishers reporting that their last boat-based fishing trip occurred on a public holiday, for example, would have been influenced by the timing of this survey.

Catch preference

The survey results indicated that the majority of surveyed recreational boat fishers (avid and non-avid) were 'generalist' fishers, as they had stated either that they targeted a 'mix' of species or that they had no particular target on their last boat fishing trip. However, consistent with the findings of Henry and Lyle (2003), many anglers reported specifically targeting easy-to-catch, inshore 'bread and butter' species (*i.e.* whiting, herring, crabs and squid). It is possible that the low numbers of fishers reporting that they specifically targeted the iconic West Australian dhufish or pink snapper, with many also stating that they targeted a 'mix' of reef fish species including the West Australian dhufish or pink snapper, reflects current bag restrictions for these iconic species. That is, in the West Coast Bioregion of Western Australia, there is a total mixed daily bag limit of only two demersal finfish (Department of Fisheries, 2013), and thus more avid anglers may elect to target a range of fish species to get the most out of their fishing journeys.

Species caught

The survey reported many fishers catching whiting (with tailor and herring also being popular), which parallels the results of Henry and Lyle (2003) and Sumner and Williamson (1999). Likewise, in the most recent State of Fisheries report produced by the Western Australian Department of Fisheries, the top three most commonly-targeted recreational finfish species were Australian herring (*Arripis georgianus*), tailor (*Pomatomus saltatrix*) and southern school whiting (*Sillago bassensis*) (Fletcher and Santoro, 2013). Sumner *et al*. (2008) comment further, describing the recreational boat-based fishery within the West Coast Bioregion as primarily a fishery for smaller, predominantly inshore, scalefish species such as whiting species, Australian herring and skipjack trevally.

As also shown in this study, blue swimmer crabs, another relatively abundant and easy-to-catch species, were also a very popular species caught by less avid fishers. The importance of recreational "crabbing" in estuaries and waterways in the Peel Region has also been documented in past recreational fisher surveys, with recreational catches often exceeding the commercial catch in both the Leschenault and Peel-Harvey Estuary (Malseed, 2000; Malseed and Sumner, 2001). Thus, due to the large number of fishers residing in the South Metropolitan and Peel Regions, this preference for targeting crabs is to be expected. In contrast, the survey showed that more avid fishers retained higher percentages of finfish, including bream, tuna/bonitos and sea perch/snappers, indicating a higher level of specialisation among these fishers, as these species are considered to be harder–to-catch, sport fish and some of which are located in deeper waters requiring accessibility to a boat and potentially more specialist gears. Understanding the catch preferences among recreational fishers is important and can ultimately assist managers in understanding the diversity and consumptive preferences of anglers within a fishery (Fisher, 1997). Furthermore, these results highlight the potential for future studies to group the angler population within the WCB by catch preference (*i.e.* crab fishers) and explore the defining characteristics of each segment.

Species released

The survey reported anglers releasing relatively large numbers of larger, more offshore finfish species, *i.e.* species such as emperors (*Lethrinus spp.),* pink snapper, wrasse/tuskfish/gropers (Labridae), rock-cod/gropers (Epinephelidae) and trevally (Carangidae). Such results could be reflective of differences in current management regulations, *i.e.* no current minimum size limits for some smaller 'inshore' species (*e.g.* Australian herring, *Arripis georgianus or* Whiting (excluding King George) Sillaginidae), compared to restrictive size limits for larger 'off-shore' reef species (*e.g. G. hebraicum* or Western blue groper, *Achoerodus gouldii*). Differences in management regulations such as these, however, recognise that the risk to sustainability posed by fishing is influenced by the different life histories and biological characteristics of the different species, where, for example, these biological characteristics make 'bread and butter' species less vulnerable to fishing than is the case for larger offshore reef species. For example, when such species as *A. georgianus* become large enough to be caught by the fishing gear, they are typically already mature and capable of breeding (Ayvazian *et al*., 2000; Fairclough *et al*., 2000a; 2000b).

Even though the exact numbers of fish that were released is unknown, consideration also needs to be given to the fact that the angling harvest includes a very broad range of different species, with large numbers of these species being released. For example, it has been estimated that, in Australia, angling discard rates are usually 30-40% of the total catch (McGlennon and Lyle, 1999; McPhee *et al.,* 2002). It is also important to recognise that discard rates and subsequently post-release mortality rates are an important issue for some species, particularly demersal reef fish species, but far less so for pelagic/semi-pelagic species. Gitschlag and Renaud (1994) (see also Diggles and Ernst, 1997) described an inverse relationship between fish survival and depth of capture, as the effect of decompression (*i.e.* barotrauma) is considered to be a critical factor influencing hooking mortality of reef fish (Diggles and Ernst, 1997; St John and Syers, 2005). For example, *G. hebraicum* are highly susceptible to post-release mortality effects, with many *G. hebraicum* caught from depths > 20 m (St John and Syers, 2005).

Gear and methods

The survey revealed that a large proportion of anglers own their own boat, which is not a surprising result as anglers were randomly selected from the RFBL database, with just over half also stating that they owned a global positioning system (GPS). In the Australian nationwide recreational fishing survey (Henry and Lyle, 2003), the largest number of boat owning households was recorded for New South Wales, however, only 52% of these vessels were reportedly used for fishing, compared to 63% in Western Australia. Henry and Lyle (2003) also noted that boat ownership was higher among households containing recreational fishers, and also the prevalence of electronic aids (*i.e*. echo sounders and GPS) increased with vessel size. Furthermore, as noted above, a growth in ownership of larger and faster boats in Western Australia's recreational fishery has also been found in recent years (Department of Fisheries, 2013). As almost half of recreational fishers in the phone survey also agreed that they often use depth contour and/or other inbuilt information in their GPS to locate new fishing spots, this suggests that technology is an important factor influencing the efficiency of the 'average' angler. It has been recognised that the modern angler has access and the ability to use a large array of technological improvements, *i.e.* high quality echo sounders, global positioning systems (GPS), new types of low diameter high strength fishing lines and chemically sharpened hooks to name a few, to better locate fish and ideal fishing locations, and then increase their success in catching fish once hooked (Cowx, 2001; Sumner *et al*., 2002; Williamson *et al*., 2006). There is also greater information available to anglers through the media and the internet regarding prime fishing locations and 'hot spots' (McPhee *et al.,* 2002).

The study revealed the more avid a fisher was the more likely they would store, and store a greater number of fishing locations in their GPS, a finding consistent with the hypothesis that avid fishers were likely to use specialised fishing gears and technologies. This result highlights the potential for 'the number of fishing locations a fisher has stored' as another possible measure of avidity, and could thus be useful for inclusion in future angler surveys.

Note, however, that due to the wording of Q.11 and the structure in the survey, it not clearly established whether the last fishing trip was on the respondent's boat and hence whether the number of fishing locations they have stored in their GPS device has any relevance to answers relating to this last fishing trip.

Movements

The use of 'bite rate' in the survey represented a novel approach to discerning angler movements. It was hypothesised that an avid fisher would be more likely than a less avid fisher to move more frequently between fishing locations in search of fish when catch rates are low, such as to maintain high catches and fishing success on fishing trips. While this hypothesis was not supported by the data, avid anglers were more likely than non-avid fishers to move from a location when bite-rates (as opposed to catch rates) were low at their best/favourite fishing location. Although not supported by the bite rate data, it is possible that, based on their greater experience, patience, and persistence, and perhaps in the hope of catching larger fish, avid anglers may also not be inclined to move as often, but this would also be likely to be dependent on the target species. Indeed, although again not supported by the bite rate data, it is also possible that less avid fishers may move around more frequently and even "aimlessly" trying to catch something/anything. Many anglers indicated the main reason for moving between fishing locations was not due to catching any fish (see below), though it is noted that other variables, *e.g.* changes in weather, catching 'undesirable' fish species, wanting to target a different fish species, wanting to change gear types etc., can also influence a fishers' decision to move (Sampson, 1991; 1994; Wilen *et al*., 2002). Future surveys may also benefit from a consideration and inclusion of lower wind categories (*i.e.* 6-10 knots) to examine the behaviour and movements of anglers at even low winds.

Given that the average reported trip duration was ~ 3.5 h, fishers typically only moved a small number of times during a trip. A similar result was found across all States and Territories in Australia, with anglers reporting a duration of fishing trips on average around 3.5 h (Henry and Lyle, 2003). As the results indicated that half of fishers only travel a small distance (< 5 km) from the boat ramp/pen to their first fishing location, from a management perspective, this highlights the need for adequate numbers of access points and the potential for localised areas of heavy fishing pressure in areas adjacent to boat ramps and launching pens (Stuart-Smith *et al*., 2008).

As noted by Abernethy *et al*. (2007), due to fishers' not being able to 'see' their prey, their movements and foraging decisions are largely based on the knowledge of prey distribution derived from catches and previous experiences. The fact that fishers reported moving only very small distances between their first successive fishing location is consistent with the view that many anglers head directly to a known fishing location where they have had previous success (noting that a number of alternative explanations for this finding exist). In terms of management, such a localised concentration of fishing effort in inshore areas in the West Coast Bioregion of south-western Australia highlights the large potential for localised depletion in such areas, as is consistent with information presented in previous stock assessments (*e.g.* Wise *et al*., 2007).

According to specialisation theory, anglers who are least specialised are more likely to consider that the most important aspect of fishing is to 'catch fish', whereas more specialised anglers tend to view non-catch related objectives as equally important (Ditton *et al*., 1992). This view is, in part, supported by the results of the survey, with more avid fishers being more likely to stay out on the water longer.

The survey showed that anglers are also more likely to fish in areas which their friends have recommended or use depth contour and/or other inbuilt information in their GPS, than to use nautical charts or the internet to locate new fishing locations. This finding is consistent with specialisation theory which suggests that the more avid the fisher is the greater the investment in the activity there is likely to be, such that avid and more specialised anglers are likely to seek out information about the activity from a variety of media sources such as magazines, internet sites, and television (Salz and Loomis, 2005).

Prior to the survey (2 March 2010), a number of general fishery regulations in Western Australia and in the West Coast Bioregion came into effect, including the introduction of a State-wide Recreational Fishing from Boat License (RFBL), which was used as the sampling frame for this survey, in combination with a two-month demersal scalefish closure 15 October to 15 December (inclusive), a daily bag limit of two high risk demersal scalefish and two pelagic fish, *i.e.* West Australian dhufish, pink snapper, and a boat limit of two West Australian dhufish (Department of Fisheries, 2012). Although fisher's responses to management changes were not directly addressed in the survey, it is recognised that angling habits over time will be influenced by management regulations and many other factors (*e.g.* fish abundance). No difference in habits or behaviours was reported by participants, except that more than half of fishers agreed with the statement that they now "tend to fish in areas outside the Perth Metropolitan Region". Caution is also recommended for any future surveys that employ such a question, as the preamble may confuse survey participants and the question itself may be viewed as a 'double-barrel question', *i.e.* whether fishing behaviour has changed in (within) the last 12 months and whether this behaviour has changed compared to previous years.

3. The characteristics, including fish-targeting behaviours, of a group of specialised boat anglers

3.1. Introduction

Typically, the most avid and specialised fishers achieve greatest catch success and are more likely to have the greatest impact on fish stocks (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). It is generally these more avid fishers who have the greatest angling experience and skill and who make the greatest investment in fishing equipment and activity (Chipman and Helfrich, 1988; Ditton *et al*., 1992; Dorow *et al*., 2010). Moreover, as noted in Chapter 2, as such specialised anglers have large social and financial investments in fishing, they are also more likely than other fishers to voice the strongest opinions in response to management actions (Wilde *et al*., 1998; Arlinghaus and Mehner, 2003; Margenau and Petchenik, 2004; Salz and Loomis, 2005). Therefore, it is particularly important for fishery managers to understand the objectives and motivations of specialised anglers such that they can better understand the characteristics of those anglers and can thus employ management strategies that are best suited to the needs of the fishery.

Studies have shown that specialised anglers are more committed and avid (Bryan, 1977; Falk *et al*., 1989; Beardmore *et al*., 2011), typically younger (Wilde *et al*., 1998; Arlinghaus and Mehner, 2003), devote more time each year to fishing (Graefe, 1980; Ditton *et al*., 1992; Salz *et al*., 2001), travel greater distances to fishing locations (Beardmore *et al*., 2013; Ward *et al*., 2013), have the greatest fishing experience and skill and make the greatest investment in fishing equipment and activity (Ditton and Holland, 1984; Chipman and Helfrich, 1988; Ditton *et al*., 1992; Dorow *et al*., 2010). They are likely to be supportive of more restrictive fishing regulations (Salz *et al*., 2001; Arlinghaus, 2007), and to have a greater catch success than less specialised fishers (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). In the context of recreational fisheries elsewhere, it is thus expected that the specialised boat-based anglers, who exploit the demersal fish stocks of the lower west coast of Australia, are likely to have similar characteristics to those found in these earlier studies, *i.e.* they will exhibit higher fishing frequency, invest more heavily in gear and technology, and fish further offshore than other, less specialised and avid anglers.

Studies in Europe and North America have found that specialised fishers are more likely to belong to angling clubs than those who are less specialised (Gigliotti and Peyton, 1993; Fisher, 1997; Arlinghaus and Mehner, 2003). This is reflected in the fact that, as clubs are likely to attract a greater proportion of specialised anglers, members of fishing clubs are likely, on average, to be more motivated and to fish more frequently, undertake longer fishing trips, have more experience and greater skill, use more specialised fishing techniques to catch target species and participate in angling competitions than those fishers who are not members of such clubs (Graefe, 1980; Ditton and Holland, 1984; Gigliotti and Peyton, 1993; Gartside *et al*., 1999).

The recreational fishery in the West Coast Bioregion (WCB) of Western Australia (see Chapter 1, Fig. 1.0) is dependent on a resource that includes a large number of demersal fish species, including two iconic species, West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Chrysophrys auratus*), which are fished over reef habitat by boat-based anglers, and whose abundances, in recent decades, have become depleted (Wise *et al*., 2007; Lenanton *et al*., 2009; Fairclough *et al*., 2014). It has also been noted that the spatial distribution of recreational boat-based fishing effort for these species in the WCB has expanded considerably in recent years (Wise *et al*., 2007), *i.e.* those fishers who target individuals of these two species now have to travel greater distances and often fish in locations further offshore to increase their chance of catching individuals of these highly targeted species (Hesp *et al*., 2002).

The characteristics that distinguish specialised anglers in any fishery are likely to reflect the distribution and behavioural characteristics of individuals of the species and the abundances of the stocks that those fishers target, *e.g*. a trout fisherman will have a different set of motivations, characteristics and targeting practices compared with those of an angler fishing for an offshore reef species such as West Australian dhufish (Bryan, 1977; Fisher, 1997; Arlinghaus, 2006). Similarly, the characteristics of more specialised anglers (*e.g.* members of recreational fishing clubs) would be expected to differ from those of less specialised anglers in the same fishery, *i.e.* in terms of the fishing gear, methods of fishing employed and catch related outcomes etc. (Bryan, 1977; Ditton and Holland, 1984; Wilde *et al*., 1998; Dorow *et al*., 2010; Beardmore *et al*., 2011). It is also likely, however, that some characteristics of specialisation in the Western Australian demersal recreational fishery would be similar to those found elsewhere, *e.g.* distance travelled offshore is likely to be related to the distribution of the target species, weather, size of boat and fishing trip duration.

As noted in the introductory chapter of this thesis, specialised boat-based anglers (SBAs) are the key agents considered in the agent-based model (ABM) that was developed for this study, and which is described in the following chapter (Chapter 4). For this ABM to provide a reliable representation of the behaviours and decisions made by such anglers, data on the behaviours of a sample of highly-skilled, boat-based recreational fishers who specifically target demersal finfish species, *i.e.* West Australian dhufish and pink snapper, were required. Accordingly, a survey directed specifically at members of angling clubs in Western Australia was undertaken to determine the demographic characteristics of those club members and to characterise aspects of their fishing activities, behaviours, movements, skill and knowledge, thereby providing data that could be used as input to the agent-based model (described in Chapter 4). By comparing the data from this angling club survey with results from the phone survey, data for which had been collected from randomly-selected boat-based recreational fishers (Chapter 2), the validity of the hypothesis that angling club members in the West Coast Bioregion of W.A. possess characteristics typically associated with more specialised fishers was investigated. In particular, it was hypothesised that, compared with the general boat-based fishers who were the subject of the survey described in Chapter 2, club members fish more frequently, travel greater distances to fishing locations and fish in deeper waters, move from a location more rapidly from a fishing location when not receiving 'good' fish bites, are more likely to target and catch West Australian dhufish and pink snapper, have greater investment in gear and technology, and make greater use of that technology.

It should be noted that the survey described in this Chapter was undertaken primarily to provide the necessary data for an agent-based model (described in the next chapter, Chapter 4). It was subsequently recognised, however, that the characteristics of these specialised boat-based anglers needed to be considered within the context of the characteristics and behaviours of typical boat-based recreational fishers. Accordingly, building on experience gained from the survey of recreational fishers from angling clubs in the West Coast Bioregion of W.A. described in this Chapter, funding was obtained from Murdoch University to undertake the phone survey described in Chapter 2. Thus, the order in which the surveys are presented in this thesis is not the order in which the two components of the study were undertaken.

3.2. **Methods**

3.2.1. **Sampling Design**

During September 2009 and December 2010, three angling clubs in the Perth Metropolitan Region, namely the (1) Marmion Angling and Aquatic Club, (2) Quinns Rock Angling Club, and (3) Ocean Reef Angling Club, were visited to recruit recreational fishers to participate in a one-off self-administered questionnaire. The angling clubs chosen were three of the most active clubs in the Perth Metropolitan Region. Furthermore, these clubs all had members interested in targeting and catching marine, demersal fish species and, in particular, the iconic West Australian dhufish and pink snapper.

Fishers were invited to attend a presentation evening, which was organised and promoted within their club and via their club's committee. Those fishers who attended the meeting were given an oral presentation by Dr Alex Hesp (Murdoch University) on the purpose of the study and fisheries modelling concepts, including the agent-based model discussed in the next chapter (Chapter 4) of this thesis. The presentation included a preliminary conceptual diagram detailing the underlying processes assumed in the model and the ways in which the behaviours of individual fishers are likely to be reflected by certain types of decisions made during fishing trips. All participants were informed by the researchers about the aims and procedures of the study and reminded of its voluntary nature. On completion of the presentation, fishers were invited to sign a consent form and to complete the questionnaire (Appendices J and K, respectively). As the majority of anglers attending these meetings (who still actively fish) completed a questionnaire, the response rate was high.

Several other angling clubs in south-western Australia were also contacted in the early stages of the study to ask their members if they would be willing to participate in the survey. Although these clubs were neither visited nor received a presentation night, six fishers from the Bunbury Angling Club and the Naturaliste Game and Sport Fishing Club chose to participate by mail. These fisher responses have been included in the final collation of the survey results. In total, 33 anglers chose to participate. The average time for completion of the questionnaire was approximately 15 min.

Note that, as details of fishing club membership are not available in the records stored within the Recreational Fishing from Boat Licence (RFBL) database, the selection of a representative sample of such fishing club members from this database would have required a large sample size and considerable filtering using a screening survey designed to filter non-club members. Resources for such a survey were not available for the current study and thus, although sampling was not probability based, the approach employed, *i.e.* directly approaching recreational fishing club members, was considered an appropriate compromise to obtain data from this specific group of fishers.

The study was approved by the Human Ethics committee of Murdoch University, W.A. and was carried out in accordance with the conditions of project number 2009/114 (see also Appendix J for Participant Consent form).

3.2.2. **Measures**

The questions included in the written questionnaire used for this study were similar to those included in the phone survey described in the previous chapter (Chapter 2). Comparisons between the two surveys were restricted to responses from either identical questions or very similar questions that were considered highly likely to have produced comparable data. As with the phone survey, all anglers participating in the survey of club members were aged 18 years of age or older and, to provide a measure of their avidity ("keen interest or enthusiasm"), participants were asked the number of separate days they had participated in recreational fishing from a boat in the past 12 months. It is considered that the higher the frequency of days fished (effort), the more avid the fisher (Graefe, 1980; Chipman and Helfrich, 1988; Ditton *et al*., 1992; Fisher, 1997). The questionnaire, which is presented in Appendix K, requested information on fisher demographics, participation rates, species preferences, methods of targeting fish, and movement patterns during the last boat-based fishing trip (prior to completing the survey).

3.2.3. **Data analysis**

All responses collected from participants in this one-off, self-administered questionnaire were kept in hard copy data format, and then entered into EXCEL prior to analysis. Calculations and statistical analyses of these data were performed using IBM SPSS Statistics version 20.0 software (IBM Corporation, 2011), EXCEL (www.microsoft.com, verified September 2010) and the R software package (R Development Core Team, 2013).

Similarly to Chapter 2, postcode data were used to classify the residential addresses of participating anglers among six separate sub-regions of the Perth Metropolitan Region, *i.e.* the Central Metropolitan, East Metropolitan, North West Metropolitan, South East Metropolitan, South Metropolitan, the West Metropolitan, or the Peel Region. Note, that the six anglers from the Bunbury Angling Club and the Naturaliste Game and Sport Fishing Club included in the survey also resided in the South West Region of Western Australia (a region ~200 km south of the City of Perth).

Fishers were classified as 'avid' if they reported that they had fished for 15 or more days in the previous 12-month period. The assumption in this study that avidity is related to the frequency of fishing has been employed in other Australian recreational fishing studies and by the Western Australian Department of Fisheries (*e.g.* Ryan *et al*., 2009; Frijlink and Lyle, 2010a; 2010b; Ryan *et al*., 2013). Further, for logistic regression analyses (see below) anglers were also classified into two groups based on whether or not they were known to be members from angling clubs, *i.e.* recreational fishers from the phone survey Chapter 2 were classified as non-members, whilst participants in the angler survey in Chapter 3 were classified as club members. Note that some fishers participating in the phone survey in Chapter 2 may have held club memberships to fishing clubs within the Region, however, these data were not available as no question relating to club membership was included in that survey.

Where appropriate, two-by-two contingency tables were constructed to (1) compare results between the more vs less avid fishers in this survey, and (2) compare results between those for the fishers in this survey and those for the avid fishers from the phone survey (reported in Chapter 2). The chi-square test was employed, with differences being considered statistically significant if the probability of the observed data, given the null hypothesis that no difference exists, was calculated to be less than 0.05.

Logistic regression analyses of the data from the club members survey and the full set of data from the phone survey, *i.e.* both non-avid and avid fishers, were also undertaken using R (R Development Core Team, 2013) to explore the above characteristics of the different groups of fishers, *i.e.* recreational fishers/club members, and to test the various hypotheses, such as whether club members travel greater distances to fish and experience greater catch rates. For all such logistic regression analyses, the dependent variable (club membership) was first recast as a dichotomous factor. The glm procedure was then employed, with family set to 'binomial', to determine for each regression the extent to which the response variable was related to the various putative explanatory factors that had been hypothesised. The strength of each relationship was assessed on the basis of four levels of significance: $P < 0.10$; $P < 0.05$; $P < 0.01$, and; $P < 0.001$. Note that, as the sample size of the survey was small, the significance level of 0.10 was employed to identify explanatory factors of borderline significance which, had a larger survey been undertaken, would have been likely to have been classified as statistically significant at the 0.05 level.

3.3. Results

3.3.1. General Demographics

Age and gender

Of the 33 surveyed recreational fishers, only male anglers (33, 100%) participated in the club survey (Table 3.0). The age category with the greatest percentage of fishers was the 45-59 age group (15 males), which accounted for almost half (45%) of all anglers surveyed (Table 3.0).

Table 3.0 Numbers of surveyed recreational fishers at angling clubs by age class and gender.

	18-29	**30-44**	**45-59**	**> 59**	**Total**
Male	9%	24%	45%	21%	**100%**
Female	0%	0%	0%	0%	**0**
Total	**3**	**8**	**15**	**7**	**33**

Experience

The majority (85%, 28 fishers) of club members surveyed had been fishing for more than 10 y. Only one of the anglers had been fishing for 0-2 y (Fig. 3.0). Comparisons of experience levels between avid recreational fishers in the phone survey (Chapter 2) and club members could not be made due to differences in survey design (*i.e.* this question was not asked in the phone survey).

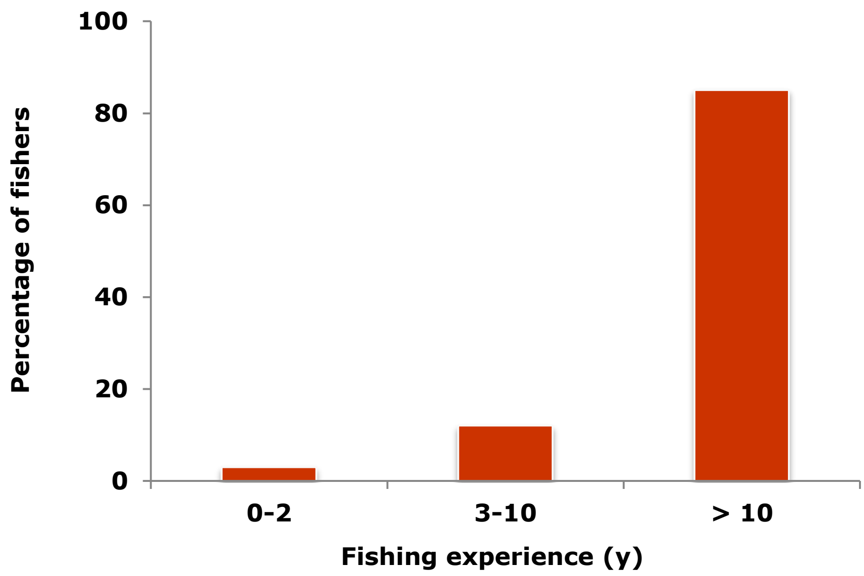


Figure 3.0 **Percentages of surveyed club members who reported that they had been fishing for 0-2, 3-10 or > 10 y.**

Region

The majority of recreational fishers (82%, 27 fishers) who participated in the survey were from the North West Metropolitan Region (Fig. 3.1). Three (9%) anglers were from the Bunbury Angling Club and a further three from the Naturaliste Game and Sport Fishing Club, which are both located in the 'South-West Region' of Western Australia. Although this region lies to the south of the Perth Metropolitan Region, the responses of these six fishers were included in the survey results as, based on discussions with club members, similar species were targeted, thus it was considered that they would exhibit characteristics and behaviours similar to those of the anglers from the fishing clubs in the Perth Metropolitan Region.

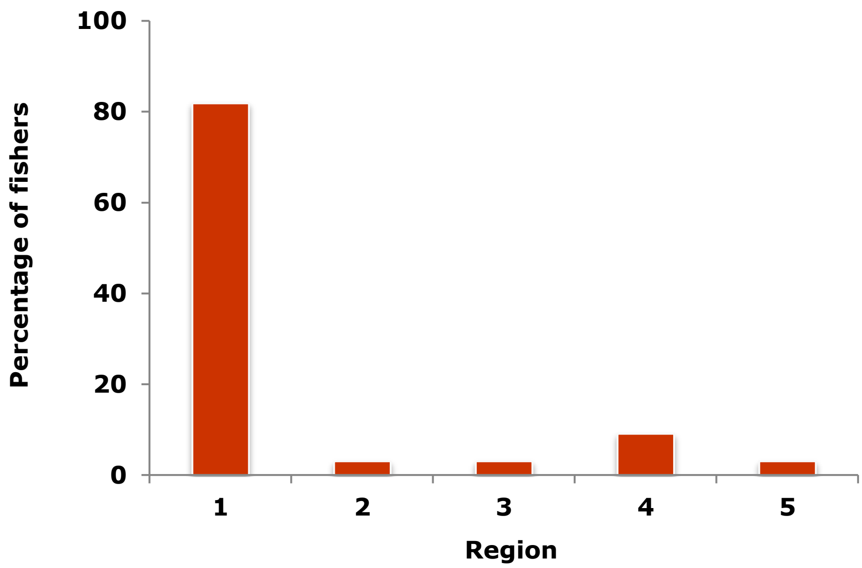


Figure 3.1 **Percentages of surveyed club members by region of residence 1. North West Metropolitan; 2. South East Metropolitan; 3. South Metropolitan; 4. South West; 5. West Metropolitan.**

Avidity

Of the 29 club members who responded that they had undertaken recreational fishing activities (boat fishing, shore fishing, crabbing, etc.) in the preceding 12 months in Western Australia, 14 individuals (48%) had fished for 15 or more days and thus were considered to be avid fishers (Table 3.1). Fishers in the remaining categories (< 5 days, 5-9 days, and 10-14 days) were considered to be non-avid fishers. The percentage of fishers who were classified as avid fishers in this survey did not differ significantly (chi-square test: $P > 0.05$) from that recorded for the phone survey (42%). However, it was found when comparing the characteristics of anglers from the phone and club surveys, that those anglers who had fished for 20 or more days, *i.e.* highly avid, in the previous 12 months were more likely to be members of recreational fishing clubs (logistic regression: $P < 0.10$) (Table 3.2).

Table 3.1 **Numbers of surveyed club members in successive avidity classes, classified according to frequency of fishing over the past 12 months.**

	Avidity class categories					
	< 5 days	**5-9 days**	**10-14 days**	**15–19 days**	**≥ 20 days**	**Total**
Frequency	2	7	6	1	13	**29**
Percent	7%	24%	21%	3%	45%	**100%**

Table 3.2 **Coefficients of explanatory variables of logistic regression model to determine factors influencing club membership. Note that values of coefficients are presented in normal font in the table below if *P* < 0.1, or in bold font if *P* < 0.05, otherwise the values are not presented.**

	Age					Days fished				
	18-29 y	30-44 y	45-59 y	60-74 y	75-99 y	<5 d	5-9 d	10-14 d	15-19 d	≥20 d
Club membership										1.30

Null dev.	199.11 on 344 degrees of freedom
Residual dev.	93.50 on 334 degrees of freedom
AIC	115.50

3.3.2. **Catch preferences**

Target species

The majority (70%, 23 fishers) of the surveyed club members reported that, on their last fishing trip, they mainly aimed to catch a mix of fish species including West Australian dhufish or pink snapper ('mixed'). A further 18% of fishers (6 fishers) reported that West Australian dhufish was their main target fish species (Fig. 3.2, Table 3.3). Although there were insufficient data to apply a chi-square test (as the expected frequency was < 5), 21% of club members had targeted West Australian dhufish and pink snapper, compared with 11% of avid recreational fishers in the phone survey in Chapter 2 who reported targeting this species. Note, however, that the questionnaire completed by club members did not include the option of reporting that they had targeted no particular species ('no target') on their last fishing trip in the preceding 12 months. Of the avid anglers interviewed in the phone survey who had reported targeting a species, 16% had targeted West Australian dhufish or pink snapper (Fig. 3.2, Table 3.3). Anglers who caught pink snapper but who had caught West Australian dhufish on their last boat fishing trip were also likely to be members of angling clubs (logistic regression: $P < 0.05$) (Table 3.4).

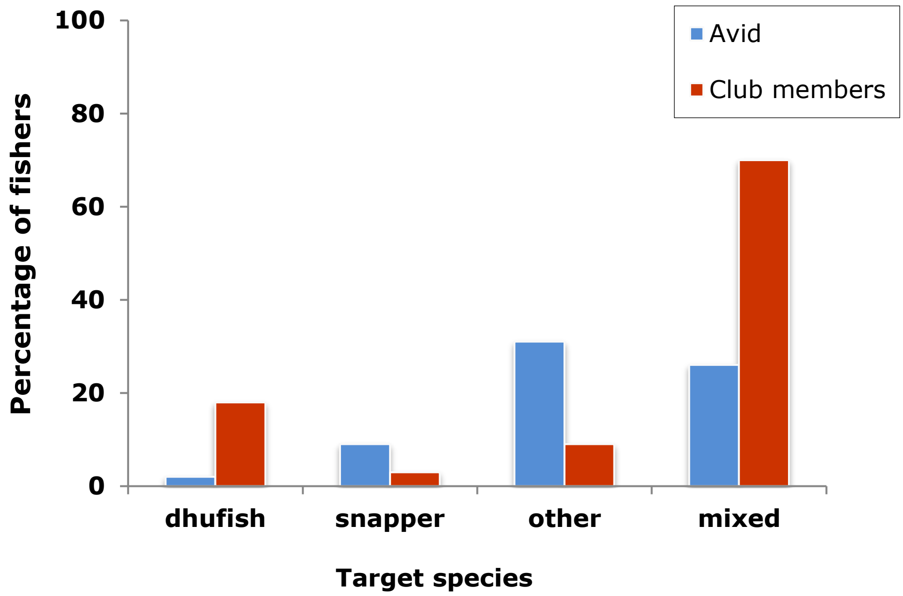


Figure 3.2 Percentages of avid anglers interviewed in the phone survey (Chapter 2), who had reported targeting a species, and recreational fishers from angling clubs, who had reported targeting the different species categories on their last boat-based fishing trip within the 12 month periods that preceded the surveys in which they were interviewed, *i.e.* August to September 2011 and September 2009 to December, 2010, respectively. Note the questionnaire completed by club members did not include the option, 'no target'.

Table 3.3 Numbers (and percentages) of avid anglers interviewed in the phone survey (Chapter 2) and recreational fishers from angling clubs who reported targeting the different species categories on their last boat-based fishing trip during the preceding 12 month period, *i.e.* August to September 2011, and September 2009 to December 2010, respectively.

Target species	Avid anglers in phone survey	Club member survey
West Australian dhufish	3 (2%)	6 (18%)
Pink snapper	12 (9%)	1 (3%)
Other	42 (31%)	3 (9%)
Mixed	35 (26%)	23 (70%)
No target	42 (31%)	Not in questionnaire
Total	134 (100%)	33 (100%)

Table 3.4 Coefficients of explanatory variables of logistic regression model to determine factors influencing club membership. ID, inshore demersal; OD, offshore demersal; IP & ID, a mix of inshore pelagic and inshore demersal; IP, inshore pelagic; and OP, offshore pelagic fish species. Note that values of coefficients are presented in normal font in the table below if $P < 0.1$, or in bold font if $P < 0.05$, otherwise the values are not presented.

	Target											**Dhufish caught**		**Snapper caught**	
	Dhufish	Snapper	Other	Mix Reef	No Target	Estuarine	ID	OD	IP&ID	IP	OP	No	Yes	No	Yes
Club membership		**-2.82**											**1.30**		

Null dev.	211.32	on 314 degrees of freedom
Residual dev.	118.13	on 301 degrees of freedom
AIC	146.13	

3.3.3. Gear and methods

Boat ownership

The majority (91%, 29 fishers) of club members responded that they lived in households that owned a boat for the purpose of recreational fishing. The level of boat ownership among avid anglers interviewed in the phone survey was 78% (Chapter 2). It should be recognised, however, that the wording of the questions in the two surveys differed slightly. The former asked whether the household owned a boat while the latter asked if the individual fisher owned a boat.

Boat usage

The majority (79%, 25 fishers) of club members responded that they fished from a boat either 'most times' or 'every time' that they went fishing. Only a small percentage of club members stated that they 'often' or 'sometimes' fished from a boat (*i.e.* 12% and 9%, respectively). None of the anglers reported that they did not fish from a boat (Fig. 3.3). Note that comparisons of boat usage between the club members and the avid recreational fishers, who had been interviewed in the phone survey (Chapter 2), could not be made due to differences in survey design (*i.e.* this specific question was not asked in the phone survey).

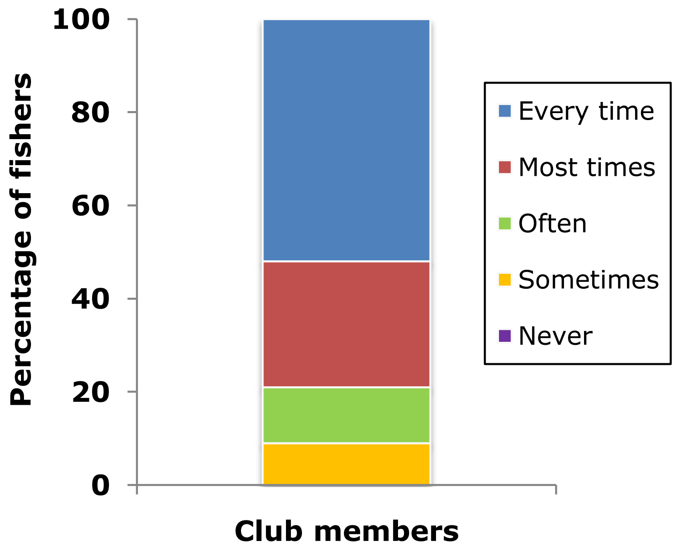


Figure 3.3 **Percentages of recreational fishers from angling clubs who went fishing from a boat in the last 12 months.**

Use of technology

All participating club members (100%, 31 fishers) stated that they owned a global positioning system (GPS). This percentage was significantly greater (chi-square test: $P < 0.001$) than that recorded for avid fishers in the phone survey, *i.e.* 63% (Chapter 2). More than a third (37%, 11 fishers) of the club members who responded to this question also had ≥ 150 locations stored in their GPS (Fig. 3.4). The percentage of club members who had stored ≥ 25 fishing locations in their GPS, *i.e.* 77%, also differed significantly (chi-square test: $P < 0.05$) from and exceeded the percentage, *i.e.* 51%, of avid recreational fishers in the phone survey (Chapter 2) with similar numbers of stored GPS locations (Fig. 3.4). Club members considered 45% of the locations that they had stored in their GPS systems to be very good fishing locations, which they visited regularly.

When asked to score their level of skill in identifying different types of habitats using an echo sounder (from 0, not skilled at all, to 10, extremely skilled), the average rating by club members for non-reef habitat, *i.e.* 5.8 was slightly less than that for reef edge 6.4 and reef top habitats 6.4. Anglers rated themselves less skilled at identifying reef caves and crevices, *i.e.* with a mean score of 5.2 than other habitats (Table 3.5).

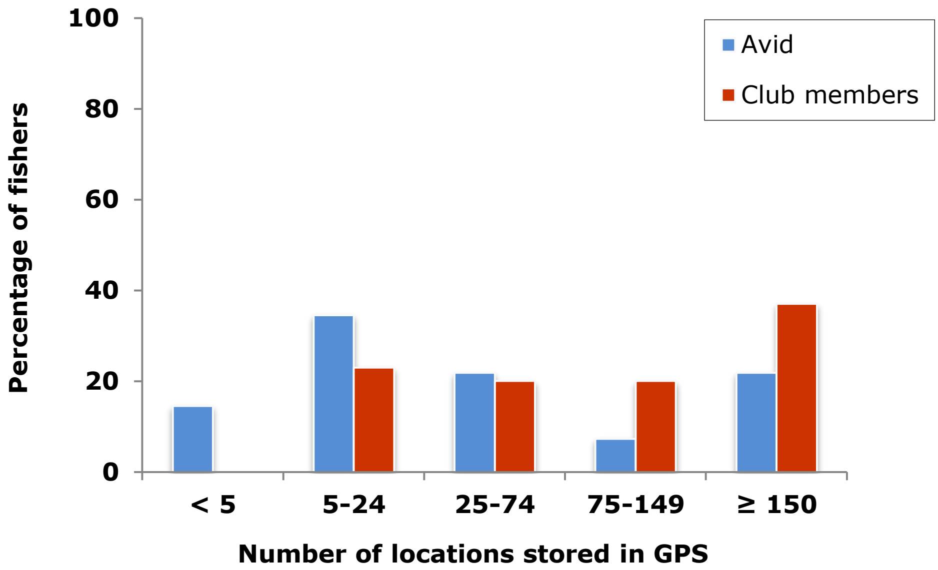


Figure 3.4 **Percentages of fishers with different numbers of locations stored in their global positioning system (GPS) recorded for the avid recreational fishers interviewed in the phone survey (Chapter 2) and the surveyed anglers from angling clubs, who reported in those surveys that they owned a GPS.**

Table 3.5 **Average of self-determined scores assigned by club members for their levels of skill at identifying different habitat types using an echo sounder (0 = not skilled at all to 10 = extremely skilled).**

	Average
Non-reef habitat	5.8
Reef edge	6.4
Reef top	6.4
Reef caves/crevices	5.2

Fishing methods

During their last fishing trip, 85, 76 and 70% of club members reported that they actively fished in the 'mid-morning', at 'sunrise/early morning' and at 'mid-day', respectively. Note that the questionnaire allowed the respondent to select multiple categories, suggesting that the above percentages reflect fishing trips that extended from early morning to mid-day. No fisher reported that he actively fished during the 'late afternoon/sunset' or 'night' time periods (Table 3.6).

Almost all (98%, 32 fishers) anglers responded that they always 'line fish', a method which includes the use of handlines, rod and lines, lines with snapper or mechanical winches. Only one fisher stated that he both line fished and spear fished, each about 50% of the time.

Table 3.6 **Numbers (and percentages) of surveyed anglers who, during their last fishing trip prior to the survey, fished at sunrise/early morning, mid-morning, mid-day, mid-afternoon, late afternoon/sunset, and at night. Note that fishers were able to nominate multiple periods in which they fished.**

	Frequency	**Percent**
Sunrise/early morning	25	76%
Mid-morning	28	85%
Mid-day	23	70%
Mid-afternoon	14	42%
Late afternoon/sunset	0	0%
Night	0	0%

3.3.4. **Commitment**

Fishing time

More than half (59%, 19 fishers) of club members responded that they had spent between 5-6 h actively fishing during their last boat-based fishing trip, *i.e.* where the duration of active fishing was specified as the period between arriving at their first fishing location and leaving their final fishing location to travel home. The second highest percentage (22%, 7 fishers) of club members had actively fished for 3-4 h. No angler reported actively fishing for longer than 8 h during his most recent boat fishing trip prior to the survey (Fig. 3.5). Note that direct comparisons between avid recreational fishers in the phone survey (Chapter 2) and club members of the amount of time anglers' spent actively fishing on their last boat-based fishing trip could not be made due to differences in the survey question (*i.e.* the time classes used in the question were not identical between surveys). It is pertinent to note, however, that the anglers interviewed in the phone survey reported an average duration of 3.7 h for their last boat-based fishing trip.

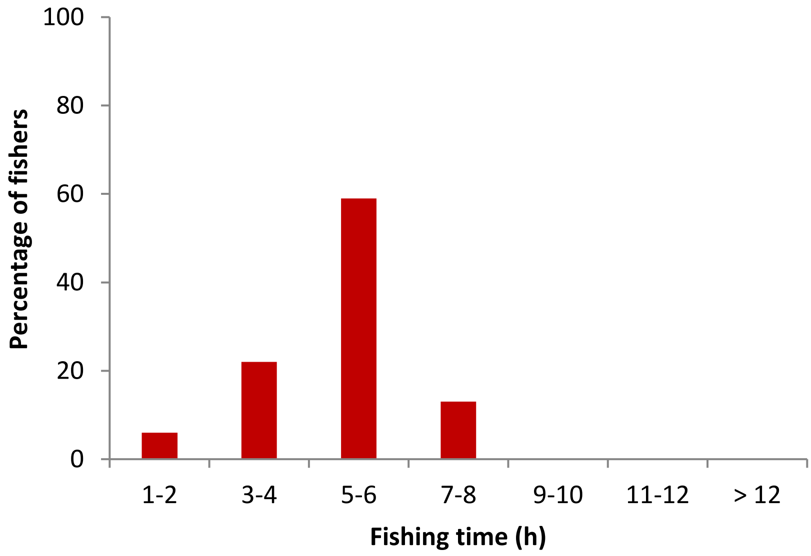


Figure 3.5 **Percentages of club members who reported that they had actively fished for the various different periods during their last boat-based fishing trip prior to the survey.**

Movements between fishing locations

More than half (60%, 20 fishers) of club members stated that they would stay at their best/favourite fishing location for either 20-29 or 30 min – 1 h, while not getting any 'good' bites (*i.e.* bites from a fish likely to be big enough that anglers would be likely to keep the fish if it was caught) (Fig. 3.6). The percentage of avid recreational fishers in the phone survey (Chapter 2) who would stay at their best/favourite fishing location for ≥ 30 min differed significantly ($P < 0.001$) and exceeded the percentage of club members who would stay for that period (Fig. 3.6).

If, however, those club members were at a new fishing location, where they had never fished before, most (60%, 20 fishers) would be willing to stay for only 15-19 min or 20-29 min (Fig. 3.7). The percentage of avid recreational fishers in the phone survey (Chapter 2), who would stay at a newly discovered fishing location for ≥ 30 min, also differed significantly ($P < 0.001$) and exceeded that of club members who would stay for a period of such duration.

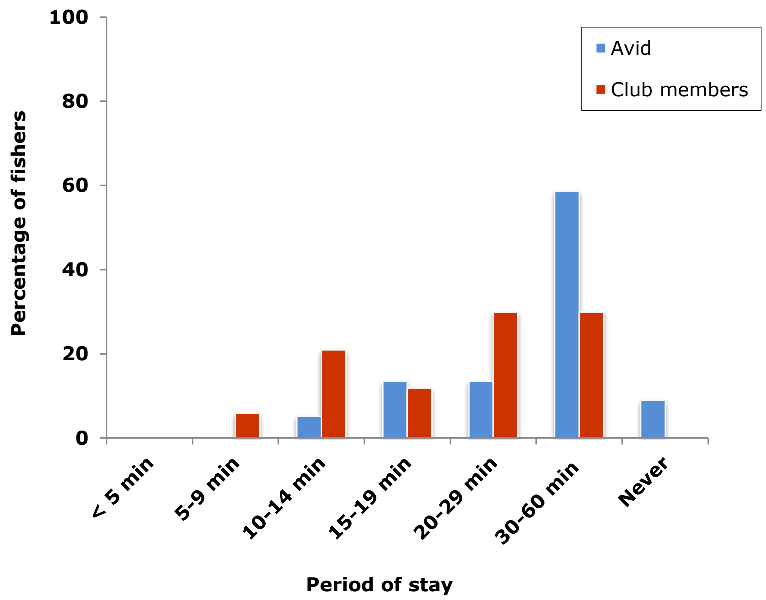


Figure 3.6 Percentages of anglers, who would stay at their best/favourite fishing location for < 5, 5-9, 10-14, 15-19, 20-29, 30-60 min, or never move, when not getting any 'good' fish bites, as reported by avid anglers from the phone survey (Chapter 2) and by recreational fishers from angling clubs, *i.e.* club members.

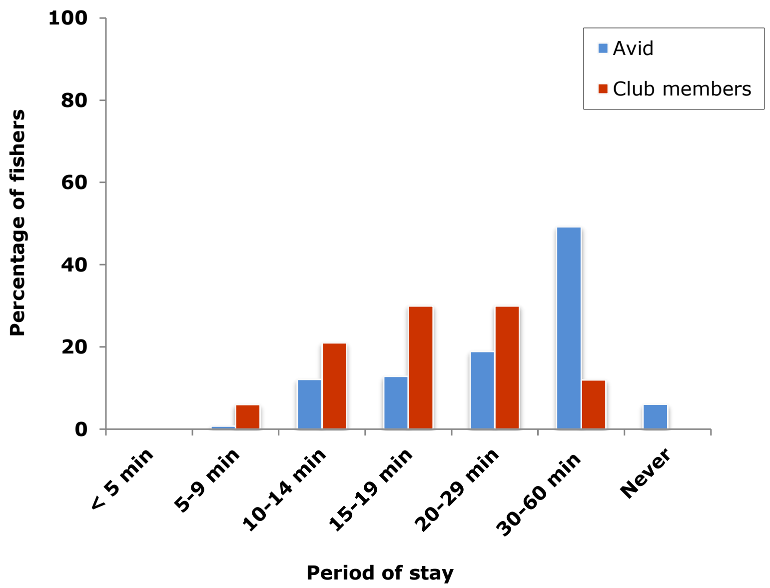


Figure 3.7 Percentages of anglers, who would stay at a 'new' fishing location for < 5, 5-9, 10-14, 15-19, 20-29, 30-60 min, or never move when not getting any 'good' fish bites, as reported by avid anglers from the phone survey (Chapter 2) and by recreational fishers from angling clubs, *i.e.* club members.

