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Developing innovative and cost-effective tools for monitoring recreational fishing in Commonwealth fisheries

FRDC Project 2007/014

Final Report

5 November 2010

• Shane Griffiths • Julian Pepperell • Mark Tonks
• Gavin Fay • William Venables • Jeremy Lyle
• Len Olyott • William Sawynok • Steven Edgar

Australian Government
Fisheries Research and Development Corporation

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OBJECTIVES:

1. Undertake a comprehensive review of the global literature relating to the existing methods used to monitor recreational fishing, which may be transferable to Commonwealth fisheries

2. Develop innovative operational and statistical tools for collecting, integrating and analysing recreational fisheries data, for the purpose of integration into stock assessment and to support resource allocation in Commonwealth fisheries

3. Recommend a cost-effective and statistically robust long-term recreational fisheries monitoring program for Commonwealth fisheries

OUTCOMES ACHIEVED

A global literature review of recreational fishing survey methods determined potential cost-effective methods for monitoring recreational fishing in Commonwealth fisheries.

National stakeholder workshops facilitated exchange of current knowledge of recreational fishing survey methodologies between state and Commonwealth government agencies and non-government stakeholders. The workshops prioritised Commonwealth-managed species and fisheries that require monitoring, and identified potential methods to cost-effectively survey recreational fishers.

Scenario modelling using stock assessments applied to data-rich and data-poor species demonstrated that the inclusion of recreational catch that exceeds 10% of commercial catches and the inclusion of age structure data from recreational fisheries can significantly influence assessments outcomes.

An innovative and cost-effective approach to sampling hard-to-reach specialised recreational fishers in the absence of a sampling frame was developed using Respondent-Driven Sampling (RDS). After reviewing all available methodologies, RDS was the recommended method for obtaining the total recreational catch of Commonwealth-managed species when combined with a mark-recapture survey of fishers in a complemented "RDS-Recapture" survey design, after the method undergoes thorough testing.

NON-TECHNICAL SUMMARY

Growing population size of coastal Australian cities and increasing availability, quality and affordability of navigation and fish-searching technologies (e.g. GPS, sonar), fishing tackle (e.g. electric reels) and fishing techniques (e.g. deep water jigging) have contributed to an increase in the efficiency and diversification of the recreational fishing sector in recent years. This has contributed to a relatively small, but rising, number of specialised recreational fishers fishing in offshore Commonwealth waters to target some species that also support commercial fisheries (e.g. striped marlin and blue eye trevalla), or are of conservation concern (e.g. southern bluefin tuna and mako shark). For some species, such as striped marlin, increasing demands by recreational fishers for a greater proportion of the resource share have led to conflict with commercial fisheries.

However, little information is available on the recreational catch of Commonwealth-managed species to inform stock assessments or resolve resource allocation issues. Unfortunately, the increasing diversification of the recreational fishery presents researchers with an increasingly difficult task of trying to use traditional survey methods to cost-effectively obtain representative data from relatively small and spatially diffuse populations of specialised fishers. Therefore, this project was developed to: i) review the global literature on recreational fishing survey methods, ii) undertake national workshops to identify the Commonwealth-managed species and fisheries of importance to recreational fishers and prioritise for monitoring, iii) determine the specific data requirements for integrating recreational fisheries data into stock assessments for priority species, iv) develop and test new and innovative recreational fishing survey methods, and v) recommend a statistically sound, practical and cost-effective long-term recreational fisheries monitoring program for Commonwealth-managed species.

A global literature review of 285 publications revealed that researchers have conducted surveys to estimate catch and/or effort by recreational fishers in at least 20 countries since 1990. Overall, 36% of such surveys were undertaken across spatial scales similar to Commonwealth fisheries. Of these, 58% were complemented access point-telephone surveys. In considering methods to apply to recreational fisheries in Commonwealth waters, several new and innovative sampling methods were identified, including the use of Australian Customs and Border Protection Service's aerial surveillance data, time-location sampling, and Respondent-Driven Sampling (RDS).

RDS is an innovative low-cost and statistically robust model-based survey method designed by epidemiologists and social scientists to representatively sample individuals from hard-to-reach populations (e.g. illicit drug users, sex workers) through social networks using a dual incentive scheme. RDS may be used to collect catch and effort data from respondents in a recall survey ("RDS Recall") for species where only catch is required for dynamic pool stock assessment models, or by recruiting fishers to a diary survey ("RDS Diary") where length composition of the catch is required for quantitative age structured stock assessment models. However, RDS does not estimate fisher population size, which is required to estimate the total recreational catch. Therefore, a complemented survey design – "RDS-Recapture" – was developed to obtain catch and effort data using multiple RDS surveys, and to estimate the fisher population size using a mark-recapture approach.

A national workshop attended by fisheries scientists, fishery managers, statisticians and recreational fishing groups determined that recreational fisheries had the most significant interaction with species, in terms of their commercial or conservation value, targeted in the SBT, SESSF, ETBF, WTBF. The highest priority species identified for a monitoring program were southern bluefin tuna, striped marlin, shortfin mako shark and blue eye trevalla. The recommended survey methods to estimate the total recreational catch of these species were: i) a telephone-diary survey, ii) Customs aerial surveillance data combined with a diary and/or access point survey, and iii) RDS-Recapture.

Before the recommended survey methods were further developed for Commonwealth species, scenario modelling was undertaken using different types of stock assessment models applied to species considered to be 'data-poor' (blue eye trevalla in the SESSF) and 'data-rich' (striped marlin in the ETBF). In both cases, including recreational catch when it exceeded 10% of commercial catch was found to be important for calculations of the total allowable catch (TAC), particularly if the magnitude of recreational catch changed over time. The simulations for striped marlin also demonstrated the importance of including age (or length) structure information for the recreational catch to estimate selectivity parameters.

Aerial surveillance data collected routinely by Border Protection Command (BPC) – a division of the Australian Customs and Border Protection Service – was identified as a potentially cost-effective method for estimating recreational fishing effort in large Commonwealth fisheries. These data were previously used in a CSIRO study to estimate the fishing effort by foreign fishing vessels (FFVs) in northern Australia. The FFV model was successfully modified to estimate recreational fishing effort and has the flexibility to incorporate additional model terms to describe time of day, week day/weekend, weather effects, which are likely to affect estimates of recreational fishing effort.

A final stakeholder workshop was held to i) discuss the results of survey method developments and stock assessment analyses, ii) present a cost-benefit analysis of potential complemented survey designs, and iii) make final recommendations as to the most statistically robust and cost-effective method for monitoring recreational fishing in Commonwealth waters. Although reasonably low cost, telephone surveys (for population size estimates and/or diarist recruitment) were considered unlikely to yield a representative sample of specialised fishers in the current absence of complete list frames and the rarity of specialised fishers in the general community. The FFV model was among the least expensive survey methods for estimating effort, although there were concerns over sampling and data quality issues. The "RDS-Recapture" complemented survey using either a recall or diary survey (depending on stock assessment model data requirements for particular species) was recommended as the most appropriate method for monitoring recreational fishing in Commonwealth fisheries. This was due to this method being capable of obtaining representative data from hard-to-reach recreational fishers in the absence of a complete sampling frame, and the low cost of implementation. However, it was strongly recommended that RDS and the mark-recapture models undergo thorough testing in recreational fisheries before widespread application to Commonwealth fisheries.

Keywords: resource allocation, recreational fishing, survey design, Time-Location Sampling, epidemiology, hard-to-reach population, Respondent-Driven Sampling.

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3. BACKGROUND

Recreational fishing is a popular sport and social activity undertaken by an estimated 11.5% of the global population (Cooke and Cowx, 2004). In many countries, recreational catches have increased rapidly, contributing to an estimated global catch of around 47 billion fish (Cooke and Cowx, 2004). In Australia, a national recreational fishing survey (NRFS) (Henry and Lyle, 2003) was conducted over a one-year period in 2000/01 and showed that 19.5% of the population, or 3.36 million people, participated in recreational fishing. During this period, it was estimated that fishers undertook 23.2 million fishing trips and caught 72 million finfish. The primary motivation for recreational fishers to participate in the activity was found to be for relaxation and/or sport, and to a far lesser extent, harvesting for food (Henry and Lyle, 2003).

In light of these results, there appears to be a general perception among the general community that recreational fishing is a benign leisure activity, which has an impact on fish populations that is considerably less than that of commercial fisheries (Kearney, 1999). However, recent studies have challenged this notion by suggesting that recreational fishing, if not properly managed, can negatively impact fish populations (McPhee et al., 2002; Post et al., 2002; Coleman et al., 2004). There are now several Australian studies that have shown the recreational catch of some finfish and invertebrates is significant, and even exceeds the commercial catch (McGlennon, 1992; West and Gordon, 1994; Ferrell and Sumpton, 1998; Malseed et al., 2000; Murray-Jones and Steffe, 2000; O'Neill, 2000; Leigh and O'Neill, 2003; Lyle et al., 2005; Reid and Montgomery, 2005; Mitchell et al., 2008).

Recreational fishing in Australia is managed by state government authorities through a variety of input (e.g. gear restrictions) and output (e.g. size and possession limits) controls. These controls are generally not specifically intended for biological management of particular species, but rather to promote equitable sharing of fisheries resources among recreational fishers. However, given the apparent impacts of recreational fisheries on some fish populations, there has been increasing need to manage recreational catches and include them in stock assessments for species shared by commercial and recreational fisheries in state waters (Leigh and O'Neill, 2003; Begg et al., 2005; Griffiths et al., 2006; Fry and Griffiths, 2010).

In recent years, however, growing population size of coastal cities, and the marked increase in availability, quality and affordability of navigation and fish-searching technologies (e.g. radar and sonar), fishing tackle (e.g. electric reels, braided lines) and fishing techniques (e.g. deep water jigging) have contributed to an increase in the efficiency and diversification of the recreational sector (Griffiths and Pepperell, 2006). There is also substantial anecdotal evidence to suggest increasing competition among recreational fishers for access to more productive locations in the face of apparently declining catch rates of popular target species in easily accessible coastal waters and because of increasing coastal Marine Protected Areas (MPAs). Such factors have resulted in more recreational fishers fishing in offshore Commonwealth waters to target some species traditionally targeted by commercial fisheries (e.g. swordfish, striped marlin, blue eye trevalla) or are of conservation concern (e.g. southern bluefin tuna (SBT)). For some species, such as striped marlin, increasing demands by recreational fishers for a greater proportion of the resource share has led to conflict with commercial fisheries (see Bromhead et al., 2004).

4. NEED

Currently in Commonwealth waters, there are no formal management arrangements for recreational fisheries. This is partly because recreational fisheries are managed by States, but also because most Commonwealth-managed fish species are distributed in offshore waters that were previously assumed to be inaccessible by the majority of recreational fishers. Although this is still generally the case, there are a relative small, but increasing, number of highly specialised recreational fishers who probably account for the majority of the total recreational catch of Commonwealth-managed species. However, there have been no dedicated recreational fishing surveys to quantify the recreational catch of Commonwealth-managed species, with the exception of limited data from the NRFS (Henry and Lyle, 2003) and fishing tournament surveys (e.g. Lowry and Murphy, 2003), which are not representative of all fishers who target Commonwealth-managed species.

The long-term sustainability and equitable sharing of Commonwealth-managed species relies upon the availability of representative data from all fishing mortality sources (i.e. recreational, commercial and indigenous) in order to allow the assessment of the biological sustainability of the stocks. In turn, this allows fishery managers to implement management measures that can control the total fishing mortality imposed upon these populations and to meet their Australian and international obligations.

As a result, there is a clear need for robust recreational catch estimates for several Commonwealth-managed species. Unfortunately, the increasing diversification of the recreational fishery presents fisheries researchers with the difficult problem of trying to use traditional survey methods to cost-effectively obtain representative data from the relatively small, often specialised and spatially diffuse population of recreational fishers who target Commonwealth-managed species. In the current absence of a complete sampling list frame of recreational fishers in Australia, the expense of sampling required to intercept specialised fishers using traditional probability-based surveys (e.g. general telephone or access point surveys) is not only cost-prohibitive but unlikely to yield a representative sample due to a variety of inherent sampling biases.

Thus, the primary aim of this project was to fill a national and international need to develop new recreational fishing survey methods that are both practical and cost-effective in their implementation for specialised recreational fisheries.

5. Objectives

1) Undertake a comprehensive review of the global literature relating to the existing methods used to monitor recreational fishing, which may be transferable to Commonwealth fisheries
2) Develop innovative operational and statistical tools for collecting, integrating and analysing recreational fisheries data, for the purpose of integration into stock assessment and to support resource allocation in Commonwealth fisheries
3) Recommend a cost-effective and statistically robust long-term recreational fisheries monitoring program for Commonwealth fisheries

6. A global review of survey methods for estimating the catch and effort of recreational fishers

6.1 Background

Fisheries scientists in many parts of the world collect data on recreational fisheries for a variety of reasons. Depending on management objectives and information needs, data collected from recreational fishing surveys may relate to behaviour, motivations for fishing, social and demographic profiles, economic activity, and catch and effort. These data types collected from a sample of fishers can then be scaled to the total recreational fishing population for inclusion in stock assessment and to inform management (e.g. Zeller et al., 2008).

However, collecting catch and effort data that is representative of the entire recreational fishing community that may impact upon a particular fish stock is a significant challenge. Unlike licenced commercial fisheries where catch and effort can be quantified from compulsory logbooks, and ideally verified by scientific observers, recreational fishers are typically not required to report their catch and/or effort, even in jurisdictions where a recreational fishing licence is required. Furthermore, even where licensing systems are in place, they often include numerous categories of exemptions, such as for children, senior citizens, and persons on welfare. As a result, researchers typically lack a complete list sampling frame from which to survey a representative sample of the recreational fishing population in order to estimate required parameters.

While a diversity of sampling methods have been developed to collect recreational catch and effort data in a range of situations, they differ significantly in the type, quality, and quantity of information they can gather, as well as their cost-effectiveness. Therefore, the objective of this review was to provide an overview of the traditional methods used to survey recreational fishing effort and catch and outlining their advantages and disadvantages, including commentary on potential biases. Examples are also provided as to how these methods have been used globally for various recreational fisheries. A second objective was to introduce new and innovative approaches that have, or may potentially, be used to estimate catch and/or effort in recreational fisheries.

In this review, an emphasis has been placed on presenting methods or discussing case studies that are applicable to monitoring recreational fishing in large-scale Commonwealth fisheries such as the Eastern Tuna and Billfish (ETBF), the Coral Sea (CSF) and the Southern and Eastern Shark and Scalefish Fisheries (SESSF), where a number of pelagic, tropical reef, Continental shelf and slope species are shared between commercial and recreational fisheries (see Griffiths and Pepperell, 2006).

6.2 Methodology

An extensive review of the global published and 'grey' literature was undertaken to identify methods that have, or may potentially, be used to collect catch and/or effort data from recreational fisheries. Electronic data searches were conducted using the following search engines: ISI Web of knowledge, Google, Google scholar, CSIRO ScienceServer, OAlster, Scirus, ADT (Australiasian Digital Theses Program Database), Scopus, and CSA (Cambridge Scientific Abstracts). Personal contact with researchers or fishery agency representatives was also made in order to access some literature sources.

In general, data were only collected and collated where sources were considered reliable, using peer-reviewed publications, newspapers, magazines, and general websites as objectively as possible.

Due to the enormity of the task of collecting all known literature on recreational fishing surveys, we limited our search to literature published after 1990. This was because grey literature was difficult to source electronically before this time, but also basic traditional methods were often used, many of which have since been modified to correct for various statistical flaws in earlier survey designs. However, a few key studies published before 1990 were included to highlight particular points. Surveys that were conducted to solely collect social and/or economic data were generally not included, since the objective of this review was to provide possible options for collecting catch and effort data from recreational fisheries. Surveys included in this review were not restricted to finfish, but also include the recreational catch of crustaceans and shellfish.

Some explanation of how surveys were classified is necessary. The classification of survey method is self-explanatory; however 'intercept' surveys include access point, roving creel, aerial surveys and fisher counts on site to measure only effort. Categorising surveys with respect to the main criteria (country, spatial scale, survey duration, etc) needs little explanation. However there are instances, for example, where a fisheries agency had changed survey methodology during a long-term monitoring program in order to better represent catch estimates. In these cases, they were recorded as multiple surveys rather than a single survey.

6.3 Traditional survey methods

A number of basic survey methods have been used to collect recreational fisheries data worldwide including mail-back surveys, door-to-door and telephone omnibus surveys, fisher logbooks, diaries and catch cards, and access point, roving, and aerial-based surveys. Pollock et al. (1994) details how these methods are used to gather catch, effort and socio-economic data from recreational fishers and their potential shortcomings. Therefore, the purpose of this review is to first provide a basic global overview of the survey methodologies used to collect data on various aspects of recreational fisheries, with an emphasis on recent application and innovative methodologies that may be applicable to large-scale Australian Commonwealth fisheries.

Survey methods used to collect recreational fishing data broadly fall into one of two categories, which largely depend upon where the data is collected. "Off-site" surveys

encompass the first four aforementioned methods, which are generally conducted away from fishing sites. They also rely upon the fisher to report their own catch and effort (i.e. self-reporting). The remaining three methods are commonly referred to as "on-site" methods because data is collected at the fishing site by trained survey staff. Historically, these methods have been used as stand-alone methods as they were initially developed for surveying fishers on relatively small water bodies. However, through time, there has been increasing need to survey larger-scale, and more complex, recreational fisheries. To effectively deal with these types of fisheries, it is now common practice to use a combination of basic survey methods, known as 'complemented surveys', such as using an on-site access point survey to estimate catch rates and an off-site telephone survey to estimate total effort in the fishery.

6.3.1 Off-site survey methods

Off-site surveys are usually based on sampling from a list of fishers (e.g. licence holders), commonly known as a 'sampling frame', and interviewing people by mail and telephone. Diaries, catch cards and logbooks are slightly different in that they can be given to fishers at fishing sites during on-site surveys. However, they are still regarded as off-site methods because the data is fisher-reported after they have left the fishing site. Off-site methods generally have the advantage of being able to cost-effectively sample a large number of fishers. However, their main disadvantage is that they rely on fisher-reported data, for which the quality and legitimacy can often not be verified without conducting expensive follow-up surveys.

Mail surveys

Traditionally, mail surveys have been used to sample fishers' attitudes and opinions about fishing issues and to develop socio-economic profiles of individual fishers or of fisher communities (Aas et al., 2000; Ditton and Hunt, 2001; Arlinghaus and Mehner, 2003; Bangsund and Leistritz, 2003; Chen et al., 2003; Kelch et al., 2006; Sutton, 2006b). However, fewer examples exist of this method being used as a stand alone method for collecting catch and effort data from recreational fisheries. Pollock (1994) suggests this is due to problems associated with recall bias, which is a diminished memory of catch and effort with increasing time after the fishing event. In a comparative study of catch rates between concurrent mail and on-site surveys on five Maine lakes (US), Roach (1999) suggested that recall bias associated with the mail survey led to an overestimation of catch rates. Furthermore, other potential biases may be apparent in particular fisheries, such as intentional deception and under-reporting if bag limits apply, or 'prestige bias' where fishers may intentionally exaggerate the number or size of fish caught. Nevertheless, in some circumstances mail surveys are a cost-effective method, for example in a fishery with a relatively small identifiable fisher group that targets trophy species (e.g. large pelagic species) where catches are infrequent and memorable.

One of the main problems with mail surveys is that sampling requires a list frame (e.g. licence holders), which is often an incomplete representation of the full spectrum of fishery participants. For example, there may be exemptions related to age, race or socio-economic status (e.g. unemployed or pension), as well as non-licence holders who

simply do not purchase a licence and fish illegally. Therefore, not including these fishers in the sampling group may bias survey results if their fishing activities differ from those surveyed.

Another major problem with mail surveys is non-response bias. The concern is not necessarily the percentage of surveys returned, although this is obviously important, it is the potential difference in type of response between those that do and do not respond. For example, it is reasonable to assume that avid fishers would be more likely to respond to a survey than more casual fishers, and the responses to survey questions are often different between these groups (Cowx, 1991). Non-response bias can be reduced by conducting follow-up mailings or by offering incentives to encourage participation. For example, Sharp et al. (2005) offered to provide a brief summary of survey results to non-respondents as an incentive to return their questionnaires. Another way of adjusting for non-response bias is to follow up a sample of non-respondents by telephone, and then compare their responses to those of the initial respondents.

In North America, several large-scale mail surveys have been conducted since the 1960's. The Michigan Department of Natural Resources Fisheries Division conducted mail surveys between 1967–1984 to collect recreational catch and effort data. These surveys were first used to assess recreational catch and effort of the first season of adult Pacific salmon on the Great Lakes, and were later expanded to include all sportfish by 1970. Additional questions were added in 1983–84 to identify market segment and economic impacts; however the survey was abandoned in 1984 due to significant problems associated with catch and effort estimates affected by self-reporting biases (Thayer, 2005).

In a more recent example, McClanahan and Hansen (2005) conducted a state-wide mail survey in Wisconsin to estimate the 2000–2001 angling catch and effort for inland lakes and rivers. The Automated License Issuance System (ALIS) was used as the sample frame, which contained the names and addresses of fishers who purchased licences for the 2000–2001 fishing season. The authors pointed out that the sample frame did not include fishers under the age of 16 or older than 73, as they were exempt from purchasing a licence. A mail survey and a reminder postcard were sent every two weeks to a random subset of the fishers from the sample frame, who were asked to report their catch and effort over the following two-week period. A follow-up survey of non-respondents was undertaken to estimate non-response bias by mailing a survey two weeks after mailing the initial survey. The two week recall period was used to limit the effect of recall bias. To estimate this bias, mail survey data from selected lakes were compared to creel survey data collected during the same period. These comparisons indicated a significant level of bias, which was then able to be corrected for.

Mail surveys have also been used to collect long-term recreational catch and effort data for lobster species; the western rock lobster (*Panulirus cygnus*) in Western Australia (Melville-Smith and Anderton, 2000) and the Caribbean spiny lobster in Florida (United States) (Sharp et al., 2005). In Western Australia, the recreational western rock lobster fishery was surveyed between 1986–1999. At the end of each year's 7.5 month fishing season 1000–22,000 survey forms were mailed to a random selection of lobster licence holders. Respondents were asked to complete a questionnaire relating to their fishing activities during the fishing season. Responses were used to estimate the proportion of

licence holders using their licences in each season, fishing method (pots or diving), fishing location, effort, and the total catch by each fisher, stratified by region (Melville-Smith and Anderton, 2000). The authors admitted that some recall and non-response biases were probably incurred, but felt that the annual catch and effort trends observed were still representative of the fishery. Usually, problems with non-response bias are addressed by sending follow-up mail surveys or telephoning a sample of non-respondents to compare their activities with respondents. Several other examples of the use of mail surveys exist, however they are usually combined with on-site methods (e.g. access point survey) and are dealt with in detail in Section 6.3.3 under 'complemented surveys'.

Telephone surveys

Like mail surveys, telephone surveys alone are not commonly used to collect both catch and effort data (but see Weithman and Haverland, 1991; Cockcroft and Mackenzie, 1997; Coleman and West, 1999; Mateo, 2004; Cahalan, 2006). However there are numerous examples where they have been used to collect socioeconomic and attitudinal information from fishers (Peachey, 1998; Thunberg, 1999; Whitehead et al., 2001; Duda et al., 2002; Baharthah and Sumner, 2003; Higgs, 2003; Arlinghaus, 2004; Sutton, 2005; Sun et al., 2007; Cook, 2008). They are usually employed to provide fishery-wide effort estimates in complemented surveys, or used to recruit fishers into more specific surveys, such as diary surveys (Henry and Lyle, 2003; Higgs and McInnes, 2003). Traditionally, telephone surveys are conducted using one of three methods: random-digit dialling, directory frames or special registration lists (Pollock et al., 1994). With random-digit dialling, all possible numbers are included (listed and non-listed) and contact is made with fishers and non-fishers. Within this method recreational fishers can be sampled in several ways. 'Basic methods' involve selecting a region of interest in a predetermined manner and then randomly selecting phone numbers within that region. This approach is commonly used to estimate participation rates within the wider community. However, this method can be inefficient for specifically surveying fishing households since a low percentage of calls generally intercept fishers. The 'Panel option' is an approach that reduces these inefficiencies by using telephone numbers that have previously been identified as fishing households from previous large-scale phone surveys.

Directory frames are telephone subscriber lists that include both fishers and non-fishers; however they do not include unlisted numbers (see Morales-Nin et al., 2005). Like random-digit dialling, there are variations in sampling approaches from directories, such as 'simple random sampling', 'systematic random sampling' and 'add-a-digit sampling'. A detailed description of these method variations can be found in Pollock (1994). There may also be an option to sample from directory frames that have been developed by commercial businesses, although these may be expensive to access and possibly not representative.

Special registration lists relate more directly to fishers and can include fishing club members, fishing licence lists and boat registrations. While these specialist lists exist, it does not always guarantee that they can be utilised for recreational fishing survey purposes. For example, in consideration of survey design for the Queensland's Department of Primary Industries and Fisheries (QDPI&F) "RFISH" program (Australia), a request to the Queensland Transport Department to access the state's boat

registration list was denied due to privacy issues (Stephen Taylor, QDPI&F, personal communication).

Random digital dialling was the preferred method for a telephone survey associated with the US Marine Recreational Fisheries Statistic Survey (MRFSS). In this survey, regions within 30–80 km of the coastline, depending upon the state, were selected in a predetermined manner and phone numbers were then randomly selected within these regions. This survey could not use list frames as many of the US states do not require fishers to posses a marine fishing licence. A similar situation exists in Australia where only NSW and Victorian marine hook and line fishers are required to hold a fishing licence. However using these current licence lists can be problematic. For example, the NSW and Victorian fishing licence have age and concession card holder exemptions, which would certainly exclude some fishers in recreational fishing surveys that use these list frames. The National Recreational and Indigenous Fishing Survey (NRFS) undertaken in Australia (Henry and Lyle, 2003) used a sampling frame based on the 'White Pages' telephone directory (electronic version) to conduct an initial screening survey to locate fishing households to which a requested was made to take part in a diary survey. Similarly, the Telecom White Pages were used in New Zealand for regional telephone-diary surveys in the early 1990's (Teirney et al., 1997). An added benefit of using directory lists rather than random-digit dialling is that business numbers and multiple household listing can be filtered out.

Telephone surveys are highly vulnerable to recall bias if the period between surveys, or the period being asked to recall, is greater than two months (Pollock et al., 1994; Hart and Reynolds, 2002). As a result, surveys usually define a recall period of less than two months (see Henry and Lyle, 2003; Comanducci and Driscoll, 2008). Other biases can also be common including prestige bias, rounding bias (rounding up or down catch numbers), and intentional deception (Pollock et al., 1994). Telephone surveys have some advantages over on-site creel surveys and mail surveys in that they can cover larger geographical areas at lower cost. Other advantages of telephone surveys include; rapid data collection and the ability to collect data from fisheries that have a night fishing component, which is often considered unsuitable for use in on-site methods due to safety concerns for survey staff. Furthermore, telephone surveys generally have higher response rates than mail surveys but have lower response rates than creel surveys (McClanahan and Hansen, 2005). A long-term state-wide study in Missouri (US) (Weithman and Haverland, 1991) achieved a very high response rate of over 90% using phone numbers from a fishing licence list. In contrast, Jennings (1992) achieved less than a 50% response rate from a 3-month telephone survey in the U.S. Virgin Islands in 1986 using directory listings. This study showed that the response rate was related to the time calls were made, where much higher responses were achieved during the evening compared to the day. More recently, response rates to telephone surveys have been declining due to a number of factors including telemarketing saturation, suspicion by the public, and the attrition of home land-lines due to the increasing use of mobile phones (N.R.C., 2006). As a result, the use of websites for conducting surveys (or catch reporting) needs consideration as an addition, or alternative to telephone surveys. Some of these online tools are discussed in Section 6.5.

Weithman and Haverland (1991) found that telephone surveys were better for estimating recreational catch and effort for the large, high-use water bodies in Missouri

(US) than creel or mail surveys due to their higher spatial coverage. In this study, samples were selected randomly from a state-wide database of licensed fishers, stratified by licence type, and contacted by phone. Fishers were then screened to see if they were interested in participating in the survey for a 2-year period. One problem with a screening process is the potential to include more avid fishers who are often more interested in participating than more casual fishers, which can contribute to avidity bias. For example in a Queensland study, Sutton (2006a) found that recreational fishers who participate in public consultation programmes are not representative of the wider recreational fishing population. He found that participants were different from non-participants because they were more avid fishers, placed a greater importance of fishing activity to their lifestyle, and they were more involved in fisheries-related organisations. Therefore, due to avidity bias it is possible that catch and effort estimates can be overestimated. Henry and Lyle (2003) also used a screening process to recruit fishers into a dairy program. During this process, fishers were asked about their fishing frequency over the previous 12 months (estimated number of days fished) and their intention to fish in the following 12 months in order to gain an understanding of fisher avidity. Only those who intended to fish in the following 12 months were invited to participate in the diary program. As a result, there was a possibility that avid fishers were overrepresented in the diary program. Subsequent analysis of the reported behaviour of diarists revealed that this had occurred and an adjustment factor was applied to account for this bias.

Diaries and catch cards

Diaries are used when detailed information for individual fishing trips is required from a large number of fishers over a long period. Diaries are usually supplied in the form of a booklet and guide the fisher in data recording. When completed, the diaries are mailed back to survey staff. Catch cards, on the other hand are generally used for single fishing trips. They are given to fishers at the beginning of their fishing trip and asked to record their catch and effort for that particular trip. Catch cards are usually returned to the survey staff at the end of their fishing trip that day, or are returned by mail.

As with the other off-site methods, examples of using diaries and catch cards alone to estimate catch and effort are uncommon. Despite being regarded as inexpensive and simple to apply, these methods, like mail and telephone surveys, have the major disadvantage of collecting self-reported data. Recall bias can be a problem but can be minimised if diaries are completed immediately after a fishing trip is completed. Lyle (2005) compared the effectiveness of recall telephone surveys with diaries and found that effort from telephone surveys was over estimated by a factor of two. Non-response, decrease in participation, and accuracy/completeness of data are other common problems in voluntary diary surveys, especially when the survey period is long (Pollock et al., 1994). For example, in New Zealand, diarists admitted during an exit survey for the 2000–2001 national survey that they did not record all of their fishing trips or all of their catch (Gowing and Boyd, 2004). This is not only due to diarists simply forgetting to complete diaries, but can also be due to ‘burnout’, if the diarists feel that the workload is too large (e.g. too many fields to complete in diaries, or the program is too long). Problems associated with prestige bias, misidentification of fish species, and incorrect recording of fish lengths and weights can make the data unreliable for catch and effort information. The vast majority of diary programs are voluntary which make

them susceptible to non-response bias. For example, Morton and Lyle (2003) received only a 10% response rate in a diary survey of gamefish catches by fishing club members in Tasmania. Similarly, only 19% of diaries were returned in a state-wide volunteer angler diary program for the 1995 fishing season throughout Mississippi (US) (Bray and Schramm, 2001). Even for recreational fisheries that have mandatory catch card reporting, response rates can be low. Kalvass and Geibal (2006) reported only a 24% return of catch cards used to record the recreational red abalone catch and effort in California (US) for the 2000 fishing season. Avidity bias can also be an issue with the use of diaries. Evidence of this type of bias is provided in a comparison of bag size frequencies reported by diarists to those interviewed by survey staff at boat ramps in New Zealand in 1996–2000. Here, diarists reported far fewer zero catch bags and also tended to have larger bag sizes compared to fisher catches sampled at access points (see Hartill et al., 2008).

A number of comparative studies in North American freshwater lakes have examined the effectiveness of fisher diaries with mixed results (Gabelhouse and Willis, 1986; Green et al., 1986; Bonney, 1987; Anderson and Thompson, 1991; Bryant and Jones, 1991; Sztramko et al., 1991; Prentice et al., 1995; Bray and Schramm, 2001). For example, Bray and Schramm (2001) found significant differences between catch rates derived from fisher diaries, electrofishing and creel surveys for black bass and crappies in waters throughout the state of Mississippi. In this study, the authors determined that the catch rates of diarists differed from the general recreational fisher surveyed in creel surveys throughout Mississippi, which would bias catch rate estimates upward. Bryant and Jones (1991) found significant differences between diary and electrofishing catch rates for largemouth bass in a North Carolina lake. However, Green et al. (1986) found no significant differences between fisher diary and electrofishing catch rates for the same species in twelve New York lakes. With respect to size structure of captured fish, Prentice et al. (1995) found no significant difference between fisher diary and electrofishing catches, suggesting that diaries were accurate in this instance.

Catch cards have been applied in the US by NOAA Fisheries in conjunction with the States of North Carolina and Maryland (1999) to monitor the recreational catches of bluefin tuna, swordfish and billfish. These state catch card programs were established to assist in the real-time monitoring of national catch quotas which are set by the International Commission for the Conservation of Atlantic Tunas (ICCAT). Survey staff seasonally distribute landing tags and collect catch cards from reporting stations, which are mainly privately-owned bait and tackle shops. Released fish are not required to be reported. When a fisher lands a listed species, they are required to complete a landing card which includes information such as fisher name, vessel permit, landing tag number and fish size. The fisher then submits the landing card and in return receives a self-locking, uniquely-numbered tail wrap tag that must then be affixed to the fish before being removed from the vessel. Compliance with this reporting method is normally problematic. However the non-compliance reported for the Maryland Catch Card program has been relatively low (about 15% 2003-05). This success has been attributed to strong awareness of the program and the willingness of fishers to cooperate. Another contributing factor is that Maryland has a small coastal size with only one port (with seven docks), which allows for thorough and cost-effective monitoring by field staff.

Door-to-door surveys

The use of door-to-door surveys will receive little attention in this review as they are not considered to be a suitable option for surveying large-scale Australian Commonwealth fisheries as they are labour intensive, expensive and logistically cumbersome. Briefly, there are two types of sampling techniques used in door-to-door surveying: quota and probability sampling (Pollock et al., 1994). Quota sampling was developed to in an effort to reduce costs by sampling only groups of 'people of interest' from a population, which can be identified from census figures. Quotas are then assigned to each of these groups in relation to their relative size to that target population. A potential bias of this method is that in contacting their quotas interviewers may choose to interview those who are easy to contact. However, if there are discrepancies in fisher characteristics between fishers who are easy and more difficult to contact, then biases are likely to result.

The second technique, probability sampling, involves selecting households to survey from a list or area frame. List frames can be derived from licence frames, while an area frame is based on a complete list of residential areas in a geographic region. With respect to list frames they have the advantage over area frames as they can be more easily targeted towards fishers. However, households on these lists may be widely dispersed, increasing travel and labour costs for the interviewer to travel large distances between households. In contrast, area frames usually reduce the long distance travelling component. Area frames are normally developed in a two stage process where initially a sub-area is chosen with some level of probability from a larger geographic region. Within this sub-area, all households are assigned a number from which a subsample is selected. While there are costs associated with this household enumeration and selection process, it is generally regarded as being less expensive than using list sampling.

Similar to other off-site methods, the major disadvantage of door-to-door surveys is that data is recalled and self-reported, resulting in biases that have already been discussed previously. However non-response bias is likely to be less of a factor in a face to face situation, compared to over the phone or by mail (Pollock et al., 1994). In terms of a large-scale example, the US National Survey of Fishing, Hunting, and Wildlife-Associated Recreation have used door-to-door sampling every five years since 1955. The survey is conducted at a state-wide level and collects data on the expenditure for different activities undertaken by hunters, fishers, and wildlife watchers. The recreational fishing component is broken down into freshwater, saltwater, and freshwater (not including the Great Lakes). In each of these categories, participation rates, overall days fished and days fished for targeted species, the number of angling trips and expenditure is recorded.