Travel

Almost half of club members (48%, 16 fishers) stated they had travelled < 10 km (*i.e.* <5 km or 5-9 km) offshore on their last boat-based fishing trip before they had started fishing. Fifteen (5 fishers) and six percent (2 fishers) of club members reported that they had travelled between 20-29 km and ≥ 30 km offshore, respectively, on their last boat-based fishing trip (Fig. 3.8). Overall, a greater percentage of club members than avid recreational fishers interviewed in the phone survey travelled 10-29 km to their first fishing location during their last boat trip. The percentage of avid recreational fishers in the phone survey (Chapter 2) who travelled ≥ 20 km to their first fishing location did not, however, differ significantly ($P > 0.05$) from the percentage of club members who travelled such distances (Fig. 3.8).

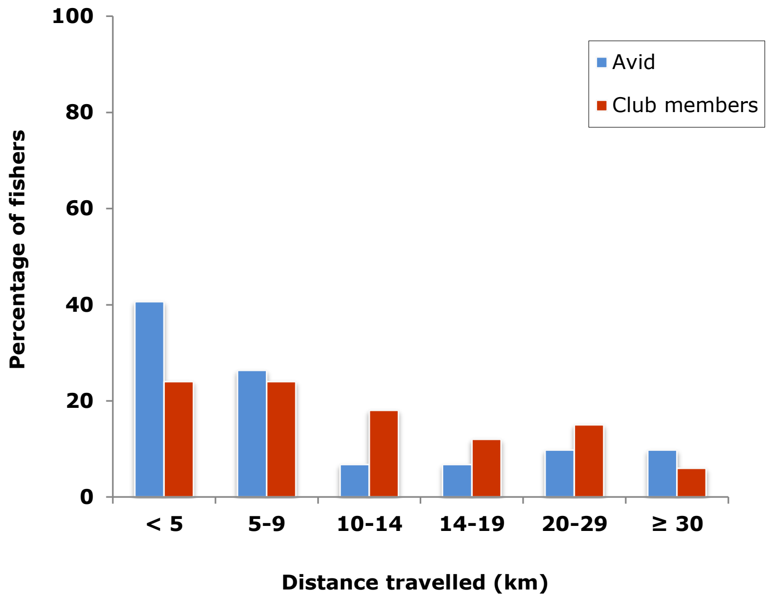


Figure 3.8 **Percentages of avid anglers in the phone survey (Chapter 2) and surveyed club members, who travelled distances of < 5, 5-9, 10-14, 14-19, 20-29 or ≥ 30 km to their first fishing location on their last boat-based fishing trip.**

Weather influences

Almost all club members (91%, 30 fishers) responded that the weather 'sometimes' stopped them from going fishing, with the remaining 9% (3 fishers) reporting that they only went boat fishing when the weather was very calm. The majority (73%, 24 fishers) of anglers stated that they would cancel an intended boat-based fishing trip if the weather forecast predicted wind strengths of 20-30 knots and/or a swell greater than 2.5 m. A further 24% (8 fishers) of club members would cancel a trip if the weather forecast was for wind strengths of 10-20 knots and/or swell of greater than 1.5 m. More than half (58%, 19 fishers) of club members stated that they would start a boat-based fishing trip earlier in the day if a 20-30 knot sea breeze was forecasted and/or stop fishing if a 20-30 knot sea breeze came up. Thirty-six percent (12 fishers) of anglers would also alter their boat fishing plans if there was a 10-20 knot sea breeze.

All interviewed club members (100%) responded that the weather conditions they encounter when boat fishing strongly influences how far they are prepared to travel offshore to a fishing spot. On a calm day, more than half of club members (64%, 21 fishers) were willing to travel ≥ 30 km offshore (Fig. 3.9). If moderate weather conditions are predicted, fishers tend not to travel as far offshore, with only 34% (11 fishers) of club members prepared to travel ≥ 30 km (Fig. 3.10). Almost half of club members (45%, 14 fishers) would only travel < 5 km offshore (Fig. 3.11) if the weather was forecasted to be a rough day (≥ 17 knots or ≥ 30 km/h wind strength).

The percentage of avid recreational fishers in the phone survey (Chapter 2) (52%), who would travel ≥ 20 km offshore if the weather was fine and the water was flat calm, differed significantly ($P < 0.001$) and was less than the percentage of club members (85%), who would do the same. The percentage of avid recreational fishers in the phone survey (Chapter 2) (21%) who would travel ≥ 20 km offshore if the weather was moderate (11-16 knots or 20-29 km/h) also differed significantly ($P < 0.001$) and was less than the percentage of club members (53%) who would travel that distance. While there were insufficient data to apply a chi-square test (as an expected frequency was < 5), the percentage of club members who would travel ≥ 20 km offshore if the forecasted weather was rough was 16%, which was far greater than the corresponding percentage reported by avid recreational fishers in the phone survey in Chapter 2 (2%).

The results of the logistic regression analyses suggest that the anglers willing to travel offshore and also travel further distances offshore in stronger (≥ 17 knots or ≥ 30 km/h wind strength) weather conditions were more likely to be members of angling clubs (logistic regression: $P < 0.10$) (Table 3.7).

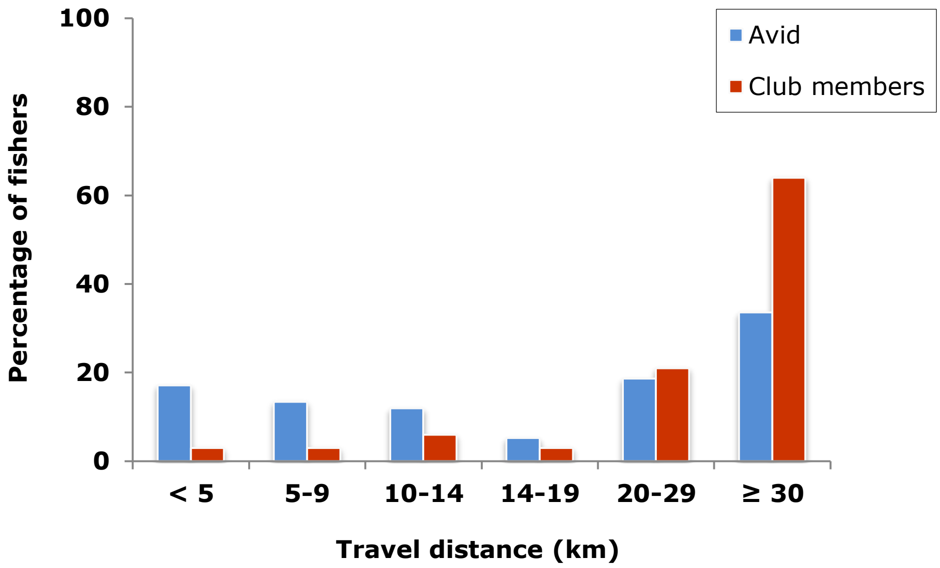


Figure 3.9 **Percentages of avid anglers in the phone survey (Chapter 2) and recreational fishers from angling clubs, *i.e.* club members, who would travel < 5, 5-9, 10-14, 15-19, 20-29 or ≥ 30 km offshore to their first fishing location if the weather was fine and the water was flat calm.**

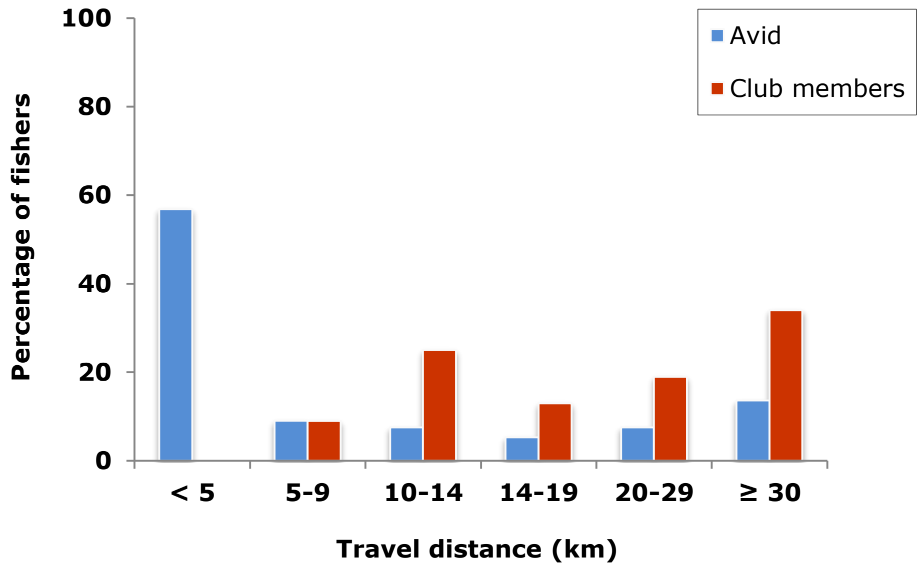


Figure 3.10 Percentages of avid anglers in the phone survey (Chapter 2) and recreational fishers from angling clubs, *i.e.* club members, who would travel < 5, 5-9, 10-14, 15-19, 20-29 or ≥ 30 km offshore to their first fishing location if moderate weather (11-16 knots or 20-29 km/h wind strength) was forecasted.

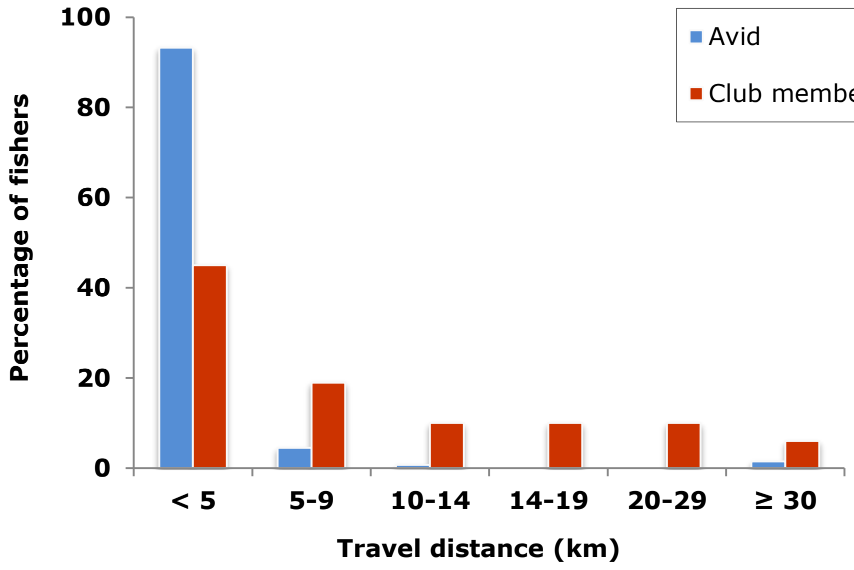


Figure 3.11 Percentages of avid anglers in the phone survey (Chapter 2) and recreational fishers from angling clubs, *i.e.* club members, who would travel < 5, 5-9, 10-14, 15-19, 20-29 or ≥ 30 km offshore to their first fishing location if rough weather (≥ 17 knots or ≥ 30 km/h wind strength) was forecasted.

Table 3.7 Coefficients of explanatory variables of logistic regression model to determine factors influencing club membership. Note that values of coefficients are presented in normal font in the table below if $P < 0.1$, or in bold font if $P < 0.05$, otherwise the values are not presented.

	Distance to first site						Distance offshore if fine						Distance offshore if moderate						Distance offshore if strong					
	<5 km	5-9 km	10-14 km	15-19 km	20-29 km	30 km or more	<5 km	5-9 km	10-14 km	15-19 km	20-29 km	30 km or more	<5 km	5-9 km	10-14 km	15-19 km	20-29 km	30 km or more	<5 km	5-9 km	10-14 km	15-19 km	20-29 km	30 km or more
Club membership																				**1.78**	**2.98**	**3.13**		2.73

Null dev.	202.57	on 337 degrees of freedom
Residual dev.	102.14	on 313 degrees of freedom
AIC	152.14	

Influence of holidays and weekends

Approximately three quarters of club members responded that they always or mostly went boat fishing on a weekend (Fig. 3.12). Note that comparisons between avid recreational fishers in the phone survey (Chapter 2) and club members of the influence on fishing of holidays or weekends could not be made due to differences in the design of the questions in the two surveys. Furthermore, note that the two surveys were undertaken at different times within the year, which is also likely to influence the comparisons of the results from the two surveys.

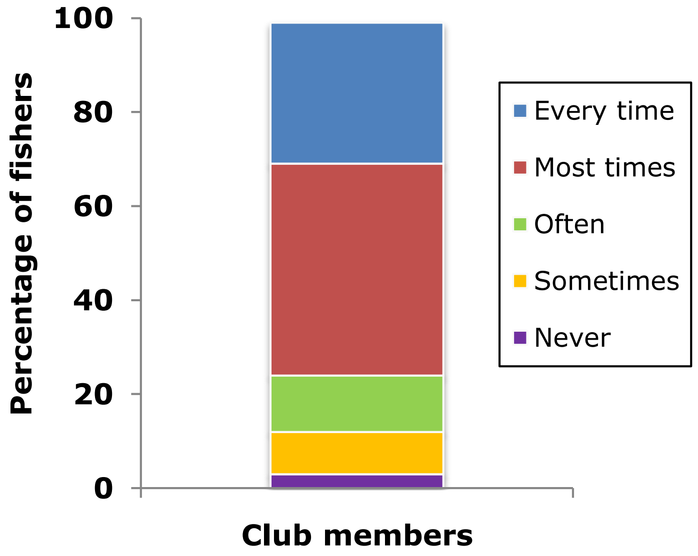


Figure 3.12 **Percentages of surveyed club members who, over the last 12 months, never, sometimes, often, most times or every time, went fishing on weekends on the occasions that they fished.**

Knowledge and behaviour

The majority (77%, 24 fishers) of club members agreed (*i.e.* strongly agree or agree) with the statement "you have many fishing spots on your GPS, but of these, there a few which you visit far more frequently than the others, because those few spots provide excellent fishing" (Table 3.8). More than half (63%, 20 fishers) of club members agreed (*i.e*. strongly agree or agree) with the statement "the areas you tend to start fishing on a particular fishing trip are often those where, on your previous fishing trip, you had good success" (Table 3.8). Mixed responses were given when club members were asked if they "often fish in areas which friends have recommended", with 38% (12 fishers) of fishers disagreeing, 31% (10 fishers) feeling neutral and 31% (10 fishers) agreeing with this statement (Table 3.8). Club members (41%, 13 fishers) agreed that they "use nautical charts or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help you start searching" (Table 3.8). More than half of fishers (66%, 21 fishers) disagreed that they would "use information available from the internet to locate new fishing locations". The majority agreed (84%, 26 fishers) that they "often use depth contour and/or other inbuilt information in your GPS to locate new fishing spots" (Table 3.8).

Table 3.8 The number (and percentage) of club members who chose to: Strongly Disagree (SD), Disagree (D), are Neutral (N), Agree (A), or Strongly Agree (SA) with the following six statements. Note that not all fishers responded to each question.

	SD	D	N	A	SA	Total
I have many fishing spots on my GPS, but of these, there are a few which I visit far more frequently than the others, because those few spots provide exceptional fishing.	1 (3%)	5 (16%)	1 (3%)	18 (58%)	6 (19%)	**31 (100%)**
The areas I tend to start fishing on a particular fishing trip are often those where, on my previous fishing trip, you had good success.	4 (13%)	3 (9%)	5 (16%)	18 (56%)	2 (6%)	**32 (100%)**
I often fish in areas which friends have recommended.	4 (13%)	8 (25%)	10 (31%)	8 (25%)	2 (6%)	**32 (100%)**
I use nautical charts, or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help me start searching for new spots.	9 (28%)	3 (9%)	7 (22%)	10 (31%)	3 (9%)	**32 (100%)**
I use information available from the internet to locate new fishing locations.	12 (38%)	9 (28%)	8 (25%)	2 (6%)	1 (3%)	**32 (100%)**
I often use depth contour and/or other inbuilt information in my GPS to locate new fishing spots.	1 (3%)	3 (10%)	1 (3%)	16 (52%)	10 (32%)	**31 (100%)**

3.3.5. **Social interactions**

The majority of club members reported that either 1-2 people (66%, 21 fishers) or 3-4 people (31%, 10 fishers) actively fished on the boat used during their last boat fishing trip (Table 3.9). The minimum and maximum numbers reported by anglers were 1 and 6 people, respectively.

Table 3.9 **Number (and percentages) of club members reporting the different numbers of fishers on-board the boats used by those members during their last boat fishing trip.**

	1-2	**3-4**	**5-6**	**7-9**	**> 10**	**Total**
Frequency	21	10	1	0	**0**	**32**
Percent	66%	31%	3%	0%	0%	**100%**

3.3.6. **West Australian dhufish specialisation**

Catch

More than half (61%, 20 fishers) of club members responded that they ‘sometimes’ caught West Australian dhufish when they went boat fishing over the last 12 months. Only 9% (3 fishers) reported that they ‘never’ caught West Australian dhufish on their fishing trips (Fig. 3.13).

In total, the surveyed anglers reported capturing 58 West Australian dhufish on their last boat-based fishing trip, with an average of three (SE = 2.71) fish each. However, 79% (46 fish) of these fish captures were subsequently reported to be released by anglers. The percentage of club members who had caught West Australian dhufish during their last trip, *i.e.* 70%, differed significantly ($P < 0.001$) from and exceeded that reported by the avid recreational fishers in the phone survey *i.e.* 9% (Chapter 2).

More than half (64%, 21 fishers) of club members did not catch and retain their bag limit (the current daily bag limit is set to two high risk demersal scalefish and two pelagic fish, *i.e.* West Australian dhufish, pink snapper, and a boat limit of two West Australian dhufish Department of Fisheries, (2012)) for West Australian dhufish during their last boat fishing trip.

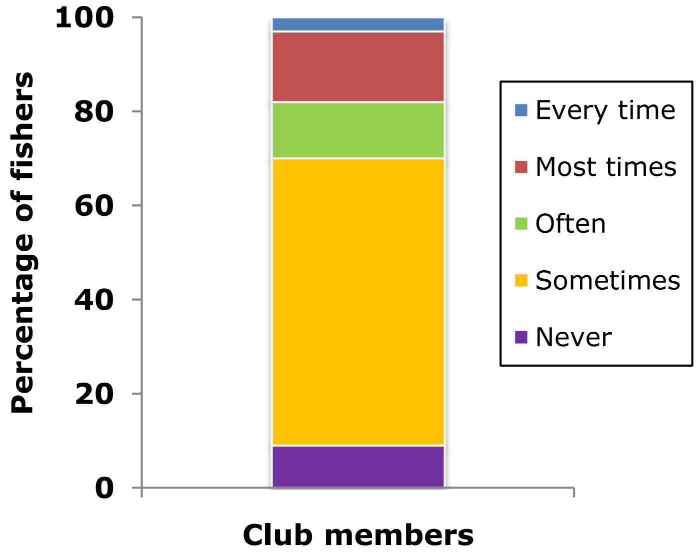


Figure 3.13 Percentages of surveyed club members, who reported that, during the last 12 months, they never, sometimes, often, most times and every time, caught West Australian dhufish when they went boat fishing.

Gear and methods

When targeting West Australian dhufish, on average, anglers reported spending 76% of their time using the method of drift fishing with a sea anchor. Almost half (42%, 13 fishers) of anglers responded that they mostly target West Australian dhufish in water depths of 35-54 m, and a further 35% (11 fishers) responded that they target West Australian dhufish in 25-34 m of water. No fisher responded that he targeted West Australian dhufish in water depths of < 15 m or ≥ 95 m (Fig. 3.14).

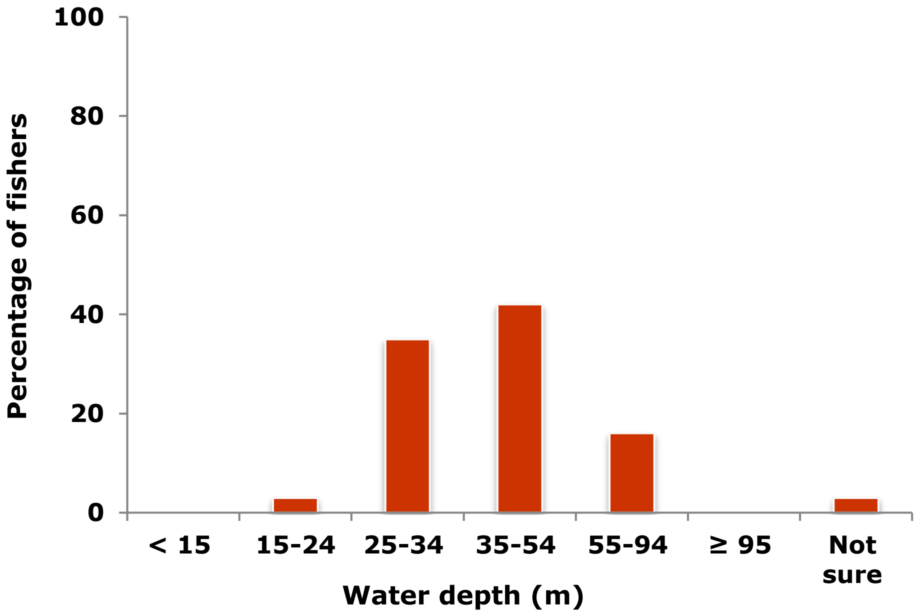


Figure 3.14 **Percentages of club members who typically target West Australian dhufish at different water depth intervals.**

Best fishing times and methods used for identifying fishing locations

Club members responded that they considered 'mid-morning' and 'sunrise/early morning' the best times of the day for catching West Australian dhufish (31%, 10 fishers and 28%, 9 fishers, respectively). However, 28% (9 fishers) of anglers also indicated that they considered there was no particular time of the day that is best for catching West Australian dhufish (Table 3.10). Almost a quarter (22%, 7 fishers) of anglers also use lunar or solunar charts for selecting the best days for catching West Australian dhufish (Table 3.10).

Fishers identified reef areas as good habitats for catching West Australian dhufish. All fishers considered 'sand more than 20 m away from reef' poor or average habitat for catching West Australian dhufish, with the majority (73%, 22 fishers) of fishers also reporting that 'sand within 20 m of reef' was poor or average habitat (Table 3.11). A greater percentage of anglers considered 'reef edges' better habitats for catching West Australian dhufish than 'reef tops', *i.e.* with 57% (17 fishers) of fishers reporting they were 'very good' compared to 13% (4 fishers) who considered reef tops to be the better habitat (Table 3.11). 'Caves found on the reef edge' were considered to be 'very good' and 'excellent' by the majority of anglers (90%, 26 fishers) (Table 3.11), with 'caves found over the reef' considered to be very good and excellent by fewer anglers (67%, 20 fishers) (Table 3.11). The same percentage (67%, 20 fishers) also considered 'isolated reef lumps' to be 'very good' and 'excellent' habitats for catching West Australian dhufish (Table 3.11).

Table 3.10 **The number of club members and percentage (of the total number of interviewed club members) reporting that they considered the specified times of day or days to be best for catching West Australian dhufish. Note that club members could nominate more than one period as the 'best'.**

	Frequency	Percent
Sunrise/early morning	9	28%
Mid-morning	10	31%
Mid-day	3	9%
Mid-afternoon	5	16%
Late afternoon/sunset	6	19%
Night	3	9%
I use lunar (solunar) chart	7	22%
No particular time is best	9	28%
Not sure – I rarely catch West Australian dhufish	4	13%

Table 3.11 The number (and percentage) of club members who perceive the following habitats to be good for catching West Australian dhufish.

	Poor	**Average**	**Good**	**Very Good**	**Excellent**	**Total**
Sand more than 20 m away from reef	23 (77%)	7 (23%)	0 (0%)	0 (0%)	0 (0%)	**30 (100%)**
Sand within 20 m of reef	9 (30%)	13 (43%)	8 (27%)	0 (0%)	0 (0%)	**30 (100%)**
Reef top	1 (3%)	15 (50%)	10 (33%)	4 (13%)	0 (0%)	**30 (100%)**
Reef edge	0 (0%)	0 (0%)	9 (30%)	17 (57%)	4 (13%)	**30 (100%)**
Caves found on the reef edge	0 (0%)	0 (0%)	3 (10%)	16 (55%)	10 (35%)	**29 (100%)**
Caves found over the reef	0 (0%)	0 (0%)	10 (33%)	12 (40%)	8 (27%)	**30 (100%)**
Isolated reef 'lumps'	0 (0%)	1 (3%)	9 (30%)	12 (40%)	8 (27%)	**30 (100%)**

3.3.7. Pink snapper specialisation

Catch

Just over half (56%, 18 fishers) of club members responded that, when they went boat fishing over the last 12 months, they 'sometimes' caught pink snapper. A further 25% (8 fishers) of anglers responded that they 'often' caught pink snapper, and 9% (3 fishers) reported that they 'never' caught pink snapper on their fishing trips (Fig. 3.15).

The surveyed anglers reported catching 44 pink snapper, in total, during their last boat fishing trip, *i.e.* an average two per fisher (SE = 2.7). Of the fish captured, however, 89% (39) were subsequently reported to be released by anglers. The percentage of club members who caught pink snapper, *i.e.* 64%, differed significantly ($P < 0.001$) from and exceeded that reported by the avid recreational fishers in the phone survey (Chapter 2), *i.e.* 13%.

The majority (85%, 28 fishers) of club members did not catch and retain their bag limit for pink snapper on their last boat fishing trip.

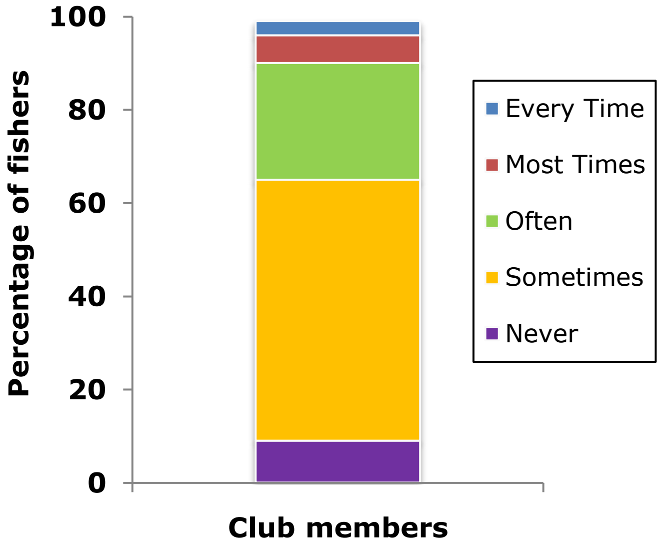


Figure 3.15 Percentages of surveyed club members who reported that, during the last 12 months, they never, sometimes, often, most times or every time, caught pink snapper when they went boat fishing.

Gear and methods

When targeting pink snapper, on average, club members reported spending 52% of their time using the method of drift fishing with a sea anchor and, for a further 23% of their time, they used the method of fishing using an anchor. Just over a quarter (26%, 8 fishers) of club members responded that they mostly targeted pink snapper in water depths of 35-54 m, followed by 23% (7 fishers) in 55-94 m and 19% (6 fishers) in 25-34 m. A few club members (6%, 2 fishers) indicated that they target pink snapper at water depths of < 15 m and a single angler reported targeting pink snapper at a water depth of ≥ 95 m (Fig. 3.16).

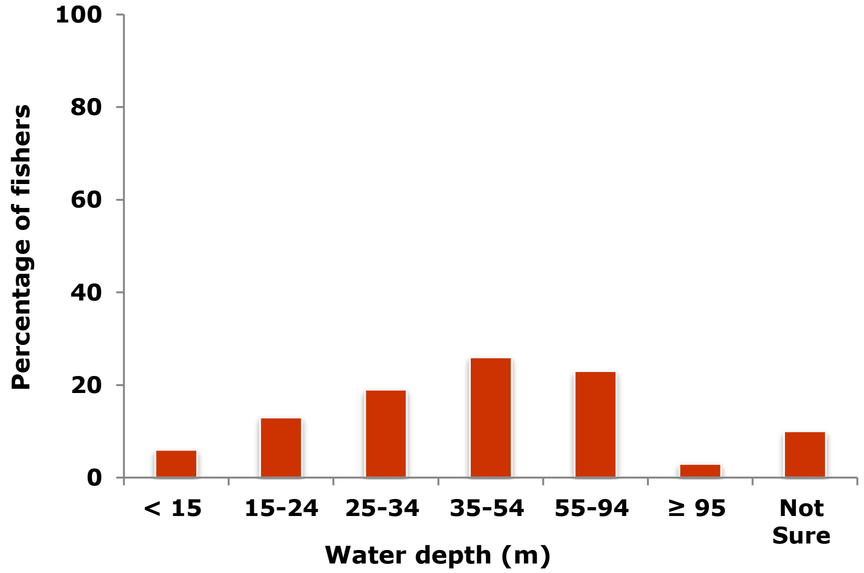


Figure 3.16 **Percentages of club members who typically target pink snapper at different water depth intervals.**

Best fishing times and methods used for identifying fishing locations

Almost half of anglers (45%, 15 fishers) responded that they considered 'late afternoon/sunset' as the best time for catching pink snapper, followed by 35% of anglers indicating 'sunrise/early morning' and 30% indicating 'night' time as good times (Table 3.12).

More than half of anglers (77%, 21 fishers) identified 'sand more than 20 m away from reef as a 'poor' or 'average' habitat for catching pink snapper (Table 3.13), and just over half (59%, 16 fishers) indicated that 'sand within 20 m of reef' was a 'poor' or 'average' habitat (Table 3.13). Anglers considered 'reef edges' better than 'reef tops' as habitats for catching pink snapper, with 82% (23 fishers) of fishers reporting they were 'good' and 'very good' compared to 57% (16 fishers), who considered reef tops to be the better habitat (Table 3.13). 'Caves found on the reef edge' were identified as 'good' and 'very good' habitats by 46% (12 fishers) of anglers with a further 12% (3 fishers) indicating these to be excellent habitats for pink snapper (Table 3.13). 'Caves found over the reef' were perceived as being of slightly lesser quality as habitats for catching pink snapper, with 39% (10 fishers) indicating that these habitats were ‘good’ or ‘very good’ and 8% (2 fishers) indicating that they were excellent (Table 3.13). The majority (75%, 22 fishers) of club members indicated that they perceived ‘isolated reef lumps’ to be ‘very good’ or ‘excellent’ habitats for catching pink snapper (Table 3.13).

Table 3.12 The number of club members and percentage (of the total number of interviewed club members) reporting that they considered the specified times of day or days to be best for catching pink snapper. Note that club members could nominate more than one period as the ‘best’.

	Frequency	**Percent**
Sunrise/early morning	12	36%
Mid-morning	3	9%
Mid-day	0	0%
Mid-afternoon	0	0%
Late afternoon/sunset	15	45%
Night	10	30%
I use solar (solunar) chart	5	15%
No particular time is best	8	24%
Not sure – I rarely catch pink snapper	5	15%

Table 3.13 The percentage of club members who perceive the following habitats to be good for catching pink snapper.

	Poor	Average	Good	Very Good	Excellent	Total
Sand more than 20 m away from reef	12 (44%)	9 (33%)	3 (11%)	3 (11%)	0 (0%)	**27 (100%)**
Sand within 20 m of reef	6 (22%)	10 (37%)	4 (15%)	5 (19%)	2 (7%)	**27 (100%)**
Reef top	1 (4%)	10 (36%)	11 (39%)	5 (18%)	1 (4%)	**28 (100%)**
Reef edge	0 (0%)	3 (11%)	9 (32%)	14 (50%)	2 (7%)	**28 (100%)**
Caves found on the reef edge	0 (0%)	11 (42%)	6 (23%)	6 (23%)	3 (12%)	**26 (100%)**
Caves found over the reef	1 (4%)	13 (50%)	3 (12%)	7 (27%)	2 (8%)	**26 (100%)**
Isolated reef 'lumps'	0 (0%)	2 (7%)	5 (17%)	12 (41%)	10 (34%)	**29 (100%)**

3.4. Discussion

3.4.1. Survey participants

This survey was focussed on a relatively small group (*n*=33) of anglers from fishing clubs, who often target certain large demersal species, such West Australian dhufish and pink snapper. It is thus very likely that the sample data obtained is biased towards highly-active (*e.g*. higher participation) and committed recreational fishers. Therefore, the results obtained in this study are unlikely to be reflective of the general population of anglers who target demersal species including West Australian dhufish and pink snapper. It should be noted that angler responses may have been influenced by the fact that some of the interviews were conducted (in September 2009) prior to the introduction of the RFBL, in combination with a two-month demersal scalefish fishery closure and reduced bag limit, and other interviews were conducted after those changes (December 2010).

3.4.2. Characteristics of fishers who are members of angling clubs

General demographic information

The fact that all survey participants were male and aged predominantly between 45-59 y, with the majority also reporting that they had many years of fishing experience in the study, is not surprising. Past surveys of fishing club members elsewhere in the world have also reported a predominance of male anglers (> 90%), with members often found to be older (average age 45 y) than non-members (Gigliotti and Peyton, 1993; Schramm and Gerard, 2004; Zischke *et al.*, 2012). Zischke *et al.* (2012) proposes that male anglers are more likely to participate in specialised fishing practices, as they tend to be either more experienced or fish more frequently. It might be postulated that older males have a greater income or accumulated wealth than younger males, and are thus more likely to be able to afford the expensive equipment and large boats required to travel further distances and catch West Australian dhufish.

As hypothesised, it was found that highly avid anglers (*i.e.* anglers who fished more than 20 days in the last 12 months) were more likely than the general population of boat fishers to be members of fishing clubs. These results are also consistent with a number of other studies (*e.g.* Gigliotti and Peyton, 1993; Fisher, 1997; Gartside *et al*., 1999). However, it was also noteworthy that only about half of the club respondents were classified as avid anglers (fished more than 15 days over the last 12 months). Thus, clearly, not all club members are avid fishers, which indicates that there would be a range of other motivations for surveyed members to have become angling club members. Further, it is noted that the number of fishing days undertaken by anglers may have also been influenced by the amount and timing of fishing competitions held within the different angling clubs. It should also be recognised that the sample of fishers used in this survey was not selected based on probability, but more in an opportunistic nature and thus may not be representative (of all club members), however, their behaviour can be seen as informative, especially for avid and experienced fishers targeting demersal fish.

In contrast to the results of the current study, Arlinghaus and Mehner (2003) discovered that, compared with the general angler population, specialised (carp) anglers in their survey tended to be younger and less experienced. These differences could possibly be related to the fact that, as carp is a freshwater species, the larger investment in gear, *e.g.* a boat capable of fishing in offshore marine waters for West Australian dhufish, is not required by specialised carp anglers (García-Berthou, 2001; Penne and Pierce, 2008). It is also possible that fishing for carp may appeal more to younger fishers because this is a species that is known to be inherently difficult to catch using fly fishing methods, the most written about fishing technique (Bryan, 1977), thereby providing these fishers a competitive 'sport-fishing' opportunity. It is also important to note that according to specialisation theory, there are different types of specialist fishers, *i.e.* technique specialists that specialise in a particular method of fishing, technique-setting specialists who have distinct preferences in methods and water types (physical setting) and also species specialists who target a particular fish species whilst angling (Bryan, 1977; Ditton *et al*., 1992; Fisher, 1997; Salz and Loomis, 2005). It is likely that the fishers described in the study by Arlinghaus and Mehner (2003) are "species specialists". Furthermore, the characteristics and behaviours of specialist anglers, who target a particular species of fish, are likely to differ from those of a specialist angler with a different set of activity-specific elements, *i.e.* a fisher who targets a different species of fish, and among species specialists in different areas and regions (Graefe, 1980; Fisher, 1997; Salz and Loomis, 2005).

Many of the club members who participated in the survey were from the northern coastal suburbs of the Perth Metropolitan Region. This, however, is most probably due to the fact that the three angling clubs visited (Marmion, Quinns Rock and Ocean Reef) are situated in those northern suburbs.

The demographic characteristics of the angling club members were very similar to those of the fishers who participated in the phone survey (Chapter 2). Note, however, that some of the recreational fishers surveyed in Chapter 2 could have also been affiliated with angling clubs within the region, and it was not possible to confirm whether this was the case with any of these fishers from the RFBL database as they were not questioned as to whether they were members of a fishing club or organisation.

Catch preference

The results of this survey showed that the majority of responding club members reported that they mainly aimed to catch a 'mix' of fish species including West Australian dhufish or pink snapper. However, a percentage of fishers reported West Australian dhufish as their main target fish species. In contrast, participants in the phone survey (see Chapter 2) were more generalist fishers, mainly aiming to catch a fish species 'other' than West Australian dhufish or pink snapper, instead choosing to target more inshore 'bread and butter' species, *i.e.* whiting, herring, crabs and squid. Moreover, the results suggest that the responding club members were almost twice as likely to target West Australian dhufish or pink snapper as boat-based avid anglers selected randomly from the recreational fishing boat licence database. Therefore, understanding the characteristics of these specialised and more committed anglers is likely to be essential for the sustainable management of fish species such as West Australian dhufish and pink snapper, but less so for many other species, *i.e.* easy to catch 'bread and butter' fish, which are probably caught in greater numbers by generalist and often less avid fishers. Also, note that the timing of the phone survey (Chapter 2) and angling clubs survey were different (between 16 August 2011 and 19 September 2011 and during September 2009 and December 2010, respectively) and thus may have influenced the responses received from recreational fishers.

Gear and methods

As hypothesised, fishing club members were more likely to own a global positioning system (GPS) than avid anglers in the phone survey (Chapter 2). The results are thus also consistent with specialisation theory, which suggests that high monetary investment in fishing equipment and use of technology is associated with highly specialised and committed anglers (Wilde *et al*., 1998; Hutt and Bettoli, 2007). Such results could also be related to the fact that key target species (*e.g.* West Australian dhufish and pink snapper) are often found offshore, near rocky reefs (Wise *et al*., 2007; Lenanton *et al*., 2009), thus it is expected that such fishing gear would be required to target them.

The results from the survey also confirmed the hypothesis that club members made greater use of fishing technologies than the population of boat fishers surveyed in Chapter 2. Thus, club fishers typically had more fishing locations, and a larger percentage of 'good' locations, stored in their GPS compared to avid fishers from the phone survey (Chapter 2). The results also showed that whilst fishers tend to visit their stored GPS locations regularly, club members were less likely to start a new fishing trip at a location where, during their previous fishing trip, they had experienced good catches. Thus, club members are more likely to distribute their fishing activities over a broader range of fishing locations and, rather than basing their choice of fishing location on recent experience, are more likely to explore the potential of obtaining good catches at other known fishing locations. That is, they are more willing to apply their broader knowledge of fishing locations stored in their GPS equipment. Overall, the results highlight the potential for a wider spread of fishing effort by club members. This storage of large numbers of fishing locations is also potentially a way of club members 'hedging their bets', *i.e.* as during/between fishing trips, they can move among a large number of alternative fishing locations and thereby potentially be rewarded with a good catch at one of those locations.

Club members considered reef habitats best for catching both West Australian dhufish and pink snapper. "Caves found on the reef edge" and "reef edges" were considered better for catching West Australian dhufish and pink snapper, respectively. When club members were asked how skilled they were at identifying different types of habitats using an echo sounder, they identified themselves as possessing a level of skill that was just 5 out of a possible 10 when identifying 'non-reef' habitat, and were only slightly more skilled at identifying 'reef edge's and 'reef tops'. Considering that the majority of anglers also indicated that they use depth contour and inbuilt information in their GPS to locate new fishing locations, the low ratings in their skill at identifying habitat types was, perhaps, surprising. However, this question does not account for the fact that club members were shown to use a range of methods for locating new fishing locations, such as nautical charts and maps, which almost half of club members responded that they are likely to use. Thus, the use of a combination of technologies and methods may, overall, result in these club members being highly knowledgeable and skilled at identifying the "reef edge" and "reef top" habitats that they consider to be good habitats for West Australian dhufish and pink snapper. In a creel survey in the same region (West Coast Bioregion) with the main species being targeted were West Australia dhufish by Sumner and Williamson (1999), recreational boat-based fishers had also adopted modern technology to increase the efficiency of their fishing activity with 36% of boats fitted with an echo-sounder and 12% using a global positioning system to find fishing locations.

In a 12-month survey during 2005/06 of recreational boat-based fishing in the West Coast Bioregion of Western Australia, the majority of boats reported undertaking ocean line fishing, with effort also reported to be higher in the more populated areas such as the Perth Metropolitan Region (Sumner *et al*., 2008). Further, Henry and Lyle (2003) also reported a preference for use of line fishing (bait, lure, jig, fly, setline) methods by fishers across all States and Territories in the national Australian recreational fishing survey. Thus, the finding from the phone and club surveys that fishers mostly used line fishing, which includes the use of handlines, rod and line or, lines with snapper or mechanical winches, for the vast majority of their fishing time, was not unexpected.

Fishing behaviours, including movements

The fishing times reported by club members, may in part reflect, to some extent, participation in club competitions although such speculation cannot be supported by the available data. If this was the case, however, it is pertinent to note that Gartside *et al*. (1999) reported that the actual time fished by anglers is usually less than the total time of the competition, with many anglers taking advantage of the tides and time of day which are considered favourable rather than fishing for the full duration of the competition. Furthermore, Zischke *et al.* (2012) reported that club members expended a higher percentage of fishing effort and used more specialised angling methods whilst fishing, with fishing trips of ~5 h in duration, which was also found to be significantly longer compared to non-fishing club members in a specialised sport fishery off eastern Australia. Thus, it is not surprising that just over half of club members spent between 5-6 h actively fishing on their last boat fishing trip, with anglers predominantly fishing during the morning period, *i.e.* sunrise, early morning through to mid–day, possibly avoiding the local afternoon sea breeze and returning for afternoon club competition weigh-ins. Monthly club competitions are also predominantly run on the weekends possibly reflecting the results that three-quarters of club members stated that they mostly fished on weekends when they had gone boat fishing. Unfortunately, these fishing behaviours of club members were unable to be compared with those of avid fishers in the phone survey (Chapter 2) due to differences in survey and question design.

As there was no significant difference between the proportions of club members vs avid fishers from the phone survey (Chapter 2) who travelled more than 20 km offshore to their first fishing location on their last boat fishing trip, this result did not lend support to the hypothesis that anglers who are fishing club members tend to travel further offshore to fishing locations. However, conversely, the results did show that club fishers are more likely to travel further offshore in more varied weather conditions (*i.e.* stronger winds and greater swells), suggesting that the club fishers are more motivated than non-club fishers in catching offshore demersal scalefish species such as dhufish and snapper. Note that travel and weather are also likely to be influenced as much by boat size as avidity, with this finding also reflected by the fact that the club members typically own larger boats, which would enable them to travel further offshore in more varied weather conditions, *i.e.* the above highlights their higher monetary and psychological investments in fishing than less specialised fishers (Salz and Loomis, 2005; Dorow *et al*, 2009). In the Perth Metropolitan Region, the reliable afternoon sea breeze, commonly referred to as the 'Fremantle Doctor', is an important factor likely to influence whether a fisher would decide to start a boat-based fishing trip earlier in the day or cease boat fishing. Thus, the finding in the survey that more than half of anglers would start a fishing trip earlier in the day if a 20-30 knot sea breeze was forecasted was not unexpected. The afternoon sea breeze may also be a contributing factor for all club members reporting fishing predominantly during the morning (see above) and also is likely to impact on fishing trip times reported in the Perth Metropolitan Region. It may also be noteworthy that that fish in deeper waters are generally less accessible and therefore potentially more protected from fishing.

Similar responses were reported for the phone survey (Chapter 2) and the club member questionnaire in regard to the number of anglers present on the boat on the angler's last boat fishing trip, with results suggesting usually 1-2 or 3-4 people were present and actively fishing. Further, although no questions relating to fisher motivations for fishing were asked in the club survey, these results (several anglers aboard) still potentially highlight the importance of non-catch motives for club members (*e.g.* to be with family and friends and/or safety reasons) as potentially important reasons as to why multiple people tend to go boat fishing together.

The hypothesis that club members were more likely to move from a fishing location sooner than avid anglers from the phone survey (Chapter 2) when not receiving any 'good' bites from fish was supported by the results of this study. The results are also consistent with the view that more committed and specialised fishers display 'context-specific primary motivations', *i.e.* they are strongly focussed on the catching aspects of fishing (Beardmore *et al.,* 2011). Such movements by club fishers may also potentially be influenced by time limits for fishing competitions, encouraging fishers to more rapidly move-on from poor fishing locations to increase their likelihood of a good catch. Further, the results from the study also showed that club members are likely to cover more fishing ground in a single fishing trip (*e.g.* fish at more fishing locations) by moving on sooner from 'poor' fishing locations. Such movements from locations at which fishers are having low success in catching their target species to locations that potentially have a greater abundance of individuals of those species are likely to contribute to better fishing success (Hilborn, 1985; Sampson, 1991), particularly in catching species like West Australian dhufish because the movements of this demersal fish species are known to be more restricted (Hesp *et al*., 2002; St John and Syers, 2005) than those of many other species, *e.g.* pelagic 'bread and butter' species (Hyndes *et al*., 1997; Fairclough *et al*., 2000a; 200b). Thus, a fisher might not expect a West Australian dhufish to move to their fishing location, whereas for 'bread and butter' species, this might not be the case (particularly if a fisher uses fish attractants, etc.).

West Australian dhufish

West Australian dhufish have experienced periods of overfishing in recent years and poor recruitment years within the WCB, thus leading to the introduction of recent management changes and development of strategies to allow for stock recovery (Wise *et al*., 2007; Department of Fisheries, 2013). These potentially low population levels, may in part explain the results of more than half of club members only 'sometimes' being successful in catching West Australian dhufish when they went boat fishing over the last 12 months. However, in total, club members reported having caught a substantial number (58) of West Australian dhufish and averaging three dhufish each on their last fishing trip, although many of these captured fish were subsequently released due to various reasons (unreported). The fact that many fish were released may also be related to the poor recruitment years mentioned above, with fishers catching many juvenile fish (Wise *et al*., 2007). Thus, it is not surprising that more than half of the club members did not catch and retain their bag limit for West Australian dhufish on their last boat fishing trip. Notably, the average number of West Australian dhufish caught by each club member was approximately three times greater than that caught by each of the avid recreational fishers in the phone survey (Chapter 2).

The survey also showed that club members preferred the method of drift fishing with a sea anchor whilst targeting West Australian dhufish, thereby enabling those anglers to potentially cover larger fishing areas and at several water depths when targeting fish. Furthermore, club members reported not utilising reef anchors, thus potentially causing fewer impacts on reef systems and the surrounding environment.

The findings of the survey that club members mostly targeted West Australian dhufish in waters offshore waters of 35-54 m or 25-34 m is to be expected as dhufish are known to be an offshore demersal reef fish (St John and Syers, 2005; Hesp *et al*., 2002) with past studies also stating that fisherman are now often fishing further offshore to obtain catches of dhufish comparable with those they had previously been able to obtain from nearer to the coast (Hesp *et al*., 2002).

Club anglers reported that they considered the early parts of the day "mid-morning" and "sunrise/early morning" as the best times for catching West Australian dhufish with almost a quarter of club members also reported using lunar or solunar charts as important tools for selecting times and days best for catching West Australian dhufish. As mentioned above, anglers identified reef areas as good habitats for catching West Australian dhufish, with "caves found on the reef edge" considered the best habitat by the majority of anglers. "Caves found over the reef" and "isolated reef lumps" were also highly rated as good habitats perceived for catching West Australian dhufish. As specialised anglers often possess a good knowledge of fish habitats, future surveys could potentially benefit from capturing such information by incorporating questions similar to those used in the current study. The potential for fisherman to assist and improve fisheries management by sharing their local knowledge in regards to the ecology, behaviour and abundance of fish and other aquatic animals in an area has been noted in the fisheries literature (Silvano and Valbo-Jørgensen, 2008). Sumner and Williamson (1999), for example, noted that anglers had adopted modern technology to catch West Australian dhufish, with a high percentage of boats having a GPS and black and white or colour echo-sounder to locate habitats likely to harbour this species.

Pink snapper

Lenanton *et al*. (2009) reported that in the Perth Metropolitan Region West Australian dhufish are the primary target species, whereas near Geraldton (400 km north of Perth) dhufish and pink snapper form part of a suite of prize species.

The high discard rates (32-48%) associated with the boat-based recreational fishing catch of pink snapper recorded in this study are consistent with those reported previously (Wise et *al*., 2007). As it has also been noted that very few fishers achieve the daily bag limits specified for demersal scalefish species under present state wide recreational fishing regulations (Sumner and Williamson, 1999), it is also not surprising that most club members did not catch and retain their bag limit for pink snapper on their last boat fishing trip. Notably, the average number of pink snapper caught by each club member was also approximately three times greater than that of avid recreational fisher in the phone survey (Chapter 2).

Henry and Lyle (2003) reported that pink snapper throughout Australia were taken almost exclusively by the method of line fishing, with boat-based fishing accounting for the vast majority (95%) of the recreational harvest in Australia. The results of this study suggest that just over half of club members preferred the method, when line fishing, of "drift fishing with a sea anchor" in deeper waters when targeting pink snapper.

Mixed responses were also reported from the survey for the best times of day for catching pink snapper, with almost half of anglers (45%) considering "late afternoon/sunset" as the best time, followed by 35% of anglers indicating "sunrise/early morning" and 30% indicating "night" time as a good time. These results are very different from those considered by anglers to be the best times for catching West Australian dhufish. As many anglers indicate the later afternoon or night time period best for catching pink snapper, this may explain the lower catches obtained for pink snapper considering all club members reported going fishing in the morning. Anglers indicated that reef habitats were good for catching pink snapper with the majority indicating that they perceived "isolated reef lumps" to be the best habitats for catching pink snapper. Club members also identified Cockburn Sound, a large sandy marine embayment, as great habitat for catching pink snapper. Catches of this species in that embayment are notably seasonal, with pink snapper known to form large spawning aggregations in early spring each year in this area (Wise *et al.,* 2007).

4. Exploring angler behaviour in a simulated multi-species fishery

This study is an extension of earlier work undertaken for a Fisheries Research and Development Corporation (FRDC) study, in which I was involved (Project 2008/033; Hesp et al., 2010). Although the computer code for the agent-based model used in this study was implemented by my supervisors, I played an important role in the FRDC study. During the model development phase, I helped test the software by running preliminary simulations and providing feedback to the programmers. I also undertook the tasks, for the FRDC study, of running model simulations for the various scenarios considered by that study, compiling the results, and further assisting in producing the report.

Following the completion of the FRDC study, I collaborated with my supervisors to refine and extend the model, and had a major role in running the simulations and in analysing and interpreting the outputs of those simulations. Several modifications (the results of which are reported in this Chapter) were made that dramatically improved the model's "behaviour and realism". One important enhancement made after the FRDC study was to allow fisher-agents to modify their perceptions regarding the quality of known fishing locations following fishing experiences. This modification substantially impacted the behaviour of the model, producing results that lend support to the view that this aspect of fisher behaviour is important in enabling successful fishers to maintain good catch rates. The main focus of this study differs from the previous FRDC study. Whilst the previous study had a focus on understanding implications of recruitment variability in fish, this study has provided a more detailed exploration of the implications of certain fisher behaviours and how these may influence catch rates, fish population abundance, and the effectiveness of fisheries management (in a multi-species fishery).

4.1. **Introduction**

In recent years, it has been realised that fisheries management is as much a 'people management' issue as it is a biological and economic one (Clay and McGoodwin, 1995; Arlinghaus, 2005). Although most research has been directed towards the latter, an understanding of fisher behaviours is becoming increasingly important in the ongoing pursuit of sustainable fisheries (Charles, 1995; Weithman, 1999; Little, 2004; Hunt *et al*., 2011). There are many aspects of fisher behaviour, such as where and how anglers allocate their effort and how they alter their behaviours in response to changes in management regulations. An understanding of such behavioural response is crucial in the determination of appropriate management strategies (Sampson, 1994; Mathiesen, 2003; Little *et al*., 2004; Branch *et al*., 2006; Metcalf *et al*., 2010).

Many methods have been used to gain an understanding of fishers' behaviours and their implications for fisheries management. These methods, which have mostly been applied to commercial fisheries, include empirical studies (*e.g.* Hilborn and Ledbetter, 1979), and use of dynamic programming models (*e.g.* Babcock and Pikitch, 2000), random utility models (RUM) (*e.g.* Eales and Wilen, 1986; Wilen *et al*., 2002; Hutton *et al*., 2004), learning models (*e.g.* Xiao, 2004; Moustakes *et al*., 2006), qualitative modelling (*e.g.* Metcalf *et al*., 2010) and individual or agent based models (Dreyfus-Leon, 1999; Little *et al*., 2004; BenDor *et al*., 2009; Bastardie *et al*., 2010; Cabral *et al.,* 2010; Gao and Hailu, 2010; 2011; 2012; 2013). The last of these types of methods provides an alternative to traditional modelling approaches such as those based on differential equations (Van Dyke Parunak *et al.,* 1998). As agent based models (ABMs) constitute a 'bottom-up' approach to modelling, they are often used for investigating the emergence of system-level properties resulting from the behaviours and interactions of 'agents' (*i.e.* individuals) with each other and their environment (Lomnicki, 1992; Grimm, 1999; Breckling *et al.,* 2006). In contrast, more traditional modelling techniques, *i.e.* state variable models, differential and difference equations and classical mathematical models such as logistic models of population growth, describe the (mean) dynamics of a pool of individuals, such as a population (Huston *et al.*, 1988; Uchmański and Grimm, 1996; Van Dyke Parunak *et al.*, 1998; Grimm, 1999; DeAngelis and Mooij, 2005; Breckling *et al.*, 2006). By aggregating and averaging critical system variables over space and time, however, traditional models ignore variation among entities at the base of the system (Van Dyke Parunak *et al*., 1998).

Whilst fishing, anglers continually make decisions in regards to which species they wish to target, where and how long to fish, and modify their behaviours and movements accordingly. These decisions, however, are ultimately influenced by a suite of factors including regulations, technology, weather, and expectations about costs of fishing, and abundances of fish (Sampson, 1991; 1994; Wilen *et al*., 2002). Thus, with fisheries managers becoming increasingly aware of the growing impacts of recreational fishing (*e.g.* McPhee *et al.*, 2002; Cooke and Cowx, 2004; Granek *et al.*, 2008; Gao and Hailu, 2010), modelling of these types of behaviours of recreational fishers represents an area where research is needed, as such behaviours are likely to influence the effectiveness of the management measures that are introduced. It is also important to recognise that, in many fisheries, only a minority of anglers, *i.e.* those who are the most avid and specialised, catch the majority of fish (Hilborn, 1985; Baccante, 1995; Henry and Lyle, 2003; Dorow *et al*., 2010; Johnston *et al*., 2010). As such, it is the behaviours of these 'avid' anglers that may be particularly important to understand.

The west coast demersal scale fishery resource includes highly sought-after marine fish species such as the West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Chrysophrys auratus*) (Wise *et al*., 2007; Lenanton *et al*., 2009; Crowe *et al*., 2013; Ryan *et al*., 2013). In the recent past, the recreational fishery experienced high exploitation rates, which led to the introduction of a range of measures to provide increased protection to the stocks of these species, including more stringent bag and size limits, and the implementation of spatial and temporal closures (Lenanton *et al*., 2009; Department of Fisheries, 2012). In fisheries such as the West Coast Demersal Fishery, it is crucial to account for their multi-species nature when considering alternative management measures (Fowler, 1999; Lenanton *et al*., 2009), such as those aimed at ensuring the sustainability of fish stocks, facilitating commercial fishers in maximising their profits, and/or maintaining high quality fishing experiences for recreational fishers. For example, for management to be effective, it is important to understand how recreational anglers are likely to respond to any new management measures (Fisher, 1997; Aas *et al*., 2000; Salz and Loomis, 2005; Branch *et al*., 2006).

The overall aim of this study was to use an agent-based model to explore the implications of the fish-targeting behaviours of avid recreational boat fishers who target these two species. The model was constructed assuming that avid recreational fishers alter certain behaviours, *e.g.* the rate at which they move between fishing locations and search for new fishing locations depending on their level of fishing success, based on the bite rates that they experience (as a proxy for the fishers' perceptions of fish abundance). Model simulations were thus undertaken to explore the extent to which those behaviours may enable fishers to maintain their catches, and assess how such behaviours might impact on several species within a multi-species fishery with an existing management regime. More specifically, the study focussed on exploring the following hypotheses:

1. As the abundance of a (simulated) key target species decreases, avid fishers are able to maintain a similar catch rate of that species by (i) moving more often between fishing locations, and spending more time during a fishing trip searching and fishing at new fishing locations, and (ii) updating their perceptions of the quality of known fishing locations following each fishing experience, and replacing 'poorer' locations in their 'knowledge bank' with newly-found locations at which they have experienced 'good' catch rates.
2. The catches of a (simulated) key target species will increase with increased fish abundance but, at high levels of abundance, the catches are constrained through management regulations (*i.e.* boat limits).

3. The behaviours of fishers in response to the abundance of one (simulated) key target fish species affect catches and thus abundances of other fish species.

4.2. Methods

The description of the model broadly follows the 'Overview, Design concepts and Details' protocol (ODD), which was first proposed by Grimm *et al.* (2006) and then later updated by Grimm *et al.* (2010), for describing individual-based models or agent-based models, such as that used in this study.

4.2.1. Software platform

The model developed during this study was constructed in Visual Basic.Net (version 3.5 SP1) within Microsoft Visual Studio 2008 (version 9.0.2122.8 RTM) (Microsoft, 2007). The data used by the model are read in from text (.txt) files.

4.2.2. Purpose

The model is designed to explore the behaviours of avid recreational anglers and how certain behaviours can influence catch rates in a demersal finfish fishery. It can also be used to explore how fishers are likely to respond to changes in certain recreational fishing regulations, *i.e.* a minimum legal length (MLL) for capture and retention, and an allowable daily boat limit for retained catches, and the possible implications of such responses for the sustainability of the fishery.

4.2.3. State variables and scales

The model consists of two interacting types of agents; fish of different species (West Australian dhufish, pink snapper and a third, 'generic' species of lower trophic level and less attractiveness to fishers, which has been labelled the 'red herring' and the biological characteristics of which were broadly based on those of the silver trevally, *Pseudocaranx georgianus*), and boat-based, recreational fishers. Note that the latter agent, *i.e.* the 'fisher', is assumed to represent (collectively) the specialised boat-based angler or anglers fishing from a single boat, where, in the case of multiple fishers within the boat, the behaviour of those fishers is assumed to be identical to that of an individual specialised boat-based angler and the probability of capturing a fish is assumed to be independent of the number of anglers within a boat. This assumption avoids the need to consider issues relating to shared decision-making and group behaviours of fishing parties, which would have introduced complexity inappropriate for inclusion within the current study. The agents interact within a simulated (artificial) marine, reef landscape for a specified time period (default value = 1 y). Each fish agent represents a single fish belonging to one of the three species, whilst each fisher agent, *i.e.* 'fisher', represents the angler(s) within a boat. The state variables characterising each fish are a unique integer identifying the fish, integer codes associated with the species and sex of that individual, a value containing details of the age of the fish, and details of the grid cell in which the fish is located. Each fisher is also identified by a unique integer.

The model employs an artificial landscape, comprising a 128 x 128 cell grid, representing a total area of 12.8 km^2, *i.e*. an area considered representative of the size of a fishing ground common to a group of boat-based fishers operating from the same boat ramp. The grid assumes 'wrap-around', such that a fish or fisher moving off the edge of the grid at one edge will re-enter the grid at the corresponding position on the opposite edge. Each grid cell in the landscape (representing an area of 100 m^2) is assigned one of five possible habitat types (see below).

4.2.4. **Process overview and scheduling**

The ABM employs a discrete event simulation engine and consists of two sub-models which guide the behaviours of the fish and fishers. Fish agents may experience three event types, *i.e.* (1) a movement, (2) an encounter with a fisher (which may or may not result in death of the fish), or (3) death through natural causes. Fishers may also experience three event types, where these events are determined by the acts of making decisions and the behavioural responses of the fisher to those decisions, *i.e.* (1) a decision to leave home and go fishing (2) a decision to commence fishing, and (3) a decision to continue fishing, move or go home. Note that a fishing trip is considered to have commenced at the time when a boat has been launched from a boat ramp, and to have finished when the boat has returned to that ramp.

When the model is initialised, an event is scheduled for each individual fish and fisher and added to an event queue, together with a 'termination' event to end the simulation at a specified time. The model's 'discrete event simulation engine' then performs the task of processing each event in the queue at the correct time, scheduling new events as existing events are processed, and eventually terminating the simulation (*e.g.* Hampton and Majkowski, 1987).

4.2.5. **Design concepts**

Emergence

Emergent properties of interest in this ABM are the abundances, sizes and age compositions of the fish in catches and in the residual population of fish, and patterns of fisher behaviour in response to differences in fish abundance, the fishers' knowledge (of good fishing locations), and management controls (*i.e.* size and boat limits).

Agent interactions

Interactions occur between the fish and fisher agents but not between individuals of the same type, *i.e.* the model does not take into consideration competitive or other interactions among fishers or between fish of the same or different species. The model considers that fishers act independently of other fishers and therefore do not share knowledge of good fishing locations. The behavioural patterns of the fish and fisher agents are guided by a set of (stochastic) probabilistic rules.

Adaptability

During a simulation, fishers can adapt by improving their knowledge of 'good' fishing locations. For each fisher, a list with a fixed number of fishing locations (*i.e.* grid cell locations) is maintained to represent his/her knowledge. This list, or 'knowledge bank', corresponds to the list of good fishing locations that a fisher stores in his/her Global Positioning System (GPS) device. Each grid cell location within the list is initially ranked according to its value as a fishing location, as perceived by the fisher (*i.e*. the habitat associated with the grid cell, modified by observation error). Fishers can also search for new fishing locations. When a new location is found that is perceived to be better than one or more in his/her current list, a fishing location in the list with a lower perceived value is replaced. Thereby, the quality of a fisher's list of locations can improve over time. The quality of an angler's fishing locations is also updated on each occasion when he/she fishes a known location, or finds and then fishes at a new location. For example, if, because a fisher is not receiving any bites from fish and he/she decides to move to a new fishing location within 30 min, then the rank score of that fishing location in the fishers' 'knowledge bank' is reduced by one. Alternatively, if the fisher decides to stay at a particular fishing location for longer than 30 min, the rank score for that location is increased by one. This, therefore, potentially enables the quality of the fisher's collection of locations to be maintained even when fish abundances at some locations in the initial list become depleted. As the fishers are assumed to be highly specialised, they are initially accorded a high level of knowledge of good fishing locations.

Model outputs

The model displays a range of diagnostic information on the computer monitor at run time (Fig. 4.0). These outputs include charts presenting, for each fish species, (1) the age compositions of female and male fish in the population at the beginning of the simulation, (2) the age compositions of female and male fish in the remaining population during the simulation, and (3) age and length compositions of female and male fish that are released and retained by fishers, (4) the number of fishers currently fishing, (5) CPUE (catch per unit of effort, measured as the average number of fish retained per trip), and (6) 'fisher knowledge', *i.e.* average (perceived, but not actual) value of the habitats of the fishing locations currently 'stored' in the 'knowledge bases' of the different fishers within the full fishing fleet. Other data presented by the user interface at run time include (i) the current value of time during the simulation (in days), (ii) the total number of fishing trips, (iii) total hours ‘actively’ fished, (iv) number of searches for new fishing locations (v) total hours spent searching, (vi) proportion of fishing time spent searching, (vii) average number of moves by fishers each trip, (viii) total number of fish bites received, (ix) number of ‘good’ fish bites, (x) numbers of released and (xi) retained fish, (xii) the proportion of fish retained, (xiii) the number of times fishers have attained their boat limits for the individual species, and (xiv) the mixed-species boat limit.

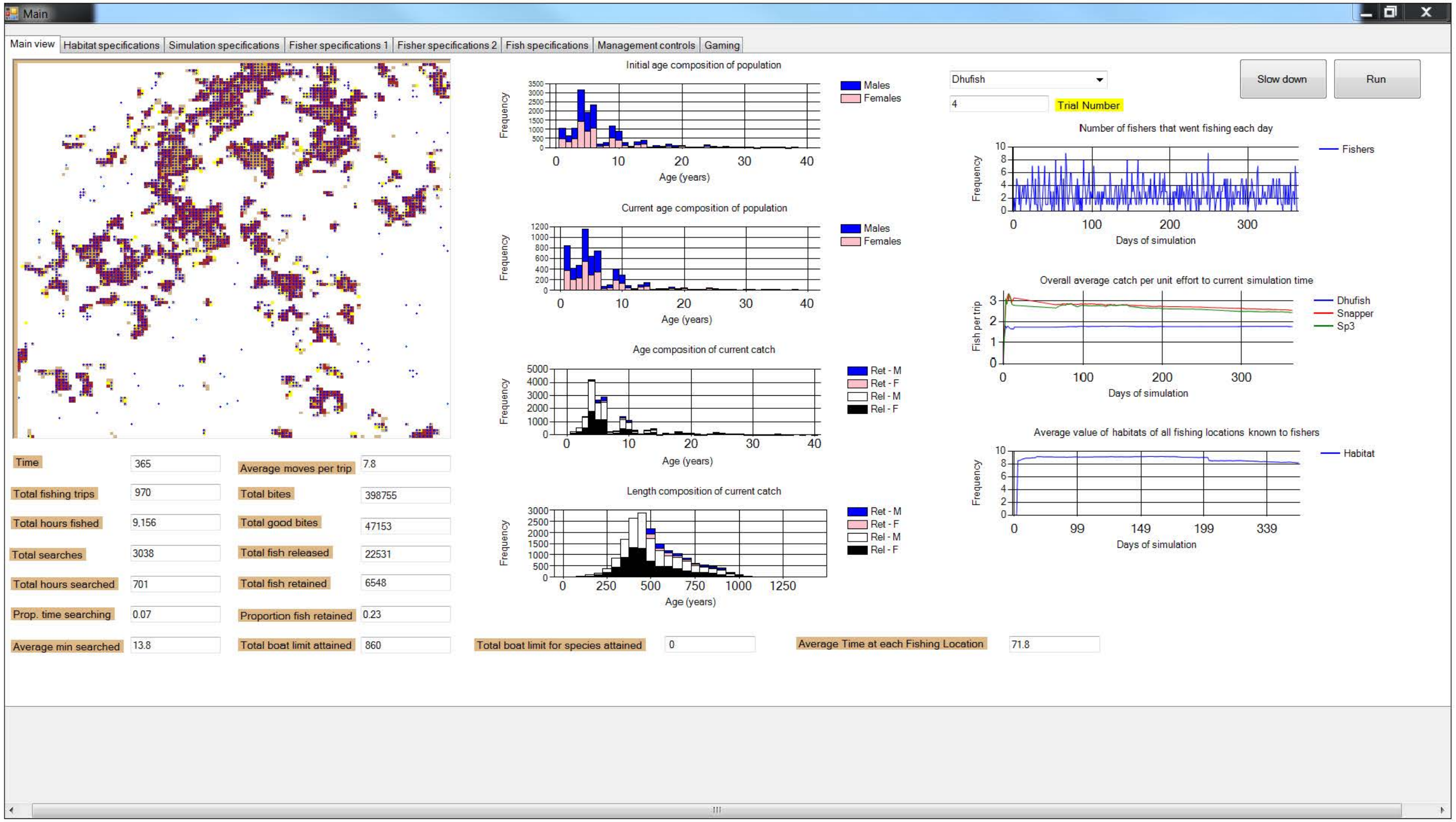


Figure 4.0 **The 'Main' program interface for displaying the results of simulations to users. The simulated landscape is located in the top left-hand corner, with the blue dots representing individual fish. The interface also displays a number of diagnostic charts for each fish species.**

4.2.6. **Initialisation**

Initialisation of the model run involves (1) setting the initial time of the simulation to zero, (2) reading specified values for the model parameters (from text files), (3) setting up the artificial landscape grid, (4) creating the fish (and distributing these over the landscape) and fisher agents, (5) creating the initial schedule of events for each fish and fisher, and (6) creating a simulation termination event.

Artificial landscape generation

The artificial landscape used by the model, which is generated using the diamond-square algorithm (Miller, 1986), contains five habitat types, namely non-reef, reef top, reef top hotspots (caves within the reef platform), reef edge, and reef edge hotspots (caves and ledges in the reef edge). The landscape is generated according to values specified for the proportions of each of the five habitat types in the landscape grid and for the degree of habitat patchiness (see Fig. 4.1). Values for habitat patchiness vary between 0 and 1, with 1 producing landscapes containing large continuous areas of reef and values approaching zero producing landscapes containing many, highly fragmented reef habitats.

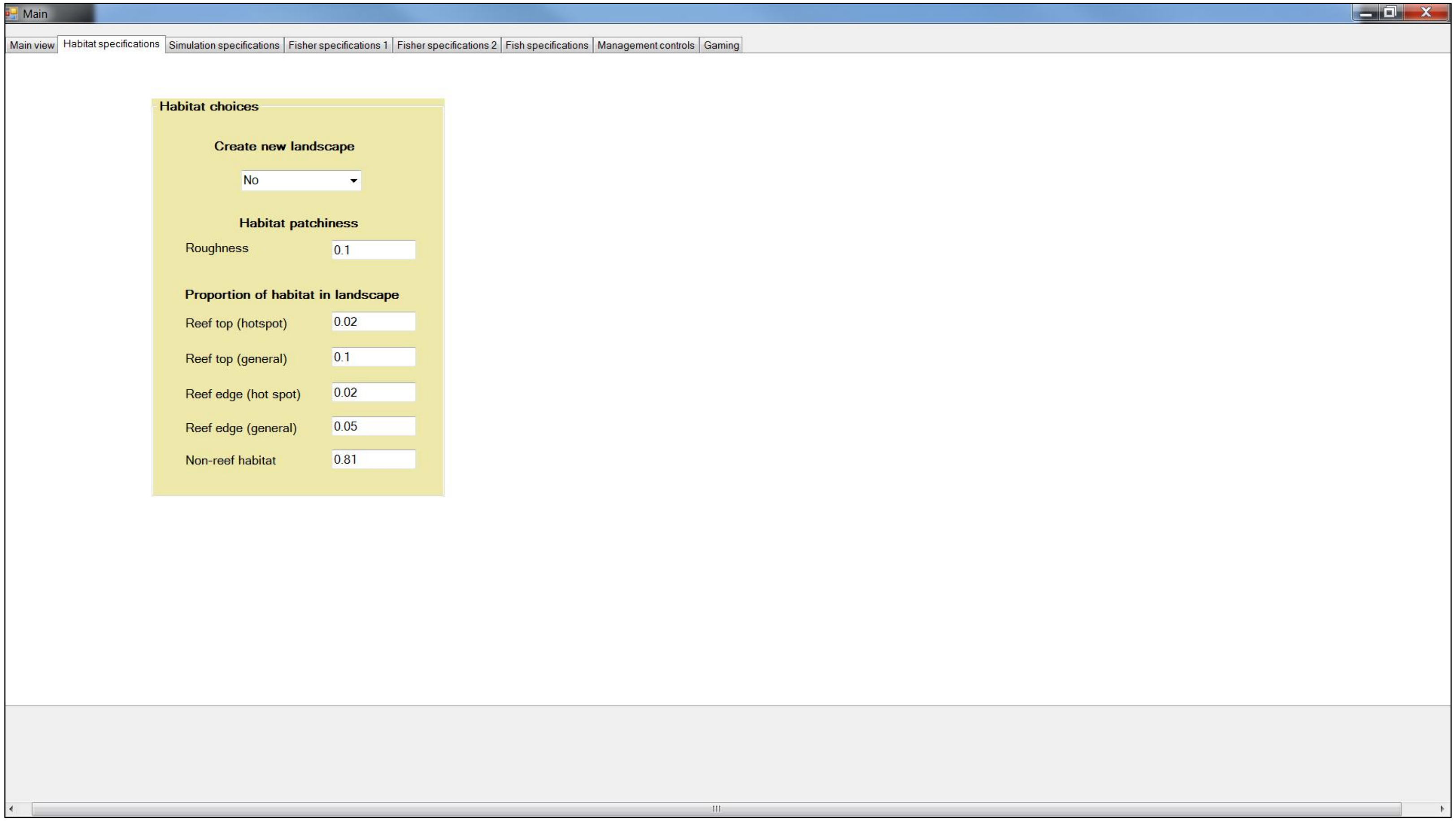


Figure 4.1 Form displaying the values of parameters used by the model to generate an artificial landscape.

Creation of fish agents

The fish are created using the age composition data (for an exploited fish population) for the females and males of each species. These data were generated by the operating model of a Management Strategy Evaluation (MSE) framework, developed by Fisher *et al*. (2011), and which were read in from an external file and used to create a random age composition sample for each species, according to the specified number of individuals for each fish species. The samples of fish used in the agent-based model are generated using the algorithm genmul, available online from RANLIB within NETLIB (http://www.netlib.no) (Devroye, 1986), which generates observed samples from a multinomial distribution (see below regarding source of input data).

Once fish in the population for each species are created, they are placed randomly among grid cells on the landscape grid with the same habitat type but with weighting among grid cells of different types according to their 'habitat preferences' (based on values of parameters that were derived from a recreational fisher survey, see Chapter 3 and Appendix K). A 'fish' event, which may be a movement, fisher encounter or natural mortality event, is then scheduled for each individual. Note that, on each occasion that a new event is scheduled for a fish, the program calculates the time till the next event for each event type, *i.e*. movement, fisher encounter or death, and that event which would be the first of the three events to occur is added to the event queue.

Creation of fisher agents

The ratings representing the fishers' ability to correctly identify the various habitat types (derived from the avid fisher survey described in Chapter 3, *i.e.* Q.20, Appendix K) were averaged over all fishers for each habitat type and divided by the maximum score of 10. The resulting value was assumed to represent the probability that a fisher would correctly identify the true habitat. For each true habitat type, it was assumed that there was an equal chance of incorrectly identifying that habitat as one of the other types, and thus the residual probability was spread equally over those other habitat types. Through this process, a table of the probabilities that fishers would correctly or incorrectly perceive each of the true habitat types to be a specific habitat type was generated (Fig. 4.2).

Each of the fishers in the fishing fleet is created with a 'knowledge base' of a specified number of 'GPS fishing locations', *i.e.* grid cell locations. Each location in this knowledge base is assigned a value from 0 (poor) to 10 (excellent) based on fishers' perceptions of each habitat's worth (*i.e.* the value of the grid cell) for catching fish (see Chapter 3 and Q.21, Appendix K) (Fig. 4.2). Allocation of each of the fishing locations known to each fisher prior to the commencement of a simulation involves (1) randomly selecting a cell, (2) undertaking a 'random walk' in the immediate vicinity of that cell for a specified number of steps, and (3) selecting the cell within that random walk with the highest perceived habitat value as the fishing location to be allocated to the fisher. This process is then repeated to allocate a specified number of good fishing locations to each fisher to serve as his/her initial knowledge base. A fishing location is considered 'good' if fishers have assigned it a value which lies above a specified threshold level.

The final stage in creating the fisher agents is to schedule a decision for each fisher to determine, at that time, whether to go fishing, or stay at home.

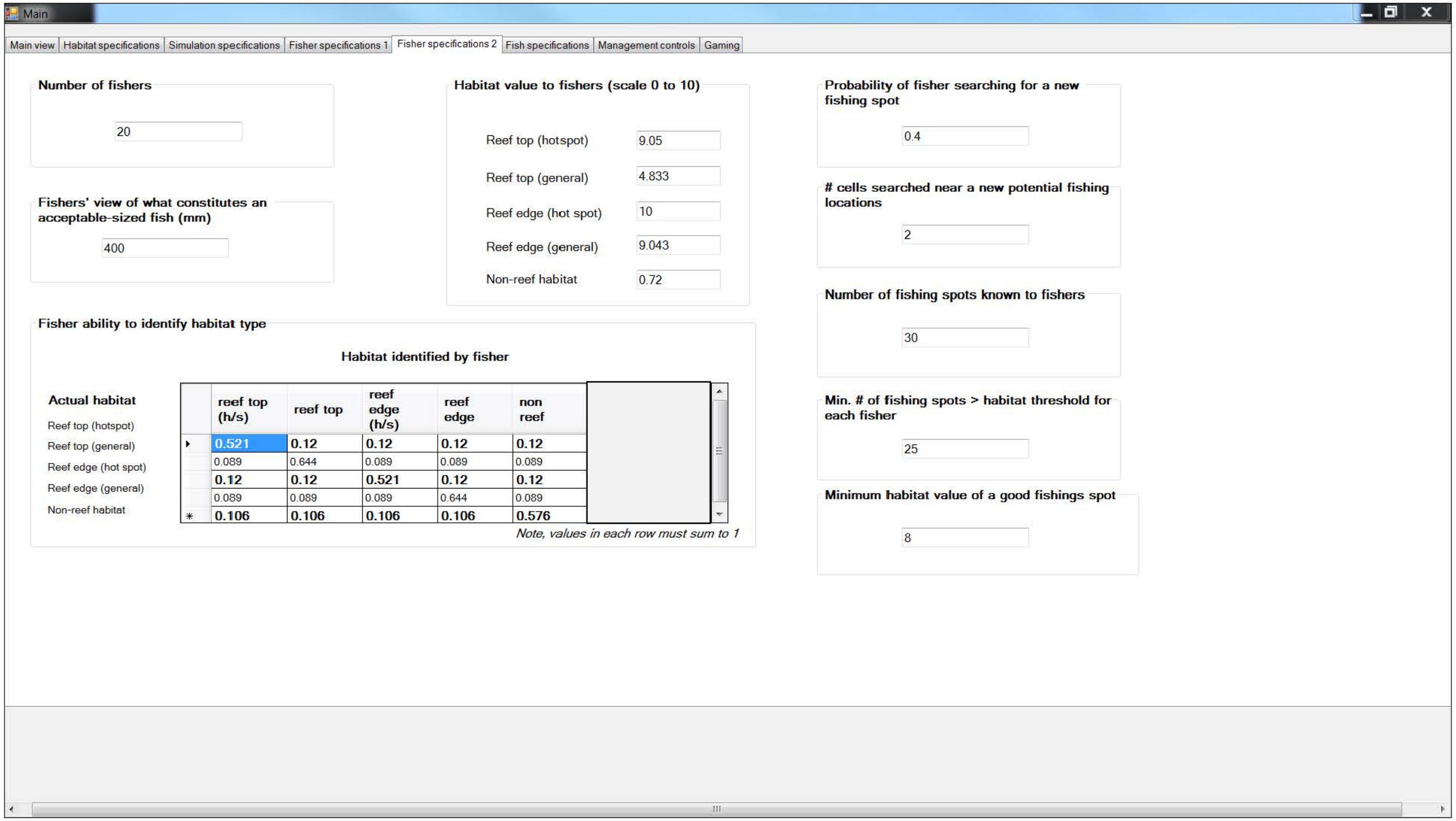


Figure 4.2 **Form displaying values of parameters used by the model, which describe a range of aspects of the fishers, and their knowledge and behaviours.**

4.2.7. **Input**

Input data are required to (1) generate the model landscape, (2) create the fish and fisher agents, (3) parameterise the decision rules of the agents, and (4) schedule a simulation termination time.

Input data for generation of a landscape

The data required for generating artificial landscapes include values for the proportions of each habitat in the landscape grid and a value for habitat patchiness (see above, Fig. 4.2).

Input data for fish agents

The data required to generate the fish agents include age composition data (for the three fish populations). As noted above, an (external single species, single area, length, age and sex-structured) operating model of a Management Strategy Evaluation (MSE) framework, developed by Fisher *et al.* (2011), was employed to determine the expected age composition for each species. For each species, this expected age composition was read into the agent-based model to provide the multinomial distribution from which, for each simulation run, a random sample of the required size was drawn to serve as the initial population of that species. For each fish species, other input data for the agent-based model included values for (1) the number of fish to be generated, (2) von Bertalanffy growth parameters and the standard deviation for the lengths at age, (3) maximum age, (4) (logistic) gear selectivity parameters, (5) probability of capture if the fish encounters a fisher and is large enough to be fully-selected into the fishery, (6) probability of death following capture and release due to fishing-induced mortality (*i.e.* where the fish may have been released because it was not of legal size for capture and retention, or the boat limit for that species had already been attained by the fisher), and (7) probabilities of movement of fish from each of the five habitat types. The values for these parameters are displayed for the user on a form and can be modified before the commencement of a new simulation (Fig. 4.3). Graphs showing the trends in growth and the size-selectivity of the three species are displayed to help users to visualise the input data. Note that details of the biological data used in this study for West Australian dhufish, pink snapper, and silver trevally (the basis for the biology of 'red herring'), and the scientific papers from which those data were drawn, have been cited in Hesp *et al*. (2010) and are provided in Appendix L.

As no data are available on the probabilities of movement of each species from different habitat types, the probabilities to be used as input data to the model were derived from the club survey data on fishers' perceptions of habitat quality. It was assumed that the probability of fish movement is related directly to the quality of the habitat that an individual of that species currently occupies. Thus, for example, species which are known to be strongly associated with reef structures, such as reef caves and crevices, are far less likely to move from such habitats than from other habitats such as sand. The perceived quality of each habitat type, *i.e. reef* top "hotspot", reef top "general", reef edge "hotspot", reef edge "general" and non-reef, was recorded by the surveyed club members (Appendix K Q.21 andQ.22). These perceived categories of habitat quality were scaled from 0 (poor) to 1 (excellent). The probability of movement of each species from each habitat was then set equal to 1 minus the scaled value of the quality of that habitat for that species.

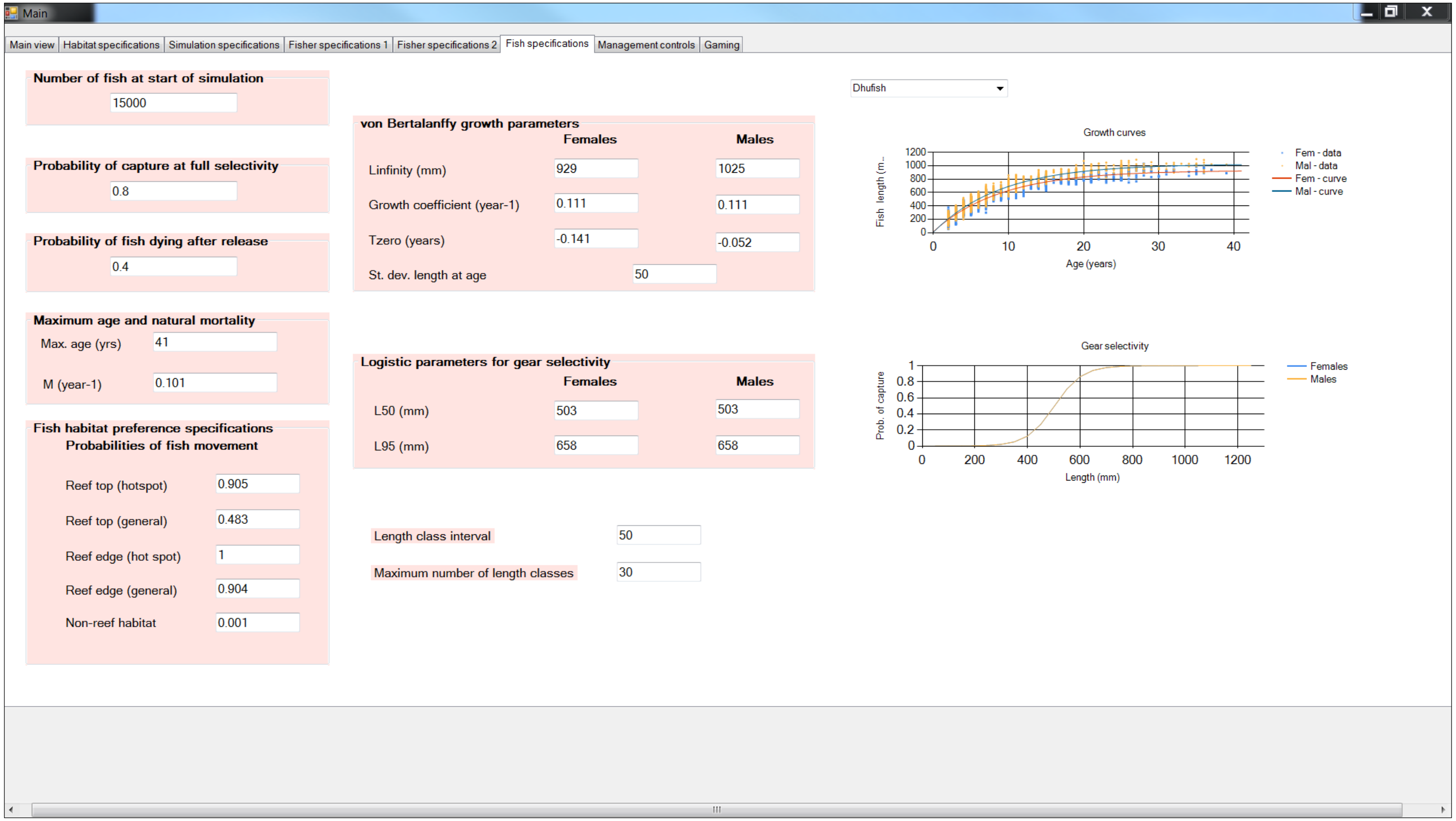


Figure 4.3 **Form displaying values of parameters used by the model, which describe the specified initial fish abundance, and aspects of the biology and movement parameters of each of the fish species.**

Data inputs for fisher agents

Data required for fisher agents included values for (1) the number of fishers in the recreational fleet, (2) probability of a fisher undertaking a search after moving from a fishing location, (3) number of fishing locations known to each fisher, (4) threshold value above which the fisher perceives the habitat type to be a good fishing spot, (5) perceived value of each habitat type to fishers for catching fish, (6) the minimum size of a fish that produces 'good' bites, (7) for each habitat type, the probability that fishers correctly identify the habitat type and, if not correctly identified, the probabilities of each of the remaining habitat types being identified (incorrectly) as that habitat type, (8) logistic parameters describing the relationships between the time elapsed since the last fishing trip and the probability that an angler will go fishing, and (9) logistic parameters describing the relationship between time elapsed since the commencement of a fishing trip and the probability that the fisher will go home. As for the parameters for fish, the values for each of the fisher parameters are displayed to the user on a form and can be modified before the commencement of a new simulation (Figs 4.2, 4.4). Graphs are provided to help users to visualise the data for describing the relationships between the (i) probability, whilst fishing, of staying at the same location and bite rate, (ii) probability of a fisher deciding to go fishing and the number of days elapsed since the last fishing trip, and (iii) probability of a fisher deciding to go home and the number of hours elapsed since the commencement of the fishing trip.

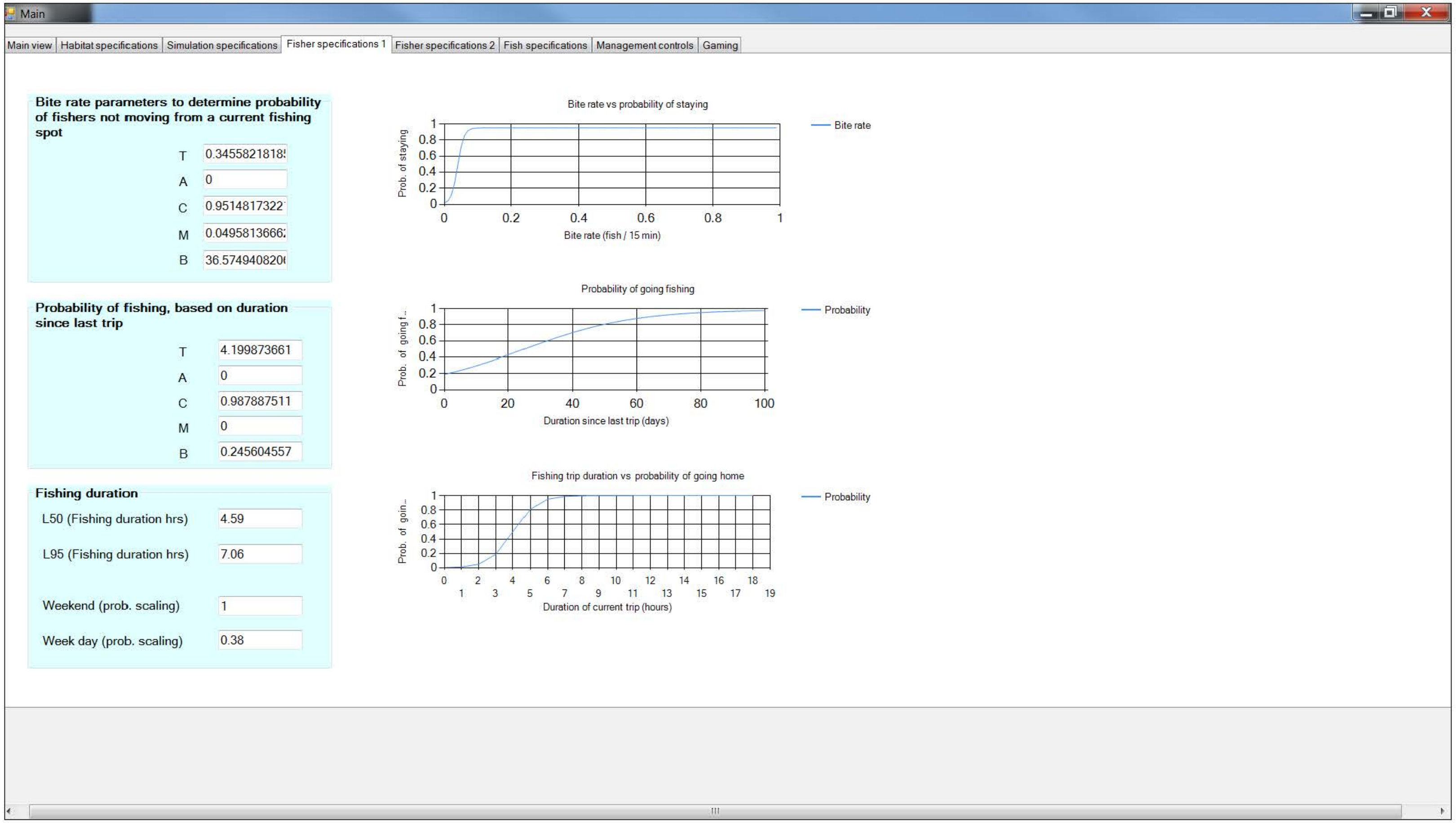


Figure 4.4 Form displaying values of parameters used by the model, specifying aspects related to fisher behaviour.

Fisheries management controls

The model considers several forms of management control, including a minimum legal length (MLL) of fish of each species for capture and retention, and boat limits for individual species. Each of the three species has a specific boat limit, *i.e.* maximum number of fish of that species that may be retained and landed. Note that fishers are assumed to cease fishing when they have achieved the bag limits for the two key target species, West Australian dhufish and pink snapper.

4.2.8. **Sub models**

Fish sub-model

1. *Fish movement event*

Scheduling: *Dependent on the instantaneous rate of fish movement*

The instantaneous rate (day^{-1}) of fish moving from a given habitat type, $R_{\text{FishMovement}}$, is calculated as:

$$R_{\text{FishMovement}} = -\ln(1 - P_{\text{FishMovement}}),$$

where $P_{\text{FishMovement}}$ is the probability of fish moving from that habitat type, and ln is the natural logarithm. This probability of movement is determined on the basis of the fish's 'preference' for the habitat type of the cell it currently occupies (see above, 'Input data for fish agents').

The period of time to the next fish movement, $T_{\text{TillFishMovement}}$, may be determined as:

$$T_{\text{TillFishMovement}} = -\ln(1 - r)\,/R_{\text{FishMovement}},$$

where *r* is a uniform random number between 0 and 1, noting that this approach is based on that described by Hampton and Majkowski (1987).

The scheduled simulation time of the next fish movement, $T_{\text{FishMovement}}$, is:

$$T_{\text{FishMovement}} = T_{\text{SimClock}} + T_{\text{TillFishMovement}},$$

where T_{SimClock} is the current time of the simulation in days. It is assumed that, when a scheduled fish movement event occurs, the fish has no knowledge of the attractiveness (*i.e.* habitat) of the cells adjacent to the current grid cell which it occupies. Accordingly, the fish is moved to a cell that is selected randomly from the set of adjacent cells, where each of those cells has an equal probability of being selected. At the conclusion of the fish movement event, a new event is scheduled for the fish. Note that, although movement of the fish into the new cell increases the probability that fishers within that cell might encounter a fish, the current model does not reschedule events for those fishers as it is assumed that the increase in probability is likely to be negligible.

2. *Fish encounters fisher event*

Scheduling: *Dependent on the number of fishers currently occupying the same grid cell as fish*

The encounter rate between a fish and a fisher, $R_{\text{FisherEncounter}}$, which depends on the number of fishers currently occupying the same grid cell as that fish, $N_{\text{FishersInCell}}$, is calculated as:

$$R_{\text{Encounter}} = [-\ln(1 - P_{\text{Encounter}})]N_{\text{FishersInCell}},$$

where $P_{\text{Encounter}}$ is the probability of a fish encountering a fisher in the same cell as itself over 24 h. Note that, as $R_{\text{Encounter}}$ depends on $N_{\text{FishersInCell}}$, the events for fish in a cell are rescheduled every time a fisher enters or leaves that cell.

The time (days) before a 'fish encounter with a fisher' event, $T_{\text{Encounter}}$, is given as:

$$T_{\text{Encounter}} = [\text{-}\ln(1 - r)]/R_{\text{Encounter}}.$$

$T_{\text{Encounter}}$ is then adjusted to determine the probability of encountering a fisher within the next 15 min (*i.e.* a period representing the time interval between successive occasions on which fishers are likely to 'consider' whether they should stay or move) of the current time of the simulation, T_{SimClock}, *i.e.,*

$$T_{\text{Encounter}} = T_{\text{SimClock}} + T_{\text{Encounter}}/(0.25 * 24).$$

When a fish encounters a fisher, it may or may not be caught and, if it is caught, it may be retained or released. If caught and released, the fish may survive or die (see Fig. 4.5).

Each encounter between a fish and fisher is considered to be a 'bite' that the fisher detects. If there are multiple fishers in the grid cell, one of those fishers is randomly selected as the fisher who experiences the bite. A record is maintained for each fisher of the number of good bites that are recorded by that fisher in the current grid cell, where determination as to whether a bite is a 'good' bite is made according to the size of the fish (that is biting) (a value specified on the 'Fisher specifications 2' form, see Fig. 4.2).

i) *Fish bites and is caught*

The probability that a fish is caught once it has encountered a fisher is dependent on the length at age of the fish and its size-dependent vulnerability to the fishing gear. For a given species, $L_{\mathrm{t,s}}$, the length at age t for a fish of sex s, was determined from the von Bertalanffy growth equation, *i.e.*,

$$L_{\mathrm{t,s}} = L_{\infty,s}\{1 - exp[-k_s(t - t_{0,\mathrm{s}})]\} + \varepsilon \ ,$$

where for each sex, s, $L_{\infty,s}$, is the asymptotic length (mm), k_{s} is the growth coefficient (y^{-1}), $t_{0,\mathrm{s}}$ is the hypothetical age at zero length, and ε is a randomly-generated normal observation error with mean of zero and specified standard deviation for lengths at age. The parameters of these growth curves, and associated values of the standard deviations, were provided for each sex of each species as input data to the agent-based model.

For each species, the probability that a fish of length L (mm) will be caught by the fishing gear, S_{L}, is given as:

$$s_{\mathrm{L}} = 1/\{1 + exp[-\ln(19)\,(L - L_{50})/(L_{95} - L_{50})]\},$$

where $\ln$ is the natural logarithm, and L_{50} and L_{95} are the lengths in mm at which 50 and 95% of fish, respectively, are selected by the fishing gear.