6.3.2 On-site survey methods

Creel surveys

Creel surveys are probably the most commonly used recreational fishing survey method, especially for specific fisheries in defined water bodies (Newman et al., 1997). Creel surveys can take the form of an access point or roving creel survey. There are many examples where creel surveys alone have been used to estimate catch and effort and/or

to collect demographic and attitudinal information (McGlennon and Kinloch, 1997; Conron and Bills, 2000; Everett et al., 2002; Hart, 2002; Allen et al., 2003; Hall and Douglas, 2003; Ferrer Montano et al., 2005; Vandevalk et al., 2005; Smallwood et al., 2006; Prior and Beckley, 2007). Sampling involves survey staff intercepting fishers at specific times and places to record data relating to their fishing activities, such as catch and effort, and sometimes biological information from retained fish (Roach et al., 1999). It also entails instantaneous 'head counts' of all active fishers during the survey period.

Access point surveys are most useful where the majority of fishers use publicly accessible sites to access the water, such as public boat ramps, piers and marinas. Traditional access point surveys are used when a limited number of access points can be sampled adequately with staff resources. However, for water bodies with many access sites, a form of the traditional access point survey – the bus route method – is generally favoured. This method involves numerous access sites being treated as a group that is sampled during one or more days. The survey route is similar to a bus route with 'stops' at designated places (access sites) on a predetermined time schedule (see Hart and Walker, 2004; Smallwood and Sumner, 2007; Braccini et al., 2008; Steffe et al., 2008; Wilberg and Humphrey, 2008). Roving surveys are used when a fishery can be accessed from too many points that can be visited by a traditional access point design (Robson, 1991; Pollock et al., 1994), or where there are private access points inaccessible to survey staff. These surveys are conducted by boats to contact on-water fishers, or by foot, bicycle or car, to contact shore-based fishers.

Spatial and temporal frames are an important consideration when designing a survey for on-site methods. Unlike list frames that are used for off-site surveys, the frame for on-site surveys consists of time and physical locations (Pollock et al., 1994). For example, in a study by Smallwood et al. (2006), roving creel surveys were used to estimate catch data from shore-based fishers in the Rottnest Island Reserve in Western Australia. Surveys were conducted for eight days per month, with four groups of consecutive days randomly selected during this time period. The surveys were stratified by weekdays/weekend days and six hourly morning and afternoon shifts. For each month an equal number of day types and shift types were sampled. At these times, vantage points and access points were visited to identify fishers and sample their catch. The survey agent travelled a consistent route around the island, where the starting points and travel direction were randomly selected on each occasion. Importantly, eight zones were created along the route to serve as checkpoints to monitor equal travel time per zone. Fixing times along routes is important to the catch and/or effort at any single location biasing overall estimates (Wade et al., 1991). It is also useful to conduct pilot studies in order to evaluate characteristics of fisheries and therefore guide the development of spatial and temporal survey design (see McGlennon and Kinloch, 1997).

Access surveys have a distinct advantage over off-site methods in that catches can be inspected to collect accurate species and size composition data, provided fishers reveal the interviewer their entire catch. Because fishers are generally interviewed on completion of a trip, recall accuracy of fishing effort and details of released fish can also be high. A disadvantage of access point surveys, as well as roving creel surveys, is that fishers may use several access points over time and survey staff may not be able to survey all fishers if the number of access points is large (Malvestuto, 1996). A disadvantage of creel surveys is that fishers are usually interviewed before their trip is

complete, which can affect the way catch rates are estimated (Hoenig et al., 1997; Pollock et al., 1997). 'Length of stay' bias is another problem that is very difficult to correct for. The premise is that fishers who fish for longer periods are more likely to be interviewed. The result is that overall mean trip length for roving surveys is considerably longer than the mean trip length determined from completed trip surveys. For example, in a review of angling surveys conducted by the FishCare Volunteer (FCV) Program for coastal and inland waters of NSW (Australia), Park (2006) found that the average fishing time for completed trips from access point surveys was 1 hour 53 minutes. However, in roving creel surveys, where an actual fishing time was recorded for start of fishing until the interview time, the average length of incomplete trips was 3 hours and 12 minutes. He attributed this discrepancy to 'length of stay' bias. This is not a problem if fishers undertaking short and long trips have similar catch rates, but in many circumstances, this may not be the case. For example, if those fishing for longer periods have been more successful than those who left the fishery early, then potentially a disproportionate number of these fishers could be interviewed resulting in catch rates biased high. The over-representation of avid fishers (those who participate more frequently) in a survey can also lead to avidity bias. Thomson (1991) estimated the avidity bias associated with Californian fishers using effort data from an on-site (access) survey. After correcting for this bias a comparison was then made between the actual participation rates (effort) and the adjusted participation rates revealing that without bias correction, fishing effort per fisher can be grossly overestimated.

Overall, on-site surveys allow species-specific catch rates and size composition data to be collected. On-site surveys have the obvious disadvantage over off-site methods in that they are labour-intensive and expensive. As a result, most studies undertaken by fisheries agencies are small-scale or short-term 'snapshots' of the recreational catch (e.g. Malseed et al., 2000; Morton and Lyle, 2003; Steffe et al., 2005a; Steffe et al., 2005b; Rangel and Erzini, 2007; Smallwood and Sumner, 2007), but a few multi-year studies have been completed (Steffe et al., 1996; McGlennon, 1999; Reid and Montgomery, 2005). However, when used in conjunction with well-designed less expensive off-site surveys (e.g. telephone and diary), detailed catch and effort information collected in on-site surveys can be scaled up to provide species-specific catch estimates for the entire recreational fishing community. Specific examples of these will be discussed in detail in Section 6.3.3.

Other potential shortcomings of on-site surveys is that they are generally only representative of the daytime catch (see O'Neill, 2000; Malseed and Sumner, 2001; Reid and Montgomery, 2005; 2005a; Steffe et al., 2005b), since night-time sampling is generally not undertaken due to safety concerns for survey staff (see Mann et al., 2003; Beckley et al., 2008) but also because it is difficult to accurately obtain a count of participating fishers. As a result, the total recreational catch can be underestimated, as was noted by Williamson et al. (2006) when surveying recreational catches of the Pilbara region in Western Australia. One partial solution is to intercept fishers very early in the morning who have fished during night hours, although fishers who depart before the interview period will obviously not be intercepted. Estimating fishing effort using roving surveys can be problematic where boat trailers are required to be counted to estimate the boat-based effort (e.g. Sumner and Williamson, 1999). Overestimates in effort are often encountered using this method, since not all boats belonging to counted trailers participate in fishing activities. Roving surveys that survey large numbers of

sites across large spatial scales are particularly susceptible to incurring this error, since it is often not possible for survey staff to monitor the activities of individual vessels. Innovative methods to monitor fishing effort at boat ramps, that do not require survey staff to be on-site, include the use of traffic counting machines or remotely operated cameras.

Aerial surveys

Aerial surveys are only used in recreational fisheries to estimate effort by counting boats and shore-based fishers (Kerr and Cholmondeley, 1992; Sylvester, 1996; Hardie et al., 2002; Scholten, 2003; Volstad et al., 2006). Usually they are combined with another on-site method (e.g. creel survey) that can estimate catch rates, which are then scaled up to the effort estimated by aerial surveys. Aerial surveys are particularly useful for recording large numbers of fishers or boats over large geographic areas in a relatively short period of time, and are considered cost-effective if the alternative is a labour-intensive on-site method for counting fishers. Usually aerial surveys cover a randomly selected portion of a fishery area where observers make progressive instantaneous counts of either individual fishers or boats. The total effort for the fishery is therefore calculated by scaling up the counts to the total fishery area, assuming effort is distributed randomly. Similar to creel surveys, aerial surveys require spatial and temporal stratification to account for variation in effort at particular time periods and locations within the fishery.

A number of factors have the potential to compromise fishing effort estimates during aerial surveys. For example, effort may be underestimated if fishers are obscured (by various forms of cover), widely dispersed (Hartill and Vaughan, 2006), or overestimated if counted boats are used for other activities other than fishing. However, the latter bias may be reduced if photographic or video evidence is used to assist in the identification of activities. The inability to fly on randomly selected days due to poor weather may also create bias. For example, Fraidenburg and Bargmann (1982) pointed out that a good flying day is usually autocorrelated with a good boating day, therefore providing effort estimates that were biased high. This could be adjusted for by on-site counts in poor weather conditions, and expanded based on weather history during the study period.

6.3.3 Complemented surveys

When two or more basic survey methods are used this is often referred to as a complemented survey. Basic survey methods can be used in various combinations depending on specific aspects of the fishery in question, such as geographic scale, cost, practicality and the types of estimates that are required (Pollock et al., 1994). Complemented surveys are used extensively for catch and effort estimation of recreational fisheries and will provide the most relevant examples for application to recreational fishing within Commonwealth fisheries. Complemented surveys are useful for dealing with large complex surveys to estimate catch and effort but they are also useful for correction of particular biases. For example, non-response bias is often present in mail surveys (see McClanahan and Hansen, 2005; Sharp et al., 2005). To address this problem, a telephone survey can be used to contact a subset of non-respondents to determine if their responses differ to respondents, and if so, the estimates from the mail survey can be corrected (see Kalvass and Geibel, 2006). In another example, catch rates from incomplete trips in roving creel surveys can be biased if they differ to those of completed fishing trips. In these instances an access point survey can be used to effectively capture completed trip catch rates to determine differences in catch rates between the two methods (see Bernard et al., 1998).

A number of local, regional or state-wide surveys, in Canada, New Zealand, the United States and Australia, have used, or are currently using, a complemented survey design with an off-site and on-site method or with a combination of two on-site methods.

The Georgia Strait Creel Survey (Hardie et al., 2002) in Canada, the Great Lakes Surveys (Lockwood et al., 2001) and the Delaware River Creel Survey (Volstad et al., 2006) in the United States, and several New Zealand regional studies (Hartill et al., 2008) all used an aerial survey combined with an access point survey. Since 2004, regional fisheries in New Zealand have primarily been assessed using this method, where an instantaneous count of all fishers or boats is made from the air. Access point surveys are conducted within the same 24-hour period to estimate catch and effort by intercepting fishers. The effort estimates derived from the air are used to scale up catch rates from the access point interview data to estimate catch for the entire fishery.

There are two forms of the aerial/access point design. The traditional method, which was used in the Georgia Strait Creel Survey and in New Zealand up until 2004, involves separating the sampling day into two or more time bins and deriving estimates of catch for these times. To achieve this, fisher counts from the air for a predetermined time period within the time bin, are multiplied by the length of the time bin to calculate the total number of hours fished. The hours fished per bin are then multiplied by catch rate estimates from boat ramp interviews to estimate total catch. This method was used in 1994 to estimate the snapper harvest in the inner Hauraki Gulf, New Zealand (Sylvester, 1996).

A more recent approach, known as an aerial ramp census, was developed in New Zealand in 1993 to survey large fisheries in which only a single flight each day is possible. This approach is different to the traditional method as the total catch from a number of representative boat ramps are recorded from dawn to dusk on a single

sampling day, rather than a catch rate estimate by interviewing a subset of fishers at several ramps. Effort estimates from the air are again used to scale up the total catches at each ramp. However, the way in which aerial fisher counts are used to scale up the catch also differs between the two methods. During the access point surveys for the 'aerial ramp census' method, fishers are asked when they were fishing. This information is used to calculate a ratio of fishers to non-fishers for time periods throughout the day and can be related to aerial counts for the same time periods. As a result, a coefficient based on this ratio is used to scale up an observed catch rather than using the traditional method where instantaneous aerial counts are used to estimate the number of hours fished for individual time bins within a day.

An advantage of using this aerial ramp-census approach is that there is no requirement to estimate average catch rates, which do not conform to any commonly used statistical distribution (Hartill et al., 2008). Furthermore, the estimate of average catch rates (and the associated variance) can be problematic on days when limited catches are reported.

In the United States the National Marine Fisheries Service (NOAA) have used the Marine Recreational Fisheries Statistic Survey (MRFSS) as the primary data source for recreational fishing in North America. The general approach is a complemented survey design combining a telephone survey (random-digit-dialling) to estimate effort and creel surveys (mainly access point) to estimate species-specific catch rates. Within this survey framework there are several specialised large-scale marine surveys, one of which is the Large Pelagics Survey (LPS) in the eastern US. This survey has direct relevance to Australian Commonwealth fisheries as the species and mode of targeting by fishers are similar.

The LPS is conducted annually from June to October in offshore waters from Maine to Virginia (~1000 kms of the eastern U.S. coastline) to estimate the annual recreational catch for large migratory pelagic species such as tunas, billfish, sharks, wahoo, dolphinfish and amberjacks. A complemented survey design is employed consisting of an access point survey to collect catch rates for each species from private and chartered vessels and a telephone survey using the 'highly migratory species' permit holder directory. Weekly or fortnightly telephone surveys are used to contact a subset of fishers on the directory list to estimate effort (number of pelagic fishing trips), which is scaled up to the size of the entire directory. The access point surveys are conducted on randomly selected days at randomly selected access points to collect catch and effort data from completed trips. During these access point surveys demographic information is also collected from fishers to ascertain whether they are 'in-frame' (i.e. own a telephone and reside within the telephone survey zone). An adjustment factor is used to expand the effort estimates from the telephone survey to account for those that fished but were not in-frame. This survey involves real-time monitoring of the fishery which is labour-intensive and therefore expensive, but produces highly accurate species-specific catch and effort data. This is particularly important with respect to Atlantic bluefin tuna catches by the recreational fishery, which are required to be monitored alongside commercial catches.

In Australia, Morton and Lyle (2003) surveyed the Tasmanian Game Fishery with a focus on SBT. This was a short-term study (April–May 2003) using on-site and off-site methods to estimate the recreational catch and biological characteristics of the catch

from chartered and private vessels. Access point surveys were conducted at one port during the peak fishing period, where individual fish were identified and measured. These on-site surveys were complemented with off-site fisher diaries, telephone interviews and charter boat logbooks. Unfortunately, no SBT were recorded from the on-site surveys, however other species provided a 'road-test' of the methodology. One of the problems with the survey was that the on-site component only covered a limited geographic area (only one port in southeastern Tasmania). Therefore, it was unlikely to have provided a good estimate of the total catch and effort for the entire Tasmanian game fishing season. The authors also noted other problems; in particular the non-club fishing component was not surveyed in other areas, meaning that the total catch estimate was underestimated. Furthermore, basing the survey around fishing tournaments was not considered adequate to account for the temporal variability in the availability of pelagic fish in Tasmanian waters.

In another Australian example, Western Australia's Department of Fisheries used a complemented survey design, with a combination of two on-site methods, to monitor recreational fishing catch and effort. The program has monitored recreational catch and effort since 1996 and has a long-term strategy to undertake 12-month creel surveys of recreational fishers in each of four bioregions on a rotational basis every 5–6 years (Penn, 2003). Catch and effort data of shore and boat-based recreational fishing were collected using a complemented bus route (access point) and roving creel survey approach (see Sumner and Williamson, 1999). The approach was successful in surveying the recreational species and size composition of the catch (and releases), effort and fisher attitudinal information across large spatial scales, such as the Pilbara, Gascoyne and west coast regions (Sumner and Williamson, 1999; Sumner et al., 2002; Williamson et al., 2006). Although on-site surveys are often expensive, the Western Australian examples demonstrate their usefulness for collecting detailed recreational fisheries data across large spatial scales, particularly in remote areas. This method is particularly relevant to large Commonwealth fisheries, such as the Coral Sea Fishery and the Southern and Eastern Scalefish and Shark Fishery (SESSF). There are several shortcomings of on-site surveys that cover large areas. For example, staff can only spend relatively short periods surveying a large number of sites, which will poorly sample rarer event captures of game fishes, such as marlin. The alternate option is to spend longer periods surveying a smaller number of main access sites (see Steffe et al., 1996), where the assumption is that the catches are representative of the entire fishery. In both cases, especially the first, the catch is generally underestimated.

Steffe (1996) also conducted a state-wide survey of recreational trailerboat fishers using a complemented on-site method. This survey was conducted over a two year period and aimed to estimate the daytime catch and effort directed towards pelagic, shelf and slope species in the offshore waters of New South Wales, Australia. Large access points (i.e. major launching ramps for offshore trailer-boat vessels) were surveyed using on-site creel surveys. Catch rate estimates were calculated from over 10,000 interviews, which represented less than 3% of the estimated number of trips over the study period. To extrapolate the catch rates over the survey region, effort data (counts of assumed fishing boats going to sea) were conducted by survey staff and by daily log sheets filled in by volunteer sea rescue bases that overlooked access points. These counts included not only trailer-boats but larger cruisers, game boats and charters boats in order to represent the all types of fishing effort. Due to the large number of on-site interviews this study

probably provided reasonable estimates of catch rates for many of the more commonly caught species. However, creel surveys were not conducted for non-trailer boats, and as a result, catch rate estimates of species such as tuna, billfish and marlin were probably underestimated, as they are generally caught by larger vessels. The inability of this survey to cover many of the medium and small access points throughout the large survey region may also have resulted in underrepresentation of some species and an underestimate of the total catch of these species. Another criticism, relates to the estimates of effort with respect to the log sheet recording of vessels by volunteers at sea rescue bases. For example, these bases do not cover the entire coastline and some vessels do not log on before fishing. Also the study could not confidently differentiate between fishing and non-fishing vessels.

The Industry and Investment NSW Gamefish Tournament Monitoring Program uses two on-site methods to estimate catch rates (number of fish caught per boat per fishing day) for species such as billfish, tuna, sharks and other sportfish caught only during major tournaments attended by clubs affiliated with the NSW Gamefishing Association (Lowry and Murphy, 2003; Lowry et al., 2007). Currently, this program collects data primarily from off Australia's NSW coast, although sampling was previously undertaken in southern Queensland. Data from scheduled hourly radio reports (or 'scheds') from game boats are used to record the fishing location within pre-defined reporting grids and species-specific catch in terms of numbers, estimated weights if not landed and tagging status. In most years, on-site interviews also take place at boat ramps, weigh stations and marinas to not only validate reported catches, but to also measure landed fish (length and weight), which include those not reported or weighed during the tournaments for a variety of reasons. The result is a more comprehensive estimate of catch from tournament participants. Unfortunately, this data is not representative of the catch or effort of the entire game fishing sector as it only covers club boats fishing in major tournaments. However, what the data does provide is a consistent measure of catch rates, from same locations and time periods, for a number of recreationally-important target species (e.g. tuna, billfish and sharks) and bait species (e.g. blue mackerel) (Lowry et al., 2006) shared with Commonwealth fisheries. This program does not have the capacity to sample land-based game fishing (Barrett, 2006) or the 'bluewater' spear fishing sector that account for additional catches of species caught in these tournaments.