The probability that, on biting, a fully-selected fish will be caught, $P_{\text{BiteCapture}}$, is determined as:

$$P_{\text{BiteCapture}} = S_L P_{\text{Capture}},$$

where P_{Capture} is a specified constant. To determine whether a fish bites and is caught when it encounters the fisher's fishing gear, a uniform random number between 0 and 1 is drawn, and if this is less than or equal to $P_{\text{BiteCapture}}$, it is assumed that the fish is caught, otherwise it escapes capture. Note that, for other decisions relating to the probability of a specific outcome required within the model, a similar approach is employed.

ii) *Fish is retained or released*

If a fish is caught, it will be retained by the fisher if it is as large as or larger than the minimum legal length for capture and retention specified for the fish species, if that fisher has not yet attained the boat limit for that species or the mixed boat limit for the combination of the two iconic species, *i.e.* West Australian dhufish and pink snapper. If retained, the fish is removed from the fish collection.

iii) *Fish suffers post-release mortality*

The probability of a fish dying following capture and release, $P_{\text{ReleaseDeath}}$, is specified as a constant. If a fish is caught and released, a uniform random number between 0 and 1 is drawn, and if this is less than $P_{\text{ReleaseDeath}}$ then the fish is assumed to die after release. If the fish dies, it is removed from the fish collection.

3. *Fish natural mortality event*

Scheduling: *Random assignment, depending on instantaneous rate of natural mortality*

For a given species, the time at which each individual would be expected to die as a result of natural mortality, if it does not first experience a movement event or encounter with a fisher, T_M, is calculated as:

$$T_M = T_{\text{SimClock}} + [-\ln(1-r)/(M/365.25)] \;,$$

where M is the instantaneous rate of natural mortality (y^{-1}) for that species. This estimate of M was obtained by inserting the maximum recorded age for the species into Hoenig's (1983) equation for fish. Note that, if the time till the next movement or encounter with a fisher is less than the time till expected death, then the first event to occur is added to the event queue, and the question of natural mortality is re-visited at the time of scheduling the next event for the fish, if it has not died as a result of an encounter with a fisher.

Fisher sub-model

1. *Fisher decision to fish event*

Scheduling: *10 pm daily*

The probability that, independent of whether the following day was a week day or weekend day, a fisher would decide to go fishing on the following day, P^*_{Fishing}, was assumed to be a function of the number of days elapsed since the fisher's last trip, D, and was described using Richards' generalised logistic equation (Richards, 1959), *i.e.,*

$$P^*_{\text{Fishing}} = A + \left[C/\left(1 + exp^{-B(D-M)^{1/T}}\right)\right],$$

where A is the lower asymptote, $A + C$ is the upper asymptote, B is a parameter that determines the rate at which the probability of going fishing increases with respect to elapsed time, T determines the shape of the curve, and M is the time of maximum rate of increase (see Fig. 4.6). The values of these parameters were estimated using data from the survey of club members, *i.e.* the number of days anglers had gone fishing from a boat in the previous 12 months (see Appendix K Q.1).

$P_{Fishing}$ was then calculated by multiplying P^{*}_{Fishing} by an adjustment factor with a value related to whether the following day of the simulation was a working day or a weekend day. These adjustment factors were calculated using club survey data that recorded, for different days of the week, whether fishers had gone fishing on those days during the past 12 months (see Appendix K Q.2d) and which were then scaled to range from 0 to 1, with 1 meaning every time.

2. *Fisher commences fishing on day event*

Scheduling: *Random time between 6 am and 12 noon following a fisher decision to fish event.*

If a decision is made to go fishing, a 'fisher commences fishing on day' event is scheduled for a (uniformly-distributed random) time between 6 am and 12 noon the following day.

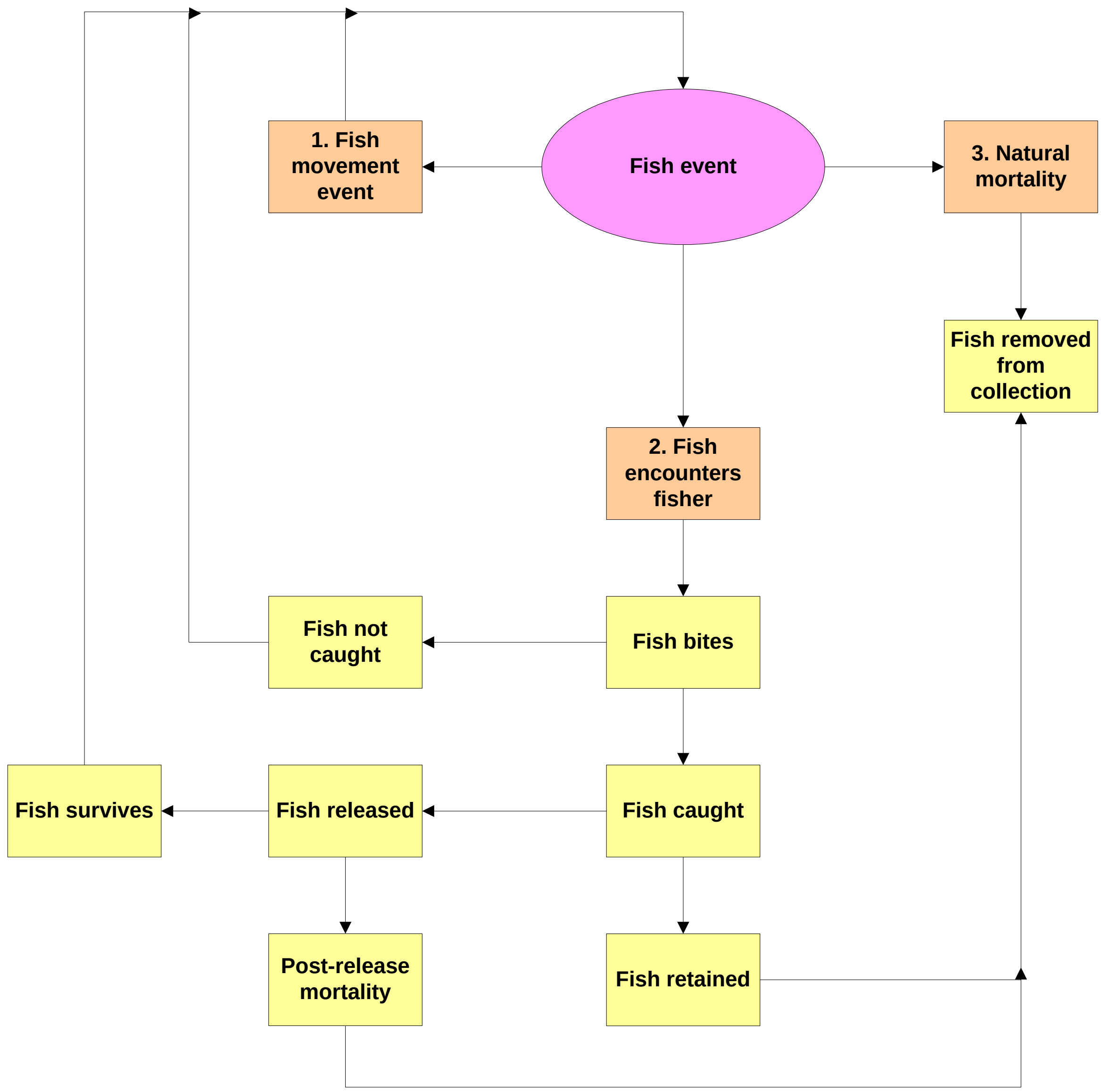


Figure 4.5 **Fish agent sub-model describing the possible fates of fish at each of the three main event types (fish movement event, fish encounters fisher event and natural mortality event).**

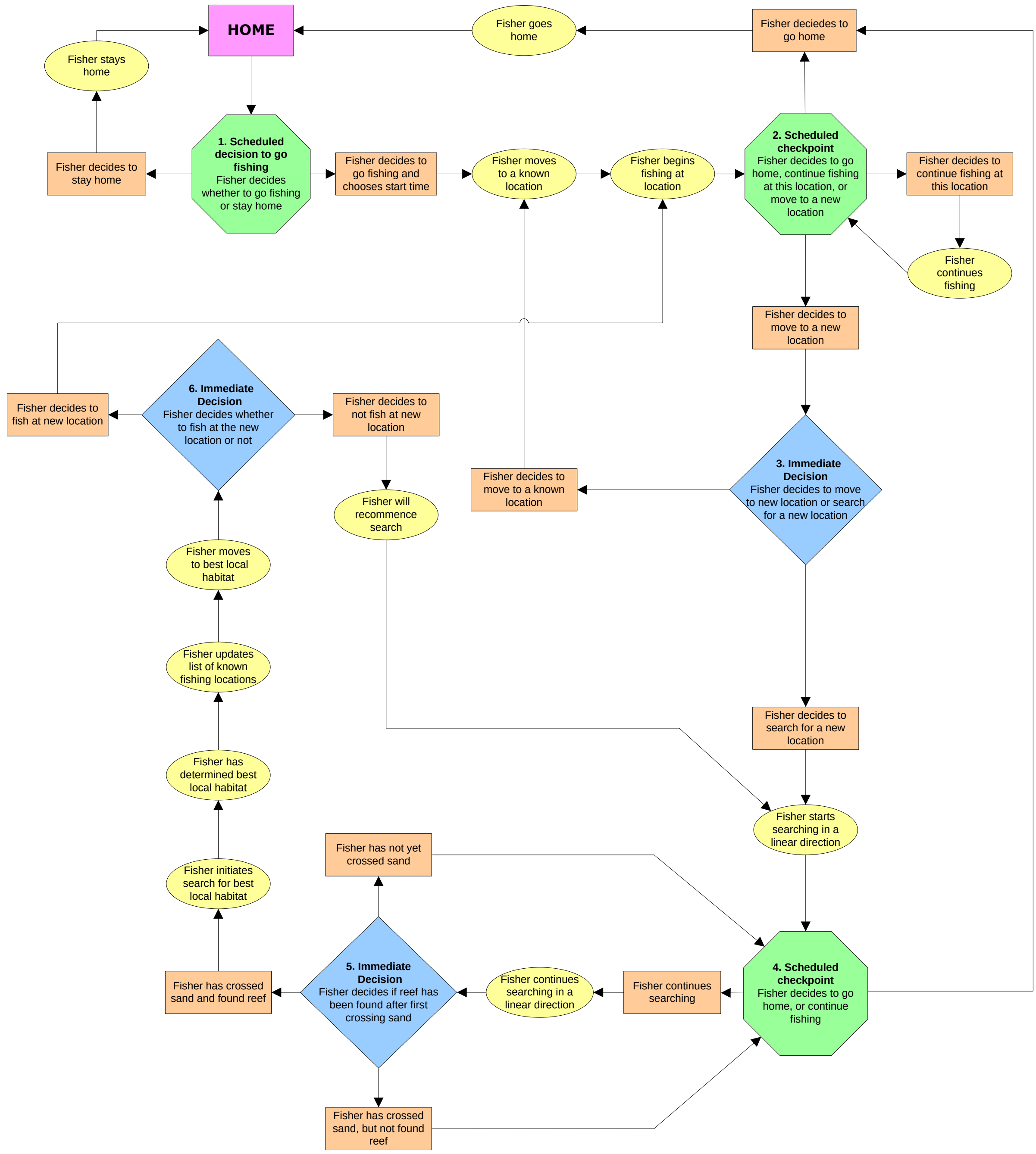


Figure 4.6 Fisher agent decision pathways. Numbers correspond to the six fisher decision points of the fisher sub-model. Octagons indicate a review checkpoint, diamonds represent an immediate decision, rectangles represent the outcomes of a decision and ovals represent the actions taken by the fisher.

3. *Fisher checkpoint event* (type I)

Fisher decides to continue fishing, go home or move to a new fishing location.

***Scheduling**: Random time every 10-20 min whilst fishing*.

(i) Decision to continue fishing

The probability of the fisher continuing to fish at the same location, $P_{\mathrm{StayInCell}}$, as a function of bite rate (min^{-1}), B_{Rate}, was calculated as:

$$P_{\mathrm{StayInCell}} = A + \left[C/\left(1 + exp^{-B(B_{\mathrm{Rate}} - B_{\mathrm{Rate50}})^{1/T}}\right)\right]$$

where B_{Rate50} is the number of 'good' bites (min^{-1}) at which 50% of fishers will decide to stay at the current fishing location, and *A*, *B*, *C*, and *T* are parameters of the generalised logistic equation (noting that these last parameters differ from those used in the equation used to calculate the probability that a fisher will decide to go fishing and that, in Fig. 4.4, the parameter B_{Rate50} is denoted by the symbol *M*). The bite rate, B_{Rate}, is calculated for the fisher as the number of bites that he/she has experienced in the cell divided by the time (min) that has been spent in the cell.

(i) Decision to return home

The probability of a fisher returning home, $P_{\mathrm{ReturnHome}}$, is calculated as:

$$P_{\mathrm{ReturnHome}} = 1/\{1 + exp[-\ln(19)(T_{\mathrm{Trip}} - T_{\mathrm{Trip50}})/(T_{\mathrm{Trip95}} - T_{\mathrm{Trip50}})]\},$$

where T_{Trip50} and T_{Trip95} are the number of hours after which 50 and 95% of fishers, respectively, will return home. Alternatively, a fisher will automatically return home if the 'mixed species' boat limit has been attained. The model includes the two key target species, West Australian dhufish and pink snapper, in the mixed species boat limit.

(ii) Decision to move to a new fishing location

P_{Move}, the probability of a fisher moving to a new fishing location is determined as:

$$P_{\mathrm{Move}} = 1 - P_{\mathrm{StayInCell}}$$

A fisher may move either to a known fishing location, or commence a search to find a new location. The probability of a fisher deciding to begin searching for a new fishing location, P_{Search}, is set as a constant. The decision is made by drawing a uniform random number between 0 and 1, and if this is less than P_{Search}, the fisher will commence searching by moving linearly in a randomly-selected direction to a new cell.

4. *Fisher checkpoint event (search mode)*

Scheduling*: every 1 min whilst searching*.

(i) Decision whether reef has been encountered, after first encountering sand

A fisher must move sufficiently far from a previous fishing location for the new location to represent a different fishing spot. The process by which this is assumed to occur involves fishers moving far enough from their previous fishing location to encounter a non-reef habitat, before then encountering a new reef (Fig. 4.6). At each one minute checkpoint whilst a fisher is searching, he/she decides whether non-reef habitat has been encountered and, if so, whether a new reef habitat has been found. Note again that if a fisher moves outside the grid, he/she will re-enter the grid at the corresponding location on the opposite edge of the grid.

Once a fisher encounters a new reef (and thus a potential new fishing location), that fisher first undertakes a local search, *i.e.* a random walk, for a specified number of cells ('Fisher specification 2' form, Fig. 4.2), to determine the cell with the (perceived) best habitat in the local vicinity of the newly-found reef location. The fisher's collection of fishing spots may then be updated, with the new location replacing an existing location, if one exists in the collection with a poorer value as a fishing spot. After updating the collection, the fisher then decides whether to fish at the new location, or whether to recommence searching (Fig. 4.6).

(ii) Decision to fish new location or a previously-known location

A newly-found location is fished if the fisher's perceived value of the habitat lies above the habitat value specified as the minimum for a good fishing location, otherwise the fisher will commence a new search (Fig. 4.6).

4.2.9. **Simulations**

The agent-based model described above was used to undertake simulations for a range of 'scenarios'. These scenarios explored the movements and behaviours of recreational fishers and their responses to changes in management regulations, *i.e.* in the MLL and boat limits. Thirty simulations were undertaken for each scenario. For each simulation run, all parameters in the model were kept constant except the one of interest. A summary of the simulations undertaken during the various scenarios are presented in Table 4.0.

Baseline data for many of the model parameters were determined either from (1) the responses of recreational fishers at angling clubs to the survey described in Chapter 3 (see Appendix K for survey questions), or (2) from the literature regarding the biological parameters for fish species (summarised in Appendix L). However, certain model parameters, *e.g*. the range of initial fish abundances explored in different simulations, were arbitrary values, over which the model (*i.e.* catches by fishers) responded differently, noting that the model represents simulated fish and fishers interacting over an "artificial" landscape. These simulated recreational fishers were considered representative of avid and specialised fishers, *i.e*. similar to the group of surveyed club anglers. It should be noted that, while the parameters relating to fishers' behaviours and characteristics of fish biology are sound, and thus predictions of the likely responses of fishers and the relative impact of those behavioural changes on catches and fishing activity are reliable, fish abundances and their distribution over the landscape are simulated and are thus not intended to represent the actual fish population and recreational fishery within any specific area of the West Coast Bioregion of south-western Australia.

The abundance of a species targeted by fishers is likely to be a key factor that influences the behaviour of fishers, and thereby is also likely to affect the numbers of both the target and other species that are caught by those fishers. In turn, the catches that are made of the different species will reduce the residual abundances of those species. The effect of this factor on catches was assessed by varying the abundance of West Australian dhufish within the simulated region from its baseline level of 5,000 fish to 20, 50, 200 and 300% of that level (Table 4.0) and re-running thirty simulations for each scenario, while maintaining all other parameters of the model at the values used for the baseline simulation.

The probability that a fisher will move from a fishing spot to a new location is determined by the bite rate (B_{Rate}), *i.e.* the number of bites per minute by fish that are considered by the angler to be likely to have been made by good-sized fish, and the acceptability of that bite rate to the fisher. While the numbers of fish that the fisher encounters are determined by the abundances of the individuals of the different species, the acceptability of the bite rate is determined by the fisher and affects his decision as to whether to remain at the same fishing location or move to a new location. The result of the behaviour resulting from such decisions is likely to be reflected in the numbers of individuals of the different species that are caught by the fisher. The effect of this factor was assessed by varying the value of the parameter B_{Rate50} over a range from ~20 to 200% of its baseline value, while maintaining the values of other parameters at their baseline levels.

The simulations explored the extent to which an increased knowledge (of good fishing locations) would influence catch rates. In the model, an angler's knowledge is represented by a value from 0 (none) to 1 (all known fishing locations of high quality). A baseline value of 0.58 for this variable was calculated from the club survey data relating to the fishers' perceptions of their extent of knowledge of good fishing locations. The effect of this factor was assessed by varying its value over the full possible range from 0 to 1.

The input value for the probability of a fisher deciding to go searching for a new fishing spot (*i.e.* probability of searching, P_{Search}), was a value between 0 (never) and 1, (always, when moving to a fishing location). An arbitrary baseline value of 0.4 was specified, against which the effect of alternative values, while maintaining the values of other parameters at their baseline levels, was explored. In terms of optimising catch success, these simulations explored the trade-off between the amount of time spent searching for new locations with potentially good abundances of fish, compared with fishing known locations, where fish have been caught recently as a consequence, may have become depleted.

The input value for the number of cells searched when potential new fishing locations were found by anglers varied from 1 to 6, with an arbitrary baseline value of 2. Simulations based on different values of this parameter, while maintaining the values of other parameters at their baseline levels, explored the possible trade-off of increasing catch success by increased search time, that would increase the likelihood of finding a high quality fishing location, and reducing success as actual fishing time decreases.

The baseline input value for trip duration (4.59 h) was based on the reported average number of hours spent fishing by club members on their last boat fishing trip, *i.e.* from the club surveys. A range of aspects related to different trip durations was explored. For example, the longer an angler spends fishing, potentially the more searches that will be undertaken and fish caught, noting however that the number of fish that can legally be retained is dependent on the management regulations in place, *e.g.* the minimum legal length and boat limit for each target species, and combined boat limit for a specified set of target species. The effect of trip duration was assessed by varying the value of the parameter over a range from 2 to 14 h, while maintaining the values of other parameters at their baseline levels.

A baseline minimum legal length of 500 mm for West Australian dhufish was set based on current management regulation in the West Coast Bioregion. Simulations were undertaken to explore the effects (*i.e.* on fish population abundance and retained and release catches) of altering this variable over the range of 400 to 600 mm, while maintaining the values of other parameters at their baseline levels. Similarly, the effectiveness of different daily boat limits was assessed by varying this limit from 1 to 5 for West Australian dhufish whilst maintaining the values of other parameters at their baseline values. The baseline value for the boat limit for West Australian dhufish corresponded to the actual current boat limit for this species, *i.e.* 2.

Table 4.0 **Details (within each row) of the agent-based model scenarios that, independently, were explored for each variable of interest. The default values for each scenario have been highlighted in bold red font. (MLL, Minimum Legal Length for retention; BL, daily allowable Boat Limit for West Australian dhufish (mixed boat limit set to sum of boat limits for West Australian dhufish and pink snapper); Abundance, number of West Australian dhufish; Bite rate for West Australian dhufish, fish per minute; Knowledge, average perceived value of the habitats of the fishing locations in fishers' 'knowledge bases'; Probability of initiating a search when moving to a new grid cell, hours; Cells searched at each new location; Trip duration, hours. Note that the number of scenarios (alternative values explored) for the different variables varied. Thirty simulation runs were employed for each scenario.**

Variable	Scenario							
Abundance	1000	2500	**5000**	10000	15000			
Bite rate, B_{Rate50}	5	15	**26.44**	30	45	60		
Knowledge	0.0	0.2	0.4	**0.58**	0.6	0.8	1.0	
Probability of searching, P_{Search}	0	0.2	**0.4**	0.6	0.8	1.0		
Cells searched	1	**2**	3	4	5	6		
Trip duration	2	4	**4.59**	6	8	10	12	14
Minimum legal length	400	450	**500**	550	600	650		
Boat limit	1	**2**	3	4	5			

4.3. **Results**

4.3.1. **Fisher behaviours/knowledge and catches, and fish abundance**

As the abundance of West Australian dhufish was increased from 1,000 to 5,000 fish, the total catch of all species (*i.e.* West Australian dhufish, pink snapper and red herring caught and retained) increased from 5,591 (± 29.64) to 6,451 (± 47.46), and then remained at about the same level as the abundance of West Australian dhufish was further increased to 15,000 fish (Table 4.1, Fig. 4.7*a*). Note that, both here and in the remainder of this chapter, the imprecision of the estimate of the mean is presented, in parentheses, as ± two standard errors, *i.e.* ± 2SE, or, when presenting or displaying an estimate of the approximate 95% confidence interval (CI), the approximate CI is reported as the value of the mean ± 2SE.

The average number of simulated moves an angler made during a single fishing trip declined slightly from 12.2 (± 0.2) to 10.1 (± 0.2) moves when the average bite rate at which a fisher would move, B_{Rate50}, was increased from 5 to 30 bites/15 min. Thereafter, the average number of moves decreased markedly, from 10.1 (± 0.2) to 3.3 (± 0.2), as this bite rate was increased from 30 to 60 bites/15 min, respectively (Fig. 4.7*b*). Further, the total catch of all species (*i.e.* West Australian dhufish, pink snapper and red herring) decreased marginally from 6,731 (± 29.17) to 6,271 (± 31.94) when B_{Rate50} was increased from 5 to 30 bites/15 min. However, the catches decreased markedly, from 6,271 (± 31.94) to 3,873 (± 52.53), as this bite rate was increased from 30 to 60 bites/15 min, respectively (data not shown).

When plotted against the average initial 'GPS knowledge' of anglers, total catch (all West Australian dhufish, pink snapper and red herring caught and retained) remained largely unchanged, with values ranging between 6,412 (± 64.9) and 6,508 (± 41.7) as the level of knowledge increased from 0 (*i.e.* no knowledge of locations of good fishing spots) to 1 (high knowledge of good fishing locations) (Fig. 4.7*c*).

As the probability of searching rather than moving to an alternative known location increased (from 0, *i.e.* always fish known locations, to 1, *i.e.* always search when moving to a new location), total catch (all West Australian dhufish, pink snapper and red herring caught and retained) essentially did not change, *i.e.* increased very slightly from 6,446 (± 40.2) to 6,449 (± 176.0), respectively (Fig. 4.7*d*). Note, for example, that the initial abundance of West Australian dhufish was set at the baseline input value of 5,000 for this simulation scenario, and only the 'search time' value was varied.

As the number of cells of the computer landscape searched by anglers was increased from 1 to 4, total catch (all West Australian dhufish, pink snapper and red herring caught and retained) increased slightly, *i.e.* from an average of 6,195 (± 55.7) to 6,598 (± 69.4) fish (Fig. 4.7*e*).

Total catch of West Australian dhufish, pink snapper and red herring increased markedly as fishing trip duration increased from 2 to 6 h and then levelled off as trip duration increased further to 14 h (Fig. 4.7*f*).

Table 4.1 **Statistics generated by the agent-based model for five simulations in which only the initial abundance variable for the West Australian dhufish was altered.**

	Initial abundance of West Australian dhufish				
Statistic	**1,000**	**2,500**	**5,000**	**10,000**	**15,000**
Total fishing trips	969	976	982	968	964
Total hours 'actively' fished	6,955	6,813	6,908	7,883	8,870
Total searches	6,356	5,409	4,285	3,309	2,860
Total hours searched	1,699	1,414	1,068	785	651
Proportion time searching	0.20	0.17	0.13	0.09	0.07
Average minute searched	16.04	15.69	14.95	14.23	13.66
Average moves per trip	16.42	13.87	10.90	8.55	7.41
Average time at fishing location	26.23	30.23	38.75	57.18	74.62
Fish bites	139,998	155,249	187,971	284,146	385,648
Good fish bites	13,293	15,588	20,457	33,004	46,192
Fish released	12,349	11,471	11,727	16,381	22,041
Fish retained	5,591	6,116	6,451	6,497	6,432
Proportion of fish retained	0.31	0.33	0.35	0.27	0.23
West Australian dhufish released	700	1,877	4,272	9,927	15,755
Pink snapper released	7,578	5,797	3,857	2,705	2,427
Red herring released	4,071	3,798	3,598	3,749	3,858
West Australian dhufish retained	408	886	1,314	1,584	1,676
Pink snapper retained	2,216	2,392	2,505	2,488	2,416
Red herring retained	2,966	2,839	2,632	2,426	2,340
CPUE (retained West Australian dhufish)	0.42	0.91	1.34	1.64	1.74
CPUE (retained pink snapper)	2.29	2.45	2.55	3.32	2.51
CPUE (retained red herring)	3.06	2.91	2.68	2.50	2.43
Multi-species boat limit attained	156	481	764	860	835
Boat limit attained for West Australian dhufish	96	318	566	739	803
Boat limit attained for pink snapper	383	427	454	445	421
Boat limit attained for red herring	6	2	0	0	0

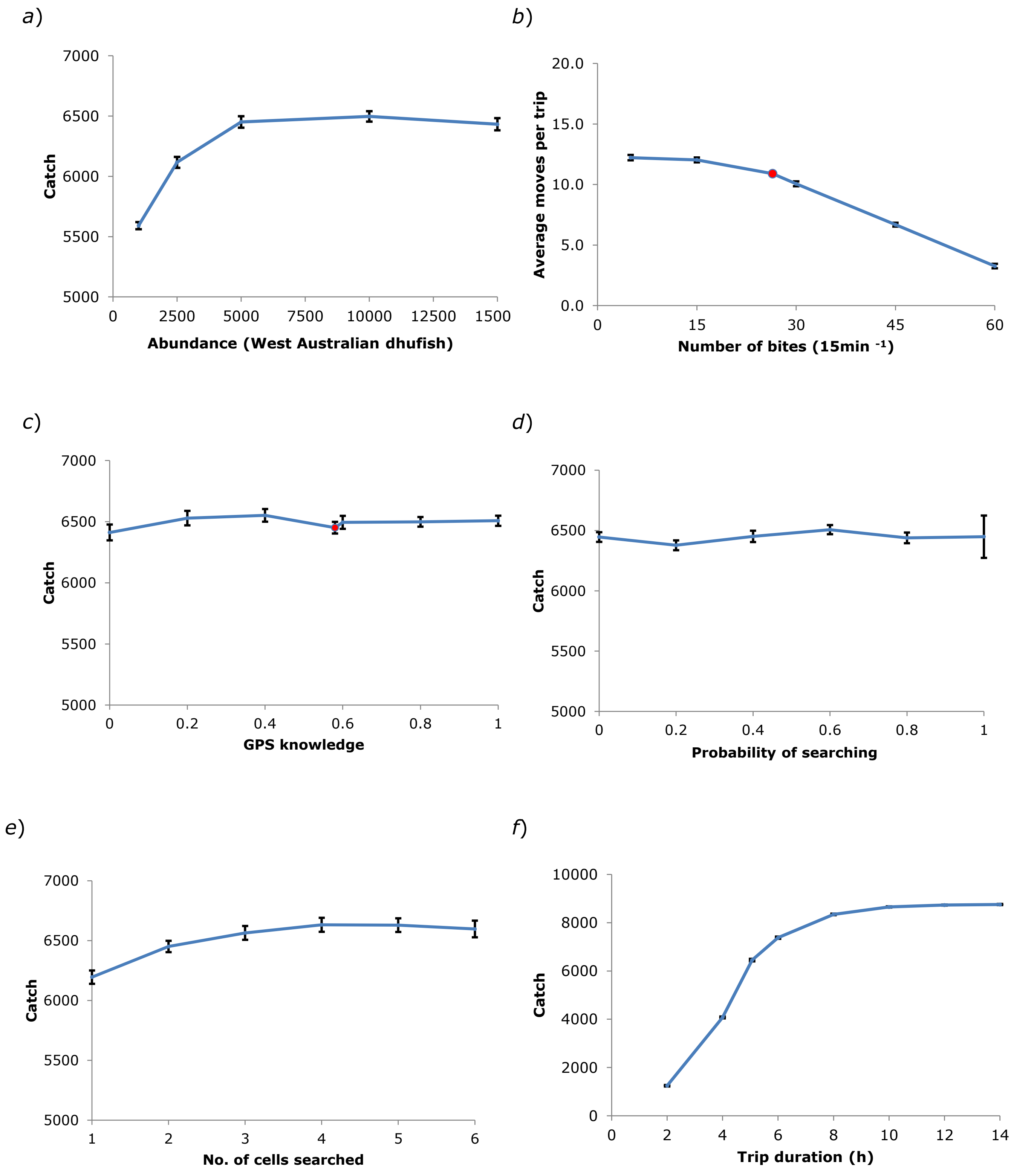


Figure 4.7 Relationships between the total number of fish retained by anglers (catch) and fisher behaviours/knowledge and fish abundance. Only the variables on the x axis have been modified in this exercise, with data sourced directly from the survey highlighted by the red data point. (Note: approximate 95% confidence intervals, calculated as the mean ± 2 SE, have been plotted, but are very small).

4.3.2. Effect of increasing fish abundance on fisher behaviours and catches

As the specified initial abundance of West Australian dhufish, for model simulations was increased, the total number of simulated searches by anglers decreased (Table 4.1, Fig. 4.8*a*). In contrast, the average time that fishers spent at each fishing location increased (Table 4.1, Fig. 4.8*b*), which resulted in a decrease in the average number of moves made by each fisher during each trip. The total number of hours 'actively' fished by anglers also increased from < 6,955 (± 40.1) when the initial abundance of West Australian dhufish was 5,000 fish or less to 7,883 (± 44.4) and 8,870 (± 50.1) when the abundance increased to 10,000 and 15,000 fish, respectively. As a consequence of the increase in active fishing time, the total number of hours searched by anglers decreased from < 1,699 (± 32.2) when the initial abundance was 5,000 fish or less to 785 (± 18.9) and 651 (± 14.9) when the abundance increased to 10,000 and 15,000 fish, respectively (Fig. 4.8*c*). This decrease in total hours searched was accompanied by a decrease in the average time that each fisher searched (Table 4.1)

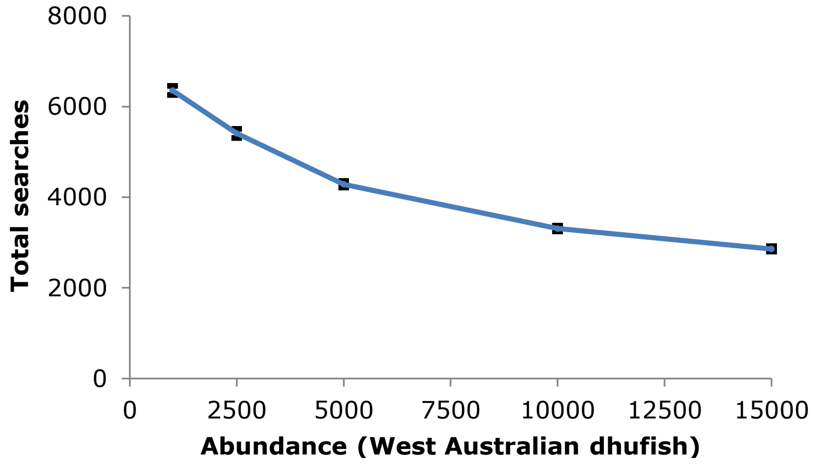
As the initial abundance of West Australian dhufish was increased from 1,000 to 15,000 fish (with the abundance of the other two species kept constant), the number of West Australian dhufish caught and released by anglers increased from 700 (± 15.9) to 15,755 (± 152.7) fish. However, the number of pink snapper released by anglers decreased from 7,578 (± 95.6) to 2,427 (± 45.9) fish and the numbers of released red herring also decreased slightly from 4,071 (± 91.2) to 3,858 (± 62.9) fish (Fig. 4.9*a*).

An increase in the initial abundance of West Australian dhufish from 1,000 to 5,000 fish resulted in an increase in the number of this species being caught and retained by anglers, *i.e.* from 408 (± 6.7) to 1,314 (± 10.9) fish. However, the increase in retained West Australian dhufish by anglers when the initial abundance was increased further from 10,000 to 15,000 fish was small, *i.e.* from 1,584 (± 12.9) to 1,676 (± 15.7), respectively. The number of pink snapper caught and retained by anglers increased slightly from 2,216 (± 15.1) to 2,505 (± 17.5) as the initial abundance of West Australian dhufish was increased from 1,000 to 5,000 fish (and when the initial abundance of pink snapper was kept the same). Subsequently, the numbers of pink snapper retained decreased slightly, *i.e.* from 2,505 (± 17.5) to 2,416 (± 18.1) as the initial abundance of West Australian dhufish was further increased from 5,000 fish to 15,000 fish. The number of retained red herring decreased from 2,966 (± 17.3) to 2,340 (± 21.7) as the initial abundance of West Australian dhufish increased from 1,000 fish to 15,000 fish (Fig. 4.9*b*). Note, that the catches that resulted from a variation in any one of the factors that were considered in the various simulations were influenced by the baseline values of the other parameters of that particular simulation scenario. Thus, for example, boat limits on both individual species and the mixed boat limit on West Australian dhufish and pink snapper acted as possible constraints on catches of the different species that were made when the initial abundance of West Australian dhufish was varied.

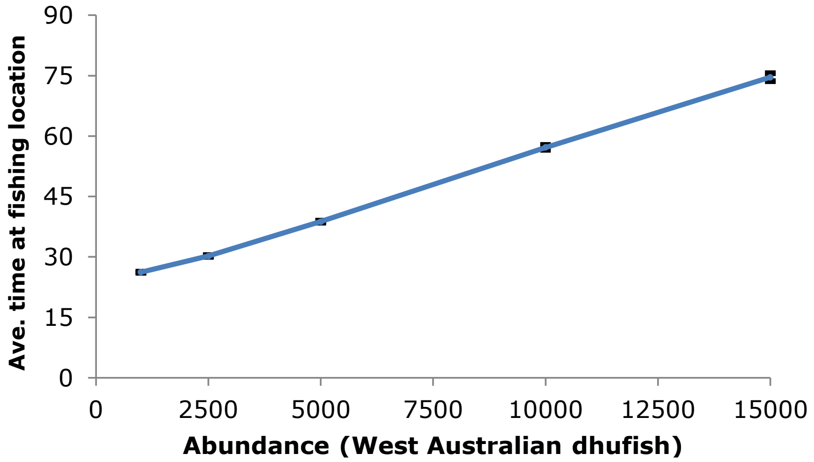
As the initial abundance of West Australian dhufish was increased from 1,000 to 15,000 fish, the number of times that the boat limit for this species was attained increased markedly from 96 (± 3.1) to 803 (± 8.0), appearing to approach a plateau as West Australian dhufish abundance increased from 1,000 to 15,000 fish. There was a slight increase in the number of times the boat limit for pink snapper was attained as the initial abundance of West Australian dhufish was increased to 5,000, *i.e*. from 383 (± 1.9) to 454 (± 4.8), but then a subsequent decline as the initial number of West Australian dhufish was increased to 10,000 then 15,000 fish, *i.e*. from 445 (± 2.6) to 421 (± 2.3). The boat limit for red herring was attained on only a few occasions and only while the initial abundance of West Australian dhufish was low, *i.e*. between 1,000 to 2,500 West Australian dhufish. The trend for the overall 'multi-species' (West Australian dhufish and pink snapper) boat limit being attained was similar to that described for West Australian dhufish, increasing from 156 (± 5.4) to 835 (± 9.5) (Fig. 4.10).

As the initial abundance of West Australian dhufish was increased from 1,000 to 5,000 fish, the total catch (over all species) per hour of active fishing steadily increased, *i.e.* from 0.80 to 0.93, but then subsequently declined as the initial number of West Australian dhufish was increased to 10,000 then 15,000 fish, *i.e*. from 0.82 to 0.73 (Fig. 4.11). A similar trend was observed when plotting catch per hour of the pooled searching and active fishing time. In contrast, however, as the initial abundance of West Australian dhufish was increased from 1,000 to 15,000 fish, the catch per hour of searching steadily increased, *i.e.* from 3.29 to 9.88 (Fig. 4.11). Note that, throughout this paragraph, 'catch per hour' refers to the total catch (all West Australian dhufish, pink snapper and red herring caught and retained) by anglers in the total number of hours fished and searched, respectively (data not shown).

a)



b)



c)

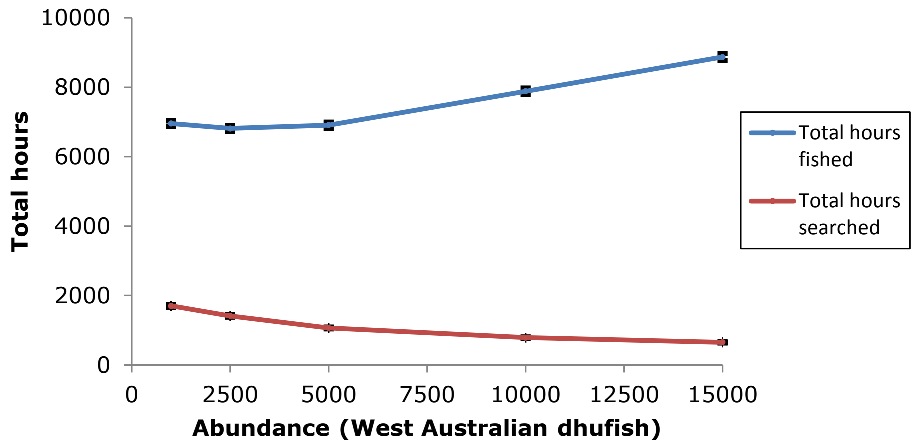
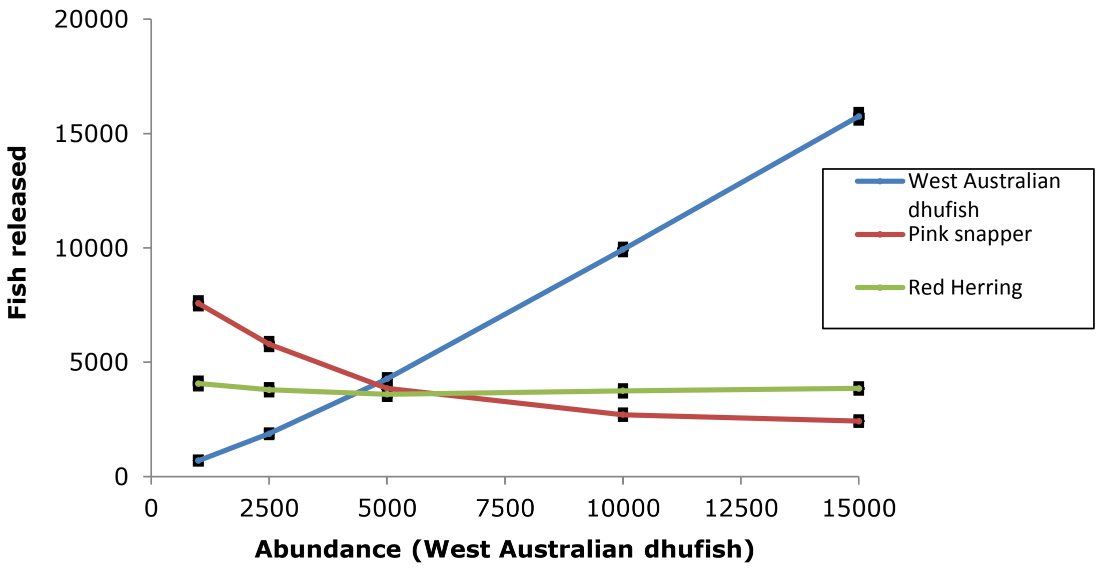


Figure 4.8 **Relationships with initial abundance of West Australian dhufish of the (*a*) Number of searches, (*b*) Average time anglers spent at each fishing location, and the (*c*) Total number of hours actively fished and searched by anglers. The initial abundances of pink snapper and 'red herring' (silver trevally) were held constant. (Note: approximate 95% CIs, calculated as the mean ± 2 SE, have been plotted, but are very small).**

a)



b)

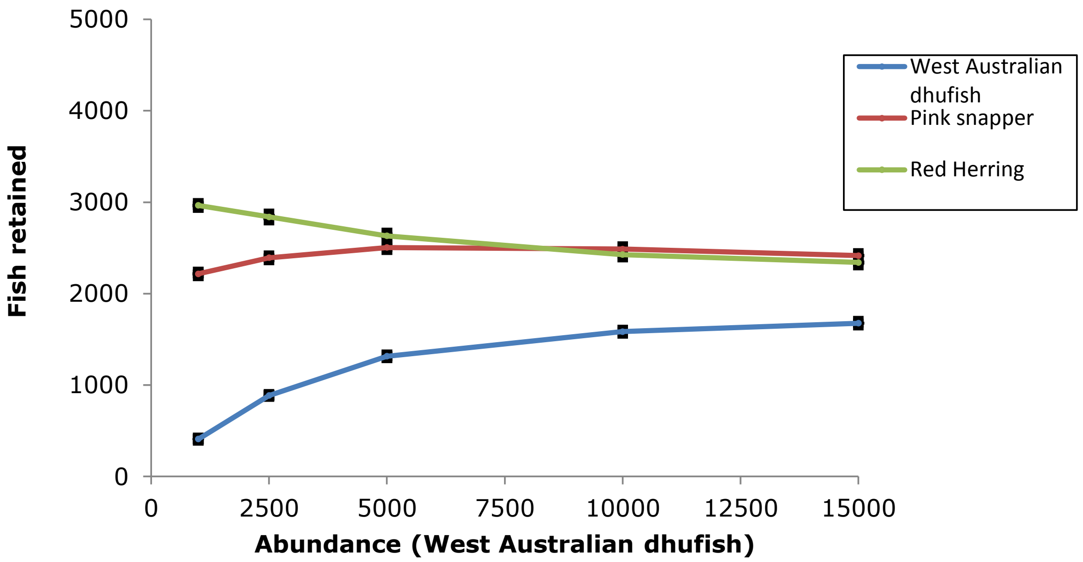


Figure 4.9 **Relationships with initial abundance of West Australian dhufish of the (*a*) Number of individuals released by anglers, and the (*b*) Number of individuals retained by anglers. The initial abundances of pink snapper and 'red herring' (silver trevally) were held constant. (Note: approximate 95% CIs, calculated as the mean ± 2 SE, have been plotted, they are just very small).**

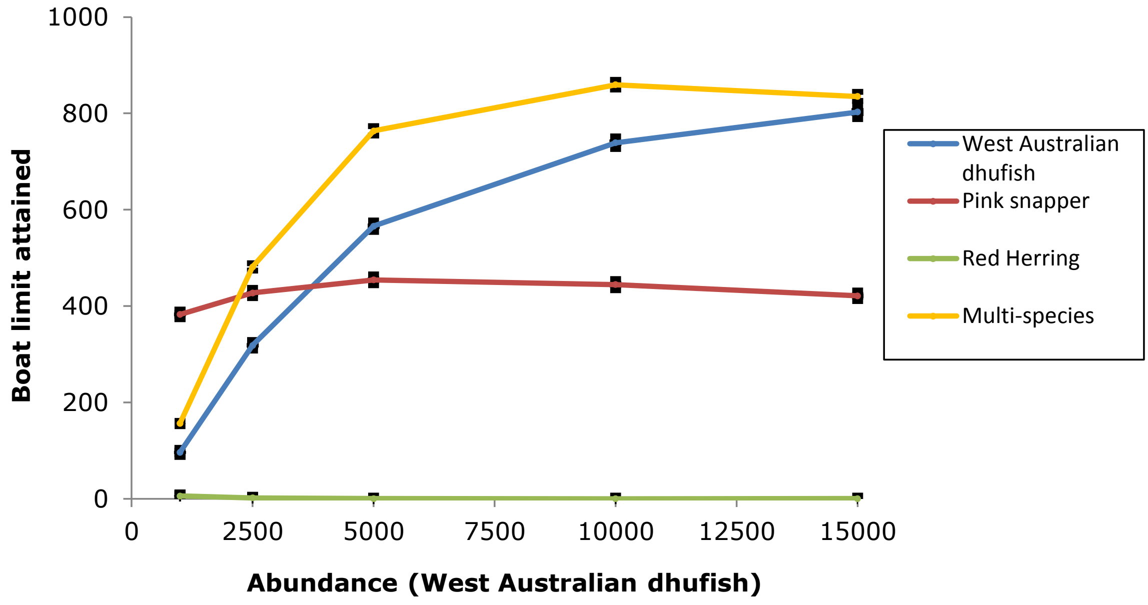


Figure 4.10 Relationships with initial abundance of West Australian dhufish of the number of times the boat limit for each species (West Australian dhufish, pink snapper and 'red herring' (silver trevally)) and also the combined 'multi-species' (West Australian dhufish and pink snapper) limit was attained. (Note: approximate 95% CIs, calculated as the mean ± 2 SE, have been plotted, but are very small).

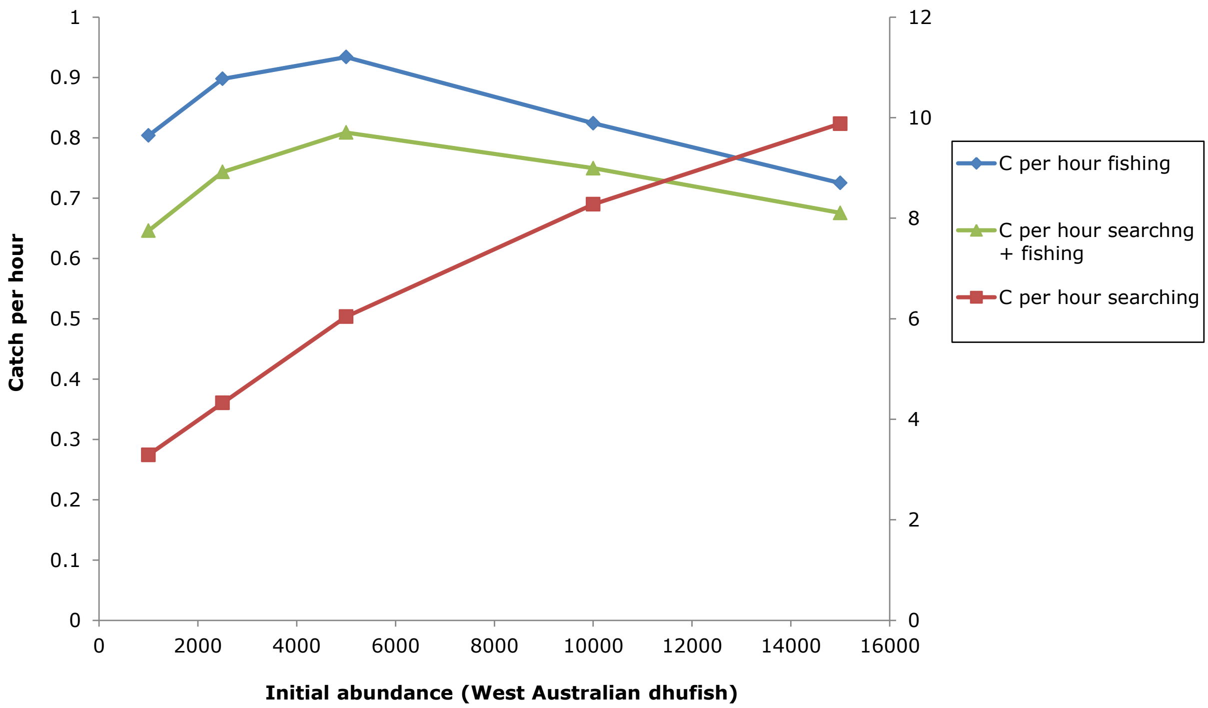


Figure 4.11 **Relationships with initial abundance of West Australian dhufish of the catch of individuals per hour fishing, catch per hour searching and catch per hour searching and fishing.**

4.3.3. Management regulations and fisher behaviours, catches and fish abundance

An increase in the allowable boat limit (BL) from 1 to 5 fish for West Australian dhufish led to an increase in the total number of West Australian dhufish, pink snapper and red herring (5,904 (± 67.46) to 7,904 (± 39.66) fish) that were caught and retained by fishers (Fig. 4.12*a*). The rate of increase declined as the boat limit increased. An increase in the minimum legal length (MLL) from 400 mm to 650 mm for West Australian dhufish led to a decrease in the total number (6,663 (± 54.62) to 5,980 (± 50.08) fish) of individuals of three species that were caught and retained by fishers (Fig. 4.12*b*).

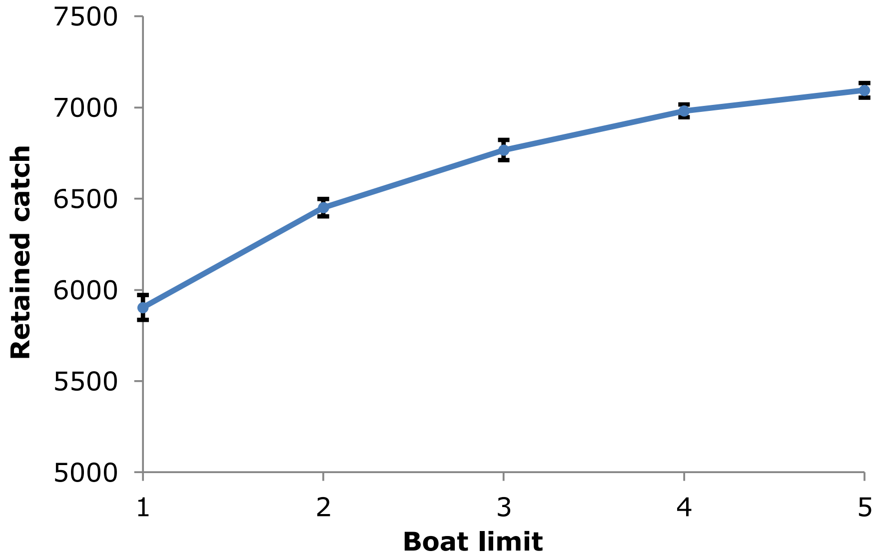
Irrespective of boat limit (BL), high numbers of West Australian dhufish between the ages of 3 to 6 y were released. The highest discard of this species (795 ± 21.3) was recorded in the 4-year-old age class for a BL of four West Australian dhufish per day (Fig. 4.13*a*). Following the introduction of a restrictive BL of one West Australian dhufish per day, while similar numbers of young West Australian dhufish (≤ 4 y) were discarded in both scenarios, greater numbers of West Australian dhufish were released in each of the older age classes for this scenario compared to the numbers released under a BL of four (Fig. 4.13*a*). Higher numbers of West Australian dhufish were retained for all age classes with a BL of four West Australian dhufish compared to a BL of one West Australian dhufish per day (Fig. 4.13*b*).

A pattern similar to that reported above for the effect of bag limit changes on the different age classes is evident in the data for the length frequency data, noting that lengths were classified into 50 mm length classes, where length class 1 represented fish with lengths ranging from 0 to 50 mm, 2 represented fish with lengths > 50 mm up to and including 100 mm, etc. Thus, similar numbers of West Australian dhufish were released between length classes of 1 to 9 in both scenarios (BL 1 and BL 4). However, a higher number of West Australian dhufish were released in the larger length classes with a BL of one West Australian dhufish per day (Fig. 4.14*a*). Higher numbers of West Australian dhufish were retained for all length classes with a BL of four West Australian dhufish compared to a BL of one West Australian dhufish per day (Fig. 4.14*b*).

The age compositions of West Australian dhufish, which were released and retained by anglers for both minimum legal length scenarios (*i.e*. MLL: 400 mm and MLL: 600 mm), were also plotted (Figs 4.15*a*,*b*). The greatest numbers of West Australian dhufish were released between the ages of 3 to 6 y, with the greatest number of this species (897 ± 22.6) being recorded for the 600 mm MLL scenario (Fig. 4.15*a*). Slightly greater numbers of West Australian dhufish aged ≥ 7 y were retained by anglers with a MLL of 600 mm (Fig. 4.15*b*).

Large numbers of West Australian dhufish were released in the 8-11 length classes under both MLL scenarios. The greatest numbers of released West Australian dhufish were recorded for this species in length classes 9 and 10 in the 600 mm MLL scenario (Fig. 4.16). The 600 mm MLL scenario produced the greatest number of released West Australian dhufish in all length classes from 1 to 12, with the 400 mm MLL scenario resulting in the greatest number of released West Australian dhufish in the remaining length classes (13 to 22) (Fig. 4.16*a*). The 400 mm MLL scenario was the only scenario for which this species were recorded as being retained in length classes 9 and 10, with 141 (± 4.1) and 141 (± 3.8) West Australian dhufish retained, respectively (Fig. 4.16*b*).

a)



b)

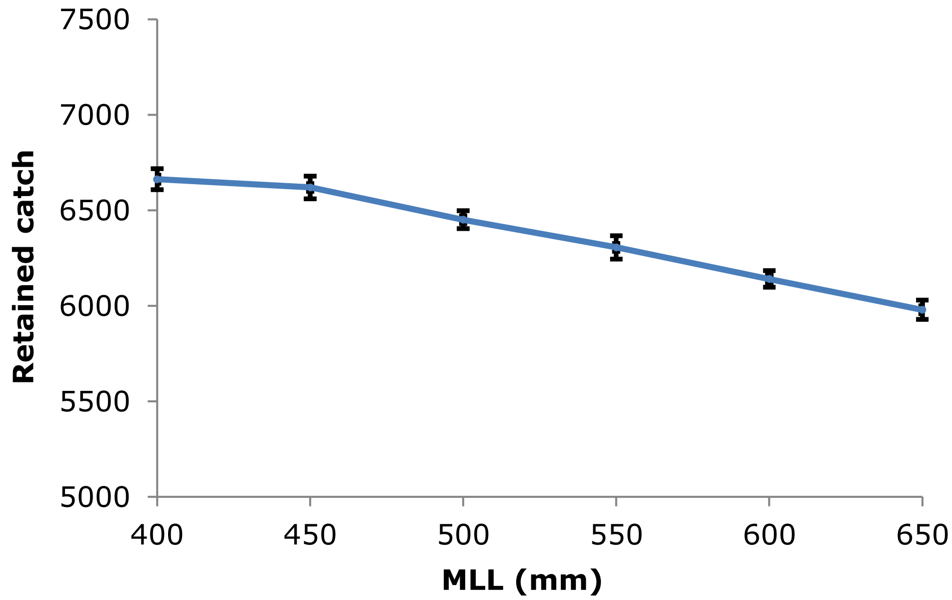
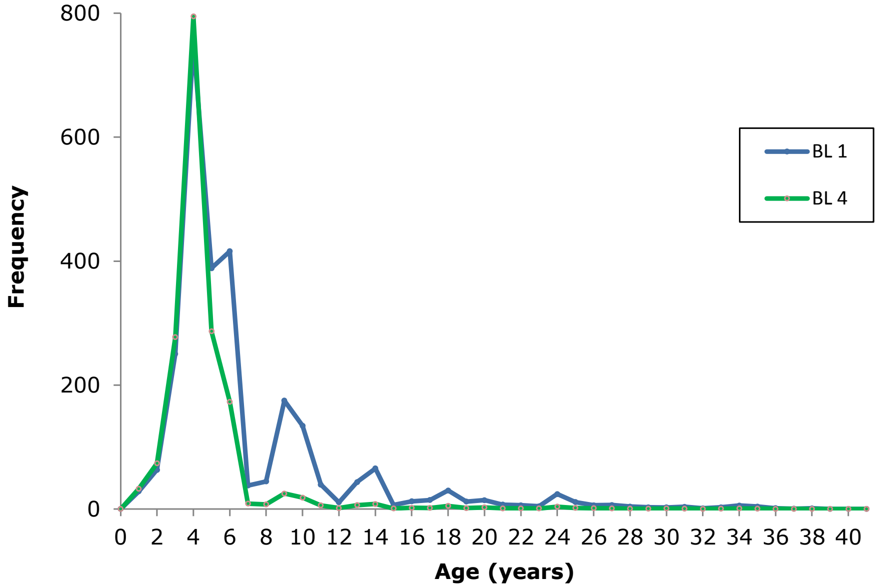


Figure 4.12 **Relationship between the total number of fish retained by anglers (catch) and changes to the management regulations of (*a*) the allowable boat limit of West Australian dhufish and (*b*) the minimum legal length (MLL) of West Australian dhufish. (Note: approximate 95% CIs, calculated as the mean ± 2 SE, have been plotted, but are very small).**

a)



b)

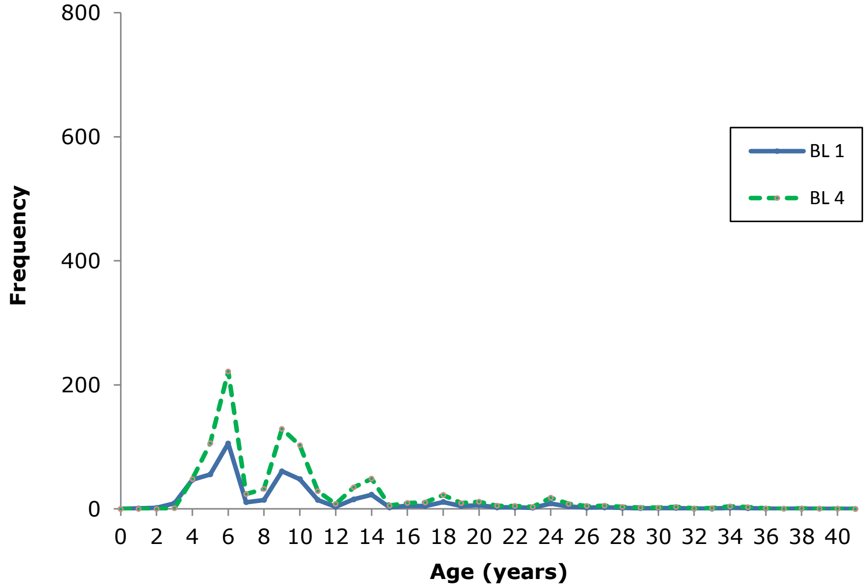
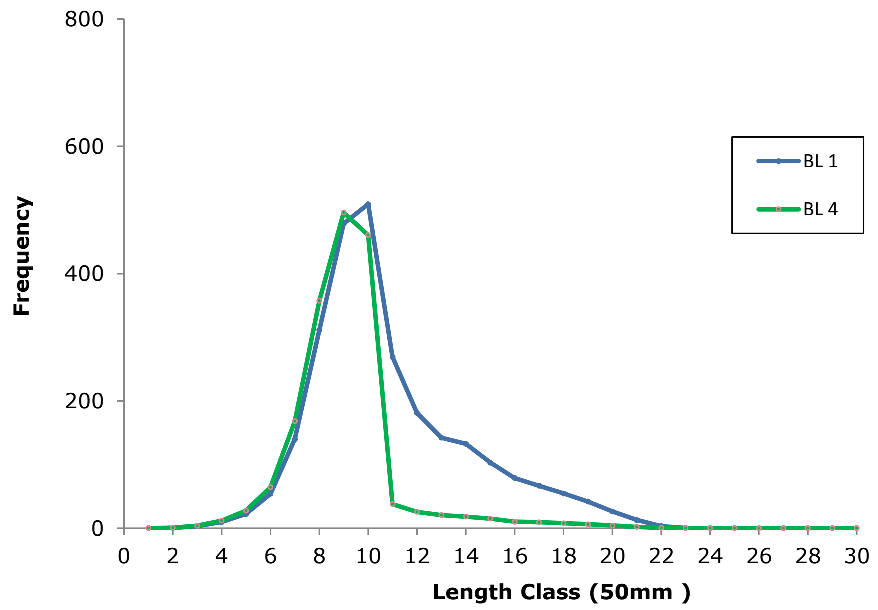


Figure 4.13 **The age compositions of West Australian dhufish that were released (*a*) and retained (*b*) by anglers when total allowable boat limits (BLs) were set to 1 or 4 fish.**

a)



b)

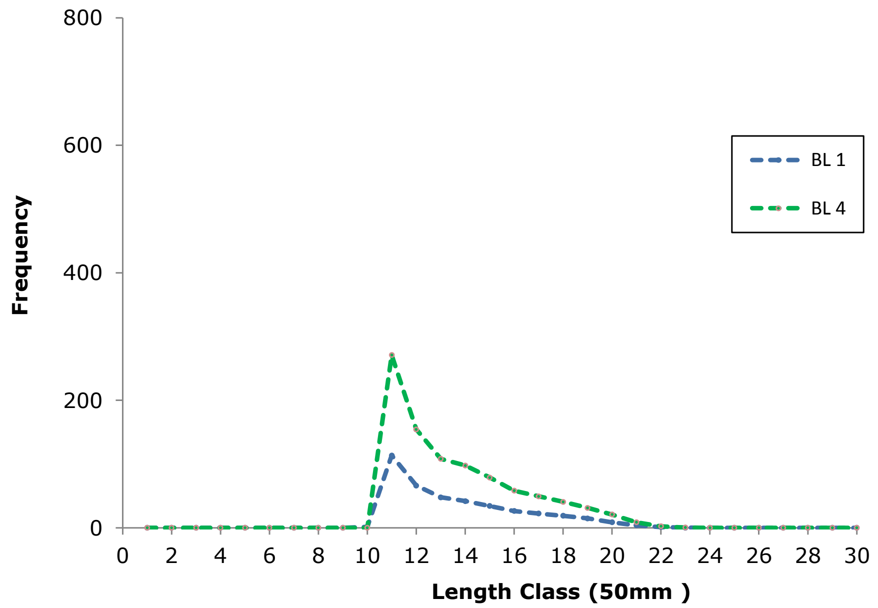
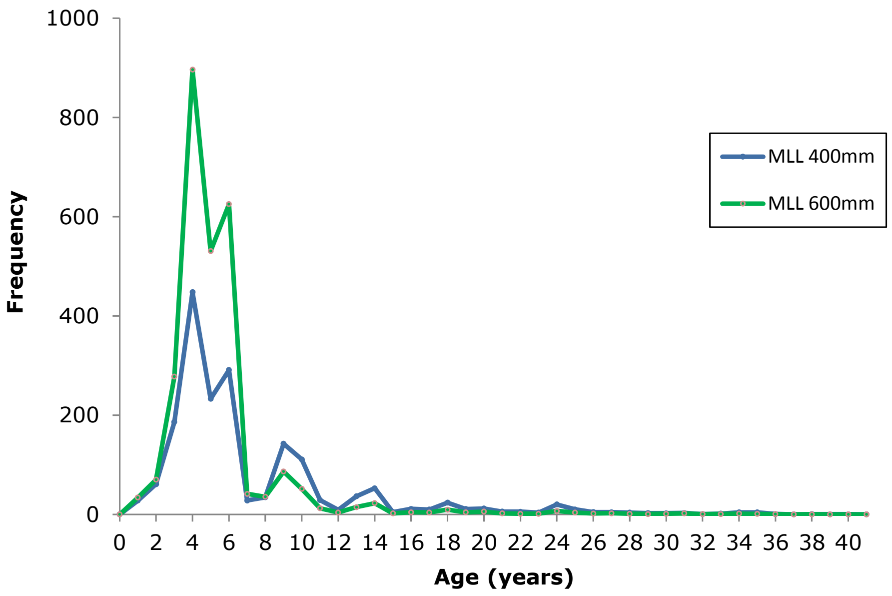


Figure 4.14 The length compositions of West Australian dhufish that were released (*a*) and retained (*b*) by anglers when total allowable boat limits (BLs) were set to 1 or 4 fish.

a)



b)

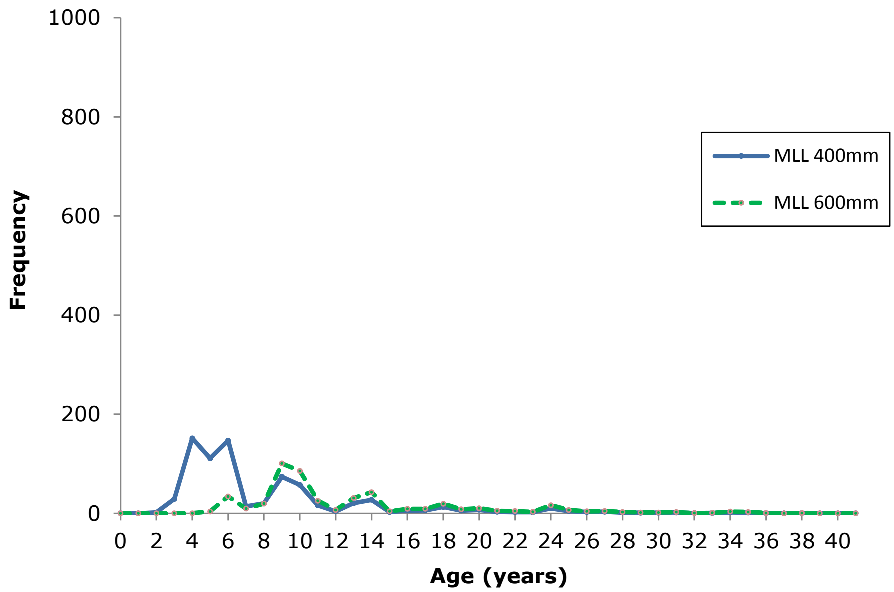
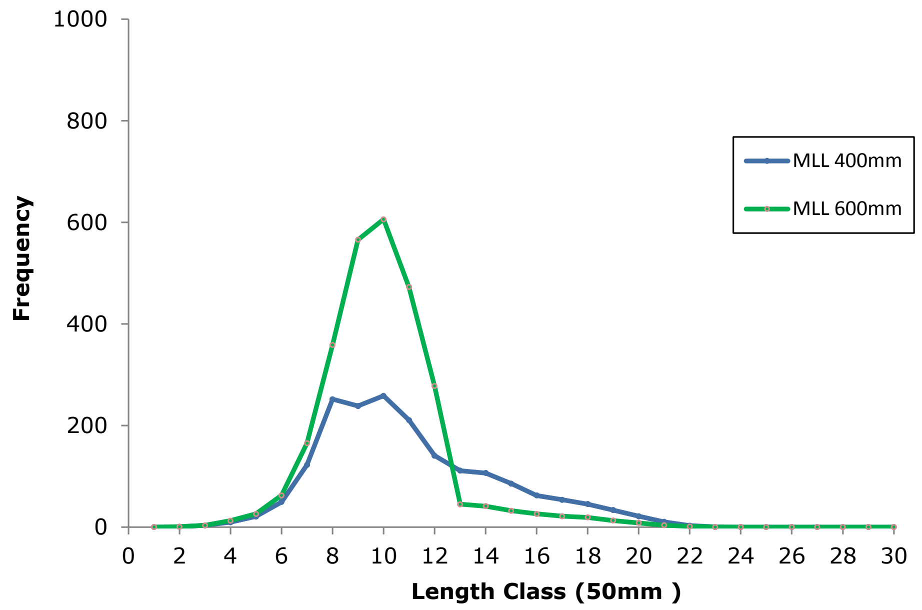


Figure 4.15 **The age compositions of West Australian dhufish that were released (*a*) and retained (*b*) by anglers when the minimum legal length (MLL) was set to 400 or 600 mm.**

a)



b)

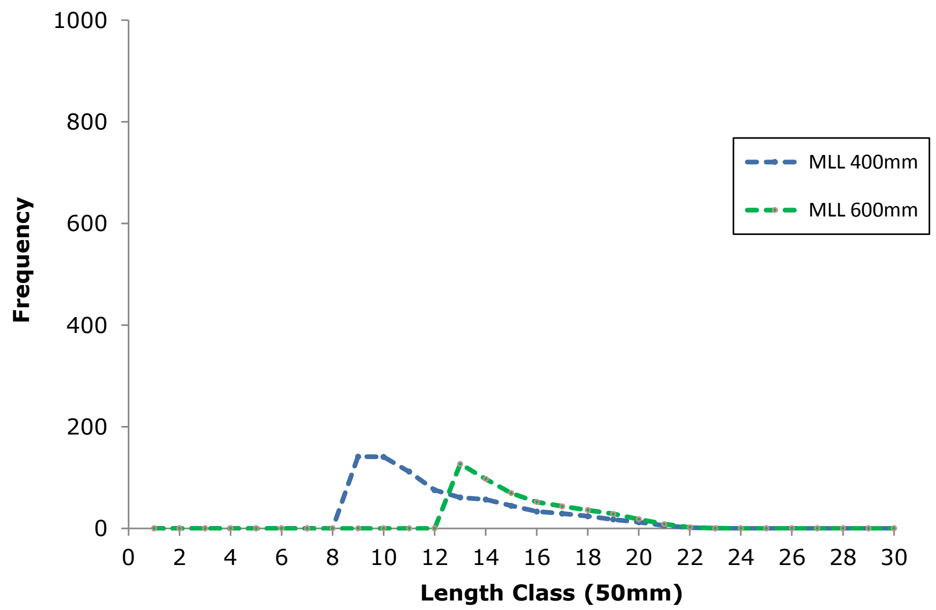


Figure 4.16 **The length compositions of West Australian dhufish that were released (*a*) and retained (*b*) by anglers when the minimum legal length (MLL) was set to 400 or 600 mm.**

4.4. **Discussion**

4.4.1. **Fisher behaviours/knowledge and catches, and fish abundance**

As hypothesised, model simulations demonstrated strong relationships between West Australian dhufish catch and variables such as initial West Australian dhufish abundance, bite rate and trip duration. Catch levels tended to 'level off' or approach a plateau once a certain level of initial West Australian dhufish abundance or trip duration had been reached, *i.e.* 5,000 initial fish for abundance and an angler's trip duration of 8 h or more. These results appear logical given that, in the model (as in the actual fishery), a daily boat limit of two West Australian dhufish (*G. hebraicum*) was imposed. Note also that the model simulations only run for one year, thus, if the model was extended to enable simulations over multiple years (*i.e.* with recruitment of fish each year, according to a stock recruitment relationship), we may see very different trends appearing. Therefore, although the overall fishing experience may be diminished or limited in terms of how many fish an angler is allowed to catch, such that it does not matter whether an angler stays out longer fishing or whether there are more fish, a fisher still cannot take home any more West Australian dhufish than the allowable bag or boat limit. However, in terms of conservation and overall sustainability of the stock, such issues raise concerns that (a) increases in discard mortality of this iconic species may result if bag limits are reduced and fishers continue to fish for other species while releasing fish in excess of the bag limit (Coleman *et al*., 2004; Stephenson and Jackson, 2005), and (b) the potential for upsizing (high-grading) of catches is likely to increase if more restrictive bag limits are imposed (Arlinghaus, 2004; St John and Syers, 2005). In response to these concerns, it should be noted that results of the angler surveys (Chapter 2 and 3) suggested that the more avid the fisher is the more likely he is to catch his bag limit and then head home.

The finding that total catch remained largely unchanged when plotted against initial 'GPS knowledge' reflected the ability of simulated anglers to quickly learn and adapt by updating their storage of known fishing locations based on finding of new locations and recent fishing experience at different locations. Such behaviour is typical of agents capable of making independent decisions, essentially an important characteristic making the agents active rather purely passive within the model (Jennings, 2000; Macal and North, 2007). Furthermore, specialisation theory would suggest that the more avid and specialised the fisher is, the more likely he would have a greater knowledge of the use of technology and skill in locating good fishing locations and would also be expected to possess knowledge of a number of high quality fishing locations (Ditton *et al*., 1992; Wilde *et al*., 1998). Thus, these results reflect the likely situation for an avid fisher.

As described by Hunt *et al*. (2011), experienced and specialised anglers are very efficient at locating optimum fishing locations, catching target fish and are also highly adaptable to new fishing areas. Thus, it might be expected, for example, if a highly experienced fisher went on a fishing holiday in a new area, he/she would be likely to very quickly determine how to find good fishing locations and catch fish within that area. This would be less likely to be true for a novice angler, however, implying that past 'GPS knowledge' is more important for the non-avid or novice fisher. To explore this further, the learning ability of anglers could be changed in the simulation by simply switching off the learning function for 'GPS knowledge', thus running the simulation with fisher agents who have a reduced ability to 'learn'. Such simulations could provide insight regarding how much/what type 'intelligence' is required by agents to maintain a good catch rate in a particular type of fishery. Similar "experiments" have been undertaken with 'zero-intelligence' (ZI) agents in the discipline of economics, with these ZI agents performing well when subjected to simple budget constraints and rules within the model (see Gode and Sunder, 1993; 1997; Duffy and Ünver, 2006).

The finding that catches approached a plateau as the number of grid cells searched by anglers was increased supports the concept of 'optimum fishing tactics' (sensu Beverton and Holt, 1957; Sampson, 1991) that there is an optimal trade-off between increasing search time to enhance the chances of finding an excellent fishing location versus increasing catch rates by maximising the time actually spent fishing (Eales and Wilen, 1986; Sampson, 1991; 1994). Note also that the value of increasing search time would diminish for anglers who already possess knowledge of numerous high quality fishing locations, a factor that could be assessed by modifying the model and undertaking further simulations. In summary, the results lend support to the conclusion that, at a fine scale, fishers adjust various behaviours to optimise their fishing efficiency and thereby be able to maintain catch rates. It is this ability to adapt and ultimately respond to changes in their environment that 'makes a good fisher a good fisher'.

4.4.2. **Fish abundance on fisher behaviours and catches**

In a previous study, Sampson (1994) concluded that the best strategy for an angler to maximise fishing success during a fishing trip is to fish at their single 'best' fishing location, as any move from this location would be likely to result in lower catch rates. However, this study indicated that when overall fish abundance is low, fishers are likely to undertake more searches and decrease the amount of time they spend at a given fishing location, in order to find locations with higher abundances of fish and thereby improve their catch rates. However, when fish abundances are higher, fishers are likely to benefit by spending a greater amount of time at each fishing location. Note also that, as the abundance of the fish population decreases, catch rates fall and fishers spend more time searching, the quality attribute of a fishing trip will be reduced (Cameron and Huppert, 1989).

The simulation result of fishers staying longer at fishing locations and thus, also reducing the number of searches they undertake when fish abundance is high, is further supported by the notion of Moustakes (2006), who noted that, while boats are catching fish, they have an incentive to stay where they are, and ultimately their willingness to move depends on how ready they are to accept the risk of giving up known catches in their present location for the chance of higher catches elsewhere. Knowledge of the total number of searches or time spent searching by anglers can also potentially reveal the extent to which fishers are maintaining their catch levels through searching to find patches of greater local abundance and thus address the potential that observed catch rates exhibit hyperstability. Such data could be used by researchers and managers to assist in drawing inferences on the population status of the stock. This area of investigation differs from the more commonly used assumption in stock assessments that there is direct proportionality between CPUEs and abundance. Issues pertaining to hyper-depletion for certain species, however, would still need to be considered (Hilborn and Walters, 1992; Gaertner, 2010). In terms of management, it is also relevant that, despite the patchy distribution often exhibited by demersal species such as West Australian dhufish (St John and Syers, 2005), fishers with sufficient knowledge and fishing technology may still readily exploit fish populations even when their abundances are low (Post *et al*., 2002).

The simulations indicated that the numbers of West Australian dhufish caught and released by anglers in model simulations may be substantial even when fish population abundances are high, which presumably reflected the impact of fishing regulations (*i.e.* the imposed daily boat limit for this species, mixed species daily boat limit, and minimum size limit). As noted by Gentner and Sutton (2008), most anglers, particularly those heavily invested in fishing (*i.e.* the more and avid and specialised fisher), will not entirely cease fishing but are more likely to switch to a new target species when more stringent management measures are introduced. Thus, this type of agent based model is potentially useful for examining the effects of alternative management actions on levels of bycatch and discarding of fish in a multi-species fishery. Results from the study suggest that an effort shift between different fish species is seen when West Australian dhufish abundance is low, with a greater number of searches undertaken by agents and more numbers of pink snapper and 'red herring' being caught and retained by anglers. Such results highlight the potential for changes in the exploitation rates of species not directly affected by the imposed regulatory change. Further, if these effort shifts by anglers are unknown or unanticipated, they can ultimately undermine management goals and reduce or negate the expected benefits of fisheries management (Busch *et al.,* 2003; Sutton and Ditton, 2005; Gentner and Sutton, 2008).

The simulation results also indicated that the trade-off between time spent fishing and time spent searching by the angler is influenced by management, *e.g.* boat limits (BL). These results suggest that changes in fisher behaviour, in response to changing abundance and constraints imposed by boat limits may cause changes in the level of exploitation of an alternative fish species and, consequently, a subsequent change in the abundance of that species.

Anglers base their decisions on fishing and allocate their efforts based on several factors, such as the quality of the fishery and the travel time and costs to access the fishing opportunity (Post *et al*., 2008). In model simulations, fishers responded to a lower abundance of West Australian dhufish by moving to new cells more frequently, thereby presumably distributing fishing effort over a greater number of grid cells and a wider range of habitats. The results also indicated that this change in fishing effort may result in fishers catching a greater abundance of non-target species (*i.e.* 'red herring') than that which would have been occurred if the fishers had not increased their frequency of movement (Genter and Sutton, 2004; Sutton and Ditton, 2005). This view is consistent with conclusions from previous studies, *i.e.* that anglers, like all natural predators, make decisions and change their foraging behaviours in response to prey populations (Sampson, 1991), including switching of target species. As described by Metcalf *et al.* (2010), such target switching in commercial fisheries in response to changing economic values or variation in abundance is a relatively common occurrence but has rarely been investigated in recreational fisheries.

As the "rules" determining the behaviour of fishers within the agent-based model of the current study did not include target switching, the increased landings of pink snapper and 'red herring' that resulted from reduced abundance of West Australian dhufish, however, cannot be attributed directly to 'target switching', but rather reflect changes in movements of fishers. The fact that, for some species in some fisheries, such an increase in frequency of movement has the potential to produce an effect on catches similar that which might be expected as a result of target-switching is interesting, as it suggests that some changes in catches that have previously been attributed to target switching might simply be due to a changed frequency of movement by fishers. The efficiency of the modern angler can also not be overlooked as improved technologies, *i.e*. vessel design, vessel power fish locating devices etc., have enabled fishers to cover more ground per unit effort thus allowing fishers to search for, find, and exploit fish populations even when their abundance is low (Greenstreet *et al*., 1999; Post *et al*., 2002).

A lower abundance of West Australian dhufish also resulted in far fewer fishers attaining their boat limits for that species or the mixed boat limit for West Australian dhufish and pink snapper, thereby having the potential to increase the total catch of that latter species. Thus, the simulations indicate that a change in the abundance of a primary target species can have a major impact on the dynamics of a fishery, by modifying the behaviours of anglers and ultimately influencing catches of the target and other species, and thus, in turn, the effectiveness of management measures for other species. As discussed by Sutton and Ditton (2005), in a multispecies fishery, anglers may have resource (*i.e.* fish species) substitution options that do not require a shift in their fishing location. However, it is important to note that in a real life scenario, personal characteristics of anglers (including the emotional attachment they may hold for targeting a specific species) are also expected to influence their willingness to target a substitute species, as this would also likely require a shift in expectations of the fishing outcome (Genter and Sutton, 2004; Sutton and Ditton 2005; Johnston *et al*., 2010). In the context of specialisation theory, more avid and specialised anglers who, because of their strong commitment to fishing, have refined their fishing skills and invested in expensive fishing equipment, are less likely to obtain the same satisfaction from an alternative type of fishing as that which they enjoy from their preferred type of fishing (Sutton and Ditton, 2005).

It was expected that, as initial abundances of West Australian dhufish were increased, the retained catch per hour of active fishing would first increase approximately linearly with abundance then, as catches became increasingly constrained by boat limits, the catch rates would approach an asymptote. A similar result had been expected for the catch per hour of combined active fishing and searching, *i.e.* total time at sea. In contrast, it had been anticipated that catch per hour of searching would increase approximately linearly as the initial abundance of West Australian dhufish was increased. While the last of these expectations was realised, *i.e.* catch per hour of searching increased linearly with increasing abundance, contrary to expectation, the resulting catches per hour of active or total fishing first increased towards a peak then declined as initial West Australian dhufish abundance was further increased. This unexpected decline with greater initial abundance of West Australian dhufish is attributed to the fact that, with increased abundance of West Australian dhufish coupled with release of fish in excess of the boat limit, the bite rate at each fishing location remained sufficiently high to reduce the incentive for fishers to move. This is likely to have resulted in 'local depletion', thereby reducing the catch per hour of active or total fishing. As noted by Post *et al*. (2008), the spatial dynamics of angler behaviour is an important feature of recreational fisheries as a more active management of fisheries distributed over landscapes is adopted in response to increasing pressure on fish stocks. Thus, these results have important implications for fisheries scientists as it suggests that, rather than employing retained recreational catch per unit of active fishing effort as a measure of abundance, there may be benefit in using recreational catch per unit of searching time as a more reliable index of abundance for some species.

Although not considered in the current study, it might be useful to use the ABM to assess the value of using the number of bites per hour of fishing at each fishing location as a measure of abundance at that location. It is highly likely, however, that the average number of bites per hour for the region would be biased by movement of recreational anglers from locations at which the bite rate is low. The extent to which commercial fishers (presumed to behave similarly) might also influence the relationship between commercial catch per unit of fishing effort and abundance, through their behavioural response to observed catch rates, should be investigated.

4.4.3. **Management regulations and fisher behaviours, catches and fish abundance**

A common management response to a decline in abundance of a fish stock (and an associated decline in angling catch rates) to a level that is considered unsustainable is the imposition of regulations to reduce harvest (Radomski *et al*., 2001; Post *et al*., 2002). As would be expected, a decrease in the daily allowable boat limit (BL) resulted in a decrease in the retained catch of West Australian dhufish by anglers. Similarly, an increase in the minimum legal length (MLL) resulted in the retained catch (of West Australian dhufish) decreasing. These results indicate that both types of management regulation are effective in reducing retained catches of a species. It is important to note, however, that an increase in MLL resulted in a decrease in retained catch numbers, but the decline by weight may be less evident because the average weights of the retained catch will be greater. Further, as a consequence of anglers' responses, changes in both the BL and MLL may have unintended consequences for the effectiveness of current management measures for the multispecies recreational fishery. Thus, for example, modified fishery regulations may produce issues relating to increased discarding with associated mortality of released fish and possible high-grading of individuals that are retained (Gillis *et al*., 1995; Coleman *et al*., 2004; Branch *et al*., 2006), or target-switching/species substitution by anglers (see above), thereby causing effort shifts and changes in exploitation rates of species not directly affected by the regulatory change (Sutton and Ditton, 2005). Thus, the implications of anglers' behavioural responses to changes in regulations for the effectiveness of those regulations and their effect on other species may best be understood through explorations using an agent-based model such as that used in this study.

The results from the study indicating that decreasing the boat limit or increasing the MLL of West Australian dhufish would result in larger numbers of fish being caught and ultimately released (due to the number of retained fish being in excess of the boat limit or fish being undersized, respectively) was expected, as a fisher seeks to maintain their catch (or maximise their profits), thus increasing the likely occurrence of discarding and high-grading of smaller individuals such that they can continue fishing (Sampson, 1994; Branch *et al*., 2006). Given that MLL restrictions typically are intended for protecting small and young fish, measures of their effectiveness need to take into account the extent to which undersized fish suffer post-release mortality (Kirchner *et al*., 2001). West Australian dhufish have been shown to be particularly susceptible to mortality after catch-and release events, with barotrauma the dominant cause of death post-release, and mortality increasing with depth of capture from 21% at 0-14 m to 86% at 45-59 m (St. John and Syers, 2005).

4.4.4. **Other agent-based models for recreational fisheries**

Until recently, the technique of using recreational fisher survey data to inform agent-based models to study angler movements and behaviours was relatively unique. However, similar angler behavioural studies have been undertaken in the Ningaloo Marine Park of Western Australia by Gao and Hailu (2010; 2011; 2012; and 2013). These studies combined an agent-based model with multiple sources of information, including survey data from a nationwide recreational fishing survey (Henry and Lyle, 2003). The Gao and Hailu model is able to predict the number of fishing trips an angler takes in a year, the choice of recreational site in any one trip, the timing of a trip in a year, the length or duration of a trip, and the angler's expected catch. Within the model, a recreational angler agent has demographic attributes (such as age, income, education level, employment status, and so on) and behaviours (such as choosing sites and catching fish). Unlike Gao and Hailu (2010; 2011; 2012; and 2013), the ABM model used in this study is based on a temperate reef ecosystem with angler survey data collected directly from the West Coast Bioregion of Western Australia's marine waters for the purposes of informing the ABM. The use of survey data to inform agent behaviours in an ABM is still a relatively new approach in recreational fisheries. However, examples of studies in other disciplines can be found, *e.g*. farming, agriculture and land-use planning

(Acosta-Michlik and Espaldon, 2008; Karali *et al*., 2011; Sun and Müller, 2013), environmental systems research (Schwarz and Ernst, 2009), to name just a few.

4.4.5. **Summary**

This study has utilised agent-based modelling techniques to explore, describe and attempt to understand angler behaviours in a simulated multi-species demersal fishery. It has provided evidence that it is ultimately the ability of the more avid and specialised of anglers to adapt and alter their behaviours in response to changes, *e.g.* fluctuations in fish abundance or variations to management regulations, and thereby maintain their catches that make them good and successful fishers. For example, such behavioural shifts seen in the model included; the updating of knowledge on 'GPS systems' of good fishing locations and increased movement between cells by agents when abundance of target species was low.

The modelling approach taken represents a useful means for exploring the importance of understanding human dimensions in fisheries and potentially predicts unforeseen consequences (*e.g.* potential for increases in discarding and by-catch and behavioural shifts such as species substitution of anglers) in a multi-species system. Such confirmation of management outcomes may potentially reduce the uncertainty surrounding the angler's response to management (Sainsbury *et al*., 2000; Nagy *et al*., 2007; Metcalf *et al*., 2010) and may be useful in the decision-making process.

It is important to note that, in this study, the results of the angler data collected from avid recreational fishers were averaged. In future studies, it would be useful to allow the fisher agents to vary in their levels of avidity, knowledge and learning ability and to explore the implications of this on simulated scenarios. For such an exploration to be undertaken it is noted that a much larger data set would be required, however. It would also be interesting to compare model predictions of behavioural responses to changes in stock abundance or management change, *e.g.* an increased number of fishing trips by anglers in response to more restrictive boat limits, with survey data. Furthermore, the implications of 'high-grading' could also be investigated, to allow for exploration on the influence of such angler behaviours on the age and size structures of fish populations and ultimately be beneficial for stock assessments.

5. General Discussion

This chapter concentrates on the broader perspectives and conclusions of this study. Interpretation of the results from the two angler surveys and agent-based modelling study can be found in the previous chapters.

5.1. Accounting for angler behaviour

The growing importance being placed on accounting for angler behaviour in fisheries systems has led to increased efforts to include information from human dimensions (HD) studies as a basis for improving management policies and regulations (Ewert, 1996; Ditton and Hunt, 2001; Arlinghaus, 2004; Little *et al*., 2004; Johnston *et al*., 2010). In Australia, including Western Australia (W.A.), the angler information that has been typically collected in fisheries surveys consists mainly of catch and effort data coupled with general demographic details (*e.g.* age, gender, motivations) and economic statistics (*e.g.* Ayvazian *et al*., 1997; Lyle and Smith, 1998; Sumner and Williamson, 1999; Malseed *et al*., 2000; Malseed and Sumner, 2001; Melville-Smith *et al*., 2001; Sumner *et al*., 2002; Henry and Lyle, 2003; Coleman, 2004; Campbell and Murphy, 2005; Lyle *et al*., 2005; Williamson *et al*., 2006; Sumner *et al*., 2008). There are, however, some notable exceptions that focus on fisher characteristics and behaviours to a greater extent, (*e.g.*, Ormsby, 2004; Smallwood *et al*., 2006; Sutton, 2006; Prior and Beckley, 2007; Frijlink and Lyle, 2010a; 2010b; Smallwood *et al*., 2011; Ryan *et al*., 2013).

The national recreational fishing survey within Australia (Henry and Lyle, 2003) was analysed primarily at the state/territory and national levels and provided a 'big picture' assessment of recreational participation, reporting on the 'average' fisher in each state/territory. Furthermore, fisheries models constructed to investigate the implications of fish-targeting behaviours by recreational fishers in Western Australia (*e.g.* Gao and Hailu, 2010; 2011; 2012; 2013) have been based on broad, regional angler response data (*i.e.* Henry and Lyle, 2003). However, as discussed throughout this thesis, anglers exhibit great diversity in terms of their social and economic characteristics, expectations, motivations, perceptions, participation patterns, and management preferences (Fisher, 1997; Arlinghaus, 2004; Salz and Loomis, 2005). Thus, while representative of the 'average' angler, the broad, aggregated results reported from such regional surveys are unlikely to reflect the full diversity of participation, experience and opinions of the anglers involved in the fishery.

As stated by Frédou *et al*. (2006), the identification and quantification of key factors influencing the dynamics of angling activities are considered to be important prerequisites for developing effective management frameworks for recreational fisheries. The results of the surveys undertaken during this study were used to facilitate a description of the various groups of boat anglers, in terms of their motivations, behaviours, fine-scale movements (*i.e.* movements between fishing grounds when searching for fish), gear and angling methods. Although previous creel surveys have been undertaken in the same study regions as considered in this study (*i.e.* the Perth Metropolitan and Peel Regions) focusing on boat-based anglers targeting demersal species (Sumner and Williamson, 1999; Sumner *et al.,* 2008; Ryan *et al*., 2013), the types of certain survey questions posed in this study, *e.g.* those relating to fine-scale movement patterns of fishers whilst targeting fish, are uncommon in the literature on fisheries surveys. Gillis (2003) recognised, however, that studying angler behaviour through the examination of specific decisions made while fishing is gaining popularity in the field of fleet dynamics research. More broadly, the importance of understanding where and how anglers allocate their effort, and how they alter their behaviours in response to changes in management regulations, has also been recognised as crucial in the determination of appropriate management strategies (Sampson, 1994; Mathiesen, 2003; Little *et al*., 2004; Branch *et al*., 2006; Metcalf *et al*., 2010).

The information relating to the behaviours of fishers derived from the boat survey in Chapter 3 were cruicial for deriving meaningful input data into the agent-based model described in Chapter 4. Although the sample size for this survey was small, it was still sufficient to provide preliminary estimates of a number of important parameters required to undertake model-based explorations of fish-targeting behaviours. Some of these included estimates for trip duration, fishers' perceptions of the quality of different habitats for certain species of fish (information which also informed assumptions regarding the movements of fish among different habitat types), and factors influencing their fish targeting behaviours, *e.g.* fish bite rates. Key to the overall modelling approach was the integration of results of survey based questions designed specifically to inform the modelling. It should also be recognised, however, that as sample sizes for surveys of fishing club members were small, the results obtained by the agent-based modelling do need to be treated with a level of caution.

The surveys used in this PhD study aimed to capture an understanding of the diversity of boat anglers by relating responses to fishers' avidities or by focussing on a specific avidity class. Thus, one survey, *i.e*. the phone survey (Chapter 2), was focussed on comparing the characteristics of non-avid and avid (boat-based) recreational fishers within a region of south-western Western Australia, *i.e.* the West Coast Bioregion, where fishers were classed as either non-avid or avid based on the number of days fished in the 12 months prior to the survey. A second survey, *i.e.* the survey described in Chapter 3, was undertaken to focus on the characteristics of fishers from recreational angling clubs, who were assumed to be more avid and specialised towards catching certain key target demersal scalefish species than the general boat fisher population.

This PhD study also explored the validity of the notion that avid and more specialised anglers achieved greater catch success (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). The results of the survey suggested that, for certain highly-prized and harder-to-catch species, fishers who specialised in catching individuals of these species obtained better catches of those species than less avid and more generalist fishers (*i.e.* fishers that target a wider range of species). In contrast, for some other fish species, *i.e.* 'bread and butter' species, fishers tended to be more generalist than specialised, and the less avid of this group of fishers obtained catches that were similar to those that were more avid.

Thus, it is concluded that a detailed understanding of the fish-targetting behaviours of avid and specialised anglers who target iconic, hard-to-catch fish species is likely to be particularly important for the sustainable management of these species, but less so for generalist fishers who target 'bread and butter' species.

The simulation (agent-based) modelling undertaken during this study suggested that specialist fishers targeting demersal scalefish species are able to maintain good catch rates when fish abundances are declining by altering certain fishing behaviours. These may include undertaking more searches for new fishing locations, moving more frequently among fishing locations when bite rates are low, and updating their knowledge and perceptions of the quality of their fishing locations in response to recent fishing experiences. Thus, potentially, these behaviours are important attributes of 'successful' fishers who target demersal scalefish species, by enabling them to adapt to a changing environment, *e.g.* changes in fish abundance or fisheries management (Sampson, 1991; Bertrand *et al*., 2004; Hunt *et al*., 2011).

This study represents one of few studies that have integrated the results of a recreational fishers' survey with a simulation model to explore the likely effectiveness of alternative management controls for such fisheries under different scenarios of fish abundance. The model results were informative for providing indications as to how recreational fishers are likely to respond to management changes and fish abundance, and for understanding the implications of such responses for sustaining fish populations. It is thus concluded that this type of approach to studying fisher behaviours can be useful for informing the development of management strategies for recreational fisheries. The need for an integrated modelling approach, which links the results of HD surveys with fisher's behaviour and fishery dynamics, has been stressed by several authors (Post *et al*., 2008; Johnston *et al*., 2010; Beardmore *et al*., 2011; Schlüter *et al*., 2012). This would assist in bridging the gap between the scientific disciplines of fisheries science and human dimensions, and thereby allow the construction of more accurate models of the effects of anglers' behaviour on exploitation, leading to more reliable assessment of the likely effectiveness of proposed changes to fisheries regulations.

5.2. Angler types

The importance of studying the more active (avid) and specialised angler has been emphasised by numerous authors (Salz and Loomis, 2005; Oh and Ditton, 2008; Dorow *et al*., 2010; Johnston *et al*., 2010), as this group is likely to display a particular set of skills when compared to more generalist, leisure-seeking fishers. Previous research has focussed mainly on describing 'technique-setting' or 'advanced species' specialists (*e.g.* Bryan, 1977; Wilde *et al*., 1998; Wilde and Ditton, 1999; Arlinghaus and Mehner 2003; Dorow *et al*., 2010), predominantly within single-species fisheries. This study, however, has focussed more on understanding the key characteristics and behaviours of the more avid and specialised boat-based angler in a multi-species fishery environment. In a single-species fishery, it is possible to adjust different facets of angler behaviour to optimise the single objective of capturing that species. Thus, in such a fishery, it is likely to be easier to identify the factors that result in greater ability to catch fish. In contrast, in a multi-species environment, different anglers are likely to adjust their behaviours in different ways to balance their fishing skills and the values they place on the mixture of species that they are likely to catch. That is, in a multi-species fishery, fishers act in a 'multiple objective decision making framework', and individuals respond to their own motivations and assessments of the values that they accord to the fishing experience.