The use of tagging data, while not used to estimate robust catch and effort information directly, can be useful in providing supplementary data in terms of species-specific size composition. It may also provide a proxy for changes in the relative abundance of species provided consistent spatial and temporal tagging efforts are conducted. This is particularly relevant for several pelagic gamefish species in Australia, such as yellowfin tuna, dolphinfish and black marlin (see Pepperell, 1994a; Dempster, 2003; Williams, 2003).

In situations where detailed information is required for large regional and even national scales, it is generally not cost-effective or practical to use any form of on-site method. For example in New Zealand, several regional and national studies between 1992 and 2001 used telephone-diary surveys. While in Australia, several state fisheries agencies including Queensland, South Australia, Tasmania, Victoria and Western Australia, have undertaken, or are currently undertaking, off-site complemented surveys (diary and/or

telephone surveys) to monitor general recreational catch and effort. The specific aims of the surveys vary between states, but these off-site surveys are used to gather information on catch, effort, motivation for fishing, participation rates, and expenditure on fishing. One of the best examples of a complemented off-site long-term program for monitoring recreational fishing is the QDPI&F "RFISH" program. The primary aim of RFISH is to collect representative catch and effort data of the recreational community to incorporate into stock assessments of particular species. The program consists of three survey methods (telephone, diary and a socioeconomic survey) that are conducted on a state-wide scale. The surveys have been repeated every two years since 1999 (Higgs and McInnes, 2003; McInnes, 2003) and are planned to continue indefinitely.

Diary surveys of volunteer fishers are used to provide information on the species composition of the catch, number of fish caught (and released) and fishing effort in individual trips, allowing species-specific catch rates to be estimated. This information is used in conjunction with the telephone survey to scale up the catch and effort data to the entire participating recreational fishing community in Queensland. As is the case with off-site survey methods, diary and telephone surveys are susceptible to a range of biases (non-response, recall, prestige, rounding, and intentional deception) that often cannot be validated or corrected. Consequently, the overall survey results are unlikely to reflect the behaviour of the wider recreational fishing community, since more motivated or regular fishers are more likely to accurately and consistently complete diaries (but see Gartside et al., 1999).

On a national level, Henry and Lyle (2003) surveyed the recreational fishing population (marine and freshwater) in Australia using a telephone-telephone survey design with fishers contacted repeatedly using a panel diary approach. As well as estimating catch and effort by species, fishing mode and region, the survey was also designed to collect socioeconomic characteristics. The survey design included an initial screening survey to identify fishing households and to recruit fishers to participate in a follow-up diary survey. The diary survey was then conducted over a 14-month period with monthly telephone contact with participants to gather economic, catch and effort data. A final telephone survey was then used to assess fisher attitudes after the diary survey was completed. The advantages of this type of survey over surveys with an on-site component are that catch and effort can be recorded from fishers who fish at night or return to private docks, jetties and moorings. However, as the data from this survey was self-reported, data reliability concerns are a major issue. In an effort to reduce these errors, fisher data recall was set at one month and they were expected to record data on a trip-by-trip basis.

In a review of the national survey, Pepperell and Dominion (1996) suggested that the use of diaries can also create 'false effort' as some fishers may feel obligated to fish between each monthly reporting period even though they would not normally do so. They also suggested that the catch and effort data was expanded from participation rates that were not current, as the telephone survey used to determine the number of fishers preceded the diary phase by over twelve months. Other aspects of this study not conducive to a long-term approach to monitor catch and effort for use in stock assessments is that the approach is labour-intensive and expensive, and as a result, the survey has not been repeated. Furthermore, measurement of fish size and weight were not required of diarists (only numbers caught and released), and therefore no data on

size composition was available to measure fishing mortality for age-based stock assessment models. Lastly, the survey did not provide high resolution species-specific data and many species groups were required to be lumped under broader categories (e.g. ‘sharks and rays’, ‘mackerels’).

6.4 Global application of survey methods

In total, at least 20 countries have conducted surveys to estimate catch and/or effort by recreational fishers (Table 6.1). Clearly, the United States, Australia, Canada and South Africa have conducted the largest number of recreational fishing surveys since 1990. Generally, intercept surveys have been used to estimate catch and/or effort from small localised fisheries, particularly on lakes, dams and streams, which are common in inland regions of the US, Canada and Australia (Table 6.1). Many of these water bodies have limited access points which allow a significant percentage of fishers and their catch to be effectively surveyed.

Larger scale regional, state-wide and national marine surveys cannot be cost-effectively sampled using intercept surveys alone, as they cover large regions with many access points, or have numerous private access points such as marinas or moorings in canals. In the US, Australia, Canada, New Zealand and South Africa where studies have focused on surveying large-scale marine fisheries, complemented surveys have been employed. In these cases, surveys have commonly consisted as an access point-telephone survey (Table 6.1).

A complete annotated bibliography of the literature used to construct Table 6.1 is given in Appendix 2.

Table 6.1: Summary of the number of surveys undertaken in various countries since 1990 that collected catch and/or effort of recreational anglers using traditional survey methods. Surveys have been stratified by spatial and temporal scale, as well as occurring in marine waters (M), Freshwater (F) or both (B).

	Local						Regional						Statewide						National					
	≤1yr			>1yr			≤1yr			>1yr			≤1yr			>1yr			≤1yr			>1yr		
	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B	M	F	B
Country and method																								
Angola																								
Mail																								
Telephone																								
Internet																								
Diary																								
Intercept	1																							
Complimented																								
Australia																								
Mail																1								
Telephone								1			1		1	1	1									
Internet																								
Diary	1							1			1					3		3						
Intercept	9	16		1			1			2														
Complimented	7			1			5			1	1		1		1	5		2			1			
Brazil																								
Mail																								
Telephone																								
Internet																								
Diary																								
Intercept					1																			
Complimented																								
Canada																								
Mail																								1
Telephone																								
Internet																								
Diary					2																			
Intercept		3			2																			
Complimented					1		1																	

England								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented			1					
France								
Mail								
Telephone								
Internet								
Diary		1						
Intercept								
Complimented							1	
Germany								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented								1
Japan								
Mail								
Telephone								
Internet								
Diary	1			1				
Intercept	1 2							
Complimented		1						
Lesotho								
Mail								
Telephone								
Internet								
Diary								
Intercept	1							
Complimented								

Mozambique								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented		1						
Namibia								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented			1					
New Zealand								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented			4	4				3
Philippines								
Mail						1		
Telephone								
Internet								
Diary								
Intercept		1						
Complimented								
Portugal								
Mail								
Telephone								
Internet								
Diary								
Intercept			1	1				
Complimented								

Puerto Rico								
Mail								
Telephone								
Internet								
Diary								
Intercept	1							
Complimented								
South Africa								
Mail								
Telephone								
Internet								
Diary								
Intercept	2			2				
Complimented	2	3		2				1
USA								
Mail	1		1		1	1		
Telephone				1	3 4 3			
Internet					1			1
Diary	1				1 3			
Intercept	11	2 14		1				
Complimented	2 4		3 1	2 1	2 3	9 1		2 1
Spain								
Mail								
Telephone								
Internet								
Diary								
Intercept	1							
Complimented	1							
Wales								
Mail								
Telephone								
Internet								
Diary								
Intercept								
Complimented								1

6.5 New innovative survey and statistical methods

One of the main problems with monitoring recreational fishing in Commonwealth fisheries is that these fisheries cover large geographical areas (see Griffiths and Pepperell, 2006) making it difficult to cost-effectively apply traditional on-site methods to estimate catch and effort. As discussed, many large-scale recreational fisheries are surveyed using off-site methods (telephone or mail) to estimate total effort. However, these methods have inherent biases, and will require expensive add-on surveys to correct for these biases. Whilst there are likely to be few alternatives to creel surveys for collecting detailed species-specific catch and size composition data, there are emerging technologies and data sources that may allow recreational fishing effort to be estimated more rapidly and cost-effectively. For example, optical satellite imagery or routinely conducted aerial surveillance by Australian Customs and Border Protection Service may provide reliable, cost-effective and near real-time options to estimate effort in large-scale Commonwealth fisheries.

Surveillance flight data

The use of aerial surveillance data from Border Protection Command (BPC) – a division of the Australian Customs and Border Protection Service – could potentially be used to measure the fishing effort in Australia's Commonwealth fisheries. BPC conduct regular (at least once daily) systematic surveying of Australia's Economic Exclusion Zone where they record all vessel types observed along predetermined flight paths on each trip. Recently, BPC data was used to develop a model to provide instantaneous counts of illegal foreign fishing vessels (FFVs) in northern Australia (Griffiths et al., 2008). These data were then used to estimate the total size of the FFV fleet in discrete regions of northern Australia. The primary consideration with using BPC data is that the spatial and temporal coverage and frequency of flights and availability of data may be unpredictable depending on specific threats to national security or quarantine. However, if the recreational fishing effort sampling design is made flexible enough, it may be possible to select flights from particular sampling strata (e.g. days, regions, seasons) without violating assumptions of particular statistical survey designs.

Another potential issue using BPC data is determining the type of fishing occurring in each observed recreational vessel. This is probably not a significant problem for game fishing, but it may be more difficult to distinguish recreational from commercial vessels that are bottom/reef fishing, unless observers can record commercial fishing licence numbers on every vessel. A further point is that only day-time effort would be estimated accurately, which may not be a significant issue as most game fishing and bottom fishing is undertaken during the day, with possibly a small amount of effort during darkness before sunrise and after sunset.

Remotely sensed imagery

There is a growing interest in applications for remote sensing systems for maritime surveillance such as maritime security, illegal fishing, oil discharge and sea pollution monitoring (Corbane et al., 2008). Unlike many commercial vessels that are required to have a Vessel Monitoring System (VMS), the activity of smaller recreational vessels is

unregulated. Remote sensing has therefore been considered as a possible cost-effective and practical alternative to provide a more comprehensive understanding of vessel movement dynamics.

Space-based imaging for ship detection and maritime traffic surveillance has been the focus of major research efforts in the fields of automatic target detection and recognition. Vessel detection and classification with satellite can be based on Synthetic Aperture Radar (SAR) or from optical imaging (e.g. Quickbird, Ikonos, SPOT-5, ADEOS); with those automatic systems developed for optical imaging, such as eCognition, being the more successful of the two (see Greidanus, 2005). However, these systems are limited in that they can currently only classify medium to large vessels (>10 m). This may be a concern since an increasing number of small (<8 m) trailer boats are targeting large pelagic fish (marlins and tunas) and slope species (e.g. blue eye and hapuka) in Commonwealth waters. Other detection problems also exist such as adverse weather (cloud cover and high seas) and night observation.

Despite these negatives, some advantages of using this technology include archived data dating back to 2001, and the capability of forward acquisition of images, whereby the client can specify coverage of a region at a particular time in the future. However, this can be unreliable due to weather and the requirements of priority clients such as the military. Nevertheless, the cost effectiveness and suitability of these data for estimating fishing effort should be considered, especially if it can be used in concert with aerial surveillance data to account for periods where BPC may be concentrating their surveillance in regions outside the fishery of interest. The overall cost of utilising this data will obviously depend upon the extent of coverage required in the context of a monitoring design. However, indicative costs of imagery at a suitable resolution (e.g. 2.5 m to identify vessels <8 m) from various satellites are: Quickbird ($15 km^{-2}); Ikanos ($10 km^{-2}), Spot-5 ($5000 for a 60 km^2 scene) and ADEOS ($1000 for a 30 km^2 scene). In addition to these costs, there may be additional orthorectification and/or mosaicing fees up to $1000 per dataset request. The total cost for obtaining data for a single day for an assumed 500,000 km^2 of the Eastern Tuna and Billfish fishery where recreational fishing is likely to take place may be between $60,000 and $7,000,000.

Traffic counters

The Capricorn Reef Monitoring program (CapReef) was initiated in 2005 to understand the effects of new marine zoning for the Great Barrier Reef on the reef ecosystem and recreational fishing (Sawynok, 2005). This program provides an example of an innovative and cost-effective approach to monitoring recreational catch and effort for pelagic and reef species for a discrete region of the Queensland coast. This program is innovative for several reasons. First, it is a community-driven rather than being operated by a government agency, and therefore is reasonably inexpensive to run since it relies on volunteer labour for sampling. It has been successful because of community ownership, resulting in high levels of co-operation from recreational fishers. Second, some methods used in this program to estimate effort are innovative, such as the use of traffic counting machines at boat ramps to estimate effort of boat-based fishers, which is an approach now being used by other state agencies (see Conran and Coutin, 1998; Steffe et al., 2005a). The CapReef program is largely coordinated and linked closely with recreational fishing clubs, the charter industry and the general public, who provide

ongoing catch and effort data (catch rates and size structure) for both line and spear fishers via access point creel surveys at boat ramps, counts of boat trailers by traffic counting machines and by observation during access point surveys. The use of on-site surveys can provide good species-specific catch rate data, particularly for species which are easily identified. However, effort estimates used to scale up the catch rate data will most likely have inaccuracies since trailer-boat counts by access point interviewers and traffic counting machines do not differentiate between fishing and non-fishing boats. In areas where access points for boats leaving or coming back from a fishing trip are not all covered by launching ramps (e.g. where private moorings are common inside estuaries), this method would also underestimate total fishing effort.

The usefulness of traffic count data at boat ramps was recently demonstrated by Steffe et al. (2008), who described a new cost-effective method for improving the accuracy and precision of fishing effort and harvest estimates using access point surveys. This improvement was achieved by supplementing the baseline survey data (from traditional access point or bus route surveys) with validated auxiliary data (from traffic counts) that quantified recreational fishing effort at access points within a fishery. This method is referred to as a supplemented access point survey (SAPS) and is a useful extension of the traditional access point method. The authors advocate that this approach outperforms other access point designs because the auxiliary data allows for better coverage of the temporal sampling frame for fishing effort.

Remotely operated internet cameras

An innovative method that could be used to address the problem of the inability of traffic counting machines to differentiate between fishing and non-fishing boats at ramps is the use of remotely operated internet cameras (or 'web cams'). Web cams have the potential to more accurately measure real-time fishing effort for trailer-boats as vessels can be observed while launching; therefore identifying those intending to fish. Currently, fisheries departments in New Zealand (Hartill et al., 2008) and Australia (NSW and WA) are trialling the use of web cameras. For example, in New Zealand at least nine web cam systems have been installed at boat ramps since 2003. These systems store time stamped images of a boat ramp every minute that can be viewed as a movie from which traffic counts can be used to provide estimates of fishing effort. Comparisons of daily web cam counts with aerial counts of all vessels classified as fishing at midday, and with harvest estimates on those days, obtained from creel survey interviews, suggest that this is a useful means of monitoring trends in both effort and harvest (Hartill et al., 2008).

Online logbooks

In recent years there has been increasing development of online tools for recording recreational catch, which may be a further option for cost-effectively monitoring recreational fishing activity and catches. For example, the Washington Department of Fish and Wildlife (US) developed an online crab catch reporting tool where the public can access a website and report their Dungeness crab catch for the season in Puget Sound. In 2008, over 35,000 fishers used the website and this has proven to be a successful alternative to traditional catch cards provided to licensed fishers. The

obligatory return of catch cards or online catch recording are important management tools for estimating seasonal recreational crab harvest in relation to area harvest quotas.

In Australia, an online recreational fishing logbook system (OLFISH Web Data Logger) has been trialled and is currently active in Western Australia. According to the website creators, the "…online logbook aims to fill the significant gap in recreational fishing catch and effort data to enable our fisheries to be sustainably managed using real recreational fishing data". This system has the flexibility to record all recreational fishing methods including shore-based and offshore fishing, crabbing and spear fishing.

Although simple to administer and cost-effective, the major disadvantage of online methods is that participation is voluntary and data is self-reported. Furthermore, fishers require access to a computer and the internet. For this reason there will always be concerns over the reliability and representativeness of the data and therefore, a likely reluctance to use it in stock assessments.

Text message reporting

There is a customised reporting method by which fishers can submit basic effort and catch data to an online database via text messages from mobile phones (Baker and Oeschger, 2009). This method was recently trialled in the US where captains from six marine for-hire operations were asked to text the effort and catch by species at the completion of each fishing trip. The syntax 'RECTEXT' was developed to facilitate the submission of a 160-character text message. Overall, 128 trip reports were submitted that reported 1,957 finfish interactions over a 4.5 month evaluation period. The results and feedback from the participants indicated that the method was easy to use, cost-effective and allowed for real-time data collection to an online database. Like the online logbooks reported previously, Baker and Oeschger (2009) recognise the biases associated with self-reported data. They suggested that future evaluations of this approach be applied to tournament fishing where real-time data collection is regulated (i.e. 'scheds') and where all fishers are known. This sampling structure may facilitate the design of an unbiased sampling method to assist in the validation of text message reporting.

National registry of recreational fishers

In this review we have established a strong requirement for complete 'list frames' for use in off-site survey methods (mail and telephone), in order to accurately and cost-effectively collect data that is representative of an entire recreational fishing community. The development of a comprehensive national registry of recreational fishers should be considered as it would provide a sampling frame from which national fishing statistics could be derived. List frames are already being used to good effect in NSW and Victoria to reduce telephone survey costs for estimating effort, and to recruit fishers for diary programs for estimating catch rates. In those instances, the lists are derived from licence databases. However, in order for fishers to comply with a national registry, where licence requirements vary, or are non-existent, it would be important to ensure that there is no registration fee and that information remains confidential and used only for the purpose of collecting fishing information. It would also be important

to ensure that a high proportion of fishers register, which may add the additional cost of compliance when using this method.