Past studies have proposed that specialised anglers are more committed and avid (Bryan, 1977; Falk *et al*., 1989; Beardmore *et al*., 2011), typically younger (Arlinghaus and Mehner, 2003), devote more time each year to fishing (Graefe, 1980; Ditton *et al*., 1992; Salz *et al*., 2001), and travel greater distances to fishing locations (Ward *et al*., 2013). Specialised boat anglers are also considered to have the greatest angling experience and skill and make the greatest investment in fishing equipment and activity (Ditton and Holland, 1984; Chipman and Helfrich, 1988; Ditton *et al*., 1992; Dorow *et al*., 2010). They are also considered to be more supportive of restrictive fishing regulations (Salz *et al*., 2001; Arlinghaus, 2007), be more likely to be members of angling clubs (Ditton and Holland, 1984; Gigliotti and Peyton, 1993; Fisher, 1997), and have greater catch success (Hilborn, 1985; Baccante, 1995; Dorow *et al*., 2010; Johnston *et al*., 2010). The variables examined in the current study (*e.g.* fishing frequency, preferred target species, gear used, distance travelled and movement patterns) were likewise demonstrated to be important attributes for defining angler sub groups and proved to be strongly associated with the social characteristics of anglers (*e.g.* motivations, club membership etc.).

Statistical analysis of contingency tables were employed in this study to compare data for (1) the non-avid and avid anglers (Chapter 2), (2) the more vs less avid club members (Chapter 3), and (3) club members and those for the avid fishers from the phone survey (reported in Chapter 2). Furthermore, logistic regression analyses of the data from the surveys were also undertaken to explore the characteristics of the above different groups of fishers, *i.e.* recreational fishers/club members, and to test the various hypotheses. These analyses contributed to a greater understanding of the defining factors (*e.g.* motivations for fishing, target species) of non-avid and avid anglers and how these factors potentially influence fishing activities. For example, avid anglers were shown to be more likely go fishing on a normal weekday, fish for relaxation and fish for the enjoyment and the sport of catching fish and be between the ages of 30-59 y. Although initial investigations of the survey data also employed recursive partitioning analysis, cluster analysis (*i.e.* hierarchical cluster analysis) and MDS analysis techniques using R (R Development Core Team, 2013), the preliminary results from these analyses suggested that larger survey sizes than those available to this study would have been required to produce reliable results from these methods and the results of these explorations were therefore not reported in this thesis. The value of such techniques is acknowledged, however, as they have been have been applied to fishery data in other studies to divide heterogeneous populations of anglers into more homogenous sub groups (*e.g.* Connelly *et al*., 2000b; Pelletier and Ferraris, 2000; Frédou *et al*., 2006; Oh and Ditton, 2006b; Arlinghaus *et al*., 2008). For example, multivariate techniques (*e.g.* multidimensional scaling ordination (MDS) plots) can be useful in identifying factors that characterise angling activities and developing an understanding of how fishers' techniques are adapted to the biological and ecological characteristics of their target species (Frédou *et al*., 2006). Such multivariate approaches as those identified above can also improve the definition of the different types of fishing activities in order to define technological categories for fishing statistics (Frédou *et al*., 2006). Other studies have also employed multivariate techniques to identify and group commercial anglers based on their fishing tactics (*i.e.* the combination of target species, gear, and fishing location, at a given time of the year), using both catch and effort data (see Pelletier and Ferraris, 2000). Fishing tactics are thought to reflect simultaneously the decisions of the fisher (*e.g.* target species, gear, location, and time of the year) and the resultant catches, and are thus beneficial for understanding the dynamics of mixed fisheries (Pelletier and Ferraris, 2000).

In this study, frequency of fishing (*i.e.* participation rates) was used as a measure of avidity of anglers, which is not uncommon in recreational fisher surveys (*e.g.* Connelly and Brown, 1995; Fisher, 1997; Henry and Lyle, 2003), along with the use of depth of fishing and club membership used as factors for logistic regression analyses undertaken in Chapter 2 and 3, respectively. There are, however, various alternative ways (*i.e.* grouping by target species or by gender or age of fisher etc.) by which the angler population could be categorised to better understand within-group differences, and which could be explored in future studies. Measures relating to angler attributes such as where they fish, their technique preferences, choice of equipment, importance of catch to fishers, their social setting of activity and preferences for resource management, could also be used to characterise recreational fishers and thereby partition them into more homogenous groups (Bryan, 1977; Ditton *et al.*, 1992).

5.3. The use of agent-based modelling

The ability to predict and effectively manage the impacts of recreational fishing on fish species requires an understanding of the complex social and ecological dynamics in fisheries systems (Johnston *et al*., 2010). Anglers continually make decisions whilst fishing. These decisions, however, are ultimately influenced by a suite of factors including the abundance of fish, management regulations, technology, weather, and expectations about costs of fishing (Sampson, 1991; 1994; McConnell *et al*., 1995; Wilen *et al*., 2002). The agent-based model presented in this study simulated the 'interplay' between fishers and fish and enabled an exploration of the impacts, on the effectiveness of management, of behavioural responses by fishers to such regulations. Thus, the insights gained from this type of integrated-modelling approach could potentially be of benefit to fisheries managers and assist them in making better informed decisions, *i.e.* as a form of 'management strategy evaluation' (Smith, 1993; Schnute *et al.*, 2007; Punt, 2008; Fisher *et al*., 2011).

A range of opportunities exist to extend the agent-based model presented in this study. For example, the model could be extended to study the effect of different movement parameters/assumptions for fish, and monitoring how these affect the distribution patterns of fish among the different habitat types, and how this, in turn, influences catches.

Another possibility is to incorporate the schooling behaviours of fish in the model. For example, pink snapper are a known schooling species that aggregate in large numbers for spawning, often at specific locations (*e.g.* Cockburn Sound, along with the adjacent Warnbro Sound in the West Coast Bioregion) requiring considerable movement by participating fish (Wakefield, 2006; Mackie *et al*., 2009). A number of studies have investigated such schooling behaviour using various modelling techniques (*e.g.* Aoki, 1982; Charles *et al*., 2000; Inada, 2001; Schönfisch, 2001; Huse *et al*., 2002; Parrish *et al*., 2002; Hubbard *et al*., 2004; Hemelrijk and Kunz, 2005; Gautrais *et al*., 2008; González *et al*., 2009). It is noted, however, that the addition of such behaviour coupled with environmental factors (temperature gradients, population dynamics, habitat etc.) in a multi-species model would not be a trivial task, adding further complexity and requiring data inputs that may not be available, and increasing simulation time.

The agent-based model could also be enhanced by allowing for variability in behaviours among different fish (*e.g.* different movement characteristics and habitat 'preferences') and fisher agents, *e.g.* differences in fish targeting behaviours among individuals of an identified grouping of fishers and among groupings such as specialist and generalist fishers. This would be more representative of the 'real-world' situation and could yield more realistic results. As described by Dreyfus-Leon (2006), agent-based models, due to their flexible nature, have the ability to treat individuals as discrete entities and thus also offer a way for accounting for individual variability, interactions among individuals and adaptive behaviours in complex fishery-related problems.

Analyses of data on the fate of individual fish recorded during simulations may be useful also for exploring, for example, how many times an individual fish is caught and released and the associated variation in the rates of post-release mortality on individuals in the population and its relationship to the spatial pattern of fishing. Such analyses would also be relevant to exploring, through simulation, the potential effects of different spatial patterns of fishing on results obtained from tagging programs.

The results from the angler surveys and discussions with recreational anglers revealed that weather is an important factor influencing their activities. The inclusion of data relating to weather, *e.g.* wind speed and swell, would allow for exploration of the effect of weather on behaviours of fishers, *e.g.* when to go fishing and where to fish, and thus on exploitation. For example, as the weather encountered was shown to influence how far fishers were willing to travel offshore in the surveys, it is possible that fish species in deeper waters are generally less accessible and thus, at least to some extent, more protected from fishing, potentially leading to a greater level of depletion in inshore waters. Thus, if a management measure such as a temporal closure over the spring/summer period (*e.g.* notably better weather months) were to be imposed, fish in deeper waters would also benefit from decreased fishing effort over these months, but such a measure might impact substantially on the overall fishing success/experience of anglers.

The addition to the model of management controls other than just size and bag and boat limits, *e.g.* spatial and temporal closures, would enable further explorations regarding the likely effectiveness of alternative management controls in this agent-based modelling framework. For example, a recent paper by Gao and Hailu (2011) used agent-based model simulations to evaluate the effects of area closures on recreational fishing in the Ningaloo Marine Park in Western Australia. Furthermore, the addition of 'different numbers' of fishers on a boat would increase realism and enable investigation into the number of fish caught and the implications for management. As noted above, however, agent-based models are computer intensive, however, and such extensions to the current model have the potential to constrain its usefulness (Breckling *et al*., 2006), due to increased model complexity (also making interpretation of results more difficult) and slowing down program speed. Such extensions of the model may also require the collection of more input data.

5.4. **Implications for management**

In the past, conventional survey techniques and group discussions with anglers have assisted in acquiring a better understanding of the use of fishery resources (*e.g.* Henry and Lyle, 2003; Smallwood *et al*., 2011; Ryan *et al*., 2013). However, an in-depth understanding of certain angler characteristics, such as their motivations, fish-targeting patterns (*e.g.* movements), and level of ability to make best use of available fishing gear and technology, are not able to be gained from standard fishery surveys. Importantly, however, these characteristics are likely to influence the catch compostion and success of the individual anglers. Thus, if the data from angler surveys are to produce accurate results, it is likely to become increasingly necessary to take such characteristics into account, and consider how they might change when the abundances of individual species change or management regulations are modified. It follows that the additional types of data that are likely to be needed in the future will need to be collected when angler surveys are conducted, and that more detailed multivariate statistical analyses will also need to be undertaken to determine the relationships between fish catches and fishing effort, and modelling will be required to understand the inter-relationships between fish and fisher behaviours and dynamics. For example, the more avid and specialised an angler is the more likely he/she is to spread angling effort over a wider geographical area compared to the effort distribution of the more generalist boat-based fisher, which is more likely to be localised and undertaken in close proximity to boat ramps and access points. The higher reported catches taken by club members (Chapter 3) than those taken by their counterparts (avid anglers) in the phone survey (Chapter 2) demonstrate that, in terms of catch objectives, the former group may be considered to be the more successful in catching fish of the two groups of recreational fishers. Again, such information is likely to be important for management.

It is also important to note that this study has collected information on the characteristics, catch preferences, behaviours, movement patterns, gear and angling methods of fishing club members, who represent a minority group of highly specialised boat anglers. The small sample size attained in this study is acknowledged, however, it is also important to recognise that the data obtained from fishers, some of whom, despite fishing infrequently, represented those specialised anglers who mainly target West Australian dhufish and pink snapper. Furthermore, to obtain a representative sample of such fishers from the Recreational Fishing from Boat Licence (RFBL) database would have required a large sample size and considerable filtering in an initial screening survey (*e.g.* designed to filter non-club members). Resources for such a survey were not available for the current study and thus, although sampling was not probability-based, the approach employed, *i.e.* directly approaching club members, was considered the most appropriate method to obtain data from this specific group of fishers. The knowledge of these anglers in catching these iconic fish species is potentially very valuable because these fishers are likely to spend more time on the water targeting/catching these species than any other fishers. Thus, it is still concluded that targeted surveys of this nature can provide useful information for fishery management.

5.5. Future inclusion of HD research in fisheries management

Recognition of the social importance of recreational fishing is growing, as are the demands placed on this (and other) fishing sector(s) for ensuring that they are fishing in a sustainable manner (McPhee *et al*., 2002; Cooke and Cowx, 2006; Lewin *et al*., 2006; Beard *et al*., 2011). Too often, HD research is equated with economic research, with economics only being a single component of the likely forces that drive human behaviour (Ewert, 1996). The use of specialisation theory can help explain why different anglers seek different types of fishing opportunities and experiences, with no one set of management regulations likely to satisfy all anglers (Fisher, 1997; Margenau and Petchenik, 2004). It is unlikely that the knowledge gained from one fishery will be totally transferable to the next. Research methods, however, are likely to be transferrable among fisheries. Identification of the different angler segments represents the first step in understanding the objectives and requirements of those different groups (Connelly *et al*., 2001). Achieving this understanding will require on-going collaboration between fisheries scientists, recreational fishers, managers, policy makers and recreational fishing or advocacy groups (Beard *et al.*, 2011).

Non-consumptive recreational fishing in the future is sure to bring about new challenges for management as more and more anglers begin to practice catch-and-release fishing. However, there is a need to better understand the characteristics of anglers who choose to participate in this type of fishing as there are indeed a whole new suite of biological, economic, cultural and ethical challenges embedded in this form of recreational fishing activity (Sutton, 2001; Sutton and Ditton, 2001; Aas, 2002; Arlinghaus, 2007; Arlinghaus *et al*., 2007).

Successful future management of recreational fisheries will involve an understanding of not only the biological aspects of the system but also of how people operate in the system and use its resources (Hahn, 1991; Weithman, 1999; Arlinghaus and Mehner, 2003; Arlinghaus, 2004; Salas and Gaertner, 2004). Management of recreational fisheries and the regulation of fishing effort will continue to be a controversial subject in many jurisdictions due to the competing objectives of management and anglers (Gao and Hailu, 2010; 2011; 2012). However, innovative approaches such as reviewing current indicators and deriving new indicators for stock assessment that recognise the effect of anglers' behaviour on observed catches and the effectiveness of alternative regulations, and increasing stakeholder involvement in the development of future management strategies, hold promise for more effective management processes.

References

6. References

Aas, Ø. (2002). The next chapter: multicultural and cross-disciplinary progress in evaluating recreational fisheries. In 'Recreational Fisheries: ecological, economic and social evaluation'. (Eds T.J. Pitcher and C. E. Hollingworth.) pp. 252-263 (Blackwell Science, Oxford.).

Aas, Ø., and Ditton, R. B. (1998). Human dimensions perspective on recreational fisheries management: implications for Europe. In 'Recreational fisheries. Social, economic and management aspects'. (Eds P. Hickley, and H. Tompkins.) pp. 153–164. (Blackwell Scientific: Oxford, UK.)

Aas, Ø., Haider, W., and Hunt, L. (2000). Angler responses to potential harvest regulations in a Norwegian sport fishery: a conjoint-based choice modeling approach. *North American Journal of Fisheries Management* **20** (4), 940-950.

Abernethy, K. E., Allison, E. H., Molloy, P. P., and Côté, I. M. (2007). Why do fishers fish where they fish? Using the ideal free distribution to understand the behaviour of artisanal reef fishers. *Canadian Journal of Fisheries and Aquatic Sciences* **64** (11), 1595-1604.

Acosta-Michlik, L., and Espaldon, V. (2008). Assessing vulnerability of selected farming communities in the Philippines based on a behavioural model of agent's adaptation to global environmental change. *Global Environmental Change* **18** (4), 554-563.

Anderson, D. K., and Ditton, R. B. (2004). Demographics, participation, attitudes, and management preferences of Texas anglers. Human Dimensions of Fisheries Research Laboratory Technical Document HD-624. Texas A&M University, College Station.

Anderson, D. K., Ditton, R. B., and Hunt, K. M. (2007). Measuring angler attitudes toward catch-related aspects of fishing. *Human Dimensions of Wildlife* **12** (3), 181-191.

Anonymous (1992). 'National Strategy for Ecologically Sustainable Development.' Available at http://www.environment.gov.au/esd/national/nsesd/strategy/index.html [accessed 6 October, 2009].

Aoki, I. (1982). A simulation study on the schooling mechanism in fish. *Bulletin of the Japanese Society of Scientific Fisheries* **48** (8), 1081-1088.

Arlinghaus, R. (2004). 'A Human Dimensions Approach Towards Sustainable Recreational Fisheries Management.' (Turnshare Ltd.: London.)

Arlinghaus, R. (2005). A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. *Aquatic Resources, Culture and Development* **1**, 145–174.

Arlinghaus, R. (2006). Overcoming human obstacles to conservation of recreational fishery resources, with emphasis on central Europe. *Environmental Conservation* **33** (1), 46–59.

Arlinghaus, R. (2007). Voluntary catch-and-release can generate conflict within the recreational angling community: a qualitative case study of specialised carp, *Cyprinus carpio*, angling in Germany. *Fisheries Management and Ecology* **14**, 161–171.

Arlinghaus, R., and Mehner, T. (2003) Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. *Fisheries Research* **61**, 19–33.

Arlinghaus, R., Bork, M., and Fladung, E. (2008). Understanding the heterogeneity of recreational anglers across an urban–rural gradient in a metropolitan area (Berlin, Germany), with implications for fisheries management. *Fisheries Research* **92**, 53–62.

Arlinghaus, R., Cooke, S. J., Lyman, J., Policansky, D., Schwab, A., Susli, C., Sutton, S. G., and Thorstad, E. B. (2007). Understanding the complexity of catch-and-release in recreational fishing: An integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. *Reviews in Fisheries Science* **15**, 75-167.

Arlinghaus, R., Mehner, T., and Cowx, I. G. *(*2002). Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. *Fish and Fisheries* **3**, 261-316.

Arterburn, J. E., Kirby, D. J., and Berry, C. R. (2001). Biologist opinions and angler attitudes concerning catfish and their management in the Mississippi River basin. *Mississippi Interstate Cooperative Resource Association, Final Report, Des Moines, Iowa*.

Arterburn, J. E., Kirby, D. J., and Berry Jr, C. R. (2002). A survey of angler attitudes and biologist opinions regarding trophy catfish and their management. *Fisheries* **27** (5), 10-21.

Australian Bureau of Statistics (2013). 'QuickStats.' Available at http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/ [accessed 28 November, 2014].

Ayvazian, S. G., Jones, G. K., Fairclough, D., Potter, I. C., Wise, B. S., and Dimmlich, W. F. (2000). Stock assessment of Australian herring. Department of Fisheries, FRDC Project 96/105, Western Australia.

Babcock, E. A., and Pikitch, E. K. (2000). A dynamic model of fishing strategy choice in a multispecies trawl fishery with trip limits. *Canadian Journal of Fisheries and Aquatic Sciences* **57**, 357-370.

Baccante, D. (1995). Assessing catch inequality in walleye angling fisheries. *North American Journal of Fisheries Management* **15**, 661-665.

Bakus, G. J. (2007). 'Quantitative Analysis of Marine Biological Communities: Field Biology and Environment.' (Wiley-Interscience: New Jersey.)

Bastardie, F., Nielsen, J. R., Andersen, B. S., and Eigaard, O. R. (2010). Effects of fishing effort allocation scenarios on energy efficiency and profitability: An individual-based model applied to Danish fisheries. *Fisheries Research* **106**, 501–516.

Beard, T. D., Arlinghaus, R., and Sutton, S. G. (2011). The Angler in the Environment: social, economic, biological, and ethical dimensions. American Fisheries Society. In 'Proceedings of the 5th World Recreational Fishing Conference, Florida, USA, 10-12 November 2011'. pp. 1-9. (American Fisheries Society: Maryland, USA.)

Beardmore, B., Haider, W., Hunt, L. M., and Arlinghaus, R. (2011). The importance of trip context for determining primary angler motivations: are more specialized anglers more catch-oriented than previously believed? *North American Journal of Fisheries Management* **31** (5), 861-879.

Beardmore, B., Haider, W., Hunt, L. M., and Arlinghaus, R. (2013). Evaluating the ability of specialization indicators to explain fishing preferences. *Leisure Sciences* **35** (3), 273-292.

Beck, K. H., Yan, A. F., and Wang, M. Q. (2009). A comparison of web-based and telephone surveys for assessing traffic safety concerns, beliefs, and behaviors. *Journal of Safety Research* **40**, 377–381.

Beddington, J. R., Agnew, D. J., and Clark, C. W. (2007). Current problems in the management of marine fisheries. *Science* **316** (5832), 1713-1716.

BenDor, T., Scheffran, J., and Hannon, B. (2009). Ecological and economic sustainability in fishery management: A multi-agent model for understanding competition and cooperation. *Ecological Economics* **68**, 1061-1073.

Benenson, I., Martens, K., and Birfir, S. (2008). PARKAGENT: An agent-based model of parking in the city. *Computers, Environment and Urban Systems* **32**, 431-439.

Bertrand, S., Díaz, E., and Ñiquen, M. (2004). Interactions between fish and fisher's spatial distribution and behaviour: an empirical study of the anchovy (*Engraulis ringens*) fishery of Peru. *ICES Journal of Marine Science: Journal du Conseil* **61** (7), 1127-1136.

Beverton, R. J. H., and Holt, S. J. (1957). On the dynamics of exploited fish populations. *Fishery Investigations Series 2: Sea Fisheries* **19**.

Billari F., Fent T., Prskawetz A., and Scheffran, J. (Eds) (2006). 'Agent-based Computational Modelling: Applications in Demography, Social, Economic and Environmental Sciences.' (Physica-Verlag: Heidelberg.)

Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences* **99** (3), 7280–7287.

Bosquet, F., and Le Page, C. (2004). Multi-agent simulations and ecosystem management: a review. *Ecological Modelling* **176**, 313-332.

Branch, T. A., Hilborn, R., Haynie, A. C., Fay, G., Flynn, L., Griffiths, J., Marshall, K. N., Randall, J. K., Scheuerell, J. M., Ward, E. J., and Young, M. (2006). Fleet dynamics and fishermen behavior: Lessons for fisheries managers. *Canadian Journal of Fisheries and Aquatic Sciences* **63**, 1647-1668.

Breckling, B., Middelhoff, U., and Hauke, R. (2006). Individual-based models as tools for ecological theory and application: Understanding the emergence of organisational properties in ecological systems. *Ecological Modelling* **194**, 102-113.

Bricker, K. S., and Kerstetter, D. L. (2000). Level of specialization and place attachment: An exploratory study of whitewater recreationists. *Leisure Sciences* **22** (4), 233-257.

Brouwer, S. L., Mann, B. Q., Lamberth, S. J., Sauer, W. H. H., and Erasmus, C. (1997). A survey of the South African shore-angling fishery. *South African Journal of Marine Science* **18** (1), 165-177.

Brown, T. L. (1991). Use and abuse of mail surveys in fisheries management. *American Fisheries Society Symposium* **12**, 255-261.

Brueckner, M., Durey, A., Mayes, R., and Pforr, C. (2013). The mining boom and Western Australia's changing landscape: Towards sustainability or business as usual? *Rural Society* **22** (2), 111-124.

Bryan, H. (1977). Leisure value systems and recreational specialisation: The case of the trout fisherman. *Journal of Leisure Research* **9**, 174-187.

Busch, W. D. N., Brown, B. L., and Mayer, G. F. (2003). Strategic guidance for implementing an ecosystem-based approach to fisheries management. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, Maryland, USA.

Cabral, R. B., Geronimo, R. C., Lim, M. T., and Alino, P. M. (2010). Effect of variable fishing strategy on fisheries under changing effort and pressure: An agent-based model application. *Ecological Modelling* **221**, 362-369.

Calvert, B. (2002). The importance of angler motivations on sport fishery management. In 'Recreational Fisheries: Ecological, Economic and Social Evaluation'. (Eds T. J. Pitcher and C. E. Hollingworth.) pp. 120-129 (Blackwell Science, Oxford.)

Cameron, T. A., and Huppert, D. D. (1989). OLS versus ML estimation of non-market resource values with payment card interval data. *Journal of Environmental Economics and Management* **17** (3), 230-246.

Campbell, D., and Murphy, J. J. (2005). The 2000-01 national recreational fishing survey: Economic report. Australian Government Department of Agriculture, Fisheries and Forestry, FRDC Project No. 99/158, Canberra.

Charles, A. T. (1995). Fishery science: the study of fishery systems. *Aquatic Living Resources* **8***,* 233-239.

Charles, S., Bravo De La Parra, R., Mallet, J. P., Persat, H., and Auger, P. (2000). Annual spawning migrations in modelling brown trout population dynamics inside an arborescent river network. *Ecological Modelling* **133** (1), 15-31.

Chipman, B. D., and Helfrich, L. A. (1988). Recreational specializations and motivations of Virginia river anglers. *North American Journal of Fisheries Management* **8**, 390-398.

Clay, P. M., and McGoodwin, J. R. (1995). Utilizing Social Sciences in Fisheries Management. *Aquatic Living Resources* **8**, 203-7.

Cochran, W.G. (1977). 'Sampling Techniques.' 3rd Edn. (Wiley, New York.)

Cockcroft, A. C., Griffiths, M. H., and Tarr, R. J. Q. (1999). Marine recreational fisheries in South Africa: status and challenges. In 'Evaluating the Benefits of Recreational Fisheries'. Fisheries Centre research reports, 7(2) (Eds T. J. Pitcher and C. E. Hollingworth.) pp. 64-70 (Vancouver BC.)

Coleman, A. P. M. (2004). The national recreational fishing survey: the Northern Territory. Northern Territory Department of Business, Industry and Resource Development, Fishery Report 72, Darwin.

Coleman, F. C., Figueira, W. F., Ueland, J. S., and Crowder, L. B. (2004). The impact of United States recreational fisheries on marine fish populations. *Science* **305**, 1958–1960.

Connelly, N. A., and Brown, T. L. (1995). Use of angler diaries to examine biases associated with 12-month recall on mail questionnaires. *Transactions of the American Fisheries Society* **124** (3), 413-422.

Connelly, N. A., and Brown, T. L. (2011). Effect of recall period on annual freshwater fishing effort estimates in New York. *Fisheries Management and Ecology* **18**, 83–87.

Connelly, N. A., Brown, T. L., and Knuth, B. A. (2000a). Do anglers and fishery professionals think alike? *Fisheries* **25** (2), 21-25.

Connelly, N. A., Brown, T. L., and Knuth, B. A. (2000b). A multiple market segmentation of Great Lakes anglers in New York. *North American Journal of Fisheries Management* **20** (2), 399-407.

Connelly, N. A., Knuth, B. A., and Brown, T. L. (2001). An angler typology based on angler fishing preferences. *Transactions of the American Fisheries Society* **130** (1), 130-137.

Cooke, S. J., and Cowx, I. G. (2004). The role of recreational fishing in global fish crises. *Bioscience* **54**, 857–859.

Cooke, S. J., and Cowx, I. G. (2006). Contrasting recreational and commercial fishing: Searching for common issues to promote unified conservation of fisheries resources and aquatic environments. *Biological Conservation* **128**, 93-108.

Cowx, I. G. (2001). Recreational sport fishing in fresh waters. *Encyclopedia of Life Support Systems*, 89-94.

Cowx, I. G. (2002). Recreational fishing. In 'Handbook of Fish Biology and Fisheries, Volume 2: Fisheries'. (Eds P. J. B. Hart and J. D. Reynolds.) pp. 367-390. (Blackwell Science Ltd: Oxford, UK.)

Crosson, S. C. (2010). A social and economic survey of recreational saltwater anglers in North Carolina. NC Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC.

Crowe, F. M., Longson, I. G., and Joll, L. M. (2013). Development and implementation of allocation arrangements for recreational and commercial fishing sectors in Western Australia. *Fisheries Management and Ecology* **20** (2-3), 201-210.

Dambacher, J. M., Gaughan, D. J., Rochet, M. J., Rossignol, P. A., and Trenkel, V. M. (2009). Qualitative modelling and indicators of exploited ecosystems. *Fish and Fisheries* **10** (3), 305-322.

Danylchuk, A. J., and Cooke, S. J. (2010). Engaging the recreational angling community to implement and manage aquatic protected areas. *Conservation Biology* **25** (3), 458-464.

DeAngelis, D. L., and Mooij, W. M. (2005). Individual-based modeling of ecological and evolutionary processes. *Annual Review of Ecology, Evolution, and Systematics* **36**, 147-168.

DeAngelis, D. L., Cox, D. K., and Coutant, C. C. (1980). Cannibalism and size dispersal in young-of-the-year largemouth bass: Experiment and model. *Ecological Modelling* **8**, 133-148.

Dempson, J., Robertson, M., Cochrane, N., O'Connell, M. F., and Porter, G. (2012). Changes in angler participation and demographics: analysis of a 17-year licence stub return system for Atlantic salmon. *Fisheries Management and Ecology* **19**, 333–343.

Department of Fisheries (2004). Proposals for community discussion on the future management of pink snapper fishing in Cockburn Sound and surrounding waters. Department of Fisheries, Fisheries Management Paper No. 187, Western Australia.

Department of Fisheries (2011). Resource assessment framework (RAF) for finfish resources in Western Australia. Department of Fisheries, Fisheries Occasional Publication No. 85, Western Australia.

Department of Fisheries (2012). Recreational fishing guide: West coast region. Government of Western Australia, Department of Fisheries, Published May 2012, Western Australia.

Department of Fisheries (2013). Recreational fishing guide 2013: Simpler rules for better fishing. Government of Western Australia, Department of Fisheries, Published February 2013, Western Australia.

Devroye, L. (1986). 'Non-uniform random variate generation.' (New York: Springer-Verlag: New York.)

Diggles, B. K., and Ernst, I. (1997). Hooking mortality of two species of shallow-water reef fish caught by recreational angling methods. *Marine and Freshwater Research* **48** (6), 479-483.

Dillman, D. A. (1978). 'Mail and Telephone Surveys.' (Wiley: New York.)

Dillman, D. A. (1991). The design and administration of mail surveys. *Annual Review of Sociology* **17**, 225-249.

Dillman, D. A. (2000). 'Mail and Internet Surveys: The Tailored Design Method.' 2nd Edn. (John Wiley and Sons: New York.)

Ditton, R. (2008). An international perspective on recreational fishing. In 'Global Challenges in Recreational Fisheries'. (Eds O. Aas.) pp. 5-12. (Blackwell Publishing Ltd: Oxford, UK.)

Ditton, R. B. (1996). Human dimensions in fisheries. In Natural resource management: The human dimension. *(*Ed A. Ewert) pp. 73–90. (Westview Press: Boulder, Colorado.)

Ditton, R. B., and Holland, S. M. (1984). Understanding involved fishermen: a survey on members of the Gulf Coast Conservation Association. *Government Reports, Announcements and Index, National Technical Information Service (NTIS), US Department of Commerce* **84** (20).

Ditton, R. B., and Hunt, K. M. (2001). Combining creel intercept and mail survey methods to understand the human dimensions of local freshwater fisheries. *Fisheries Management and Ecology* **8**, 295-301.

Ditton, R. B., Loomis, D. K., and Choi, S. (1992). Recreation specialization: Re-conceptualization from a social worlds perspective. *Journal of Leisure Research* **24** (1), 33-51.

Dockner, E. J., Jorgensen, S., Van Long, N., and Sorger, G. (2000). 'Differential games in economics and management science.' (Cambridge University Press: Cambridge, UK.)

Donnelly, M. P., Vaske, J. J., and Graefe, A. R. (1986). Degree and range of recreation specialization: Toward a typology of boating related activities. *Journal of Leisure Research* **18**, 81–95.

Dorow, M., Beardmore, B., Haider, W., and Arlinghaus, R. (2009). Using a novel survey technique to predict fisheries stakeholders' support for European eel (*Anguilla anguilla* L.) conservation programs. *Biological Conservation* **142** (12), 2973-2982.

Dorow, M., Beardmore, B., Haider, W., and Arlinghaus, R. (2010). Winners and losers of conservation policies for European eel, *Anguilla anguilla*: an economic welfare analysis for differently specialised eel anglers. *Fisheries Management and Ecology* **17**, 106–125.

Dreyfus-León, M. (2006). Modelling cooperation between fishermen with a cellular automaton. A framework for fishing effort spatial dynamics. *Ecological Informatics* **1** (1), 101-105.

Dreyfus-León, M., and Kleiber, P., (2001). A spatial individual behaviour-based model approach of the yellowfin tuna fishery in the eastern Pacific Ocean. *Ecological Modelling* **146**, 47–56.

Dreyfus-León, M. J. (1999). Individual-based modelling of fishermen search behaviour with neural networks and reinforcement learning. *Ecological Modelling* **120**, 287-297.

Duffy, J., and Ünver, M. U. (2006). Asset price bubbles and crashes with near-zero-intelligence traders. *Economic Theory* **27** (3), 537-563.

Eales, J., and Wilen, J. E. (1986). An examination of fishing location choice in the pink shrimp fishery. *Marine Resource Economics* **2** (4), 331-351.

Ewert, A. W. (1996). 'Natural Resource Management: The Human Dimension.' (Westview Press: Oxford.)

Fairclough, D. V., Dimmlich, W. F., and Potter, I. C. (2000a). Length and age compositions and growth rates of the Australian herring *Arripis georgiana* in different regions. *Marine and Freshwater Research* **51** (6), 631-640.

Fairclough, D. V., Dimmlich, W. F., and Potter, I. C. (2000b). Reproductive biology of the Australian herring *Arripis georgiana*. *Marine and Freshwater Research* **51** (6), 619-630.

Fairclough, D.V., Molony, B.W., Crisafulli, B.M., Keay, I.S., Hesp, S.A. and Marriott, R.J. (2014). Status of demersal finfish stocks on the west coast of Australia. Department of Fisheries, Fisheries Research report No. 253, Western Australia.

Falk, J. M., Graefe, A. R., and Ditton, R. B. (1989). Patterns of participation and motivation among saltwater tournament anglers. *Fisheries* **14** (4), 10–17.

FAO (2008). Fisheries technical guidelines for responsible fisheries. Technical Paper No. 4 (suppl 2, Add 1). Food and Agriculture Organisation of the United Nations, Rome.

FAO (2012). The state of the world fisheries and aquaculture. Food and Agriculture Organisation of the United Nations, Rome.

Fedler, A. J., and Ditton, R. B. (1994). Understanding angler motivations in fisheries management. *Fisheries* **19** (4), 6-13.

Fenichel, E. P., Abbott, J. K., and Huang, B. (2013). Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature. *Fish and Fisheries* **14** (2), 137-157.

Fisher, E. A., Hesp, S. A., and Hall, N. G. (2011). Exploration of the effectiveness of alternative management responses to variable recruitment. Centre for Fish and Fisheries Research, Murdoch University, FRDC Project Report 2008/006, Western Australia.

Fisher, M. R. (1996). Estimating the effect of nonresponse bias on angler surveys. *Transactions of the American Fisheries Society* **125**, 118-126.

Fisher, M. R. (1997). Segmentation of the angler population by catch preference, participation, and experience: A management-oriented application of recreation specialization. *North American Journal of Fisheries Management* **17** (1), 1-10.

Fletcher, W. J., and Santoro, K. (Eds) (2012). Status Reports of the Fisheries and Aquatic Resources of Western Australia 2011/12: The State of the Fisheries. p.376. (Department of Fisheries, Western Australia.)

Fletcher, W.J., and Santoro, K. (Eds) (2013). Status Reports of the Fisheries and Aquatic Resources of Western Australia 2012/13: The State of the Fisheries. p.377. (Department of Fisheries, Western Australia.)

Fowler, C. W. (1999). Management of multi-species fisheries: from overfishing to sustainability. *ICES Journal of Marine Science: Journal du Conseil* **56** (6), 927-932.

Frédou, T., Ferreira, B. P., and Letourneur, Y. (2006). A univariate and multivariate study of reef fisheries off northeastern Brazil. *ICES Journal of Marine Science: Journal du Conseil* **63** (5), 883-896.

Frijlink, S.D., and Lyle, J.M. (2010a). A socio-economic assessment of the Tasmanian recreational rock lobster fishery. p.67. (Tasmanian Aquaculture and Fisheries Institute, Hobart, Tasmania.)

Frijlink, S. D., and Lyle, J. M. (2010b). An evaluation of motivations, attitudes and awareness of Tasmanian recreational fishers. p.62. (Tasmanian Aquaculture and Fisheries Institute, Hobart, Tasmania.)

Gaertner, D. (2010). Common trends model in catch per unit of effort for the tropical tunas. *Collective Volume of Scientific Papers ICCAT* **65** (2), 417-429.

Gao, L., and Hailu, A. (2010). Integrating recreational fishing behaviour within a reef ecosystem as a platform for evaluating management strategies. In 'Advanced Information Networking and Applications (AINA), 2010 24th IEEE International Conference, Perth, Western Australia, April 2010'. pp. 1286-1291.

Gao, L., and Hailu, A. (2011). Evaluating the effects of area closure for recreational fishing in a coral reef ecosystem: The benefits of an integrated economic and biophysical modeling. *Ecological Economics* **70**, 1735–1745.

Gao, L., and Hailu, A. (2012). Ranking management strategies with complex outcomes: An AHP-fuzzy evaluation of recreational fishing using an integrated agent-based model of a coral reef ecosystem. *Environmental Modelling & Software* **31,** 3-18.

Gao, L., and Hailu, A. (2013). Identifying preferred management options: An integrated agent-based recreational fishing simulation model with an AHP-TOPSIS evaluation method. *Ecological Modelling* **249**, 505-527.

García-Berthou, E. (2001). Size-and depth-dependent variation in habitat and diet of the common carp (*Cyprinus carpio*). *Aquatic Sciences* **63** (4), 466-476.

Gartside, D. F., Harrison, B., and Ryan, B. L. (1999). An evaluation of the use of fishing club records in the management of marine recreational fisheries. *Fisheries Research* **41** (1), 47-61.

Gautrais, J., Jost, C., and Theraulaz, G. (2008). Key behavioural factors in a self-organised fish school model. *Annales Zoologici Fennici* **45** (5), 415-428.

Gentner, B., and Sutton, S. (2008). Substitution in recreational fishing. In 'Global Challenges in Recreational Fisheries'. (Eds O. Aas.) pp. 150-170. (Blackwell Publishing Ltd: Oxford, UK.)

Gigliotti, L. M., and Peyton, R. B. (1993). Values and behaviors of trout anglers, and their attitudes toward fishery management, relative to membership in fishing organizations: a Michigan case study. *North American Journal of Fisheries Management* **13** (3), 492-501.

Gillis, D. M., Peterman, R. M., and Pikitch, E. K. (1995). Implications of trip regulations for high-grading; a model of the behavior of fishermen. *Canadian Journal of Fisheries and Aquatic Sciences* **52** (2), 402-415.

Gillis, D. M. (2003). Ideal free distributions in fleet dynamics: a behavioural perspective on vessel movement in fisheries analysis. *Canadian Journal of Zoology* **81** (2), 177-187.

Gitschlag, G. R., and Renaud, M. L. (1994). Field experiments on survival rates of caged and released red snapper. *North American Journal of Fisheries Management* **14** (1), 131-136.

Gode, D. K., and Sunder, S. (1993). Allocative efficiency of markets with zero-intelligence traders: Market as a partial substitute for individual rationality. *Journal of Political Economy* **101**, 119-37.

Gode, D. K., and Sunder, S. (1997). What makes markets allocatively efficient. *Quarterly Journal of Economics* **112** (2), 603-30.

González, J. C., Dalforno, C., Suppi, R., and Luque, E. (2009). A fuzzy logic fish school model. In *Proceedings of the 9th International Conference on Computational Science: Part I* . (Allen *et al*., eds.), pp. 13-22. Springer Berlin Heidelberg.

Graefe, A. R. (1980). The relationship between level of participation and selected aspects of specialization in recreational fishing. PhD Thesis, Texas A&M University, College Station.

Graefe, A. R., and Fedler, A. J. (1986). Situational and subjective determinants of satisfaction in marine recreational fishing. *Leisure Sciences* **8** (3), 275-294.

Granek, E. F., Madin, E. M. P., Brown, M. A., Figueira, W., Cameron, D. S., Hogan, Z., Kristianson, G., De Villiers, P., Williams, J. E., Post, J., Zahn, S., and Arlinghaus, R. (2008). Engaging recreational fishers in management and conservation: Global case studies. *Conservation Biology* **22**, 1125-1134.

Gray, R., Fulton, E., Little, R., and Scott, R. (2006). Ecosystem model specification with an agent based framework. CSIRO Marine and Atmospheric Research, Technical Report No. 16, Western Australia.

Greenstreet, S. P., Spence, F. B., Shanks, A. M., and McMillan, J. A. (1999). Fishing effects in northeast Atlantic shelf seas: patterns in fishing effort, diversity and community structure. II. Trends in fishing effort in the North Sea by UK registered vessels landing in Scotland. *Fisheries Research* **40** (2), 107-124.

Greiner, R., and Gregg, D. (2010). Considering recreational catch and harvest in fisheries management at the bio-regional scale. *Fisheries Management and Ecology* **17**, 336–345.

Grimm, V. (1999). Ten years of individual-based modelling in ecology: what have we learned and what could we learn in the future? *Ecological Modelling* **115**, 129–148.

Grimm, V., and Railsback, S. F. (2005). 'Individual-based Modeling and Ecology.' (Princeton: Princeton University Press.)

Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S., Huse, G., Huth, A., Jepsen, J. U., Jørgensen, C., Mooij, W. M., Müller, B., Pe'er, G., Piou, C., Railsback, S. F., Robbins, A. M., Robbins, M. M., Rossmanith, E., Rüger, N., Strand, E., Souissi, S., Stillman, R.A., Vabø, R., Visser, U., and DeAngelis, D. L. (2006). A standard protocol for describing individual-based and agent-based models. *Ecological Modelling* **198**, 115–126.

Grimm, V., Berger, U., DeAngelis, D. L., Polhill, J. G., Giske, J., and Railsback, S. F. (2010). The ODD protocol: A review and first update. *Ecological Modelling* **221**, 2760–2768.

Grimm, V., Revilla, E., Berger, U., Jeltsch, F., Mooij, W. M., Railsback, S. F., Thulke, H. H., Weiner, J., Wiegand, T., and DeAngelis, D. L. (2005). Pattern-oriented modeling of agent-based complex systems: Lessons from ecology. *Science* **310**, 987-991.

Hahn, J. (1991). Angler specialization: measurement of a key sociological concept and implications for fisheries management decisions. *American Fisheries Society Symposium* **12**, 380–389.

Hampton, J., and Majkowski, J. (1987). A simulation model for generating catch length-frequency data. In 'Length-based methods in fisheries research Conference Proceedings, Kuwait'. (Eds D. Pauly and G.R. Morgan.) pp. 193-202. (Kuwait Institute for Scientific Research: Safat, Kuwait.)

Hejleh, M. (2014). 'Metropolitan Perth and Regional Western Australia.' Available at http://www.perthandregionalwesternaustralia.com/ [accessed 28 November, 2011].

Hemelrijk, C. K., and Kunz, H. (2005). Density distribution and size sorting in fish schools: an individual-based model. *Behavioral Ecology* **16** (1), 178-187.

Henry, G. W., and Lyle, J. M. (2003). The National Recreational and Indigenous Fishing Survey. Australian Government Department of Agriculture, Fisheries and Forestry, FRDC Project No. 99/158: NSW Fisheries Final Report Series No. 48, Canberra.

Hesp, S. A., Burch, R. J., Tink, C. J., and Hall, N. G. (2010). Development of an agent- based model to communicate implications of recruitment variability of finfish to recreational fishers. Centre for Fish and Fisheries Research, Murdoch University, FRDC Project Report 2008/033, Western Australia.

Hesp, S. A., Potter, I. C., and Hall, N. G. (2002). Age and size composition, growth rate, reproductive biology, and habitats of the West Australian Dhufish (*Glaucosoma hebraicum*) and their relevance to the management of this species. *Fishery Bulletin* **100** (2), 214-227.

Hesp, S. A., Tweedley, J. R., McAuley, R., Tink, C. J., Campbell, R. A., Chuwen, B. M., and Hall, N. G. (2012). Informing risk assessment through estimating interaction rates between Australian sea lions and Western Australia's temperate demersal gillnet fisheries. Centre for Fish and Fisheries Research, Murdoch University, FRDC Project Report 2009/096, Western Australia.

Hickley, P. (1998). Recreational fisheries – social, economic and management aspects. In 'Recreational Fisheries: Social, Economic and Management Aspects'. (Eds P. Hickley and H. Tompkins). pp. 137-157. (Fishing News Books: Oxford.)

Hilborn, R. (1985). Fleet dynamics and individual variation: Why some people catch more fish than others. *Canadian Journal of Fisheries and Aquatic Sciences* **42**, 2-13.

Hilborn, R., and Ledbetter, M. (1979). Analysis of the British-Columbia salmon purse-seine fleet - dynamics of movement. *Journal of the Fisheries Research Board of Canada* **36**, 384–391.

Hilborn, R., and Walters, C. J. (1992). 'Quantitative fisheries stock assessment: choice, dynamics and uncertainty.' (Chapman and Hall, New York.)

Hilborn, R., Branch, T. A., Ernst, B., Magnusson, A., Minte-Vera, C. V., Scheuerell, M. D., and Valero, J. L. (2003). State of the world's fisheries. *Annual Review of Environment and Resources* **28** (1), 359-399.

Hubbard, S., Babak, P., Sigurdsson, S. T., and Magnússon, K. G. (2004). A model of the formation of fish schools and migrations of fish. *Ecological Modelling* **174** (4), 359-374.

Hunt, K. (2001). Use of angler information in fisheries management. *LakeLine* **21** (3), 37-39.

Hunt, L., Haider, W., and Armstrong, K. (2002). Understanding the fish harvesting decisions by anglers. *Human Dimensions of Wildlife: An International Journal* **7** (2), 75-89.

Hunt, L. M., Arlinghaus, R., Lester, N., and Kushneriuk, R. (2011). The effects of regional angling effort, angler behavior, and harvesting efficiency on landscape patterns of overfishing. *Ecological Applications* **21** (7), 2555-2575.

Hunt, L. M., Kushneriuk, R., and Lester, N. (2006). Developing Agent-Based Models of Recreational Behaviours at a Landscape Scale: The case of Recreational Fishing in Northern Ontario. In 'Exploring the Nature of Management. Proceedings of the Third International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas.' (Eds D. Siegrist, C. Clivaz, M. Hunziker, and S. Iten). pp. 307-310. (University of Applied Sciences Rapperswil: Switzerland.)

Hunt, L. M., Kushneriuk, R., and Lester, N. (2007). Linking agent-based and choice models to study outdoor recreation behaviours: A case of the Landscape Fisheries Model in northern Ontario, Canada. *Forest Snow and Landscape Research* **81**, 163–174.

Hunt, L. M., Sutton, S. G., and Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology* **20** (2-3), 111-124.

Huse, G., Railsback, S., and Feronö, A. (2002). Modelling changes in migration pattern of herring: collective behaviour and numerical domination. *Journal of Fish Biology* **60** (3), 571-582.

Huston, M., DeAngelis, D. L., and Post, W. (1988). New computer models unify ecological theory. *Bioscience* **38**, 682-691.

Hutt, C. P., and Bettoli, P. W. (2007). Preferences, specialization, and management attitudes of trout anglers fishing in Tennessee Tailwaters. *North American Journal of Fisheries Management* **27** (4), 1257-1267.

Hutton T., Mardle S., Pascoe S., and Clark R.A. (2004). Modelling fishing location choice within mixed fisheries: English North Sea beam trawlers in 2000 and 2001. *ICES Journal of Marine Science* **61**, 1443-1452.

Hyndes, G. A., Platell, M. E., and Potter, I. C. (1997). Relationships between diet and body size, mouth morphology, habitat and movements of six sillaginid species in coastal waters: implications for resource partitioning. *Marine Biology* **128** (4), 585-598.

IBM Corporation. (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

ID Consulting Pty Limited (n.d.). 'Community profiles', ID Consulting Pty Limited. Available at http://home.id.com.au [accessed 28 November, 2011].

Inada, Y. (2001). Steering mechanism of fish schools. *Complexity International* **8**, 1-9.

Jennings, C. A. (1992). Survey of non-charter boat recreational fishing in the US Virgin Islands. *Bulletin of Marine Science* **50** (2), 342-351.

Jennings, N. R. (2000). On agent-based software engineering. *Artificial intelligence* **117** (2), 277-296.

Johnston, F. D., Arlinghaus, R., and Dieckmann, U. (2010). Diversity and complexity of angler behaviour drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. *Canadian Journal of Fisheries and Aquatic Sciences* **67**, 1507-1531.

Joyce, S. J., Tomlin, S. M., Somerford, P. J., and Weeramanthri, T. S. (2013). Health behaviours and outcomes associated with fly-in fly-out and shift workers in Western Australia. *Internal Medicine Journal* **43** (4), 440-444.

Justus, J. (2005). Qualitative scientific modeling and loop analysis. *Philosophy of Science* **72**, 1272–1286.

Kaitala, V., and Munro, G., (1995). The economic management of high seas fishery resources: some game theoretic aspects. In 'Control and Game-Theoretic Models of the Environment'. (Eds C. Carraro and J.A. Filar.) pp. 299-318 (Birkhäuser: Boston.)

Karali, E., Rounsevell, M. D., and Doherty, R. (2011). Integrating the diversity of farmers' decisions into studies of rural land-use change. *Procedia Environmental Sciences* **6**, 136-145.

Kempf, A. M., and Remington, P. L. (2007). New challenges for telephone survey research in the twenty-first century. *The Annual Review of Public Health* **28**, 113-126.

Kennedy, R. C., Lane, K. E., Fuentes, A., Hollocher, H., and Madey, G. (2009). Spatially aware agents: an effective and efficient use of GIS data within an agent-based model. In 'Proceedings of the 2009 Spring Simulation Multiconference.' pp. 1-8. (Society for Computer Simulation International).

Kerstetter, D. L., Confer, J. J., and Graefe, A. R. (2001). An exploration of the specialization concept within the context of heritage tourism. *Journal of Travel Research* **39** (3), 267-274.

Kim, S. S., Kim, J. H., and Ritchie, B. W. (2008). Segmenting overseas golf tourists by the concept of specialization. *Journal of Travel & Tourism Marketing* **25** (2), 199-217.

Kirchner, C. H., Holtzhausen, J. A., and Voges, S. F. (2001). Introducing size limits as a management tool for the recreational line fishery of silver kob, *Argyrosomus inodorus* (Griffiths and Heemstra), in Namibian waters. *Fisheries Management and Ecology* **8** (3), 227-237.

Koen-Alonso, M. (2009). Some observations on the role of trophodynamic models for ecosystem approaches to fisheries. In 'The Future of Fisheries Science in North America'. (Eds R. J. Beamish and B. J. Rothschild.) pp. 185-207. (Springer: Canada.)

Kuentzel, W. F., and Heberlein, T. A. (1992). Does specialization affect behavioral choices and quality judgments among hunters?. *Leisure Sciences* **14** (3), 211-226.

Kuentzel, W. F., and McDonald, C. D. (1992). Differential effects of past experience, commitment, and lifestyle dimensions on river use specialization. *Journal of Leisure Research* **24** (3), 269-287.

Kyle, G., Norman, W., Jodice, L., Graefe, A., and Marsinko, A. (2007). Segmenting anglers using their consumptive orientation profiles. *Human Dimensions of Wildlife* **12**, 115–132.

Larkin, M. F., Ault, J. S., Humston, R., and Luo, J. (2010). A mail survey to estimate the fishery dynamics of southern Florida's bonefish charter fleet. *Fisheries Management and Ecology* **17** (3), 254-261.

Latour, R. J., Brush, M. J., and Bonzek, C. F. (2003). Toward ecosystem-based fisheries management. *Fisheries* **28** (9), 10-22.

Lee, J.H., and Scott, D. (2004). Measuring birding specialization: A confirmatory factor analysis. *Leisure Sciences* **26** (3), 245-260.

Lenanton, R., St. John, J., Keay, I., Wakefield, C., Jackson, G., Wise, B., and Gaughan, D. (2009). Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 2: Stock structure and biology of two indicator species, West Australian dhufish (*Glaucosoma hebraicum*) and pink snapper (*Pagrus auratus*), in the West Coast Bioregion. Final report to Fisheries Research and Development Corporation on Project No. 2003/052. Fisheries Research Report No. 174, Department of Fisheries, Western Australia.

Lewin, W. C., Arlinghaus, R., and Riera, V. (2006). Documented and potential biological impact of recreational fishing: insight for management and conservation. *Reviews in Fisheries Science* **14**, 305–367.

Little, L. R., Kuikka, S., Punt, A. E., Pantus, F., Davies, C. R., and Mapstone, B. D. (2004). Information flow among fishing vessels modelled using a Bayesian network. *Environmental Modelling and Software* **19**, 27-34.

Little, L. R., Punt, A. E., Mapstone, B. D., Begg, G. A., Goldman, B., and Williams, A. J. (2009). An agent-based model for simulating trading of multi-species fisheries quota. *Ecological Modelling* **220**, 3404-3412.

Lomnicki, A. (1992). Population ecology from the individual perspective. In 'Individual-based Models and Approaches in Ecology: Populations, Communities and Ecosystems.' (Eds. D. L. DeAngelis and L. J. Gross). pp. 3-17. (New York: Chapman and Hall.)

Lyle, J. M. (2008). Application of a telephone-diary methodology to estimate catch and effort in recreational fisheries: examples from Australia. In 'ICES Annual Science Conference, Halifax: Canada, 22-26 September 2008.' p. 10.

Lyle, J. M., and Smith, J. T. (1998). Pilot survey of licensed recreational sea fishing in Tasmania 1995-96. Department of Primary Industry and Fisheries, Technical Report No. 51, Tasmania.

Lyle, J. M., Coleman, A. P. M., West, L., Campbell, D., Henry, G. W. (2002). New large-scale survey methods for evaluating sport fisheries. In 'Recreational Fisheries: ecological, economic and social evaluation'. (Eds T. J. Pitcher and C. E. Hollingworth). pp. 207–226 (Blackwell Science: Oxford.)

Lyle, J. M., Morton, A. J., and Forward, J. (2005). Characterisation of the recreational fishery for southern rock lobster, *Jasus edwardsii*, in Tasmania, Australia: implications for management. *New Zealand Journal of Marine and Freshwater Research* **39** (3), 703-713.

Macal, C. M., and North, M.J. (2007). Agent-based modeling and simulation: Desktop ABMS**.** *Proceedings of the 2007 Winter Simulation Conference.* (Eds S. G. Henderson, B. Biller, M. H. Hsieh, J. Shortle, J. D.Tew, and R. R.Barton). pp. 95-106. (Center for Complex Adaptive Agent Systems Simulation, U.S.A.)

Mackie, M., McCauley, R. D., Gill, H.S., and Gaughan, D.J. (2009). Management and Monitoring of Fish Spawning Aggregations within the West Coast Bioregion of Western Australia, Draft final report (December 2008) to Fisheries Research and Development Corporation on Project No. 2004/051 (Subject to FRDC approval). Fisheries Research Report, Department of Fisheries, Western Australia.

Malseed, B. E., and Sumner, N. R. (2001). A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. Department of Fisheries, Fisheries Research Report No. 127, Western Australia.

Malseed, B. E., Sumner, N. R., and Williamson, P. C. (2000). A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. Fisheries. Western Australia, Fisheries Research Report No. 120, Western Australia.

Margenau, T. L., and Petchenik, J. B. (2004). Social aspects of muskellunge management in Wisconsin. *North American Journal of Fisheries Management* **24**, 82–93.

Mathews, R. B., Gilbert, N. G., Roach, A., Pohill, J. G., and Gotts, N. G. (2007). Agent-based land-use models: a review of applications. *Landscape Ecology* **22** (10), 1447–1459.

Mathiesen, C. (2003). Analytical framework for studying fishers' behaviour and adaptation strategies. In 'Proceedings of The Eight Conference of the Circumpolar Arctic Social Sciences Ph. D. Network, August, 2003.'

McCluskey, S. M., and Lewison, R. L. (2008). Quantifying fishing effort: a synthesis of current methods and their applications. *Fish and Fisheries* **9**, 188–200.

McConnell, K. E., Strand, I. E., and Blake-Hedges, L. (1995). Random utility models of recreational fishing: Catching fish using a poisson-process. *Marine Resource Economics* **10**, 247-262.

McFarlane, B. L. (1994). Specialization and motivations of birdwatchers. *Wildlife Society Bulletin* **22** (3), 361-370.

McFarlane, B. L. (1996). Socialization influences of specialization among birdwatchers. *Human Dimensions of Wildlife* **1** (1), 35-50.

McGlennon, D., and Lyle, J. M. (1999). Bycatch in Australian recreational fisheries: Is it an issue? In 'Establishing meaningful targets for bycatch reduction in Australian fisheries, Australian Society for Fish Biology Workshop Proceedings, Sydney'. (Eds C. D. Buxton and S. E. Eayrs). pp. 82-86. (Australian Society for Fish Biology: Sydney.)

McIntyre, N. (1989). The personal meaning of participation: Enduring involvement. *Journal of Leisure Research* **21** (2), 167-179.

McIntyre, N., and Pigram, J. J. (1992). Recreation specialization re-examined: The case of vehicle based campers. *Leisure Sciences* **14** (1), 3-15.

McLane, A. J., Semeniuk, C., McDermid, G. J., and Marceau, D. J. (2011). The role of agent-based models in wildlife ecology and management. *Ecological Modelling* **222** (8), 1544-1556.

McPhee, D. P., Leadbitter, D., and Skilleter, G. A. (2002). Swallowing the bait: Is recreational fishing ecologically sustainable? *Pacific Conservation Biology* **8**, 40–51.

Melville-Smith, R., Anderton, S. M., and Caputi, N. (2001). Predicting the recreational western rock lobster (*Panulirus cygnus*) catch in Western Australia. *Marine and Freshwater Research* **52** (8), 1527-1534.

Metcalf, S. J., Moyle, K., and Gaughan, D. J. (2010). Qualitative analysis of recreational fisher response and the ecosystem impacts of management strategies in a data-limited situation. *Fisheries Research* **106**, 289–297.

Miller, G. S. (1986). The definition and rendering of terrain maps. In ''86 Proceedings of the 13th Annual Conference on Computer Graphics and Interactive Techniques, 1986, August'. pp. 39-48. (ACM: New York.)

Miller, T. J. (2007). Contribution of individual-based coupled physical-biological models to understanding recruitment in marine fish populations. *Marine Ecology Progress Series* **347**, 127-138.

Moustakes, A., Silvert, W., and Dimitromanolakis, A. (2006). A spatially explicit learning model of migratory fish and fishers for evaluating closed areas. *Ecological Modelling* **192**, 245-258.

Nagy, L., Fairbrother, A., Etterson, M., and Orme-Zavaleta, J. (2007). The intersection of independent lies: increasing realism in ecological risk assessment. *Human and Ecological Risk Assessment* **13** (2), 355-369.

O'Sullivan, D. (2008). Geographical information science: Agent-based models. *Progress in Human Geography* **32**, 541-550.

Oh, C. O., and Ditton, R. (2006a). Using recreation specialization to understand multi-attribute management preferences. *Leisure Sciences: An Interdisciplinary Journal* **28** (4), 369-384.

Oh, C. O., and Ditton, R. B. (2006b). Specialization differences in anglers' preferences for red drum (*Sciaenops ocellatus*) harvest regulations. In 'Proceedings of the 57th Gulf and Caribbean Fisheries Institute, November 08 – 12, 2004'. pp. 869-880. (Gulf and Caribbean Fisheries Institute: St. Petersburg, Florida USA.)

Oh, C. O., and Ditton, R. B. (2008). Using recreation specialization to understand conservation support. *Journal of Leisure Research* **40** (4), 556-573.

Oh, C. O., Ditton, R. B., and Riechers, R. (2007). Understanding anglers' preferences for fishing tournament characteristics and policies*. Environmental Management* **40**, 123–133.

Ormsby, J. (2004). A review of the social, motivational and experiential characteristics of recreational anglers from Queensland and the Great Barrier Reef Region. Great Barrier Reef Marine Park Authority, Research publications series no. 78, Australia.

Parrish, J. K., Viscido, S. V., and Grünbaum, D. (2002). Self-organized fish schools: an examination of emergent properties. *The Biological Bulletin* **202** (3), 296-305.

Pelletier, D., and Ferraris, J. (2000). A multivariate approach for defining fishing tactics from commercial catch and effort data. *Canadian Journal of Fisheries and Aquatic Sciences* **57** (1), 51-65.

Penne, C. R., and Pierce, C. L. (2008). Seasonal distribution, aggregation, and habitat selection of common carp in Clear Lake, Iowa. *Transactions of the American Fisheries Society* **137** (4), 1050-1062.

Pikitch, E., Santora, E. A., Babcock, A., Bakun, A., Bonfil, R., Conover, D. O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E. D., Link, J., Livingston, P. A., Mangel, M., McAllister, M. K., Pope, J., and Sainsbury, K. (2004). Ecosystem-based fishery management. *Science* **305**, 346-347.

Pitcher, T. J., and Hollingworth, C. E. (2002). Fishing for fun: where's the catch?. In 'Recreational Fisheries: ecological, economic and social evaluation'. (Eds T. J. Pitcher and C. E. Hollingworth). pp. 1-16. *(*Blackwell Science: Oxford.)

Plagányi, É. E. (2007). Models for an ecosystem approach to fisheries. Food and Agriculture Organisation of the United Nations No. 477, Rome.

Policansky, D. (2002). Catch-and release recreational fishing: a historical perspective. In 'Recreational Fisheries: ecological, economic and social evaluation'. (Eds T. J. Pitcher and C. E. Hollingworth.) pp*.* 74-93 *(*Blackwell Science: Oxford.)

Policansky, D. (2008). Trends and developments in catch and release. In 'Global Challenges in Recreational Fisheries'. (Ed O. Aas.) pp. 202-208. (Blackwell Publishing Ltd: Oxford, UK.)

Pollock, K. H., Jones, C. M., and Brown, T. L. (1994). 'Angler survey methods and their applications in fisheries management.' (American Fisheries Society, Special Publication 25: Bethesda, Maryland.)

Pollock, K. H. (2010). Review of the Telephone Diary Survey of the Tasmanian Recreational Rock Lobster Fishery. Prepared for Tasmanian Association for Recreational Fishing Inc., Tasmania, Australia.

Post, J. R., Persson, L., Parkinson, E. V., and Kooten, T. V. (2008). Angler numerical response across landscapes and the collapse of freshwater fisheries. *Ecological Applications* **18** (4), 1038-1049.

Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walters, C. J., Parkinson, E. A., Paul, A. J., Jackson, L., and Shuter, B. J. (2002) Canada's recreational fisheries: the invisible collapse?. *Fisheries* **27** (1), 6-17.

Pradervand, P., and Baird, D. (2002). Assessment of the recreational line fishery in selected Eastern Cape estuaries: trends in catches and effort. *South African Journal of Marine Science* **24** (1), 87-101.

Prior, S. P., and Beckley, L. E. (2007). Characteristics of recreational anglers in the Blackwood Estuary, A popular tourist destination in southwestern Australia. *Tourism in Marine Environments* **4**, 15-28.

Punt, A. E. (2008) Refocusing stock assessment in support of policy evaluation. In 'Fisheries for Global Welfare and Environment'. (Eds K. Tsukamoto, T. Kawamura, T. Takeuchi, T. D. Beard Jr., and M. J. Kaiser) pp. 139-152. (5th World Fisheries Congress: Terrapub, Tokyo.).

R Development Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Radomski, P. J., Grant, G. C., Jacobson, P. C., and Cook, M. F. (2001). Visions for recreational fishing regulations. *Fisheries* **26** (5), 7-18.

Raguragavan, J., Hailu, A., and Burton, M. (2010). Economic valuation of recreational fishing in Western Australia. *Australian Journal of Agricultural and Resource Economics,* in press. Available at http://ageconsearch.umn.edu/handle/97473 [accessed 28 November, 2014].

Railsback, S. F. (2001). Concepts from complex adaptive systems as a framework for individual-based modelling. *Ecological Modelling* **139**, 47-62.

Reid, D. (2008). Overview of recreational fishing in Australia. In 'Global Challenges in Recreational Fisheries'. (Ed O. Aas). pp. 13-18. (Blackwell Publishing Ltd: Oxford, UK.)

Reynolds, J. D., Dulvy, N. K., Goodwin, N. B., and Hutchings, J. A. (2005). Biology of extinction risk in marine fishes. *Proceedings of the Royal Society B: Biological Sciences* **272** (1579), 2337-2344.

Richardson, D., and Denniss, R. (2011). *Mining the truth: The rhetoric and reality of the commodities boom*. Australia Institute.

Roach, B., Trial, J., and Boyle, K. (1999). Comparing 1994 angler catch and harvest rates from on-site and mail surveys on selected Maine lakes. *North American Journals of Fisheries Management* **19**, 203–208.

Rose, K. A., and Cowan, J. H. (1993). Individual-based model of young-of-the-year striped bass population dynamics. I. Model description and baseline simulations. *Transactions - American Fisheries Society* **122**, 415-438.

Rothschild, B. J. (2000). 'Fish stocks and recruitment': The past thirty years. *ICES Journal of Marine Science* **57**, 191-201.

Ryan K.L., Morison, A.K., and Conron, S. (2009). Evaluating methods of obtaining total catch estimates for individual Victorian bay and inlet recreational fisheries. Final report to Fisheries Research and Development Corporation Project No. 2003/047. Department of Primary Industries, Queenscliff. 124 pp.

Ryan, K. L., Wise, B. S., Hall, N. G., Pollock, K. H., Sulin, E. H., and Gaughan, D. J. (2013). An integrated system to survey boat-based recreational fishing in Western Australia 2011/12. Fisheries Research Report No. 249, Department of Fisheries, Western Australia.

Sainsbury, K. J., Punt, A. E., and Smith, A. D. M. (2000). Design of operational management strategies for achieving fishery ecosystem objectives. *ICES Journal of Marine Science* **57**, 731–741.

Salas, S., and Gaertner, D. (2004). The behavioural dynamics of fishers: management Implications. *Fish and Fisheries* **5**, 153-167.

Salz, R. J., and Loomis, D. K. (2005). Recreation specialization and anglers' attitudes towards restricted fishing areas. *Human Dimensions of Wildlife* **10** (3), 187-199.

Salz, R. J., Loomis, D. K., and Finn, K. L. (2001). Development and validation of a specialization index and testing of specialization theory. *Human Dimensions of Wildlife: An International Journal* **6** (4), 239-258.

Sampson, D. B. (1991). Fishing tactics and fish abundance, and their influence on catch rates. *ICES Journal of Marine Science: Journal du Conseil* **48** (3), 291-301.

Sampson, D. B. (1994). Fishing tactics in a two-species fisheries model: the bioeconomics of bycatch and discarding. *Canadian Journal of Fisheries and Aquatic Sciences* **51** (12), 2688-2694.

Saul, S., Die, D., Brooks, E.N., and Burns, K. (2012). An individual-based model of ontogenetic migration in reef fish using a biased random walk. *Transactions of the American Fisheries Society* **141** (6), 1439-1452.

Schlüter, M., Mcallister, R. R. J., Arlinghaus, R., Bunnefeld, N., Eisenack, K., Hölker, F., Milner-Gulland, E. J., Müller, B., Nicholson, E., Quaas, M., and Stöven, M. (2012). New horizons for managing the environment: review of coupled social-ecological systems modeling. *Natural Resource Modeling* **25** (1), 219-272.

Schönfisch, B. (2001). Simple individual based models of movement, alignment and schooling behaviour. *Future Generation Computer Systems* **17**, 873–882

Schramm, H. L., Jr., Bray, G. S., and Gill, D. A. (1998). Determination of factors that affect angler retention and recruitment. Completion report. U. S. Fish and Wildlife Service Division of Federal Aid, Arlington, Virginia.

Schramm, H. L., and Gerard, P. D. (2004). Temporal changes in fishing motivation among fishing club anglers in the United States. *Fisheries Management and Ecology* **11** (5), 313-321.

Schnute, J. T., Maunder, M. N., and Ianelli, J. N. (2007) Designing tools to evaluate fisherymanagement strategies: can the scientific community deliver? *ICES Journal of Marine Science* **64**, 1077-1084.

Schwarz, N., and Ernst, A. (2009). Agent-based modeling of the diffusion of environmental innovations-an empirical approach. *Technological Forecasting and Social Change* **76** (4), 497-511.

Scott, D., and Godbey, G. (1994). Recreation specialization in the social world of contract bridge. *Journal of Leisure Research* **26** (3), 275-295.

Shin, Y. J., and Cury, P. (2001). Exploring fish community dynamics through size-dependent trophic interactions using a spatialized individual-based model. *Aquatic Living Resources* **14**, 65-80.

Shin, Y. J., Shannon, L. J., and Cury, P. M. (2004). Simulations of fishing effects on the southern Benguela fish community using an individual-based model: learning from a comparison with Ecosim. *African Journal of Marine Science* **26** (1), 95-114.

Silvano, R. A., and Valbo-Jørgensen, J. (2008). Beyond fishermen's tales: contributions of fishers' local ecological knowledge to fish ecology and fisheries management. *Environment, Development and Sustainability* **10** (5), 657-675.

Smallwood, C. B., Beckley, L. E., and Sumner, N. R. (2006). Shore-based recreational angling in the Rottnest Island Reserve, Western Australia: Spatial and temporal distribution of catch and fishing effort. *Conservation Biology* **12**, 238-251.

Smallwood, C.B., Pollock, K.H., Wise, B.S., Hall, N.G., and Gaughan, D.J. (2011). Quantifying recreational fishing catch and effort: a pilot study of shore-based fishers in the Perth Metropolitan area. Department of Fisheries, Fisheries Research Report No. 216, Western Australia.

Smith, A. D. M. (1993) Risks of over- and under-exploiting new resources. In 'Riskevaluation and biological reference points for fisheries management.' (Eds S. J. Smith, J. J. Hunt, and D. Rivard). pp. 261-267. (Canadian Special Publication of Fisheries and Aquatic Sciences 120)

Smith, W., Kyle, G., and Sutton, S. G. (2012). Angler segmentation using perceptions of experimental quality in the Great Barrier Reef Marine Park. In 'Proceedings of the 2010 Northeastern Recreation Research Symposium'. pp. 98-104. *(*USDA Forest Service.)

St John, J., and Syers, C. J. (2005). Mortality of the demersal West Australian Dhufish, *Glaucosoma hebraicum* (Richardson 1845) following catch and release: The influence of capture depth, venting and hook type. *Fisheries Research* **76**, 106–116.

Stephenson, P., and Jackson, G. (2005). Managing depleted snapper stocks in inner Shark Bay, Western Australia. *Fisheries Assessment and Management in Data-Limited Situations, Alaska Sea Grant Program*, 1-20.

Storey, K. (2001). Fly-in/fly-out and fly-over: mining and regional development in Western Australia. *Australian Geographer* **32** (2), 133-148.

Stuart-Smith, R. D., Barrett, N. S., Crawford, C. M., Frusher, S. D., Stevenson, D. G., and Edgar, G. J. (2008). Spatial patterns in impacts of fishing on temperate rocky reefs: Are fish abundance and mean size related to proximity to fisher access points?. *Journal of Experimental Marine Biology and Ecology* **365** (2), 116-125.

Sullivan, P. J., Breidt, F. J., Ditton, R. B., Knuth, B. A., Leaman, B. M., O'Connell, V. M., Parsons, G. R., Pollock, K. H., Smith, S. J., and Stokes. S. L. (2006). "Review of recreational fisheries survey methods." *Ocean Studies Board–Division on Earth and Life Studies, National Research Council of the National Academies, Washington, DC* (2006).

Sumner, N. R., and Williamson, P. C. (1999). A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 1996-97. Fisheries Research Report No. 117. Department of Fisheries, Western Australia.

Sumner, N. R., Williamson, P. C., Blight, S. J., and Gaughan, D. J. (2008). A 12-month survey of recreational boat-based fishing between Augusta and Kalbarri on the West Coast of Western Australia during 2005-06. Fisheries Research Report No. 177. Department of Fisheries, Western Australia.

Sumner, N. R., Williamson, P. C., and Malseed, B. E. (2002). A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. Department of Fisheries, Fisheries Research Report No. 139, Western Australia.

Sun, Z., and Müller, D. (2013). A framework for modeling payments for ecosystem services with agent-based models, Bayesian belief networks and opinion dynamics models. *Environmental Modelling & Software* **45**, 15-28.

Sutinen, J. G., and Johnston, R. J. (2003). Angling management organizations: Integrating the recreational sector into fishery management. *Marine Policy* **27**, 471-487.

Sutton, S. G. (2001). Understanding catch-and-release behavior of recreational anglers. PhD Thesis, Texas A&M University, College Station.

Sutton, S. G. (2006). An assessment of the social characteristics of Queensland's recreational fishers. CRC Reef Research Centre, Technical Report No. 65, Australia.

Sutton, S. G., and Ditton, R. B. (2001). Understanding catch-and-release behavior among US Atlantic bluefin tuna anglers. *Human Dimensions of Wildlife* **6** (1), 49-66.

Sutton, S. G., and Ditton, R. B. (2005). The substitutability of one type of fishing for another. *North American Journal of Fisheries Management* **25** (2), 536-546.

Thapa, B., Graefe, A. R., and Meyer, L. A. (2005). Moderator and mediator effects of SCUBA diving specialization on marine-based environmental knowledge-behavior contingency. *The Journal of Environmental Education* **37** (1), 53-67.

Thapa, B., Graefe, A. R., and Meyer, L. A. (2006). Specialization and marine based environmental behaviors among SCUBA divers. *Journal of Leisure Research* **38** (4), 601.

Thunberg, E. M., Bresnyan, E. W., and Adams, C. M. (1995). Economic analysis of technical interdependencies and the value of effort in a multi-species fishery. *Marine Resource Economics* **10**, 59-76.

Tracey, S. R., Reinfrank, R., and Lyle, J. M. (2011). Evaluation of a recreational angler logbook program for Tasmania. (Institute for Marine and Antarctic Studies, University of Tasmania: Hobart, Tasmania.)

Tseng, Y. P., Kyle, G. T., Shafer, C. S., Graefe, A. R., Bradle, T. A., and Schuett, M. A. (2009). Exploring the crowding–satisfaction relationship in recreational boating. *Environmental Management* **43** (3), 496-507.

Uchmański, J., and Grimm, V. (1996). Individual-based modelling in ecology: what makes the difference? *Trends in Ecology & Evolution* **11**, 437-441.

Van Dyke Parunak, H., Savit, R., and Riolo, R. L. (1998). Agent-based modeling vs. equation-based modeling: A case study and users' guide. In 'Multi-Agent Systems and Agent-Based Simulation'. (Eds J. Sichman, R. Conte, and N. Gilbert). pp. 10-25. (Springer: Berlin, Heidelberg.)

Van Winkle, W., Rose, K. A., and Chambers, R. C. (1993). Individual-based approach to fish population dynamics: an overview. *Transactions of the American Fisheries Society* **122** (3), 397-403.

Vaske, J. J., Donnelly, M. P., and Heberlein, T. A. (1978). Perceptions of crowding and resource quality by early and more recent visitors. *Leisure Sciences* **3**, 367–381.

Virden, R. J., and Schreyer, R. M. (1988). Recreation specialization as an indicator of environmental preference. *Environment and Behavior* **20** (6), 721- 739.

Wakefield, C.B. (2006) Latitudinal and temporal comparisons of the reproductive biology and growth of snapper *Pagrus auratus* (Sparidae), in Western Australia. *Western Australia.[PhD Thesis]. Centre for Fish and Fisheries Research, Murdoch University, Western Australia*.

Ward, H.G.M., Quinn, M.S., and Post, J.R. (2013) Angler characteristics and management implications in a large, multistock, spatially structured recreational fishery. *North American Journal of Fisheries Management* **33** (3), 576-584.

Weithman, A. S. (1999). Socioeconomic benefits of fisheries. In 'Inland Fisheries Management in North America'. 2nd Edn. (Eds C.C. Kohler, and W.A. Hubert.) pp. 193-213. (American Fisheries Society: Bethesda, Maryland.)

Wellman, J. D., Roggenbuck, J. W., and Smith, A. C. (1982). Recreation specialization and norms of depreciative behavior among canoeists. *Journal of Leisure Research* **14** (4), 323-340.

Whipple, S. J., Link, J. S., Garrison, L. P., and Fogarty, M. J. (2000). Models of predation and fishing mortality in aquatic ecosystems. *Fish and Fisheries* **1**, 22-40.

Wilde, G. R., and Ditton, R. B. (1999). Differences in attitudes and fishing motives among Texas catfish anglers. *American Fisheries Society Symposium* **24**, 395–405.

Wilde, G. R., Ditton, R. B., Grimes, S. R., and Riechers, R. K. (1996). Status of human dimensions surveys sponsored by state and provincial fisheries management agencies in North America. *Fisheries* **21** (11), 12-17.

Wilde, G. R., Riechers, R. K., and Gitton, R. B. (1998). Differences in attitudes, fishing motives, and demographic characteristics between tournament and nontournament Black Bass anglers in Texas. *North American Journal of Fisheries Management* **18**, 422–431.

Wilen, J. E., Smith, M. D., Lockwood, D., and Botsford, L. W. (2002). Avoiding surprises: Incorporating fisherman behaviour into management models. *Bulletin of Marine Science* **70** (2), 553-575.

Williamson, P. C., Sumner, N. R., and Malseed, B. E. (2006). A 12-month survey of recreational fishing in the Pilbara region of Western Australia during 1999-2000. Department of Fisheries, Fisheries Research Report No. 153, Western Australia.

Wise, B., St. John, J., and Lenanton, R. (2007). Spatial scales of exploitation among populations of demersal scalefish: implications for management. Part 1: Stock status of the key indicator species for the demersal scalefish fishery in the West Coast Bioregion. Final Report to the Fisheries Research and Development Corporation on Project No. 2003/052. Fisheries Research Report No. 163. p.130. (Department of Fisheries: Western Australia.)

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenburg, A.A., Watson, R., and Zeller, D. (2009). Rebuilding global fisheries. *Science* **325** (5940), 578-585.

Xiao, Y., (2004). Modelling the learning behaviour of fishers: learning more from their successes than from their failures. *Ecological Modelling* **171**, 3–20.

Yu, R., Pan, M., Railsback, S. F., and Leung, P. S. (2009). A prototype agent based fishery management model of Hawaii's longline fishery. In '18th World IMACS / MODSIM Congress, Cairns, 13-17 July 2009'. pp. 2170-2177. (Cairns, Australia.)

Zischke, M. T., Griffiths, S. P., and Tibbetts, I. R. (2012). Catch and effort from a specialised recreational pelagic sport fishery off eastern Australia. *Fisheries Research* **127**, 61-72.

Appendices

Appendix A Recreational fisher phone survey. Interview script for computer-assisted telephone interviewing (CATI) system (provided by Edith Cowan University (ECU) Survey Research Centre, Joondalup, W.A.)

Pre-amble

Good afternoon/morning/evening, my name is _________ and I'm calling from the Edith Cowan University Survey Research Centre, on behalf of a researcher at Murdoch University.

May I please speak with _____________.

We're conducting a survey about recreational fishing in W.A. and your boat licence number was randomly selected from the recreational fishing boat licence register held by the Department of Fisheries.

The survey asks questions related to recreational fishing in W.A. and will contribute to a 3-year research study. Although the findings of the survey may be published, none of the information you provide will be linked back to you as an individual.

The survey has been approved by the Murdoch University Human Ethics committee. It is completely voluntary and if you decide to take part, you can choose to opt out at any time.

The survey will take approximately 15 minutes to complete. May I please run through it with you now?

Before we begin, I want to assure you of confidentiality for any answers you may give, and let you know that parts of this survey may be listened to for training and quality control purposes.

Questions

1. Firstly, thinking back over the last 12 months have you undertaken any recreational fishing (boat fishing, shore fishing, crabbing etc.) at all in Western Australia, whether you were successful in catching anything or not?

- Yes ☐
- No (end of survey) ☐

2. During the last 12 months, on how many separate days did you do any kind of recreational fishing (boat fishing, shore fishing, crabbing etc.) at all in Western Australia?

- Less than 5 days ☐
- 5 – 9 days ☐
- 10 – 14 days ☐
- 15 – 19 days ☐
- 20 or more days ☐

3. Did you do any fishing from:

- The shore (only) (end of survey) ☐
- A boat (only) ☐
- The shore and a boat ☐

4. Did you do any fishing in:

- Freshwater (only) (end of survey) ☐
- Saltwater (only) ☐
- Both freshwater and saltwater ☐

5. I am going to read out eight statements relating to your motivations for going fishing. Please rate each of these factors as either 1. Very Important, 2. Quite Important, 3. Not Very Important or 4. Not At All Important:

	Very Important	**Quite Important**	**Not Very Important**	**Not At All Important**	**Don't Know**	**Refused**
To relax or unwind.	☐	☐	☐	☐	☐	☐
To be outdoors, in the fresh air, to enjoy nature.	☐	☐	☐	☐	☐	☐
To be on your own, to get away from people.	☐	☐	☐	☐	☐	☐
To spend time with family.	☐	☐	☐	☐	☐	☐
To spend time with friends.	☐	☐	☐	☐	☐	☐
To compete in fishing tournaments.	☐	☐	☐	☐	☐	☐
For the enjoyment or sport of catching fish.	☐	☐	☐	☐	☐	☐
To catch fresh fish for food.	☐	☐	☐	☐	☐	☐

6. Please let me know the extent to which you, 1. Strongly Disagree, 2. Disagree, 3. are Neutral, 4. Agree, 5. Strongly Agree with this statement:

Your last fishing trip was successful (or enjoyable).

Strongly Disagree ☐

Disagree ☐

Neutral ☐

Agree ☐

Strongly Agree ☐

Unsure ☐

7. Do you own a fishing boat?

Yes (move onto Q.8) ☐

No (skip to Q.13) ☐

8. What is the size of your fishing boat?

Feet __________

or Metres __________

9. Does the boat have a GPS?

Yes (move onto Q.10) ☐

No (skip to Q.15) ☐

10. Do you have fishing locations stored in your GPS?

Yes (move onto Q.11 & then Q.12) ☐

No (skip to Q.15) ☐

11. How many fishing locations do you have stored in your GPS?

(READ OUT)

Less than 5 ☐

5 – 24 ☐

25 - 74 ☐

75 - 149 ☐

150 or more ☐

12. In the last 12 months, how often did you visit your best/favourite fishing location?

(READ OUT)

Once	☐
Twice	☐
3-4 times in the year	☐
5-9 times in the year	☐
10-19 times in the year	☐
20 or more times	☐

13. What was the size of the boat that you last used on your last boat fishing trip?

(Note: that if a fisher had answered "Yes" to Q.7 they would be skipping Q.13 and Q.14, as these two questions are only for fishers that do not own a fishing boat.)

Feet _______

or Metres _______

14. Did that boat have a GPS?

Yes	☐
No	☐
Unsure	☐

15. If you went boat fishing at your best/favourite fishing location, how long would you stay there if you were not getting any 'good' bites from fish?
(By good bites, we mean bites from a fish likely to be big enough that you would keep the fish if you managed to catch it)

(READ OUT)

Less than 5 minutes	☐
5 – 9 minutes	☐
10 – 14 minutes	☐
15 – 19 minutes	☐
20 – 29 minutes	☐
30 minutes – 1 hour	☐
DON'T READ OUT Rarely or never move	☐
DON'T READ OUT Not sure	☐

16. If you went boat fishing at a new fishing location where you have never fished before, how long would you stay there if you were not getting any 'good' bites from fish?
(By good bites, we mean bites from a fish likely to be big enough that you would keep the fish if you managed to catch it)

(READ OUT)

Less than 5 minutes	☐
5 – 9 minutes	☐
10 – 14 minutes	☐
15 – 19 minutes	☐
20 – 29 minutes	☐
30 minutes – 1 hour	☐
DON'T READ OUT Rarely or never move	☐
DON'T READ OUT Not sure	☐

17. On your last boat fishing trip you:

(READ OUT)

- Mainly aimed to catch dhufish. ☐
- Mainly aimed to catch snapper. ☐
- Mainly aimed to catch a fish species other than dhufish or snapper (record species targeted). ☐
- Mainly aimed to catch a mix of reef fish species including dhufish or snapper. ☐
- Were not aiming to catch any specific fish species. ☐

18. If you were not successful in catching your target species during a fishing trip, how long would you wait before you switch to a new target species?

(READ OUT)

- Up to 1 hour ☐
- 1 – 1 hour 59 minutes ☐
- 2 – 2 hour 59 minutes ☐
- 3 – 3 hour 59 minutes ☐
- 4 – 4 hour 59 minutes ☐
- 5 hours or more ☐
- (DON'T READ OUT) Never ☐

19. On your last boat fishing trip, including yourself, how many people were on the boat and actively fishing?

People __________

20. **a)** Did you catch any fish on this trip?
(Int: Include fish that were subsequently released)

- Yes ☐
- No (skip to Q.25) ☐

The next question relates to the number and the fish species that you caught on your last boat fishing trip:

21. **i)** On your last boat fishing trip which species of fish did you keep?

(A max of 10 species could be selected/recorded)

Do NOT included species released

____

____

____

____

____

____

____

____

____

____

And how many did you keep?

[Interviewer recorded a response for each species kept]

Kept _________

22. ii) Which species of fish did you release?
(A max of 10 species can be selected)

23. iii) Why did you release ____?
(Single response – record each reason and number separately)

[Interviewer recorded a response for each species released]

REASONS FOR RELEASE

Too small (personal preference, not related to regulations)	☐
Undersized (below legal limit)	☐
Too many (didn't want/need)	☐
Above legal bag limit	☐
Catch and release fishing (fish not tagged before release	☐
Other – greater than legal limit)	☐
Other – too big	☐
Other – too few	☐
Other – tag and release	☐
Other – conservation (other than legally protected species)	☐
Other – sick (fish has signs of disease)	☐
Other – deformed (not sick or damaged)	☐
Other – dangerous	☐
Other – specify	☐
Other – female (eggs, etc.)	☐
Other – poor eating quality	☐
Other – species unknown	☐
Other – poisonous	☐
Other – did not have tag to keep	☐
Other – protected species	☐
Other – mistake (caught but got away)	☐
Other – not specified	☐
No other reason	☐

24. **iv)** And how many did you release because they were_____?

(Record for each response given)

[Interviewer recorded a response for each species released]

RELEASED: __________

REASONS: ___________

25. On your last boat fishing trip, how many hours did you spend fishing – not including travelling time.

(READ OUT)

- Less than 2 hours ☐
- 2 – 3 hours ☐
- 4 – 5 hours ☐
- 6 – 7 hours ☐
- 8 – 9 hours ☐
- 10 – 11 hours ☐
- 12 hours or more ☐

26. On your last boat fishing trip, how many hours did you spend using each of these gear types?

(These hours SHOULD add up to total length of fishing trip hours as per previous question (Q.25))

- Spearfishing _________
- Rod and line fishing _________
- Handline _________
- Manual hand winch (or snapper winch) _________
- Mechanical winch _________
- Other (crabbing) _________

27. On your last boat fishing trip, did you fish

(READ OUT - MULTIPLE RESPONSE POSSIBLE)

- Using a sand anchor ☐
- Using a reef anchor (or reef pick) ☐
- By drift fishing using a sea anchor ☐
- By drift fishing without using a sea anchor ☐
- Other - specify ☐

28. On your last boat fishing trip, in what water depths did you fish?

(READ OUT - MULTIPLE RESPONSE POSSIBLE)

- Less than 15 metres ☐
- 15 – 24 metres ☐
- 25 – 34 metres ☐
- 35 – 54 metres ☐
- 55 – 94 metres ☐
- 95 metres or more ☐
- (DON'T READ OUT) Unsure ☐

29. On your last boat fishing trip, how far did you travel from the boat ramp/pen to your first fishing spot?

(READ OUT)

- Less than 5 km ☐
- 5 – 9 km ☐
- 10 – 14 km ☐
- 14 – 19 km ☐
- 20 – 29 km ☐
- 30 km or more ☐
- (DON'T READ OUT) Unsure ☐

30. How many locations did you fish at on your last boat fishing trip?

Number of locations _______

31. **i)** On your last boat fishing trip, how many kms did you move from your first fishing location to the next (second) location?

Metres _______

or km _______

32. **ii)** On your last boat fishing trip what was the greatest distance travelled between any one fishing location and the next?

Metres _______

or km _______

33. For the move we just asked you about, where you travelled furthest between fishing locations, you did this because …?

(READ OUT)

You weren't catching any fish.	☐
You obtained your catch/bag limit for the fish species you were targeting and decided to target a different fish species somewhere else.	☐
You decided to travel to one of your favourite fishing locations, which happened to be a long distance from where you had been fishing.	☐
You were heading home and decided to stop to fish at a location along the way.	☐
The weather turned rough, so you headed to a fishing spot in a more sheltered location/closer to shore.	☐
The weather became calm, so you decided to try a fishing sport further offshore.	☐
Other - specify	☐

34. On your last boat fishing trip, you decided to head home because …?

(READ OUT)

You obtained your catch/bag limit	☐
You weren't catching any fish	☐
You had been on the water all day/ getting late	☐
The weather turned bad	☐
You had commitments at home	☐
You weren't catching your target fish	☐
Other – specify	☐

35. You would cancel a fishing boat trip if …?
(READ OUT)

[The third box should be ticked if the second box has been ticked and so on…]

Forecast of moderate wind strength (11-16 knots or 20-29 km/h)	☐
Forecast of fresh wind strength (17-21 knots or 30-39 km/h)	☐
Forecast of strong wind strengths (22-27 knots or 40-50 km/h – strong wind warning)	☐
Forecast of near gale strength (28-33 knots or 51-62 km/h – strong wind warning)	☐

36. **i)** How many kilometres offshore would you travel if the weather was fine and the water was flat calm?

km _______

37. **ii)** How many kilometres offshore would you travel if the forecasted wind strength is moderate (11-16 knots or 20-29 km/h)?

km _______

38. **iii)** How many kilometres offshore would you travel if the forecasted wind strength is strong (22-27 knots or 40-50 km/h – strong wind warning)?

km _______

39. Would you start a boat fishing trip earlier in the day if the weather forecast predicted a fresh or strong early afternoon sea breeze?

Yes ☐

No ☐

Unsure ☐

40. During your last boat fishing trip, you fished on a:

(READ OUT - SINGLE RESPONSE)

Public holiday ☐

Normal weekday ☐

Normal weekend ☐

41. I am going to read out six (6) statements. Please let me know the extent that you 1. **Strongly Disagree**, 2. **Disagree**, 3. are **Neutral**, 4. **Agree** or 5. **Strongly Agree** with each statement:

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Unsure**	**NA**
You have many fishing spots on your GPS, but of these, there are a few which you visit far more frequently than the others, because those few spots provide exceptional fishing.	☐	☐	☐	☐	☐	☐	☐
The areas you tend to start fishing on a particular fishing trip are often those where, on your previous fishing trip, you had good success.	☐	☐	☐	☐	☐	☐	☐
You often fish in areas which friends have recommended?	☐	☐	☐	☐	☐	☐	☐
You use nautical charts, or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help you start searching for new fishing spots.	☐	☐	☐	☐	☐	☐	☐
You use information available from the internet to locate new fishing locations	☐	☐	☐	☐	☐	☐	☐
You often use depth contour and/or other inbuilt information in your GPS to locate new fishing spots.	☐	☐	☐	☐	☐	☐	☐

We have come to the last question, and I am going to read out five (5) statements relating to your fishing behaviours in the last 12 months and whether these have changed in the last year compared to previous years.

42. Using the same scale as the previous questions, where 1. is **Strongly Disagree**, 2. is **Disagree**, 3. are **Neutral**, 4. **Agree** or 5. **Strongly Agree** please let me know the extent that you agree with each statement.

(Perth Metropoiltan boundaries include areas between Cape Bouvard – Wedge Island (just north of Lancelin))

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Unsure**	**NA**
Your fishing trips tend to be shorter in duration.	☐	☐	☐	☐	☐	☐	☐
You go out fishing more regularly.	☐	☐	☐	☐	☐	☐	☐
You now catch a wider range of fish species.	☐	☐	☐	☐	☐	☐	☐
You target a different fish species	☐	☐	☐	☐	☐	☐	☐
You tend to fish in areas outside the Perth Metropolitan Region	☐	☐	☐	☐	☐	☐	☐

..And just a couple of demographic questions to help us classify responses.

1. Are you:
   (DO NOT ASK – INTERVIEWER TO CODE GENDER)

Male	☐
Female	☐

2. How old are you?
   (Age in years) ☐

3. What is your current postcode?

Post Code ☐

That is the end of the interview.

Thank you for your time. Just to remind you my name is ___________, I am from the Survey Research Centre at Edith Cowan University.

If you would like more information abut this survey you can call the researcher (Calais Tink) 08 9360 2256 or look up the website www.cffrfisheriesmodelling.net/.

If you have any questions about this research you can telephone our office on 08 6304 2100.

Appendix B Edith Cowan University (ECU) Survey Research Centre certificate of accreditation.

NCS International

CERTIFIED MARKET RESEARCH

AS ISO 20252

Edith Cowan University

ECU Survey Research Centre,
Joondalup Campus,
270 Joondalup Drive
Joondalup WA 6027

Operates a management system
that complies with the requirements of:

AS ISO 20252:2007

Provision of market and social research utilising:

Telephone interviewing for quantitative data collection
Telephone recruitment for quantitative and qualitative research
Central location interviewing for quantitative data collection

Date of Issue:	19 February 2009
Expiry Date:	31 January 2012
Certificate Number:	14219-01
Certification Number:	14219
Certification Date:	16 January 2009

On behalf of the board members

NCS International

AMSRO ASSOCIATION OF MARKET & SOCIAL RESEARCH ORGANISATIONS

Appendix C Formal approval documentation from the Human Research Ethics Committee, Murdoch University, W.A. (Project Number 2009/114).

Murdoch UNIVERSITY

Research Ethics Office
Division of Research and Development

www.murdoch.edu.au

Chancellery Building
South Street
MURDOCH WA 6150
Telephone: 9360 6677
Facsimile: 9360 6686
human.ethics@murdoch.edu.au
www.research.murdoch.edu.au/ethics

Monday, 18 May 2009

Dr Alex Hesp
65A The Promenade,
Mt Pleasant,
WA 6153

Dear Alex,

Project No. 2009/114
Project Title Development of an agent-based model to communicate implications of recruitment variability of finfish to recreational fishers

Your application in support of the above project, received on 23 April 2009, was reviewed by the Murdoch University Human Research Ethics Sub-Committee and was

APPROVED – subject to the following CONDITIONS:

a) **Provide a list of indicative questions for the focus group**
b) **Please provide separate Information and Consent letters.**
c) **Information Letter should include contact details for the Ethics Office. See www.research.murdoch.edu.au/ethics/hrec/advice.html for the standard wording.**

You are not authorised to commence data collection until all conditions listed have been addressed to the satisfaction of the Human Research Ethics Committee. Your response to the conditions should be forwarded in writing to the Research Ethics Office. Once the Committee is satisfied that the conditions have been met, you will be issued with a formal approval.

Please quote your ethics project number in all correspondence.

Kind Regards,

Dr. Erich von Dietze
Manager of Research Ethics

cc: Prof Norm Hall; Miss Calais Tink; Miss Rowena Burch

CRICOS Provider Code: 00125J
ABN 61 616 369 313

Research Ethics Office
Division of Research and Development

www.murdoch.edu.au

Chancellery Building
South Street
MURDOCH WA 6150
Telephone: 9360 6677
Facsimile: 9360 6686
human.ethics@murdoch.edu.au
www.research.murdoch.edu.au/ethics

Thursday, 07 July 2011

Dr Alex Hesp
65A The Promenade
Mt Pleasant WA 6153

Dear Alex,

Project No.	2009/114
Project Title	Development of an agent-based model to communicate implications of recruitment variability of finfish to recreational fishers

AMENDMENT: **Run the survey as a one-off telephone interview, as advised.**

Your application for an amendment to the above project, received on 4/07/2011 was reviewed by the Murdoch University Research Ethics Office and was;

APPROVED

Approval is granted on the understanding that research will be conducted according the standards of the *National Statement on Ethical Conduct in Human Research* (2007), the *Australian Code for the Responsible Conduct of Research* (2007) and Murdoch University policies at all times. You must also abide by the Human Research Ethics Committee's standard conditions of approval (see attached). **All reporting forms are available on the Research Ethics web-site.**

I wish you every success for your research.