A review of US recreational fishery survey methods (Anon., 2006), led to the implementation of the Marine Recreational Information Program (MRIP) in 2009, to replace the Marine Recreational Fisheries Statistic Survey (MRFSS) and to address its shortcomings. The MRIP brings together federal, state, and interstate partners and constituents who are experts in fisheries management, survey design, statistics, and extension to improve recreational fishing data collection. One of its main objectives will be to develop a US national saltwater fisher registry. The logistics of developing and maintaining such a registry in Australia has been suggested to be difficult and costly (Pepperell and Dominion, 1996). Still, despite the enormity of this task, it would be very desirable to have such a register in Australia. Now that such a registry is to be attempted in the US, consultation between US MRIP representatives and Australian stakeholders may be mutually beneficial and assist in the development of such a registry.

Bayesian models and 'expert' elicitation

Although we have detailed a number of traditional and new innovative methods for collecting recreational catch and effort data, there are many logistical and statistical constraints associated with individual sampling methods that may make them of little use in Commonwealth fisheries for the purpose of collecting data for stock assessment. One such statistical approach that may be a powerful and cost-effective way to overcome some of these constraints is the use of Bayesian models, where expert elicitation can be employed to quantify anecdotal or patchy data sources.

Bayesian methods allow for the integration of different types of information into quantitative models, including scientific judgment or expert opinion of fishers, while formally accommodating and incorporating the uncertainty in the information provided. Historically, expert knowledge has been used qualitatively in comparisons with quantitative data, however there has been an increasing number of successful applications of Bayesian methods to a range of ecological and social situations (Kuhnert et al., 2005; McCarthy and Masters, 2005; Griffiths et al., 2007). In data-limited situations expert knowledge of fishers and scientists may be a particularly useful means to quantify many elements relating to recreational catches, effort, and in particular, the size composition of the catch, which is important for age-structured stock assessment models.

Chain-referral sampling

Recreational fishers who target Commonwealth-managed species use specialised techniques and represent a very small minority within the wider recreational fishing community. Because complete sampling list frames do not exist for these fishers, they can therefore, be considered somewhat of a hidden or 'hard-to-reach' population. chain-referral sampling (also commonly known as 'snowball' sampling) is a common method used in epidemiology and social sciences to access members of populations that are rare, hidden, or physically difficult to locate within the general population, such as homeless people, illicit drug users, HIV carriers and prostitutes (Coleman, 1958; Goodman, 1961; Erickson, 1979; Biernacki and Waldorf, 1981). The power of snowball

sampling for sampling hidden populations was realised after the development of the "small world" theory (Killworth and Bernard, 1978) that demonstrated that every person in the United States is indirectly associated with every other person via six intermediaries. Consequently, each person could theoretically be reached by the sixth referral 'wave' within a chain-referral, independent of how cryptic an individual may be.

Chain-referral methods has been particularly successful in identifying and surveying individuals that would normally be physically difficult to locate (i.e. homeless persons) (Faugier and Sargeant, 1997), posses rare or socially sensitive disorders or diseases, such as HIV (Heckathorn, 1996; Magnani et al., 2005), or are involved in activities that are socially or politically sensitive, illegal, or stigmatised such as prostitution (Faugier and Sargeant, 1997), illicit drug use (Kaplan et al., 1987; Willems et al., 1997; Wang et al., 2005; Abdul-Quader et al., 2006; Platt et al., 2006), and victims of child or sexual abuse (Evans-Campbell et al., 2006; Bjørkhaug and Hatløy, 2009). Surprisingly, despite the existence of equally hard-to-reach components within recreational fisheries (e.g. game fish angling), which in itself is a relatively elusive population within the wider community, there are no studies among the peer-reviewed literature that have used any form of chain-referral sampling as a method to estimate population size or even identify fishers to provide estimates of catch or effort.

Snowball sampling is a non-random statistical method that works by the researcher interviewing a randomly chosen set of initial subjects from the target population, who serve as "seeds" for an expanding chain of referrals, with subjects from each 'wave' referring subjects of subsequent waves, hence the 'snowball' effect. Names and contact details of other potential subjects who participate in the same activity are provided to the researcher by the seeds and their subsequent referrals. A fixed number of names from each list are selected by the researcher until no new names are identified in further waves, indicating all individuals in the population have been identified. Alternatively, sampling ceases when the researcher is confident that a sufficient sample size has been attained to be representative of the total population undertaking the specific activity based upon a power analysis sampling asymptote.

However, because of the non-random basis of snowball sampling, the method has several inherent biases. The primary bias is that the selection of the first set of seed subjects is often non-random since subjects are often selected based on common social characteristics that allow their initial identification (e.g. popularity) leading to 'force field bias' (Rapoport, 1957; Erickson, 1979) or 'volunteerism' bias (Erickson, 1979). These individuals may then refer the researcher to individuals to close friends that are likely to have very similar characteristics, in terms of behaviour and/or willingness to participate (Newman, 2003). Furthermore, these seeds may have longer social networks than an average member of the hidden population. As a result, a small number of seed respondents can have a significant effect on the final composition of participants, and thus the overall data being collected from these 'ego-centred networks' (Newman, 2003). However, this bias can largely be avoided, or at least great reduced, by if a sufficiently large sample of seed subjects can be recruited randomly and be considered representative of the target community, but also ensuring that the final sample size is large enough to dilute any potential biases inherent at the seed stage (Heckathorn, 1997). If a large number of randomly selected seed respondents are co-operative, there

is a high probability that a large and representative sample of the entire community can be sampled.

A further potential bias is non-response bias or refusal of participation by an individual referred to the researcher by a subject in the previous wave. Similarly, because the confidentiality of other members of the population is being violated by an interviewed subject, they may refuse to refer the researcher to their peers or provide false or incomplete contact details; both of which are forms of 'masking' bias (Heckathorn, 2002).

A recent extension of snowball sampling designed to minimise the bias caused by the non-random selection of seeds and reduce other forms of bias (e.g. volunteerism and masking) is respondent-driven sampling (RDS) (Heckathorn, 1997;2002). RDS combines a modified form of snowball sampling with a model that weights the sample to compensate for the non-random selection of subjects. The primary difference between snowball sampling and RDS is that the researcher retrieves the names and contact details of each respondent's peers in snowball sampling, which can have significant ethical ramifications in some situations (Heckathorn, 2002). However, RDS respondents are not asked to identify other potential respondents to the researcher, but instead recruit them to the study themselves by passing on a coupon that can be relinquished to the researcher for a reward. This peer recruitment can significantly reduce the effect of 'masking' and can also eliminate the violation of subject confidentiality. A further difference between the two methods is that in RDS initial seeds do not need to be selected at random, but simply need only to be a member of the target population.

Despite the cost of snowball sampling being only a fraction of traditional probability-based sampling (i.e. random digit telephone surveys), the relative cost of RDS is even lower than for snowball sampling since the respondents are responsible for making contact with potential respondents instead of the researcher. With the increasing access to computers by the general community and the proliferation of online networks, such as chat forums for recreational fishing, it is possible to even further reduce survey costs by recruiting subjects, or at least seeds, using online RDS. A recent web-based application of RDS (termed "webRDS") (Wejnert and Heckathorn, 2008) showed that not only was this approach as effective as traditional RDS methodology, but it recruited respondents and completed the study about 20 times faster. Furthermore, it was far less reliant on staff to recruit respondents and manage databases, resulting in significantly lower costs compared to implementation of traditional RDS surveys.

Overall, the cost-effectiveness of chain-referral sampling, particularly RDS, as a result of respondents actively identifying other eligible individuals subjects, make this an ideal method for surveying specialised fishers who target Commonwealth-managed species and are relatively rare within the recreational fishing community, which in itself, represents a minority within the broader community.

Time-Location Sampling

Many hard-to-reach populations tend to gather or congregate at certain types of locations at particular times. For example, epidemiologists found that hidden populations of illicit drug users tend to congregate at 'shooting galleries' or in other areas where drug or needle transactions take place, and often in the evenings. Venue-based or targeted sampling (Watters and Biernacki, 1989), often referred to as Time-Location Sampling" (TLS), capitalises on these types of predictable behaviours of the target population, whereby a researcher identifies aggregation sites in a geographic region of interest prior to a survey as a sampling 'universe' and a subset of the sites is chosen as a probability sample (Muhib et al., 2001; Stueve et al., 2001). The researcher then interviews individuals entering or leaving an aggregation location over a pre-defined period (e.g. a randomly chosen 3 hour interval on a randomly chosen day).

TLS is a similar concept to access point surveys. However, access point surveys at boat ramps for example, fishers who fish from vessels that can be launched from a trailer. Land-based fishers and fishers owning larger vessels berthed in marinas, moorings or private properties are missed using boat ramp access point surveys. This may cause a significant bias in total catch and effort estimates for the overall fishery. In contrast, TLS may be used to obtain a representative sample from the recreational fishing community if locations can be found where a representative cross-section of fishers congregates. One such approach is to conduct a survey of customers at fishing tackle stores, since most fishers, regardless of ability, fishing experience, avidity or mode of fishing, need to purchase fishing tackle at some point. A similar approach was used by Pepperell (1994b) to sample game fishers on the east coast of Australia.

It is possible that tackle store customer surveys may under-represent certain fishers since there is an apparently increasing number of highly specialised and avid fishers who purchase their tackle through websites or overseas. This can be due to a lack of supply of specialised equipment in Australia and/or favourable foreign currency exchange rates. Nonetheless, these fishers are likely to enter tackle stores at some point to purchase minor items, or to simply view and handle particular products before purchasing the products online or by mail order. Therefore, if sufficient sampling is undertaken across a range of stores in a particular region, it would be theoretically possible to attain a representative sample of the target fishers.

Although TLS could cost-effectively provide a representative sample of the catch and effort of recreational fisheries targeting Commonwealth-managed species, TLS is unable to directly estimate population size in order to expand sample estimates to estimate the total catch of particular species. However, if surveys were undertaken at each site on multiple occasions and respondent details are recorded, respondents could be asked if they had been interviewed previously. Therefore, by identifying the number of respondents that are 'recaptured' in each subsequent survey, it is possible to use mark-recapture methods to estimate population size, which has been used for hidden populations of illicit drug users (Hay 2000), HIV carriers (Mastro et al. 1994) and the homeless (Dávid and Snijders 2002).

6.6 Implications for Commonwealth fisheries

Recreational fisheries data is difficult and often expensive to collect and analyse, as a result there is currently only limited information on the recreational catches of a few Commonwealth-managed species that can be included in stock assessments. In order to ensure the long-term sustainability and equitable sharing of fish resources exploited by recreational and commercial sectors, increased effort is required by fisheries management agencies to better quantify the recreational fishing catches in Australia. While Australian state fishery agencies have been attempting to address this issue for decades, Commonwealth fishery agencies are lagging in this area, primarily due to a perceived lack of recreational effort in Commonwealth fisheries.

The difficulties in surveying recreational catch and effort have been well established in this review, but the logistical difficulties and costs increase dramatically with the geographic size of the fishery. The design of a program to monitor the recreational catches of Commonwealth-managed species needs careful thought. It is evident that strong consideration must be given to the characteristics of a fishery (e.g. spatial and temporal scales, access points, modes of fishing, cost) in order to effectively design a survey method to meet the intended objectives and to minimise potential biases. The objectives of these surveys should aim to cost-effectively collect consistent and reliable catch and effort data for the intended target species over the long-term in order to detect relative changes in abundance and size/age structure. The surveys ultimately proposed for the Commonwealth fisheries will most likely be of a complemented nature as these are most effective for dealing with large complex fisheries to estimate catch and effort, and they are also useful for correction of biases. The following sections in this report describe the processes of selecting potential survey methods, through a national methods development workshop involving key Commonwealth fishery stakeholders, and specific survey development to tailor survey methods for Commonwealth-managed species and/or fisheries.

7. SCOPING OF SURVEY OPTIONS FOR COMMONWEALTH FISHERIES – NATIONAL WORKSHOP 1

Deciding on the most statistically robust and cost-effective method for monitoring recreational fishing for Commonwealth-managed species is a difficult task given the range in size and remoteness of Commonwealth fisheries and the rarity of recreational fishers in the wider community. The size of the monitoring area alone is likely to restrict the number of survey options, since it is generally cost prohibitive to employ on-site methods that can be implemented to collect representative catch and effort data. Furthermore, the most appropriate method(s) is largely dependent upon the species that recreational fishers target, which can be numerous in some fisheries such as the Coral Sea Fishery.

A national workshop involving scientists and fishery stakeholders from Australia and New Zealand was held at the CSIRO Cleveland Laboratories on 4-5 November, 2009 to develop statistically robust and cost-effective survey methods for monitoring recreational fishing in Commonwealth fisheries. Because many of the more cost-effective survey options, such as fisher diaries and online surveys, rely on the active participation of recreational fishers, it was imperative that recreational fishery stakeholder groups were represented at the workshop to advise scientists on the feasibility of any proposed methods that may involve fishery-dependent sampling. Workshop participants and their affiliations are listed in Appendix 3.

The three main objectives of the workshop were to:

1) To facilitate an exchange of up-to-date information between state, Commonwealth fisheries research and management agencies and recreational fishery stakeholders relating to recreational fishing research including new survey approaches and technologies, sampling and statistical issues identified in existing surveys.

2) To identify the Commonwealth fisheries and species having the highest interactions with recreational fisheries and prioritise their importance for monitoring.

3) Establish a range of survey options for a long-term monitoring program for recreational fisheries in Commonwealth waters that can be immediately applied or further developed to cost-effectively provide reliable estimates of the total recreational catch of identified priority species.

7.1 Case studies and new survey designs

The first day of the two-day methods development workshop was dedicated to each workshop participant presenting an oral presentation on their recent recreational fishing survey work, highlighting successful and less successful components of the surveys. Participants were asked to focus on aspects of their survey designs that are relevant to surveying recreational fishers in large-scale Commonwealth fisheries, including innovative or cost-effective survey ideas that may be useful but remain untested.

The agenda of oral presentations (Appendix 5) began at the broadest level with an overview of recreational fisheries and management needs in Australia in order to establish the specific recreational catch data requirements for stock assessment and fishery managers. The following session comprised presentations describing general case studies of recreational catch and effort surveys undertaken by state fishery agencies. This was followed by a session dedicated to more specific surveys that focused on species relevant to Commonwealth fisheries, such as SBT, or methods that have been employed to cover large spatial scales, such as the entire north island of New Zealand. The final session was dedicated to innovative and cost-effective recreational fishing survey options, such as the use of aerial surveillance data routinely collected by Border Protection Command, online reporting, and new approaches of using social networks to access specialist recreational fishers.

Structuring the presentations in this way provided all workshop participants with sufficient background to be able to objectively assess the feasibility of various survey options developed by the workshop group for Commonwealth-managed species on day two of the workshop. A number of important discussions arose from the presentations that helped participants understand both the political, statistical and logistical difficulties in monitoring recreational fishing in Commonwealth fisheries, which are summarised under the following discussion categories.

Management and data requirements for recreational fisheries in Commonwealth waters

Recreational fishing in Australia is currently managed by state authorities. The Australian Fisheries Management Authority (AFMA) has the jurisdiction to manage recreational fishing in Commonwealth waters if it is specifically written into a management plan. However, this is currently not the case for any Commonwealth fishery. Before recreational fishing will be considered for inclusion into a management plan, AFMA needs to be certain that recreational catches are significant enough to warrant investment in a monitoring program in order to estimate a Recommended Biological Catch (RBC) for particular species, from which a Total Allowable Commercial Catch (TACC) can be set.

Despite recreational fishing being a low management priority, AFMA has an obligation to report to regional fisheries on all mortality sources for some species, and consequently, there may be a significant requirement for the recreational catch of some species to be known. An example is the catch of wahoo and other ‘tuna-like’ species in state waters, as the Offshore Constitutional Settlement (OCS) between the states and the

Commonwealth requires such species to be managed by state fisheries agencies, but they are often caught in large numbers in Commonwealth fisheries such as the ETBF.

Given these issues, there appears to be a lack of clarity in the policy over recreational fishing issues in Commonwealth waters, which is contrary to the Memorandum of Understanding (MOU) established in 2004 between the Commonwealth and state governments, which states that management arrangements need to be clearly stated. This includes resource sharing between Commonwealth and state commercial and recreational fisheries.

Recreational fishing research, development and extension

The Fisheries Research and Development Corporation (FRDC) is one of the main funding providers for recreational fisheries research in Australia. It provides funding to projects that are aligned with eight key priority areas that are established by the Recfishing Research Committee, which is comprised of key recreational fisheries stakeholders. In the absence of specific recreational fisheries research advisory bodies (FRABs), the Recfishing Research Committee assumes this role to some extent and assists in commissioning recreational fishing projects, facilitates the extension of research outcomes to the wider recreational fishing community, and undertakes reviews of governance arrangements.

Some scientists expressed concern that the Recfishing Research Committee may not be capable of providing adequate feedback on research proposals or assessments of completed research due to an underrepresentation of scientists on the committee.

The perspective from recreational fishery representatives

The recreational fishing sector, as represented by Recfish Australia, was described to have a different view to fishery managers regarding the status of recreationally-important species and how these species should be managed. Recreational fishers believe that most recreationally-important fish stocks are being fished at sustainable levels by the recreational fishing sector. Therefore, the recreational sector would prefer to see researchers and managers place a greater importance upon the economic and social benefits of recreational fishing, that is, quantifying the value of a fish to the recreational fishing community.

There is an apparent strong feeling by representatives of the recreational sector that they should be better engaged in fishery management processes. This may be facilitated by trialling co-management arrangements between government and recreational fishing peak bodies and having some responsibility for conducting research and ongoing monitoring, which may lower costs and enhance a sense of ownership of the resource by recreational fishers.

Although most scientists at the workshop saw value in engaging recreational fishers in research, there were some concerns over the potential biases with volunteer fishers undertaking ‘citizen science’, particularly avidity and volunteerism bias. By forming close partnerships with scientists and statisticians, it is possible to maintain scientific rigour in community monitoring programs so that catch estimates can be more

confidently used for stock assessment and management. This is particularly important if long-term projects are undertaken, where the relative fishing power may incrementally change with time.

Recreational fisheries data requirements for stock assessment

Harvest strategy policies clearly state that mortality from all sources needs to be included in stock assessments. For some regional stocks, such as the 34 Southern and Eastern Scalefish and Shark Fishery (SESSF) quota species, recreational catches may make a significant contribution to the total mortality, and therefore recreational fisheries data is critical for inclusion in stock assessments. In contrast, some ocean-basin assessments for some species, such as some species of tuna and billfish, have such large variability in biomass estimates of the stock that incorporation of recreational catch data may have limited value. This is because the magnitude of recreational catches may only be within the error estimates of the commercial catch data.