Please quote your ethics permit number in all correspondence.

Kind Regards,

Dr. Erich von Dietze
Manager of Research Ethics

cc: Prof Norm Hall; Calais Tink and Rowena Burch

CRICOS Provider Code: 00125J
ABN 61 616 369 313

Appendix D Number of anglers who participated in the phone survey and who aimed to catch each of the various fish species when targeting species 'other' than West Australian dhufish or pink snapper during their last boat fishing trip. Fishers have been separated according to avidity class. Note: NA stands for not applicable. Note also that the table contains a summary of the raw interview data and that the species or species groups recorded by the interviewer are reported without editing.

Species/ species group	Avidity class categories					
	< 5 days	5-9 days	10-14 days	15-19 days	≥ 20 days	Total
NA	39	41	39	20	72	**211**
Barramundi.	0	1	0	0	0	**1**
Black bream	0	0	1	0	2	**3**
Black bream and crabs	0	0	0	0	1	**1**
Blue manner [*sic*] crab	0	1	0	0	0	**1**
Blue manner [*sic*] crabs	1	0	0	0	0	**1**
Blue swimmer crab.	1	0	0	0	0	**1**
Blue swimmer crabs.	1	0	1	0	0	**2**
Blueline emperor.	1	0	0	0	0	**1**
Bread and butter fish, herring, garfish,	0	1	0	0	0	**1**
Bream black.	0	1	0	0	0	**1**
Coral trout, red emperor	0	0	1	0	0	**1**
Crab	1	0	0	0	0	**1**
Crabbing	1	2	0	0	1	**4**
Crabbing blue swimmer	1	0	0	0	0	**1**
Crabbing blue swimmer.	1	0	0	0	0	**1**
Crabs	4	0	2	0	0	**6**
Crayfish	0	0	0	0	1	**1**
Herring	1	0	1	0	0	**2**
Herring and Skippy.	0	0	0	0	1	**1**

Herring and squid.	0	1	0	0	0	**1**
Herring and Taylor.	0	0	0	0	1	**1**
Herring and whiting	0	0	1	0	1	**2**
Herring garfish Skippy(sand)	0	1	0	0	0	**1**
Herring, pike,	0	0	0	0	1	**1**
Herring, tailor. yellow fin whiting and silver trevally	0	0	0	0	1	**1**
Herring, trevally, king George whiting,	0	0	1	0	0	**1**
Herring, whiting	0	2	0	0	0	**2**
Herring, whiting, Skippy	0	1	0	0	0	**1**
Herring. Blue swimmer crabs	0	1	0	0	0	**1**
King George whiting	0	1	0	0	0	**1**
King George whiting, black bream	0	0	0	0	1	**1**
King George whiting, herring, squid	0	0	0	0	1	**1**
King George whiting.	0	1	0	0	1	**2**
King George whiting/southern school	0	0	0	1	0	**1**
Mackerel	1	0	0	0	0	**1**
Mackerel, bonito	0	1	0	0	0	**1**
Mackerels	0	0	0	0	1	**1**
Mahi mahi	0	1	0	0	0	**1**
Mahi mahi, marlin	0	0	1	0	0	**1**
Mangrove jack	0	0	0	0	1	**1**
Red emperor	0	0	0	0	1	**1**
Redfin perch	0	0	0	0	1	**1**
Reef fish not including West Australian dhufish or pink snapper	0	0	0	0	1	**1**
Salmon, Skippy, whiting and bream	0	0	0	0	1	**1**
Sand and king George whiting, squid	1	0	0	0	0	**1**
Sand or king George whiting	1	0	0	0	0	**1**
Sand whiting	0	0	0	0	1	**1**
Skippy/trevally/whiting king George..	1	0	0	0	0	**1**
Skippy/whiting king George.	0	1	0	0	0	**1**

Southern school whiting	0	0	1	1	1	**3**
Spanish mackerel	1	0	0	1	0	**2**
Spanish mackerel and other surface fish.	0	0	0	1	0	**1**
Spanish mackerel, tuna,	1	0	0	0	0	**1**
Spanish mackerel.	0	0	0	0	1	**1**
Spanish mackerel/pelagic	0	0	0	0	1	**1**
Squid	1	3	0	0	1	**5**
Squid.	0	0	0	3	0	**3**
Squid. Sand whiting	0	0	0	0	1	**1**
Tailor	0	0	0	0	1	**1**
Whiting	1	1	0	1	2	**5**
Whiting herring crabs	0	1	0	0	0	**1**
Whiting sand.	0	0	0	0	1	**1**
Whiting-King George	0	1	1	0	0	**2**
Whiting-King George and yellow fin	0	0	0	0	1	**1**
Whiting-sand	0	0	2	0	0	**2**
Whiting-western school	0	0	1	0	0	**1**
Whiting, herring	0	0	0	1	1	**2**
Whiting, herring or Skippy.	0	0	1	0	0	**1**
Whiting, squid	0	0	0	0	1	**1**
Whiting.	0	2	0	0	1	**3**
Whiting/herring/skipjack.	1	0	0	0	0	**1**
Yellow tail king fish. Samson fish	0	0	1	0	0	**1**

Appendix E Number of anglers who participated in the phone survey and who targeted each of the various groups of species when aiming to catch a fish species 'other' than West Australian dhufish or pink snapper during their last boat fishing trip. Fishers have been separated according to avidity class.

High level grouping	Key species grouping	Common name	Taxon	Avidity Class Categories					
				< 5 days	5-9 days	10-14 days	15-19 days	≥ 20 days	Total
FINFISH	Australian herring	Herring - Australian	*Arripis georgianus*	1	0	1	0	0	**2**
	Barramundi	Barramundi	*Lates calcarifer*	0	1	0	0	0	**1**
	Bream	Bream - black	*Acanthopagrus butcheri*	0	1	1	0	2	**4**
	Emperors	Emperor - red	*Lutjanus sebae*	0	0	0	0	1	**1**
		Emperor - blue lined	*Lethrinus fraenatus*	1	0	0	0	0	**1**
	King George whiting	Whiting - King George	*Sillaginodes punctata*	0	3	1	0	1	**5**
	Mackerels	Mackerel - Spanish	*Scomberomorus commerson*	1	0	0	1	1	**3**
		Mackerel - unspecified	Scombridae	1	0	0	0	1	**2**
	Sea perch/snappers	Snapper - mangrove jack	*Lutjanus argentimaculatus*	0	0	0	0	1	**1**
	Tailor	Tailor	*Pomatomus saltatrix*	0	0	0	0	1	**1**
	Whiting	Whiting - sand	*Sillago ciliata*	0	0	2	0	2	**4**
		Whiting - southern school	*Sillago bassensis*	0	0	1	1	1	**3**
		Whiting - western school	*Sillago vittata*	0	0	1	0	0	**1**
		Whiting - mix	Sillago spp.	1	0	0	1	1	**3**
		Whiting - unspecified	Sillaginidae	1	3	0	1	3	**8**
	Kingfish/ samson fish	Kingfish / samson fish mix	Seriola spp.	0	0	1	0	0	**1**
FINFISH	Other	Mahi mahi	*Coryphaena hippurus*	0	1	0	0	0	**1**
CRABS & LOBSTERS	Blue swimmer crab	Crab - Blue Swimmer	*Portunus pelagicus*	5	1	1	0	0	**7**
	Crabs	Crabs - unspecified	Scylla spp.	6	2	2	0	1	**11**

	Crayfish	Crayfish - unspecified	Palinuridae	0	0	0	0	1	**1**
CEPHALOP-ODS	Squid/cuttlefish	Squid	Teuthoidea	1	3	0	3	1	**8**
MIX	Mix of spp.	Inshore pelagic (IP)	*(herring, King George whiting, skippy, squid, mackerel)*	0	4	1	0	3	**8**
		Inshore pelagic and demersal (IP & ID)	*(herring, garfish, squid, whiting spp., crabs, skippy, trevally, tailor)*	3	6	2	1	6	**18**
		Offshore demersal (OD)	*(coral trout, red emporer, reef fish)*	0	0	1	0	1	**2**
		Offshore pelagic (OP)	*(spanish mackerel, marlin, tuna, mahi mahi)*	1	0	1	1	1	**4**
		Estuarine / riverine (E)	*(black bream, crabs , redfin perch, whiting)*	0	0	0	0	4	**4**

Appendix F Number of individuals of each of the various species and groups of species caught and retained by anglers, who participated in the phone survey, during their last boat fishing trip. Retained catches have been separated according to each angler's avidity class, determined according to the frequency of fishing of the individual fisher over the past 12 months.

High level grouping	Key species grouping	Common name	Taxon	Avidity Class Categories					
				< 5 days	**5-9 days**	**10-14 days**	**15-19 days**	**≥ 20 days**	**Total**
FINFISH	Australian herring	Herring - Australian	*Arripis georgianus*	4	12	7	2	9	**34**
	Barramundi	Barramundi	*Lates calcarifer*	0	1	0	0	0	**1**
	Bream	Bream - black	*Acanthopagrus butcheri*	0	2	0	1	3	**6**
		Bream - Northwest black	*Acanthopagrus palmaris*	0	0	0	0	1	**1**
		Bream - unspecified	*Sparidae*	0	0	0	1	0	**1**
	Coral trout	Trout - barcheek coral	*Plectropomus maculatus*	0	0	0	0	1	**1**
		Trout – yellow edge coronation	*Variola louti*	0	0	0	0	1	**1**
		Common coral trout	Serranidae	2	2	1	1	0	**6**
	Dhufish	Dhufish - West Australian	*Glaucosoma hebraicum*	3	8	3	2	9	**25**
	Drummer	Drummer - silver/ buffalo bream	*Kyphosus sydneyanus*	0	0	0	0	1	**1**
	Emperors	Emperor - grass	*Lethrinus laticaudis*	2	1	0	1	4	**8**
		Emperor - red	*Lutjanus sebae*	2	0	1	0	1	**4**
		Emperor - red throat	*Lethrinus miniatus*	1	2	1	0	1	**5**
		Emperor - spangled	*Lethrinus nebulosus*	1	6	2	1	6	**16**
		Emperor - yellow tail	*Lethrinus atkinsoni*	0	0	0	0	1	**1**
	Garfish	Garfish - southern	*Hyporhamphus melanochir*	0	0	1	0	0	**1**

		Garfish - robust	*Hemiramphus robustus*	0	1	0	0	0	**1**
		Garfish - unspecified	Hemiramphidae	0	1	0	0	1	**2**
	King George whiting	Whiting - King George	*Sillaginodes punctata*	3	7	5	2	8	**25**
	Leatherjackets	Leatherjacket	Monacanthidae	0	1	1	0	0	**2**
	Mackerels	Mackerel - school	*Scomberomorus queenslandicus*	0	1	0	0	0	**1**
		Mackerel - Spanish	*Scomberomorus commerson*	1	4	2	5	6	**18**
		Mackerel - spotted	*Scomberomorus munroi*	0	0	0	1	0	**1**
		Mackerel - unspecified	Scombridae	0	1	1	0	0	**2**
		Wahoo	*Acanthocybium solandri*	0	0	0	1	1	**2**
	Morwong	Morwong - blue	*Nemadactylus douglasii*	1	2	0	0	0	**3**
		Morwong - dusky	*Dactylophora nigricans*	0	0	1	0	0	**1**
	Mullet	Mullet - sea	*Mugil cephalus*	0	1	0	0	0	**1**
	Mulloway/jewfish	Jewfish - black	*Protonibea diacanthus*	0	0	0	0	2	**2**
		Mulloway	*Argyrosomus japonicus*	0	0	0	0	1	**1**
	Pike	Snook	*Sphyreana novaehollandiae*	0	0	0	0	1	**1**
	Red mullet	Goatfish - blue-spotted	*Upeneichthys vlamingii*	0	0	0	0	1	**1**
	Redfish	Redfish - bight	*Centroberyx gerrardi*	1	0	0	0	0	**1**
	Rock-cod/gropers	Cod - breaksea	*Epinephelides armatus*	1	2	1	1	4	**9**
		Cod - chinaman	*Epinephelus rivulatus*	0	1	0	1	4	**6**
		Cod - rankin	*Epinephelus multinotatus*	1	2	0	0	5	**8**
		Cod - other	Epinephelidae	0	0	2	0	0	**2**
		Hapuku	Polyprion spp.	0	0	1	0	0	**1**
		Harlequin	*Othos dentex*	0	0	1	0	0	**1**
		Rockcod - black spotted	*Epinephelus malabaricus*	1	0	0	0	0	**1**
	Sea perch/snappers	Chinamanfish	*Symphorus nematophorus*	1	0	0	0	0	**1**
		Snapper - crimson	*Lutjanus erythropterus*	0	1	0	0	2	**3**
		Snapper - golden	*Lutjanus johnii*	0	0	0	1	0	**1**

		Snapper - goldband	Pristipomoides multidens	0	0	0	0	2	**2**
		Snapper - mangrove jack	*Lutjanus argentimaculatus*	0	0	0	0	1	**1**
		Snapper - stripey	*Lutjanus carponotatus*	1	0	0	0	0	**1**
		Snapper - unspecified	Lutjanidae	1	0	1	1	1	**4**
	Sharks/rays	Sharks - hammerhead	Sphyrnidae	0	0	0	0	1	**1**
		Shark - school	*Galeorhinus galeus*	0	0	0	0	1	**1**
		Shark - whiskery	*Furgaleus macki*	0	0	0	0	1	**1**
		Shark - unspecified	Several families	0	0	0	0	1	**1**
	Pink snapper	Snapper - pink	*Chrysophrys auratus*	4	8	3	3	13	**31**
	Sweep	Sweep - banded	*Scorpis georgianus*	1	0	0	0	0	**1**
	Tailor	Tailor	*Pomatomus saltatrix*	2	3	0	0	3	**8**
	Threadfin salmon	Threadfin - blue	*Eleutheronema tetradactylum*	0	0	0	0	1	**1**
	Trevally	Trevally - golden	*Gnathanodon speciosus*	1	1	1	0	0	**3**
		Trevally - sand	*Pseudocaranx wrighti*	4	3	0	1	2	**10**
		Trevally - silver	*Pseudocaranx dentex*	3	3	5	3	4	**18**
		Turrum	*Caranx ignobilis*	0	0	0	0	1	**1**
		Trevally - other	Carangidae	0	1	1	0	2	**4**
	Tuna/bonitos	Tuna - mackerel	*Euthynnus affinis*	0	0	0	0	1	**1**
		Tuna - northern bluefin	*Thunnus tonggol*	0	0	0	1	1	**2**
		Tuna - skipjack/ striped	*Katsuwonis pelamis*	0	1	0	0	0	**1**
		Tuna - southern bluefin	*Thunnus maccoyii*	0	0	0	0	1	**1**
		Tuna - yellowfin	*Thunnus albacares*	0	0	2	1	2	**5**
	Whiting	Whiting - southern school	*Sillago bassensis*	1	0	2	3	2	**8**
		Whiting - western school	*Sillago vittata*	1	2	2	0	4	**9**
		Whiting - yellowfin	*Sillago schomburgkii*	6	3	4	1	5	**19**
		Whiting - other	Sillaginidae	2	0	1	0	4	**7**
	Wrasse/tuskfish/ gropers	Groper - baldchin	*Choerodon rubescens*	1	3	2	0	6	**12**
		Grouper - duskytail	*Epinephelus bleekeri*	0	0	0	0	1	**1**

		Parrotfish - bluebarred	*Scarus ghobban*	0	0	0	1	0	**1**
		Tuskfish - blackspot	*Choerodon schoenleinii*	0	1	0	0	0	**1**
		Tuskfish - blue	*Choerodon cyanodus*	1	0	0	0	1	**2**
		Wrasse - brownspotted	*Notolabrus parilus*	0	1	0	0	0	**1**
		Wrasse - Maori	Labridae	0	1	1	0	0	**2**
		Wrasse - western king	*Coris auricularis*	0	0	1	0	0	**1**
	Kingfish/samson fish	Kingfish - yellowtail	*Seriola lalandi*	0	0	0	0	1	**1**
		Samson fish	*Seriola hippos*	0	0	0	0	1	**1**
FINFISH	Other	Cobia	*Rachycentron canadum*	0	0	0	0	2	**2**
		Mahi - mahi	*Coryphaena hippurus*	0	0	2	0	0	**2**
		Sea perch	Ellerkeldia spp.	1	0	0	0	0	**1**
		Sweetlips - painted	*Diagramma pictum*	1	0	0	0	1	**2**
SMALL BAITFISH	Small baitfish	Small baitfish	Several families	0	0	0	0	1	**1**
	Herring/pilchards	Herring - other	Clupeidae	2	1	2	0	2	**7**
CRABS & LOBSTERS	Blue swimmer crab	Crab - blue swimmer	*Portunus pelagicus*	13	7	6	1	3	**30**
	Mud crab	Crab - green mud	Scylla spp.	0	0	0	0	1	**1**
		Crab - brown mud	Scylla spp.	0	1	0	0	0	**1**
	Lobsters	Lobster - painted rock	*Panulirus cygnus*	0	1	0	0	0	**1**
PRAWNS		Prawns	Penaeidea	0	1	0	0	0	**1**
CEPHALO-PODS	Squid/cuttlefish	Cuttlefish	Spirulidae	0	0	1	0	0	**1**
		Squid	Teuthoidea	6	5	4	4	7	**26**

Appendix G Number of individuals of each of the various species and groups of species caught and released by anglers, who participated in the phone survey, during their last boat fishing trip. Released catches have been separated according to each angler's avidity class, determined according to the frequency of fishing of the individual fisher over the past 12 months.

High level grouping	Key species grouping	Common name	Taxon	Avidity Class Categories					
				< 5 days	5-9 days	10-14 days	15-19 days	≥ 20 days	Total
FINFISH	Australian herring	Herring - Australian	*Arripis georgianus*	5	2	2	1	4	**14**
	Barramundi	Barramundi	*Lates calcarifer*	0	1	0	0	0	**1**
	Bream	Bream - black	*Acanthopagrus butcheri*	0	2	1	2	5	**10**
		Bream - Northwest black	*Acanthopagrus palmaris*	0	0	0	0	1	**1**
	Butterfish	Butterfish - western	*Pentapodus vitta*	0	0	1	0	1	**2**
		Butterfish - unspecified	Scatophagidae	0	0	1	1	0	**2**
	Catfish	Catfish - unspecified	Plotosidae	0	0	0	0	1	**1**
	Coral trout	Trout - barcheek coral	*Plectropomus maculatus*	0	1	0	0	0	**1**
		Common coral trout	Serranidae	1	1	1	0	2	**5**
	Dhufish	Dhufish - West Australian	*Glaucosoma hebraicum*	1	3	3	3	8	**18**
	Drummer	Drummer - silver/ buffalo bream	*Kyphosus sydneyanus*	0	0	0	0	1	**1**
	Emperors	Emperor - grass	*Lethrinus laticaudis*	1	1	0	1	4	**7**
		Emperor - red	*Lutjanus sebae*	0	0	1	0	2	**3**
		Emperor - red throat	*Lethrinus miniatus*	0	2	1	0	1	**4**
		Emperor - spangled	*Lethrinus nebulosus*	1	4	3	1	5	**14**
		Emperor - yellow tail	*Lethrinus atkinsoni*	0	0	1	0	1	**2**
	Flathead	Flathead - unspecified	Platycephalidae	1	1	1	0	1	**4**
	Garfish	Garfish - unspecified	Hemiramphidae	0	0	0	1	0	**1**

	King George whiting	Whiting - King George	*Sillaginodes punctata*	4	5	4	0	1	**14**
	Leatherjackets	Leatherjacket	Monacanthidae	0	2	0	0	1	**3**
	Mackerels	Mackerel - Spanish	*Scomberomorus commerson*	1	2	1	1	4	**9**
		Mackerel - unspecified	Scombridae	0	0	1	0	1	**2**
	Pike	Barracuda - striped	*Sphyraena obtusata*	0	0	0	1	0	**1**
	Red mullet	Goatfish - blue-spotted	*Upeneichthys vlamingii*	0	0	0	0	2	**2**
	Redfish	Redfish - bight	*Centroberyx gerrardi*	0	1	0	0	0	**1**
	Rock-cod/gropers	Cod - breaksea	*Epinephelides armatus*	0	1	1	0	4	**6**
		Cod - chinaman	*Epinephelus rivulatus*	0	1	0	1	2	**4**
		Cod - rankin	*Epinephelus multinotatus*	1	1	0	0	0	**2**
		Cod - other	Epinephelidae	0	1	1	0	2	**4**
		Cod - unspecified	Epinephelidae	0	0	1	0	1	**2**
		Rockcod - black spotted	*Epinephelus malabaricus*	0	0	1	2	1	**4**
		Rockcod - frostback	*Epinephelus bilobatus*	0	0	0	0	1	**1**
	Scorpionfish/gurnard	Gurnard	Triglidae	0	0	0	0	2	**2**
	Sea perch/snappers	Snapper - crimson	*Lutjanus erythropterus*	0	0	0	0	1	**1**
		Snapper - goldband	*Pristipomoides multidens*	0	0	0	0	1	**1**
		Snapper - mangrove jack	*Lutjanus argentimaculatus*	0	0	0	0	1	**1**
		Snapper - stripey	*Lutjanus carponotatus*	0	1	0	0	1	**2**
		Snapper - unspecified	Lutjanidae	0	0	1	0	1	**2**
	Sharks/rays	Rays/skates - other	Several families (incl. Rhinobatidae, Dasytidae)	1	0	0	0	0	**1**
		Rays/skates - unspecified	Several families (incl. Rhinobatidae, Dasytidae)	0	0	1	0	1	**2**
		Sharks - bronze whaler	*Carcharhinus brachyurus*	2	0	0	0	0	**2**
		Sharks - gummy	*Mustelus antarcticus*	0	0	1	0	0	**1**
		Shark - Port Jackson	*Heterodontus portusjacksoni*	0	0	1	0	1	**2**
		Shark - whaler	*Carcharhinus spp.*	0	0	0	1	0	**1**

		Shark - other	Several families	0	1	1	1	0	**3**
		Shark - unspecified	Several families	0	0	0	1	2	**3**
	Pink snapper	Snapper - pink	*Chrysophrys auratus*	4	10	2	3	11	**30**
	Sweep	Sweep - sea	*Scorpis aequipinnis*	0	0	0	0	1	**1**
	Tailor	Tailor	*Pomatomus saltatrix*	1	0	0	0	0	**1**
	Trevally	Trevally - golden	*Gnathanodon speciosus*	1	1	0	0	2	**4**
		Trevally - sand	*Pseudocaranx wrighti*	2	4	0	0	1	**7**
		Trevally - silver	*Pseudocaranx dentex*	0	2	2	1	2	**7**
		Trevally - giant /turrum	*Caranx ignobilis*	0	0	0	0	1	**1**
		Trevally - other	Carangidae	0	0	0	0	1	**1**
	Tuna/bonitos	Tuna - northern bluefin	*Thunnus tonggol*	0	0	0	0	1	**1**
		Tuna - other	Scombridae	0	0	1	0	1	**2**
		Tuna - yellowfin	*Thunnus albacares*	1	0	0	0	0	**1**
	Whiting	Whiting - southern school	*Sillago bassensis*	1	0	1	2	1	**5**
		Whiting - western school	*Sillago vittata*	0	1	1	0	2	**4**
		Whiting - yellowfin	*Sillago schomburgkii*	0	3	0	0	3	**6**
		Whiting - other	Sillaginidae	1	0	0	0	3	**4**
	Wrasse/tuskfish/ gropers	Groper - baldchin	*Choerodon rubescens*	0	2	1	0	2	**5**
		Parrotfish - bluebarred	*Scarus ghobban*	0	0	0	0	1	**1**
		Parrotfish - unspecified	Labridae	0	0	1	0	0	**1**
		Pigfish - goldspot	*Bodianus perditio*	0	0	0	0	1	**1**
		Tuskfish - blue	*Choerodon cyanodus*	0	0	0	0	1	**1**
		Tuskfish - unspecified	Labridae	0	0	1	0	0	**1**
		Wrasse - brownspotted	*Notolabrus parilus*	1	2	0	1	1	**5**
		Wrasse - Maori	Labridae	1	0	0	0	0	**1**
		Wrasse - other	Labridae	2	0	2	0	1	**5**
		Wrasse - unspecified	Labridae	1	0	1	0	3	**5**
		Wrasse - western king	*Coris auricularis*	1	1	0	0	0	**2**
	Kingfish/samson fish	Samson fish	*Seriola hippos*	0	0	0	0	4	**4**

FINFISH	Other	Fish - other		2	0	1	1	2	**6**
		Long tom	Belonidae	0	0	0	0	1	**1**
		Marlin - blue	*Makaira mazara*	0	0	0	1	0	**1**
		Queenfish	Scomberoides spp.	0	0	0	1	0	**1**
		Sergeant baker	*Aulopus purpurissatus*	0	0	1	1	0	**2**
		Scad - other	Carangidae	0	0	0	0	1	**1**
		Swallowtail	*Centroberyx lineatus*	0	1	1	0	0	**2**
		Sweetlips - painted	*Diagramma pictum*	0	1	0	0	0	**1**
		Toads/ pufferfish /boxfish/ blowfish	Several families	3	3	0	1	2	**9**
		Trumpeter - grunters/javelin	Latrididae	1	0	0	0	1	**2**
		Trumpeter - other	Latrididae	0	0	0	0	1	**1**
		Trumpeter - unspecified	Latrididae	0	1	1	0	1	**3**
		Western blue devil fish	*Paraplesiops meleagris*	0	0	0	0	1	**1**
SMALL BAITFISH	Herring/pilchards	Herring - other	Clupeidae	0	0	1	0	0	**1**
CRABS & LOBSTERS	Blue swimmer crab	Crab - blue swimmer	*Portunus pelagicus*	12	6	5	1	3	**27**
	Mud crab	Crab - green mud	Scylla spp.	0	0	0	0	1	**1**
	Lobsters	Lobster - painted rock	*Panulirus cygnus*	0	1	0	0	0	**1**
CEPHALOP-ODS	Squid/cuttlefish	Cuttlefish	Spirulidae	0	0	1	0	0	**1**
		Squid	Teuthoidea	2	1	2	0	1	**6**

Appendix H **Number of recreational anglers who participated in the phone survey and who reported each of the various 'other' reasons why, during their last boat fishing trip, they undertook their greatest movement between successive fishing locations. Note that the table contains a summary of the raw interview data as recorded by the interviewer and reported without editing.**

'Other' reasons for travelling the furthest between fishing locations	Avidity class categories					
	< 5 days	5-9 days	10-14 days	15-19 days	≥ 20 days	Total
Because fish hide behind the weed.	0	0	0	0	1	**1**
Had finished in one spot for a while and just decided to try a new different spot.	0	0	0	1	0	**1**
Had my brother-in-law from NZ over, and I was showing him places and exploring locations.	0	0	0	1	0	**1**
I was trolling from one location to the next.	0	1	0	0	0	**1**
I was trolling.	0	0	0	1	0	**1**
Just decided to try another spot.	1	0	0	0	0	**1**
Just targeting larger fish.	0	1	0	0	0	**1**
To become in line with the breeze on the way.	0	0	0	0	1	**1**
Too small.	0	0	1	0	0	**1**
We just drifted that far.	0	0	0	0	1	**1**
We were getting to know the area and just wanted to try another area. We were on a trip up north and wanted to try as many spots as possible.	0	0	0	0	1	**1**
We were not catching size fish.	0	0	0	0	1	**1**

Appendix I Number of recreational anglers who participated in the phone survey and who reported each of the various 'other' reasons why they decided to head home at the end of their last boat fishing trip. Note that the table contains a summary of the raw interview data as recorded by the interviewer and reported without editing.

'Other' reasons to head home.	Avidity class categories					
	< 5 days	5-9 days	10-14 days	15-19 days	≥ 20 days	Total
I was running out of fuel so had to head back.	0	0	1	0	0	**1**
Fisher had hook in hand and needed medical attention.	1	0	0	0	0	**1**
Had a good day, needed to eat, wash boat and clean fish.	1	0	0	0	0	**1**
I had had enough.	0	0	0	1	0	**1**
It was getting really cold, night fishing.	0	0	0	1	0	**1**
Mechanical failure.	0	1	0	0	0	**1**
Mooring before dark.	0	0	0	0	1	**1**
One of us got sick.	0	0	0	1	0	**1**
Part of competition and had to be back by a certain time.	1	0	0	0	0	**1**
Ran out of air in the diving tanks.	1	0	0	0	0	**1**
Ran out of bait.	0	0	0	1	0	**1**
Tide was changing.	0	1	0	0	0	**1**
Time limit, enough time out.	0	1	0	0	0	**1**
We had enough, didn't need anymore.	0	1	0	0	0	**1**
We had to tow a bloke in whose boat had broken down.	0	0	1	0	0	**1**
We just wanted to catch enough to have a meal then we came in.	0	0	0	1	0	**1**
We went on a charter.	0	1	0	0	0	**1**

Appendix J Consent to participate in the recreational fisher survey form.

Consent form

Project title: "Development of an agent-based model to communicate implications of recruitment variability of finfish to recreational fishers (FRDC Project 2008/033)"

---

1. I agree voluntarily to take part in this study.
2. I have read the background information provided about the project and have been given a full explanation of the purpose of this study, of the procedures involved and of what is expected of me.
3. I understand I am free to withdraw from the study at any time without needing to give any reason.
4. I understand that the findings of this study may be published. However, no information which can specifically identify me will be published.
5. I understand that the questions being asked of me are not of a personal nature, and that my name and identity will not be linked in any way to the data being requested.
6. I understand that the questions being asked in the survey and focus group discussion are of a general nature, which aim to capture fisher knowledge on the habitats and movements of dhufish and snapper, and the ways in which fishers target these species.
7. I understand that the information provided by me will be used to develop a computer model for exploring interactions between recreational fishers and fish, and that this model will be made freely available for download to the general public via the Centre for Fish and Fisheries Research website (http://www.cffr.murdoch.edu.au/).

Signature of Participant: ________________________ Date: …..../..…../…….
(Name)

Signature of Investigator: ________________________ Date: ..…../…..../…….
(Name)

Appendix K Questionnaire for angling club survey.

1. Over the last 12 months, how many times do you think you would have gone fishing from a boat? (Please enter number in box to the right). ☐

2. Please tick the most appropriate box for each of the following statements?

	Never	**Sometimes**	**Often**	**Most times**	**Every time**
When I went fishing over the last 12 months, I fished from a boat.	☐	☐	☐	☐	☐
When I went boat fishing over the last 12 months, I caught **Dhufish.**	☐	☐	☐	☐	☐
When I went boat fishing over the last 12 months, I caught **Snapper.**	☐	☐	☐	☐	☐
When I went boat fishing over the last 12 months, I fished on weekends.	☐	☐	☐	☐	☐

3. On your last boat fishing trip, how many people were on the boat and actively fishing? (Please enter number in box to the right). ☐

4. On your most recent boat fishing trip, how long did you spend fishing? (Specifically, how much time did you spend on the water, between having arrived at your first fishing location and having left from your final fishing location to travel home)

(Please tick only **<u>one</u>** box):

- 1 – 2 hours ☐
- 3 – 4 hours ☐
- 5 – 6 hours ☐
- 7 – 8 hours ☐
- 9 – 10 hours ☐
- 11 – 12 hours ☐
- More than 12 hours ☐

5. If you went boat fishing at one of your favourite fishing locations, how long would you stay there if you were not getting any "good" bites from a fish? (By good bites, we mean bites from a fish likely to be big enough that you would keep them, if you caught those fish) Please tick only **one** box:

- Less than 5 minutes ☐
- 5 – 10 minutes ☐
- 10 – 15 minutes ☐
- 15 – 20 minutes ☐
- 20 – 30 minutes ☐
- 30 minutes – 1 hour ☐
- Rarely or never move ☐

6. If you went boat fishing at a location where you have never fished before, how long would you stay there if you were not getting any "good" bites from fish.
(By good bites, we mean bites from a fish likely to be big enough that you would keep them, if you caught those fish) Please tick only **one** box:

- Less than 5 minutes ☐
- 5 – 10 minutes ☐
- 10 – 15 minutes ☐
- 15 – 20 minutes ☐
- 20 – 30 minutes ☐
- 30 minutes – 1 hour ☐
- Rarely or never move ☐

7. Which times of the day do you consider best for catching **Dhufish**?
(Please tick multiple boxes if required):

- Sunrise/ early morning ☐
- Mid morning ☐
- Mid day ☐
- Mid afternoon ☐
- Late afternoon/sunset ☐
- Night ☐
- I use a lunar (or solunar) chart ☐
- No particular time is best ☐
- Not sure – I rarely catch dhufish ☐

8. Which times of the day do you consider best for catching **Snapper**?
(Please tick multiple boxes if required):

- Sunrise/ early morning ☐
- Mid morning ☐
- Mid day ☐
- Mid afternoon ☐
- Late afternoon/sunset ☐
- Night ☐
- I use a lunar (or solunar) chart ☐
- No particular time is best ☐
- Not sure – I rarely catch snapper ☐

9. On my last boat fishing trip:
(Please tick only **one** box)

- I was mainly aiming to catch **Dhufish** ☐
- I was mainly aiming to catch **Snapper** ☐
- I was mainly aiming to catch **fish species other than Dhufish or Snapper** ☐
- I was aiming to catch a **mix of fish species including Dhufish or Snapper** ☐

10. On your last boat fishing trip, how many Dhufish did you catch? ☐
(Please enter number in box to the right).

11. On your last boat fishing trip, how many Snapper did you catch? ☐
(Please enter number in box to the right).

12. On your last boat fishing trip, how many Dhufish did you release? ☐
(Please enter number in box to the right).

13. On your last boat fishing trip, how many Snapper did you release? ☐
(Please enter number in box to the right).

14. On your last boat fishing trip, did you catch and retain the bag limit for **Dhufish**?

(bag limit = 1 fish per day)

Yes ☐

No ☐

15. On your last boat fishing trip, did you catch and retain the bag limit for **Snapper**?

(bag limit = 2 fish per day)

Yes ☐

No ☐

16. On your last boat fishing trip, which times of the day were you actively fishing?
(Please tick multiple boxes if required):

Sunrise/ early morning ☐

Mid morning ☐

Mid day ☐

Mid afternoon ☐

Late afternoon/sunset ☐

Night ☐

17. When you go boat fishing, what percentage of your time do you spend using the two types of fishing methods listed below?
(**Note:** If you fish by both methods, the percentages should add up to 100%):

Line fishing (that is, using a handline, rod and line, line with snapper or mechanical winch) ☐

Spearfishing ☐

18. When fishing for **Dhufish**, what percentage of your time do you spend: (**Note:** If you fish using more than one of the methods listed below, the percentages should add up to 100%):

Fishing using an anchor ☐

Drift fishing with a sea anchor ☐

Drift fishing without a sea anchor ☐

I never target dhufish when I go fishing ☐

19. When fishing for **Snapper**, what percentage of your time do you spend: (**Note:** If you fish using more than one of the methods listed below, the percentages should add up to 100%)

Fishing using an anchor ☐

Drift fishing with a sea anchor ☐

Drift fishing without a sea anchor ☐

I never target snapper when I go fishing ☐

20. In your opinion, how skilled are you at identifying each of the following habitat types using an echo sounder:
(Please enter a value ranging from 0 = not skilled at all to 10 = extremely skilled):

Non-reef habitat ☐

Reef edge ☐

Reef top ☐

Reef caves/crevices ☐

21. How good do you think the following habitats are for catching **Dhufish**?

	Poor	**Average**	**Good**	**Very Good**	**Excellent**
Sand more than 20 m away from reef	☐	☐	☐	☐	☐
Sand within 20 m of reef	☐	☐	☐	☐	☐
Reef top	☐	☐	☐	☐	☐
Reef edge	☐	☐	☐	☐	☐
Caves found on the reef edge	☐	☐	☐	☐	☐
Caves found over the reef	☐	☐	☐	☐	☐
Isolated reef "lumps"	☐	☐	☐	☐	☐

22. How good do you think the following habitats are for catching **Snapper (when fishing in areas outside of Cockburn Sound, Warnbro Sound and other embayments where this species aggregates to spawn)**?

	Poor	**Average**	**Good**	**Very Good**	**Excellent**
Sand more than 20 m from reef	☐	☐	☐	☐	☐
Sand within 20 m of reef	☐	☐	☐	☐	☐
Reef top	☐	☐	☐	☐	☐
Reef edge	☐	☐	☐	☐	☐
Caves found on the reef edge	☐	☐	☐	☐	☐
Caves found over the reef	☐	☐	☐	☐	☐
Isolated reef "lumps"	☐	☐	☐	☐	☐

23. Do you have a GPS?

Yes ☐

No ☐

24.a) If you answered "**YES**" to Q19. , how many fishing spots do you have marked in your GPS? ☐

b) What percentage of your collection of fishing spots marked in your GPS do you consider to be very good fishing locations that you would visit regularly? ☐
(0% = none, 100% = all of the fishing spots)

25. In what water depths would you mostly target **Dhufish**?
(Please tick only **<u>one</u>** box):

- Less than 15 metres ☐
- 15 – 25 metres ☐
- 25 – 35 metres ☐
- 35 – 55 metres ☐
- 55 – 95 metres ☐
- More than 95 metres ☐
- Not sure – I never target dhufish ☐

26. In what water depths would you mostly target **Snapper**?
(Please tick only **<u>one</u>** box):

- Less than 15 metres ☐
- 15 – 25 metres ☐
- 25 – 35 metres ☐
- 35 – 55 metres ☐
- 55 – 95 metres ☐
- More than 95 metres ☐
- Not sure – I never target snapper ☐

27. How important is the weather in influencing your decisions as to whether you would go boat fishing on a particular day?
(Please tick only **one** box)

- The weather almost never stops me going fishing ☐
- The weather sometimes stops me going fishing ☐
- I only go boat fishing when the weather is very calm ☐

28. I would cancel a boat fishing trip if:
(Please tick only **one** box)

- Forecasted wind strength is 10-20 knots and/or swell greater than 1.5 m ☐
- Forecasted wind strength is 20-30 knots and/or swell greater than 2.5 m ☐
- Only if a weather warning is current ☐

29. I would start boat fishing earlier and/or stop boat fishing if there is a:
(Please tick only **one** box)

- 10 – 20 knot sea breeze ☐
- 20 – 30 knot sea breeze ☐
- Greater than 30 knot sea breeze ☐

30. On your most recent boat fishing trip, how far offshore did you travel before you started fishing?

Less than 5 km	☐
5 – 10 km	☐
10 – 15 km	☐
15 – 20 km	☐
20 – 25 km	☐
25 – 30 km	☐
More than 30 km	☐

31. Does the weather you encounter when boat fishing strongly influence how far you are prepared to travel offshore to go to a fishing spot?

Yes	☐
No	☐

32. If you answered "**YES**" to Q27., please answer the following:

i) On a calm day, I would travel up to_____________km offshore.

ii) On a day of moderate conditions, I would travel up to _____________km offshore.

iii) On a rough day, I would travel up to _____________km offshore.

33. Do you **Strongly Disagree**, **Disagree**, **Agree** or **Strongly Agree** with the following statements?

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
I have many fishing spots on my GPS, but of these, there are a few which I visit far more frequently than the others, because those few spots provide exceptional fishing.	☐	☐	☐	☐	☐
The areas I tend to start fishing on a particular fishing trip are often those where, on my previous fishing trip, I had good success.	☐	☐	☐	☐	☐
I often fish in areas which friends have recommended?	☐	☐	☐	☐	☐
I use nautical charts, or other charts (such as those available from tackle shops with approximate coordinates of fishing locations) as a guide to help me start searching for new fishing spots.	☐	☐	☐	☐	☐
I use information available from the internet to locate new fishing locations.	☐	☐	☐	☐	☐
I often use depth contour and/or other inbuilt information in my GPS to locate new fishing spots.	☐	☐	☐	☐	☐

Very many thanks, you have now completed the survey!

Could you please now take the time to answer the next few general questions about yourself and any thoughts you have on the survey you just completed.

We will then start the group discussion.

GENERAL DEMOGRAPHIC INFORMATION ON SURVEY PARTICPANTS

1. Are you:

Male	☐
Female	☐

2. Aged between:

18 – 29 years	☐
30 – 44 years	☐
45 – 59 years	☐
Over 59 years	☐

3. What is your current postcode?

Post Code ☐

4. How long have you been fishing?

0 – 2 years	☐
2 – 10 years	☐
More than 10 years	☐

5. Do you live in a household that owns a boat used for recreational fishing?

Yes	☐
No	☐

Please provide any comments you would like to make regarding the survey or any additional information you would like to give? Some suggested areas on which you may wish to comment:

1.) Any aspects you feel should have been included in the survey and why
2.) What you understand about the habitats of Dhufish and Snapper and their movements
3.) How you use your knowledge about Dhufish and Snapper to increase your fishing success
4.) What do you do differently to target Dhufish vs Snapper?
    i) Fish at different times of the day for the different species,
    ii) Use different fishing techniques,
    iii) Fish over different habitats?
5) What features on an echo sounder are most indicative of the best habitats for Dhufish and Snapper, and why (that is, what do those features indicate to you about the habitat)

Appendix L **Values of parameters used for each fish species in the simulation runs of the agent based model. Superscripts refer to the relevant data source for each parameter (listed below the table).**

Species	West Australian dhufish	Pink snapper	'Red Herring' (Silver Trevally)
		Maximum age and mortality	
Maximum age (years)	41[1]	38[6]	18[8]
M (year^{-1})	0.101[1]	0.109[6]	0.232[8]
ProbOfDeathAfterRelease	0.4[2]	0.2[2]	0.05[2]
		Growth parameters	
L_{∞} (Females) (mm)	929[1]	1150[6]	477[8]
L_{∞} (Males) (mm)	1025[1]	0.12[6]	0.24[8]
k (Females) (yr^{-1})	0.111[1]	-0.41[6]	-0.37[8]
k (Males) (yr^{-1})	0.111[1]	1127[6]	459[8]
t_0 (Females) (yr)	-0.141[1]	0.12[6]	0.27[8]
t_0 (Males) (yr)	-0.052[1]	-0.46[6]	-0.22[8]
StDevLengthAtAge	10[2]	10[2]	25[28]
		Gear selectivity parameters	
L_{50} (Females) (mm)	503[3]	372[7]	290[9]
L_{95} (Males) (mm)	658[3]	480[7]	441[9]
ProbOfCaptureAtFullSelectivity	0.8[2]	0.8[2]	0.8[2]
		Fish movement parameters	
ProbOfMoving (ReefTopHotspots)		0.069[4]	
ProbOfMoving (ReefTop)		0.448[4]	
ProbOfMoving (ReefEdgeHotspots)		0.001[4]	
ProbOfMoving (ReefEdge)		0.969[4]	
ProbOfMoving (NonReef)		0.999[4]	
		Management parameters	
Minimum legal length (mm)	500[5]	410[5]	250[5]
Boat limit (fish)	2[5]	4[2] *	16[2] *
Mixed species boat limit (fish)		6 (2 West Australian dhufish, 4 Snapper)[2]	
		Fish abundance	
Number of fish	5000[2]	5000[2]	5000[2]

Data sources: 1. Hesp *et al.* (2002), 2. Specified by A. Hesp, 3. A. Hesp, unpublished data, 4. Determined from the results of recreational fisher survey (undertaken in this project) 5. Department of Fisheries, Western Australia, Recreational fishing regulations for the west coast bioregion 6. Lenanton *et al.* (2009) – based on results of research by M. Moran, C. Wakefield and G. Jackson, 7. C. Wakefield, unpublished data, 8. Farmer *et al.* (2005), 9. D. French, unpublished data.

*Specified by A. Hesp as a boat limit no longer exists for these species in Western Australia. Values specified = twice the current bag limit. Note that the number of West Australian dhufish in one of the simulations differed (reduced to 2,500 fish), to explore the implications of changes in abundance in a population of this species.

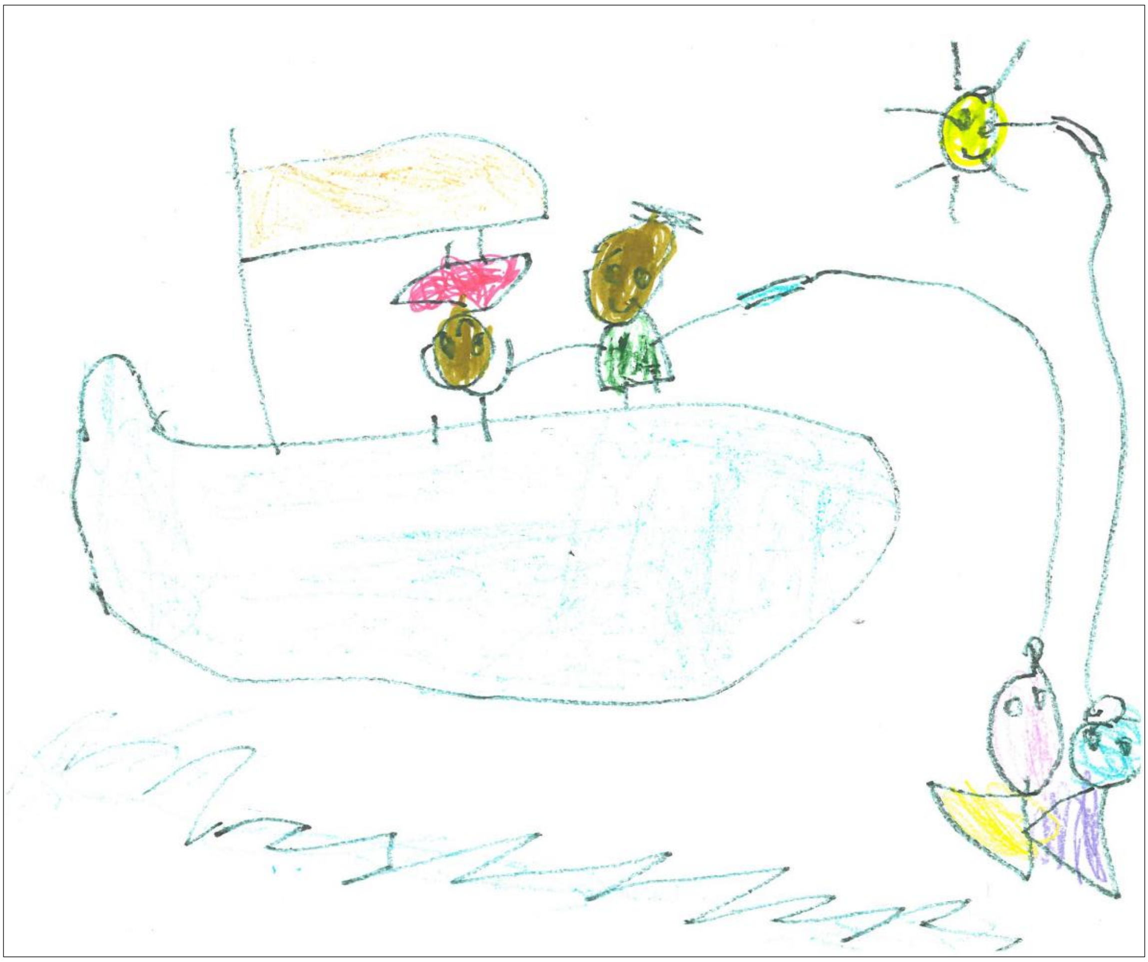


Image supplied by my other very talented god daughter Caitlyn Barrett, age 4.