There are a range of recreational fisheries data requirements for stock assessments, depending on the model being used. In the SESSF for example, some data-limited species are assessed using relatively simple population dynamics models, and so the minimum requirement in these cases would be catch and/or effort. In more sophisticated age-structured models, higher quality data is required, such as standardised CPUE, catch-at-age and selectivity schedules.

Recreational fishing surveys

Recreational fishing surveys have been undertaken in at least 20 countries since the 1960s. Most of the early surveys were small-scale at the level of a single water body, but in recent years the temporal and spatial scale of surveys has increased to representatively cover jurisdictional regions. Since 1990, 58% of large-scale surveys have been complemented telephone-diary survey designs aiming to estimate the total recreational catch.

Before undertaking a survey, the researcher needs to have a clear idea of who needs the data, what types of data are required, and who is responsible for funding the survey. Each survey needs to be tailored to each individual situation, since no single survey design will work in all situations. Most state agencies in Australia have used some type of complemented survey design, generally either a telephone-diary survey or a telephone-access point survey. These designs were identified to suffer from various biases, with the largest being the lack of a complete list frame to estimate total effort, or to draw a representative sample of subjects for a diary survey.

Restrictions on the use of electronic White Pages, an increasing number of unlisted numbers and mobile phone use, and ‘out-of-frame’ fishers (e.g. ‘grey nomads’ in northern Queensland) are apparently having an increasing negative effect on accessing recreational fishers. In South Australia, it was estimated from marine on-site surveys that 79% of recreational fishers have a listed telephone number. In the Northern Territory, the majority of indigenous recreational fishers do not have a phone, so other list frames like the Australia Post database may be an alternative means to contact out-of-frame fishers.

In all states where a licence is compulsory, the licence frames are far from complete. In a recent survey in Victoria (Ryan et al., 2009), around 60% of fishers were found to be exempt from holding a licence, while around 50% of fishers failed to provide a phone number to survey staff when interviewed during on-site surveys. In Western Australia, a licence is required for boat-based fishers, but not for land-based fishers, which can create a different suite of sampling and statistical issues.

Regardless of jurisdiction, the common need for undertaking recreational fishing surveys is generally to obtain a reliable estimate of the catch for inclusion in stock assessment, and to a lesser extent, for resource allocation among sectors. However, stock assessment modellers advocate a need for long time series of representative recreational catch estimates for inclusion in stock assessments, rather than focusing on obtaining a single annual catch estimate.

Specialised surveys designs for Commonwealth-managed species

There was clear evidence from a range of presentations at the workshop that the most cost-effective traditional recreational fishing survey designs for large-scale fisheries, namely telephone-diary complemented designs, are likely to be inadequate for obtaining representative catch and effort data for the majority of Commonwealth-managed species.

Despite fisher diaries being a useful method for collecting detailed information for individual fishing trips, generally from more avid fishers, the response by gamefish club fishers in Tasmania to report SBT catches was shown to be poor (Morton and Lyle, 2003). For some species (especially SBT) there may be resistance by recreational fishers to report catches due to an apparent perception that the true extent of catches will be known by fishery managers, who may impose new catch limits.

In South Australia, a state-wide survey using the NRFS methodology revealed only 1% of the total number of fish recorded by survey staff was Commonwealth-managed (Jones, 2009). Catch estimates for Commonwealth-managed species were based on less than 30 fishing events, resulting in enormous error estimates, which made expansion to the state level difficult in that survey.

Most previous surveys of pelagic gamefish (e.g. tunas and billfish) have relied to some degree on tournaments (e.g. Lowry and Murphy, 2003), since intercepting game fishers in general recreational fishing surveys using on-site or off-site methods can be difficult. Tournament data is highly biased towards more avid club-based fishers. However there are attempts by Industry and Investment NSW to try and use their tournament monitoring program data and historic club catch data as an input for stock assessment. During discussions at the workshop there were suggestions to use a dual-frame survey methodology to complement the tournament data with data collected from non-fishing club fishers using social network methods such as Respondent-Driven Sampling (see Sections 6.5 and 10), which can potentially access these hard-to-reach fishers.

New and cost-effective survey options for Commonwealth waters

There have been apparently few developments in recreational fishing survey design since the widespread adoption of complemented survey designs such as telephone-diary surveys over a decade ago in several countries where recreational surveys have been undertaken. It is clear that such designs are not capable of accessing the rarely encountered recreational fishers in Commonwealth waters without access to a complete sampling frame, such as a National Recreational Fishing Registry mentioned in Section 6.5. Five types of largely untested survey types were presented by workshop attendees as potential cost-effective survey options, including community monitoring, online reporting, use of BCP aerial surveillance data, Time-Location Sampling and Respondent-Driven Sampling.

Community monitoring (or 'Citizen Science') was presented as a cost-effective option to engage recreational fishers for collecting catch and effort data, which has the potential benefit of increasing their sense of ownership of the project and increase the uptake of any management measures arising from the project. However, there were concerns from scientists that without the involvement of scientists and statisticians, community-operated projects are unlikely to generate reliable catch estimates due to a range of significant biases, in particular avidity bias. Given the potential uncertainty of data quality from these programs and a likely reluctance by scientists to use the data in stock assessments, there were concerns that such programs actually end up being more expensive than a well-designed research project undertaken by scientific staff. Nonetheless, there are some situations where community monitoring may be the only means to cost-effectively collect recreational fishing data and there are examples where these programs have worked successfully with close scientific engagement, such as the CapReef program in central Queensland.

Online reporting appeared to be the cheapest method available for collecting recreational data, due to low labour and operating costs. However, this method suffers from potentially enormous biases that severely limit the usefulness of catch estimates for stock assessment. The primary biases include: i) restriction of sampling to people with computer and internet access, ii) non-reporting of zero catch trips due to prestige bias or simply the failure to understand the importance of reporting a zero catch, and iii) inability to expand the data since the population size of potential participants is not known.

Researchers from New Zealand demonstrated the efficacy of using aerial surveys for estimating effort (see Hartill et al., 2008), although it was thought that Commonwealth fisheries are too large to survey cost-effectively using this method. However, BPC undertake routine surveillance flights – often daily – Australia-wide and every vessel observed is categorised and recorded. These data were used by CSIRO to estimate the fishing effort by foreign fishing vessels (FFVs) operating illegally in the Australian EEZ (Griffiths et al., 2008). Several model estimators have been developed to estimate instantaneous effort and fleet size of FFVs. With some modification, it was proposed that these estimators could be used for recreational vessels. A potential issue was that researchers do not have control of where the flights are conducted at any given time since BPC often rapidly change flight plans in response to security threats.

Given the rarity of recreational fishers who fish for Commonwealth-managed species in the wider community, a number of sampling methods (TLS, Snowball Sampling and RDS) were proposed that use social networks to access these hard-to-reach fishers.

Apart from an informal application of TLS (Pepperell, 1994b), these methods have never been used anywhere in the world to estimate catch and effort of recreational fishers. TLS was seen to be a reasonable method for accessing a representative sample of specialised recreational fisheries at specific aggregation points, such as fishing tackle stores and tackle/boat shows. However, there were concerns that this method may under-represent the many specialist fishers who purchase their tackle online or overseas and may not visit Australian tackle stores.

RDS appeared to be the only method that was theoretically capable of reaching these rare fishers and obtaining representative data cost-effectively. Combined with a mark-recapture methodology, an "RDS-Recapture" design was proposed that could obtain both catch and population size within the same survey. Because RDS has only been used in epidemiology and social sciences, it is unknown how the method will work in recreational fisheries. However, the method gained support from the workshop participants as a theoretically statistically sound and cost-effective option, although thorough testing of the method was strongly recommended.

7.2 Prioritisation of fisheries and species requiring monitoring

Following presentations on survey designs, the Commonwealth fisheries and species were prioritised in order to discuss which method(s) would be required in each case. For this purpose the group relied upon a the results of a previous AFMA-funded project (Griffiths and Pepperell, 2006) – a pre-cursor to the current project – that detailed the recreational fishing interactions with each of the Commonwealth-managed fisheries and species. The workshop group constructed a table (Table 7.1) to identify those species, or species groups, that are caught by Commonwealth commercial licence holders and recreational fishers in significant quantities. Further, it was intended to identify those species, or species groups, for which data on recreational catches might be most likely to be required in the future. In doing so, various criteria were taken into account by workshop participants. The purpose of assigning or listing these criteria was to enable such factors to be taken into account when designing the most appropriate survey method to estimate recreational catch and effort for each species or species group. The criteria were as follows:

- Whether or not the species was a Commonwealth commercial target species
- The status of the stock, as defined in the 2008 BRS Fishery Status Report (B.R.S., 2008)
- The perceived relative level of recreational catch of the species or species group
- The iconic or target status of the species among recreational fishers
- The component of the recreational catch that is believed to released
- The component of the recreational catch taken by members of fishing clubs
- The geographic range of recreational catches of the species or species group
- The main recreational fishing 'platforms' used to catch the species
- The number of access points that might be used to conduct field surveys
- Whether the recreational fishery operates only by day, night, or both

- The seasonality of targeting of the species by the recreational fishery
- Identification of recreational fishing licence frames for possible use in surveys

There was some discussion regarding actual or potential 'vulnerability' of a species or species group. At present, there are only three species in (Table 7.1) that are listed under the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act* 1999 List of Threatened Fauna, and all of these are listed under the lowest level of threat, that is, 'Conservation Dependent'. These are school shark (*Galeorhinus galeus*), the eastern Australian population of the eastern gemfish (*Rexea solandri*) and orange roughy (*Hoplostethus atlanticus*). Only the first two are caught in any numbers by recreational fishers.

No other species in (Table 7.1) are listed under any other category in the EPBC Act (e.g. critically endangered, endangered, vulnerable). However, some species are listed under other legislation. For example, SBT is listed as an endangered species under the *Fisheries Management Act of NSW*, shortfin mako sharks may soon be affected by listing as a migratory species under the Convention on Migratory Species (CMS) to which Australia is a signatory, and several other shark species are listed in different categories by the International Union for the Conservation of Nature (IUCN).

Table 7.1 Outcome of working group prioritising Commonwealth fisheries and species with respect to extent of interaction with recreational fisheries. Overfished or current overfishing of commercial target species (listed in blue) indicated in red (yes), orange (uncertain), green (no), blank (no assessment).

Fishery	Species	Over-fishing?	Over-fished?	Rec Catch	Iconic or Target	Release Component	Club Component	Distribution (Rec catches)	Recreational Platforms	Recreational Access	Diurnal Nocturnal	Seasonal	Licence Frame
ETBF	Striped marlin			High	V. High	V. High	V. High	NSW-Tas	Trailer, cruiser, charter	Many access points, but a few 'hot spots'	Day	Sp, Su, Aut	NSW
	Yellowfin tuna			V. High	High	High	Moderate	NQld-Tas	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	NSW
	Bigeye tuna			Low	Low	High	?	NQld-NSW	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	NSW
	Albacore			Moderate	Moderate	Moderate	Moderate	NSW, Vic, Tas	Trailer, cruiser, charter	Many access points, but a few 'hot spots'	Day	Win	NSW, VIC
	Broadbill Swordfish			Low	V. High	High	V. High	SQld-NSW	Trailer, cruiser, charter	Many access points	Night	Aut, Win	NSW
	Blue marlin			Low	V. High	V. High	V. High	SQld-NSW	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	NSW
	Black marlin			High	V. High	V. High	V. High	NQld-NSW	Trailer, cruiser, charter	Many access points	Day	Sp, Su	NSW
	Sailfish			High	V. High	V. High	V. High	Qld	Trailer, cruiser, charter	Many access points, but a few 'hot spots'	Day	Sp, Su	NSW
	Longtail tuna			Moderate	High	High	Moderate	NQld-NSW	Trailer, landbased	Many access points for boats, 'hot spots' for landbased	Day	Su, Aut	NSW
	Skipjack tuna			Moderate	Moderate	Low	Moderate	NQld-NSW	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	NSW
	Other gamefish			Moderate	Moderate	High	Low-Mod	NQld-Tas	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	NSW, VIC
	Pelagic sharks			Moderate	High	Moderate	Mod-High	SQ-Tas	Trailer, cruiser, charter	Many access points	Day & Night	All year	NSW
WTBF	Striped marlin			High	V. High	V. High	V. High	SW	Trailer, cruiser, charter	Rel few access points	Day	Sp, Su, Aut	WA Boat Lic
	Yellowfin tuna			V. High	High	V. High	High	West coast	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	WA Boat Lic
	Bigeye tuna			Low	Low	High	Moderate	South	Trailer, cruiser, charter	Rel few access points	Day	Sp, Su, Aut	WA Boat Lic
	Albacore			Moderate	High	Moderate	Moderate	South	Trailer, cruiser, charter	Rel few access points	Day	Win	WA Boat Lic
	Broadbill Swordfish			Low	V. High	High	?	South	Trailer, cruiser, charter	Rel few access points	Night	Aut, Win	WA Boat Lic
	Blue marlin			Low	V. High	V. High	V. High	SW	Trailer, cruiser, charter	Rel few access points	Day	Sp, Su, Aut	WA Boat Lic
	Black marlin			High	V. High	V. High	V. High	West coast	Trailer, cruiser, charter	Rel few access points	Day	Sp, Su	WA Boat Lic
	Sailfish			High	V. High	V. High	V. High	NW	Trailer, cruiser, charter	Rel few access points	Day	Sp, Su	WA Boat Lic
	Longtail tuna			Moderate	High	Moderate	Moderate	NW	Trailer, cruiser, landbased	Many access points	Day	Su, Aut	WA Boat Lic
	Skipjack tuna			Moderate	High	High	Moderate	Whole fishery	Trailer, landbased	Many access points for boats, 'hot spots' for landbased	Day	Su, Aut	WA Boat Lic
	Other gamefish			Moderate	Moderate	High	Low-Mod	Whole fishery	Trailer, cruiser, charter	Many access points	Day	Sp, Su, Aut	WA Boat Lic
	Pelagic sharks			Low	High	Moderate	Low-Mod	Whole fishery	Trailer, cruiser, charter	Rel few access points	Day & Night	All year	WA Boat Lic
SBT	South bluefin tuna			Moderate	V. High	Moderate	low-Mod	Southern Australia	Trailer, cruiser, charter	Many access points, but a few 'hot spots'	Day	Aut, Win	NSW/VIC
SESSF	Blue warehou			Moderate	Low	Moderate	Low-Mod	Vic, Tas	Trailer, landbased	Limited access points	Day	All year	VIC
	Eastern gemfish			Moderate	Low	Moderate	Low-Mod	NSW, Vic	Trailer, cruiser	Many access points	Day	All year	NSW/VIC
	Gulper sharks			Low	Low	Moderate	Low-Mod	NSW	Trailer, cruiser	Many access points	Day	All year	NSW/VIC
	Jackass morwong			Moderate	Low	Moderate	Low-Mod	NSW, Vic	Trailer, cruiser	Many access points	Day	All year	NSW/VIC
	Orange roughy			Nil	N/A	N/A	N/A	Tas	N/A	N/A	N/A	N/A	N/A
	Redfish			Moderate	Low	Low	Low-Mod	NSW, Vic	Trailer, cruiser	Many access points	Day & Night	All year	NSW/VIC
	John Dory			Low	Moderate	Low							
	School shark			Low	Moderate	Moderate	Low-Mod	NSW, Vic,Tas, SA	Trailer, cruiser	Many access points	Day/Night	All year	NSW/VIC
	Gummy shark			High	V. High	Moderate	Low-Mod	NSW, Vic, Tas, SA	Trailer, cruiser, charter	Many access points	Day & Night	All year	VIC
	Elephant fish			High	V. High	Low	Low-Mod	Vic, Tas	Trailer, cruiser, charter	Rel few access points	Day & Night	All year	VIC
	Flatheads			Moderate	Moderate	Moderate	Low-Mod	NSW, Vic,Tas, SA	Trailer, cruiser, landbased	Many access points	Day & Night	All year	NSW/VIC
	Silver Trevally			High	V. High	Moderate	Low-Mod	NSW	Trailer, cruiser, landbased	Many access points	Day & Night	All year	NSW/VIC
	Snapper (OCS-bycatch)			High	V. High	V. High	Low-Mod	NSW, Vic, SA	Trailer, cruiser, landbased, charter	Many access points	Day & Night	All year	NSW/VIC
	Blueye			Moderate	V. High	Moderate	Low-Mod	NSW, Vic, Tas	Trailer, cruiser	Many access points	Day	All year	NSW/VIC/TAS
	Ling			Low	Low	Moderate	Low-Mod	NSW, Vic, Tas	Trailer, cruiser	Rel few access points	Day	All year	NSW/VIC
	Sawshark			Low-Mod	Low	Moderate	Low-Mod	Vic	Trailer, cruiser	Rel few access points	Day & Night	All year	VIC
	Hapuka			Moderate	V. High	Low	Low-Mod	NSW, Vic, Tas	Trailer, cruiser	Many access points	Day	All year	NSW/VIC/TAS
	Bar cod			High	V. High	Low	Low-Mod	NSW, Vic, Tas	Trailer, cruiser	Many access points	Day	All year	NSW/VIC/TAS
	Bass Groper			Moderate	V. High	Low	Low-Mod	NSW, Vic, Tas	Trailer, cruiser	Many access points	Day	All year	NSW/VIC/TAS
Small Pelagics	Blue mackerel			High	V. High	Low-Mod	Low	SQld, NSW, Vic, Tas	Trailer, cruiser, landbased, charter	Many access points	Day	All year	NSW/VIC
	Yellowtail			High	V. High	Low-Mod	Low	SQld, NSW, Vic, Tas	Trailer, cruiser, landbased, charter	Many access points	Day	All year	NSW/VIC
	Jack mackerel			Moderate	Moderate	Low	Low	Vic, Tas	Trailer, cruiser, charter	Many access points	Day	All year	VIC
	Redbait			Low	Low	Low	Low	Vic, Tas	Trailer, cruiser, charter	Rel few access points	Day	All year	VIC
GAB	Bight Redfish			Moderate	High	Low	Low-Mod	SA, sth WA	Trailer, cruiser	Many access points	Day & Night	All year	WA
Coral Sea	Many reef species			High	Some spp	Low	Low	Coral Sea	Cruiser, charter	Many access points	Day & Night	All year	
Torres Strait	Coral trout etc			Moderate	High	Low	Low	Torres Strait	Trailer	Relatively few access points	Day	All year	
	Spanish mackerel			Moderate	High	Low	Low	Torres Strait	Trailer	Relatively few access points	Day	All year	

7.3 Survey designs recommended for further development

The workshop group assessed recreational fishing survey options on a fishery-by-fishery basis and focusing on priority species within each fishery. To tackle this large problem, three breakout groups were each assigned three fisheries to discuss the most appropriate methods for sampling the priority species identified in Section 7.2. The fisheries were:

- Eastern Tuna and Billfish Fishery (ETBF)
- Southern Scalefish and Shark Fishery (SESSF) (tiger flathead, eastern gemfish, Redfish 'nannygai', silver trevally)
- SESSF (Shark complex)
- SESSF Hook and Line (Blue eye, hapuka, gulper sharks)
- Great Australian Bight Fishery (GAB) (Bight Redfish)
- Torres Strait Fishery (TSF) (Spanish mackerel and various reef fish)
- Western Tuna and Billfish Fishery (WTBF)
- Small Pelagic Fishery (SPF)
- Southern Bluefin Tuna (SBT)
- Coral Sea Fishery (CSF) (various reef fishes)

The outcomes of discussions within the three breakout groups are summarised by fishery and species (or species group) in Table 7.2.

Table 7.2: Outcomes of breakout workshop groups discussing potential survey options for each species with a significant recreational catch in within various Commonwealth-managed fisheries.

Fishery	Species	Survey method	Comments
ETBF	Tuna, billfish, pelagic sharks	Telephone-diary survey	• White Pages telephone list frame possible to find some fishers for diary component, but they are unlikely to be representative. Same list frame possible to estimate population size, but cost will be enormous • Additional issue of recent restrictions on use of electronic White Pages, so costs will increase dramatically if manual dialling required. • Specialised frames may be developed from other methods such as Respondent-Driven Sampling, Time-Location Sampling, or introduction of a National recreational fisher register or species-specific licence for Commonwealth species (*viz*. USA Highly Migratory Species permit). If these methods possible it will be cost effective, but development of these frames is not complete (e.g. RDS) and there are likely to be significant political barriers for registers/licences
		Telephone recall survey	• Same sampling frame issue as telephone-diary survey • Major recall bias unless fishery is seasonal and captures memorable • Data reliability a major concern. Will require access point surveys to validate recalled data, which then dramatically increases survey costs
		Aerial survey	• Difficulty identify participating fishers • Extremely expensive in large fisheries • Require onsite surveys for the day of flights • BPC surveillance data a very cheap option, but reliability unknown for rec boats and possibly inconsistent spatial and temporal coverage of a study region due to reactions to national security threats
		Access Point survey	• Extremely expensive and surveys need to be tailored to species/areas of interest. For example, the entire ETBF cannot be cost-effectively sampled • Tailored surveys/sites depending on species • Data may be highly biased towards trailer boats due to difficulty in accessing private marinas/jetties • Effort is required using another method to expand to the entire population. This is likely to be a telephone survey, so same problems encountered as the telephone recall and telephone diary surveys

		Respondent-Driven Sampling	• Theoretically ideal for accessing minority populations for a one-off recall survey for catch. • Cheap and statistically sound • Possible to use RDS to recruit diarists since data will be more reliable than by recall • Estimation of sample size possible using repeated RDS surveys via capture-recapture models • Method requires a pilot study to thoroughly test before considering implementation
		Catch tags (e.g. HMS Maryland, USA)	• If implemented perfectly, the total harvest of each species known without error. However, number of released fish and unreported captures will not be known without a parallel survey • Implementation and compliance will be costly • Needs to be run across states, or the Commonwealth runs the entire program. There will be uncertainty who pays
		Online reporting	• Very cheap to establish and run over a long period • Too many data reliability issues and biases to seriously consider this method, especially under-reporting of zero catch trips • Population size of fishery unknown and will require other expensive telephone methods
SESSF	Tiger flathead, Eastern Gemfish, Redfish, Silver Trevally	Same survey options as ETBF	• Due to species identification issues, onsite surveys are required at some point in offsite methods are deemed suitable for these species. • There are significant identification issues for silver trevally, which comprises 2 or 3 species in southern Australia. Silver trevally are caught in significant numbers in estuaries and coastal regions in state waters. Therefore, any survey conducted by the Commonwealth will need to involve relevant state agencies that survey inshore areas. • Other issues with silver trevally is that catches in some areas are both boat-based and land-based. Therefore, different methods will need to be employed to sufficiently sample both sub-fisheries.
	Shark complex (e.g. gummy and school sharks, sawshark)	Telephone-diary survey	• Catches reasonably common throughout the general recreational fishing community, so possible to pick up shark fishers from a the NSW and Vic licence frame • National register of recreational fishers would solve to issue but politics are complex.
	Blue eye, hapuka, gulper sharks	Telephone-diary survey	• Private boat registry and charter logbook suitable for most species, but not for warehous, these may be picked up in state surveys
		Respondent-Driven Sampling	• Ideal for deepwater species where fishers used specialised gear and the fishery is comprised of a small number of participants

GAB	Bight redfish	Telephone-diary survey	• Catches reasonably common throughout the SA recreational fishing community, so possible to pick up redfish fishers from a the Vic licence frame, but not in SA where there is no licence but most fishing for this species occurs • National register of recreational fishers would solve to issue but politics are complex.
		Charter boat logbook	• Recognised as comprising a different component of the recreational fishery due to experience of skippers, but there is value in using these data since it provides a time series of catch and effort. However, charter operators are not required to provide numbers of released fish, therefore, underestimation of catch likely.
TSF	Spanish mackerel and a large number of reef fish (primarily coral trout, lutjanids, lethrinids)	Access point survey	• Recreational fishery small but increasing. Very few access points (mainly Bamaga) on Cape York Peninsula so cost-effective spatial and temporal coverage possible • Reasonable indigenous component of the fishery accessing the fishery from several small islands throughout the Torres Strait. Probably to costly and logistically difficult to cover these islands
		Aerial survey – boat-based effort	• Chartering flights probably a very effective and cost-effective option to cover boat-based and land-based effort in this small region. • Data from BPC surveillance flights a very good cost effective option since the Torres Strait has very high daily flight coverage due to high incidence of illegal foreign fishers from Papua New Guinea and Indonesia.
		Respondent-Driven Sampling	• Possibly a very effective method for surveying the entire population, especially the indigenous component with the assistance from indigenous community representatives to overcome any language barriers.
		Telephone-diary survey	• Cost-effective to cover this relatively small geographic region, but unlikely to be an option due to many households not having a landline telephone, especially on the small islands. • Literacy and language problems may be prevalent among indigenous population
WTBF	Tuna, billfish, pelagic sharks	Telephone-diary survey	• Boat licence frame available for ~40,000 fishers in WA, which is manageable and reasonably cost effective. However, this frame does not exist in SA and N will not cover land-based fishers who probably take a reasonable number of longtail tuna • There may be non-coverage of households in top end regions but questions over the importance of these regions with respect to catches of Commonwealth species • Previous phone surveys in SA-NT using white pages experienced very low hit rate of gamefishers. Will need to use combination of frames, such as white pages and boat license frame • Consider completing the survey every 5 years to establish a time series

			• Species identification not likely to be an issue, but some on-site info required for length-weight of the catch
		Charter boat logbook	• Recognised as comprising a different component of the recreational fishery due to experience of skippers, but there is value in using these data since it provides a time series of catch and effort. However, charter operators are not required to provide numbers of released fish, therefore, underestimating catch.
		Remote web cameras	• Cost effective for obtaining detailed effort data • Probably only possible to run at larger access points • Vandalism is likely to be a problem, especially in NT
		Aerial survey	• Not likely to be cost effective if chartering flights for routine surveys given the enormous size of the WTBF • Sharing flight time of commercial tuna spotter planes may be a viable option, but restricted to areas they are interested in surveying
SPF	Blue mackerel, jack mackerel, red bait	Diary survey	• Recreational catch is very small compared to the commercial fishery, but local depletions may exist • Unlikely that catch will be reliably recorded. Will be very inaccurate since fishers don't often pay attention to specific numbers or sizes of baitfish. Significant recall issues will be evident, even on day of fishing • Species identification an issue. On-site validation may be too costly, but diarists may be able to provide photos to verify their identifications.
		Vantage point survey (effort only)	• Possible to monitor effort at 'bait grounds' from vantage points
SBT	Southern bluefin tuna	Telephone diary survey	• Private boat registry may be a good sampling frame if stratified by boat type/size. Access to registry in all states may be an issue, as already experienced in Qld. • Various biases likely due to self-reported data (numbers/size) and under-reporting of zero catch events. A solution may be regular feedback to improve quality of reported data and keep fishers enthused.
		Adaptive Access Point (AAP) method	• Recreational captures usually only at a few hot spot access points and is highly seasonal and often occurs in pulses within the season • Very expensive and logistically difficult to adapt survey to cover pulse fishing • Under-coverage of all areas where SBT landed, leading to underestimate of catch. Need to employ a parallel sampling method (e.g. diary) to validate • Insider knowledge required for this method to intensively sample pulse events

		Charter boat logbook	• Results in complete catch estimate, but validation of numbers and sizes required, including releases • Similar issues for other states that do not have charter reporting • On-board cameras for charters would help match up catch with logbook data • If other states on board with diary survey, total catch is therefore possible • Prestige bias may be significant for charter and private boats with gamefish fishers • Potential issues with clubs coercing members not to provide data, or provide misleading data to protect their local fishery
		National register of fishers	• Would solve the issues of finding these rare gamefishers • Critical to have cooperation with states to have a systematic compliance approach • Needs careful consideration whether it is a compulsory or voluntary register? • Aerial spotter may help calibrate game fisher numbers on the water • Politics and cost vs. other screening methods need further consideration
		Respondent-Driven Sampling	• Theoretically an ideal method for accessing these rare fishers who target SBT • Currently an untested method and requires validation before using with SBT • Spatial issues need consideration. Need several "seeds" fishers to start the surveys in major Aust cities and regional areas where SBT are caught. Need to ensure there is sufficient connectivity between clusters to be sure the entire population is surveyed
CSF	Various reef fish (e.g. coral trout, lutjanids, lethrinids)	Telephone-diary survey	• Only a small number of large charter and private boats fish in Coral Sea • Best option is to keep close contact with individual operators with phone/diary survey • Aerial survey initially required to validate numbers of participants in the fishery • Species identification a significant problem. Photos from operators completing diaries may be used for validation. On-site surveys for validation not an option due to enormous number of access points and only a few boats participating in the fishery • Catches from international boats that never land in Australia may be reasonable and will likely remain an unaccountable catch

7.4 Workshop outcomes and further method development

The workshop participants successfully met all three workshop objectives, by exchanging up-to-date information on recreational fishing survey methodologies, prioritising the Commonwealth fisheries and species that require monitoring for recreational catches, and making recommendations as to the most statistically robust and cost-effective options for monitoring the recreational catch in Commonwealth fisheries. Some important outcomes from presentations and groups discussions are summarised below.

There are important interactions between almost all Commonwealth fisheries and recreational fisheries. Fisheries with the most significant interactions in terms of commercial or conservation value of species taken by recreational fisheries are: SBT, SESSF, ETBF, and WTBF. The highest number of interactions occurred in the SESSF, CSF, TSF and the ETBF.

No single survey approach can representatively sample recreational fishers in all Commonwealth fisheries, or even every species in a single fishery. Some species in the ETBF require very different sampling methods, for example the majority of the striped marlin are caught by trolling lures or baits offshore, while in contrast longtail tuna are primarily caught by lure-casting and on live baits in inshore waters and from the shore.

The primary hindrances in being able to cost-effectively sample the recreational catch of almost all Commonwealth-managed species are: i) that fishers who target Commonwealth-managed species are often specialists and are rare within the general recreational fishing population, and ii) the lack of complete sampling frame from which to draw a representatively sample of fishers to survey. Although several large list frames exist for recreational fishers (e.g. licence lists), they are incomplete or are not consistent across the scale of most Commonwealth fisheries. The proposition of a National Register of Recreational Fishers would alleviate many of the problems of incomplete list frames to recruit subjects for cost-effective telephone and/or diary surveys, although there are likely to be significant political and social barriers in its implementation and compliance.

Three main survey options were recommended across all Commonwealth fisheries, although the same survey type (e.g. telephone-diary survey) would need to be specifically tailored for a given fishery or species. These main surveys are complemented in nature and consist of: i) a telephone-diary survey for catch and effort in situations where a complete list frame exists; ii) BPC aerial surveillance data to estimate effort, combined with an off-site diary or on-site access point survey to estimate catch, and iii) infiltrating social networks of hard-to-reach specialised fishers using Respondent-Driven Sampling to estimate both catch rate and population size.

Social network sampling, such as Respondent-Driven Sampling and Time-Location Sampling, has the potential to penetrate the minority groups of specialised fishers who fish in Commonwealth waters. These methods are widely and effectively used in epidemiology and social sciences to access rare or ‘hidden’ components within the general population, but have never been used in recreational or commercial fisheries research. Social network sampling methods have great potential as a statistically robust

and cost-effective means of representatively sampling recreational fishers, but require testing and validation of results before widespread implementation in a recreational fishing monitoring program for Commonwealth fisheries.

Following the workshop, the project team aimed to assign costs for an annual survey using each of the survey designs recommended by the workshop participants for key Commonwealth fisheries or species. Further work, which is described in detail in subsequent chapters, was then undertaken on developing the recommended designs for optimal cost-effectiveness but to also retain sufficiently robust data for use in stock assessment. Our initial approach was to first determine the influence of including different types of recreational fishing data, ranging from a single annual catch estimate, to a time series of standarised catch and effort data, on the outcomes of stock assessment for data-poor and data-rich Commonwealth-managed species. After these analyses were completed, further development was undertaken to adapt the CSIRO's FFV model to estimate recreational fishing effort using the Coastwatch aerial surveillance data, and further investigation as to how Respondent-Driven Sampling could be used to estimate the total catch of Commonwealth-managed species.

8. INCLUDING RECREATIONAL FISHERIES DATA IN STOCK ASSESSMENTS FOR COMMONWEALTH SPECIES

8.1 Introduction

The inclusion of recreational fisheries data in stock assessments for Commonwealth species is rare. This is largely due to a lack of reliable recreational fisheries data, particularly when compared with that from commercial fisheries. However, recreational fishing may account for a significant proportion of the catch and effort for some Commonwealth-managed species. For example, Griffiths and Pepperell (2006) identified three major species groups that potentially have high levels of interactions between recreational and commercial fishing operations, which include pelagic fishes (e.g. tunas and billfishes), demersal slope and shelf species, and tropical reef species.

Australia's harvest strategy policy "applies to fish stocks throughout their range and mortality resulting from all types of fishing" (A.F.M.A., 2007). This suggests that scientific advice used to recommend management action ought to include recreational fisheries, either in the assessment itself, or as part of the harvest control rule. This is a rule that translates a stock indicator from the results of a stock assessment analyses to quantities used for management, such as recommended catch. Indeed, improper accounting for sources of mortality when conducting stock assessments – this can include the magnitude of commercial catch, discard, age structure, or recreational catch – can result in biased estimates of stock indicators (e.g. current biomass) and reference points (Williams, 2002).

Data from recreational fisheries can be readily incorporated into stock assessments. Indeed, for many fisheries managed at the state level in Australia, recreational fishing activity is the motivation for conducting stock assessments. Inclusion of such data could, in principle, be incorporated into assessments of Commonwealth stocks. However, the methods for, and value of, doing this will vary depending on the species, the assessment method, and type of management employed. Methods for stock assessment applied within the Southern and Eastern Shark and Scalefish Fishery (SESSF) and eastern tuna and billfish (ETBF) fisheries are typically determined by the types and quality of data available. The majority of stock assessments and applications of harvest strategies are catch driven, either as a result of needing to accurately account for removals in a population dynamics model, or applying the results of a data-poor stock indicator (such as recent trend in catch rates) to an estimate of current catch in order to determine suitable management action.

The objective of this section was to review the stock assessment methods currently used in the SESSF and ETBF, along with applications of the harvest strategy policy in these fisheries, with the purpose of indicating where data from recreational fishing can fit in to the process. These commercial fisheries were identified in workshop 1 as having species that are likely to have a high interaction with recreational fisheries. Scenario modelling was then undertaken to illustrate, for a data-rich assessment of an ETBF species (striped marlin) and a data-poor SESSF stock (blue eye trevalla), and the implications of including recreational fisheries data in the assessments.

8.1.1 SESSF stock assessments and harvest strategy framework

The provision of scientific advice for quota-managed stocks within the SESSF is performed under a harvest strategy framework (HSF) (Smith and Smith, 2005; Smith et al., 2008). The HSF is composed of a 'Tier' framework of assessment methods and harvest control rules (HCRs), with the choice of tier level dependent upon the information available for the species. Lower Tier levels reflect greater uncertainty regarding stock status. Under a precautionary approach, lower Tiers should lead to higher stock biomass and lower catches. As assessed stocks are managed using a Total Allowable Catch (TAC), quantification of removals is needed for assessment purposes and application of the harvest strategy. Consequently, stock assessments and application of harvest strategies are catch-driven.

Data-rich, Tier 1 assessments calculate a Recommended Biological Catch (RBC) based on removals by statistically fitting a population dynamics model to a range of available data, which typically includes standardised catch-per-unit-effort (CPUE), length composition, age composition and discard proportions. Assessment results include time series of biomass, and estimates of stock status relative to biological reference points. There is a growing trend in the SESSF toward using Stock Synthesis (e.g. Methot, 2009) as a standard software package, which is a sufficiently flexible approach that can accommodate data types other than those mentioned above, where available. Assessments using Stock Synthesis generally assume that catches (retained) are known without error, with total catch (including discards) estimated. However, it is possible to fit models to catch data and recognise uncertainty in these data. In general, the fitting of these types of assessment models allows for explicit accounting for different levels of uncertainty among data sources.

In contrast, the data-poor Tier 3 and 4 HCRs translate a stock indicator from a simple assessment (e.g. catch curve analysis, relative levels of standardised CPUE) to a RBC using an estimate of current catch levels (Klaer et al., 2009; Little et al., 2009). In general, the assessment analysis is done on a broad scale within the fishery with the stock indicator coming from the sector of the fishery with the most information, or that deemed most representative of the fishery/stock dynamics.

The RBC represents total kill. Across Tier levels, the RBC is translated to the TAC by subtracting removals from other sources (e.g. state commercial catches, discards), and applying appropriate modifiers depending on Tier level (discount factor to accommodate increased uncertainty due to data limitations), and other considerations. While the harvest strategy framework consists of these control rules, the annual assessment process also allows for the consideration of additional data, liaison with stakeholders, and alternative/additional management arrangement such as area closures and gear restrictions. Such a format, allowed for within the harvest strategy policy, enables consideration of alternative indicators that might provide information on fishery status while not formally being included in the HCRs.

8.1.2 ETBF stock assessments

In contrast to assessments for SESSF species, which typically only comprise Australian waters, stock assessments for target species within the ETBF are conducted on a much larger scale (ocean-wide), and incorporate information from fishing fleets of numerous nations. Assessments are mostly conducted on a regional fisheries management organisation basis, with the Western Central Pacific Fisheries Commission (WCPFC), by the Secretariat of the Pacific Community (SPC). Given the wide spatial distribution of target species, the ETBF encompasses only a small part of the assessment area.

As opposed to output control via say a TAC, focus for management in the ETBF has been on effort limitation (A.F.M.A., 2009), with steps in recent years to move toward a comprehensive harvest strategy framework for managing effort levels within the fishery (Campbell et al., 2007).

As with the data-rich stocks in the SESSF, the assessment procedure for ETBF target species typically involves fitting a model of population dynamics to a range of available data from multiple fishing fleets. Assessments have been undertaken using MULTIFAN-CL software (Fournier et al., 1998), where catches are usually fit to time series of effort.

In general, catches tend to be treated as uncertain, more so than in the SESSF. As data come from several nations, Australian commercial catches tend to comprise a small percentage of the overall exploitation of species. Consequently, levels of recreational catch for ETBF species in Australia might be considered a smaller percentage and possibly therefore well within the level of uncertainty already ascribed to the magnitude of catches within the fishery as a whole.

8.2 Approaches for incorporating recreational fisheries data into stock assessments for Commonwealth-managed species

This section discusses how data from recreational fishing could be incorporated into current stock assessment procedures and HCRs for SESSF and ETBF species.

8.2.1 Data-rich assessments – Age/length-structured and catch at age models

The flexibility of the assessment models and software packages typically utilised when conducting assessments for data-rich species in the SESSF and ETBF means that, in principle, inclusion of recreational data in these assessments is relatively straightforward. The challenge is ensuring that these data are representative of the respective fisheries. Indeed, there are instances where statistical catch-at-age models of fished populations managed at the federal level have been fit to data from fisheries where the majority of information (and exploitation) has come from recreational fisheries (e.g. Cope and Key, 2009).

In application, recreational fisheries are simply included as separate fleets with their own parameters governing selectivity, catchability, and so on. This allows for incorporation of catch levels, and that recreational fisheries are likely to exploit a different age structure or portion of the population than commercial fisheries.

Such implementation generally implies that the following are available:

1. removals (retained or total) or effort (when fitting to catches), and
2. some metric of the component of the population impacted, such as a size/age metric from the catch (e.g. mean length or complete length composition)

The latter is necessary to be able to estimate the relative selectivity of the recreational fleet.

Where such information might not be available, alternative assumptions need to be made regarding the population targeted by recreational fisheries. This might typically involve assuming that the recreational selectivity is the same as the commercial sector, effectively adding recreational catches to the commercial catch. For example, the 2006 assessment for striped marlin in the Southwest Pacific (Langley et al., 2006) utilised information on Australian and New Zealand recreational fisheries. Size data were available for the New Zealand recreational fleet (see Kopf et al., 2005), and so a separate selectivity pattern was able to be estimated for this fleet. Conversely, no size data were available from the Australian recreational sector, and so it was assumed that this fishery had the same selectivity as the Australian commercial catch in order to include the recreational catch data.

The fitting of statistical catch-at-age models (sometimes referred to as 'integrated analysis') is conducted under a 'use it where you have it' concept, so that missing data are easily accommodated. A full time-series of data is not required, and mismatches among the length and timing of different datasets is not problematic.

As the software used to conduct these assessments is generally flexible, additional data types can be accommodated. Standardised CPUE series are a standard input, but it is possible to include catch in numbers rather than weight, size indicators such as mean length, or proportions by size class (e.g. 'small, 'medium', or 'large'), which may be more typically collected from recreational fisheries as opposed to comprehensive size or age composition data. These data can be easily incorporated in Stock Synthesis.

8.2.2 Data-poor assessments – SESSF Tier 3 & 4

Unlike the data-rich assessments, the manner in which data from recreational fishing would be included in data-poor assessments and harvest control rules is less straightforward.

In the SESSF, data-poor stock/performance indicators are generally derived at an aggregate basis from the fleet and/or area taking the majority of the catch. This would in most cases be the commercial catch, and so the length frequency and CPUE data from recreational fishing would likely not be included in the assessment analysis itself.

However, calculation of RBC requires accurate estimates of current removals and/or effort, and it is in the determination of both reference catch levels (used to define targets) and the current catch levels where information from the recreational catch could be input into these procedures. Consequently, the primary information of interest in these instances would be the magnitude of recreational catches.

Aside from the formal assessment procedures and harvest control rules, calculation of empirical stock indicators from recreational data can be informative regarding differential impacts among fleets. Indeed, less data intensive assessment methods may also gain value from the inclusion of representative recreational fisheries data when evaluating the impact of different fishing fleets on fish stocks, and subsequent translation to management responses. For example, comparison of CPUE trends among recreational and commercial sectors.

8.3 Testing the performance of data-rich assessments for striped marlin with a recreational fishery

This section describes a simulation modeling approach to evaluate how the performance of a data-rich stock assessment (Stock Synthesis applied to striped marlin) changes after the inclusion of data from a recreational fishery. The work focuses on a case where a recreational fishery is present, but the information from that component of the catch is varying. The work examines the impact of necessary assumptions (ignoring recreational catches, assuming selectivity is the same as commercial) on the ability of the stock assessment to estimate spawning biomass related quantities, and compares assessment performance with assessment models that fully recognize the recreational fishery, and instances where the magnitude of the commercial catch is uncertain. The specific questions addressed by this work include:

- How does not including recreational data impact assessment performance?
- How does including different quantities of data improve assessment performance?
- How does assessment performance change when there is uncertainty in the commercial catch?

The latter point is particularly pertinent to ETBF species, where the catch information is derived from a range of sources, and at the regional scale the assessments are conducted, catches from recreational fishing in one country may be within the uncertainty associated with the catch data themselves. A preliminary analysis investigating the ability to determine that an observed commercial catch level was less than the total catch (commercial plus recreational) showed that even with moderate levels of (unbiased) uncertainty in the commercial catch, distinguishing data as being different from the total catch was difficult (Figure 8.1).

8.3.1 Methods

A Monte Carlo simulation approach is used to test alternative assessment models for striped marlin, which differ in the data that are available from the recreational fishery. The simulations use the 2006 SW Pacific assessment for striped marlin (Langley et al., 2006) to tune an operating model for striped marlin that includes both a commercial and a recreational fishery. These data are used to represent the state of the true system that the data available to the assessment models are generated from. Striped marlin is used as a case study to investigate model behaviour, the interest is not in replicating reality, and so the models utilised are less complex than those that would be employed for stock assessment purposes.

Simulation framework

Scenarios considered included consideration of differences in:

- The magnitude of recreational catches, with the current catch levels (either 10 t, 100 t, or 1000 t) assumed to have increased linearly over time from zero over the last fifteen years of the assessment, beginning in 1989 (Figure 8.2).
- True pattern for selectivity at length for the recreational fishery (Figure 8.2),
- Whether the commercial catch data is known correctly, or with error (distributed lognormally with a CV of 0.07 or 0.2),
- Whether catch from the recreational fishery was included in the assessment or not,
- Whether length data from the recreational fishery was available to the assessment or not, determining whether or not to estimate a separate selectivity pattern for the recreational fishery.

A fully crossed experiment was conducted given the different levels for each factor in the scenarios, except where this did not make sense. For example, the estimated selectivity at length for the recreational fishery was only allowed to be different from that of the commercial catch when length data from the recreational fishery were included in the assessment.

Note that where the recreational fishery was included in the assessment, the catches were assumed to be known correctly without error. Although not realistic, this was so the relative value of including these data given the uncertainties in the commercial data could be ascertained.

Operating Model

The operating model consists of an age-structured sex-specific population dynamics model, exploited by two fleets (commercial and recreational), and with fishing assumed to take place in the middle of the year. Full technical specifications for the generalized version of the operating model are detailed in Fay et al. (2009). The values for life-history parameters (e.g. growth, natural mortality, fecundity), parameters governing the

stock-recruitment relationship, and the time series of commercial catch (based on reported longline catch) were taken from the analyses detailed in Langley et al. (2006), and are shown in Figure 8.2.

The population was assumed to be unexploited with equilibrium age structure in 1920. The operating model was therefore run forward with recruitment variability for some 30 years before the first commercial catches were introduced. This was to 'burn in' the population such that the age structure was not in equilibrium as a result of recruitment variability.

For the true selectivity at length of the recreational fishery, three alternative assumptions were made (Figure 8.2):

1. that the recreational fishery targets the same portion of the population as the commercial fishery
2. the recreational fishery only targets large fish (adults)
3. the recreational fishery only targets small fish (juveniles)

Data were generated from the operating model dynamics given pre-specified levels of observation error. For the commercial fishery, this comprised of catch data (with or without error), a 50-year time series of CPUE (log-normal with CV=0.2 and constant catchability), and 40 years of length data (annual effective sample size of 250). The effective sample size used is higher than those assumed in the 2006 stock assessment (where they were capped at 100), however the simulations here did not include data from average weights, and so the information content of the length data was increased to reflect that more data should be available. Data from the recreational fishery, when generated, was limited to the time series of catch and, for some scenarios, length composition data. This was collected in proportion to the commercial catch length data.

Stock assessment model

The stock assessment models were similar to the operating model in that it considers exploitation of a singe stock by commercial and (for some cases) recreational fisheries. The population was assumed to be in unfished equilibrium, with an equilibrium age structure, in 1950. Spawning biomass in 1950 (SB_{1950}) is therefore used as the estimate of unfished spawning biomass, SB_0. Note that the operating model did not have an equilibrium age structure at this time, as the impacts of historical recruitments on age structure were included.

All assessment models assumed that the catch data were correct. However, for scenarios where there was uncertainty in the commercial catch data generated from the assessment model, this was not included in the stock assessment model.

Three assessments were used to estimate stock status for the different scenarios, these differed in the way in which data from the recreational fishery was included:

1. No recreational data, only data from the commercial fleet was included in the assessment

2. Recreational catch data available, selectivity assumed to be the same as the commercial
3. Recreational catch and length data, with estimation of a separate selectivity pattern for the recreational fleet

In general, the biological parameters of the assessment model and the parameters of the stock-recruit relationship (apart from the average level of unfished recruitment) were fixed at their 'correct' values as used in the operating model. The population dynamics model, and the statistical approach used in the fitting of the model to the various types of data, are given fully in the technical description of the Stock Synthesis assessment software (Methot, 2009) and are not reproduced here. Statistical fitting of the population dynamics model to the available data is achieved by minimising an objective function consisting of several likelihood components, reflecting the different types of data input (commercial CPUE, length compositions), and also the distribution of annual recruitment deviations around the stock-recruit relationship.

The estimated parameters of the assessment model were: average recruitment before fishing, annual recruitment deviations from 1958, and the parameters determining the functional form of the selectivity pattern for each fleet (allowed to be dome-shaped).

Note that this assessment approach is a little different to that actually used in the MULTIFAN-CL assessments. However, the availability of software to conduct the simulations meant that Stock Synthesis was a more feasible choice. MULTIFAN and SS both behave in similar ways, in that they are types of integrated analysis that make use of multiple data sets and attempt to reconcile the parameters of a population dynamics model to these data. While not completely the same, it is not unreasonable to assume that general patterns of performance observed when comparing the scenarios would also be obtained were the actual assessment software used.

Evaluating model performance

Assessment performance was compared among scenarios using the distribution of the percent relative errors (%REE) for the following quantities of interest:

1. unfished spawning biomass, B_0
2. current (2005) spawning biomass (B_{2005})
3. current relative spawning biomass (B_{2005}/B_0)

These quantities do not include productivity related quantities such as B_{MSY} or F_{MSY}, largely because the assessment model does not estimate steepness, growth or natural mortality (M), although it does estimate selectivity.

8.3.2 Results

Figure 8.3, Figure 8.4, and Figure 8.5 show the distributions for the percent relative error of estimate (%REE) for the current spawning biomass, current spawning depletion (current spawning biomass relative to unfished), and unfished spawning biomass. Each Figure summarises the results of the various scenarios, with each box and whisker representing the output from 100 simulations. Ideally, the median black line inside the box should be around 0 (unbiased), and the box and whisker height should be small (precise).

When the recreational catch is small (current 10 t), it makes little difference whether these catches are included in the assessment or not. For larger recreational catches (100 t and 1000 t), the assessment estimates biomass and relative biomass more poorly when recreational catches are not included (Figure 8.3, Figure 8.4, and Figure 8.5, compare distribution of %REE among rows). The bias in the estimates obtained from the assessment when not including recreational data is greater when the true selectivity is different from the commercial catch, which is the effect of not including those data is greater. This is important as recreational fisheries most likely impact different size or age structures to the commercial fleets, due to differences in gear, and spatial and temporal distribution of fishing effort.

When the true recreational selectivity is different from the commercial fishery, not having length data from the recreational fleet still results in biased estimates, particularly for the relative spawning biomass (Figure 8.4). This bias is removed when recreational length data is included in the assessment, enabling a separate selectivity pattern to be estimated.

When there is observation error in the commercial catch, the assessment models generally estimate biomass more poorly than when catch is known correctly, especially for the estimates of unfished biomass (Figure 8.5). There appears to be some evidence for a smaller effect of not including recreational catch data when the commercial catches are uncertain on the estimates of current depletion (relative spawning biomass, Figure 8.4), although this is not universal. Indeed, when the true selectivity of the recreational fleet is different to that of the commercial fleet, and the commercial catch data has a CV of 20%, the assessment that ignores recreational catches results in the worst estimates of current and unfished spawning biomass (with a large positive bias). The observed behaviour in response to uncertainty in the commercial catch data may be a result of the fact that this uncertainty was added as noise (i.e. the catch data contained error but were unbiased). In reality, catch data, if they are imprecise, are most likely to be under-reported (i.e. have a negative bias). This may then have a different effect on the model behaviour, which could be more intuitive with respect to whether this error effectively includes the recreational catch or not. The simulation results suggest that, despite whether the commercial catch data are uncertain or not, improved assessment performance results from including recreational data within the assessment framework.

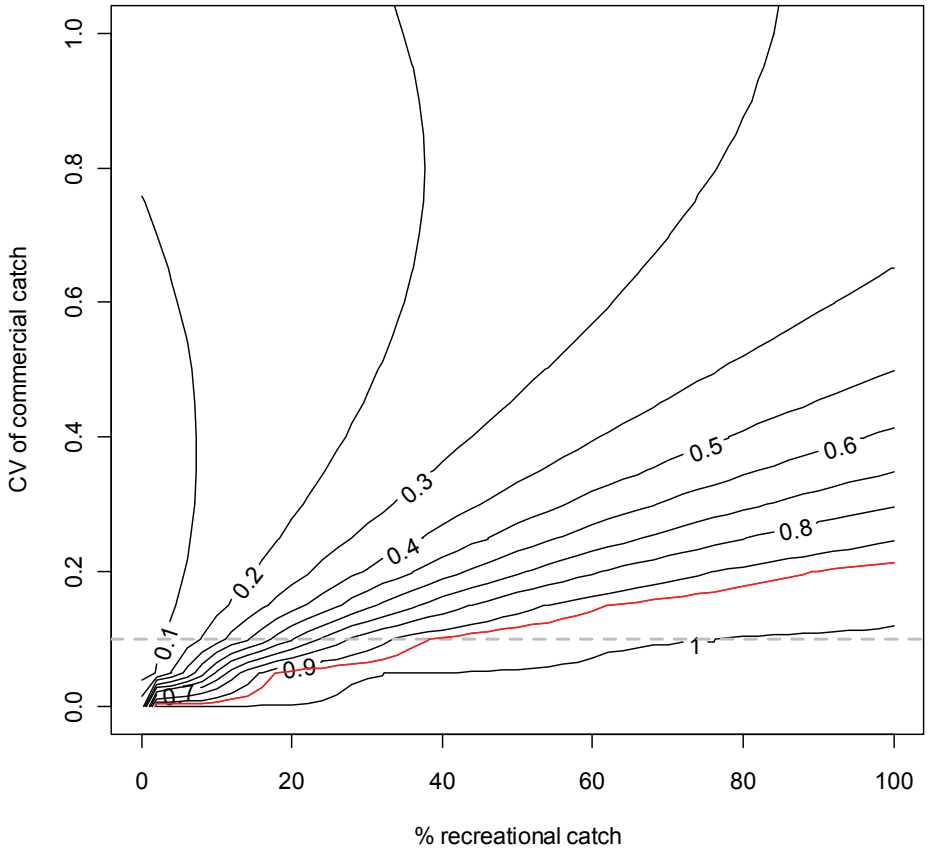

Figure 8.1: The probability of accepting that a given observed commercial catch level is less than a total catch (commercial plus recreational) for different levels of recreational catch relative to the commercial, and different levels of error associated with the commercial catch data.

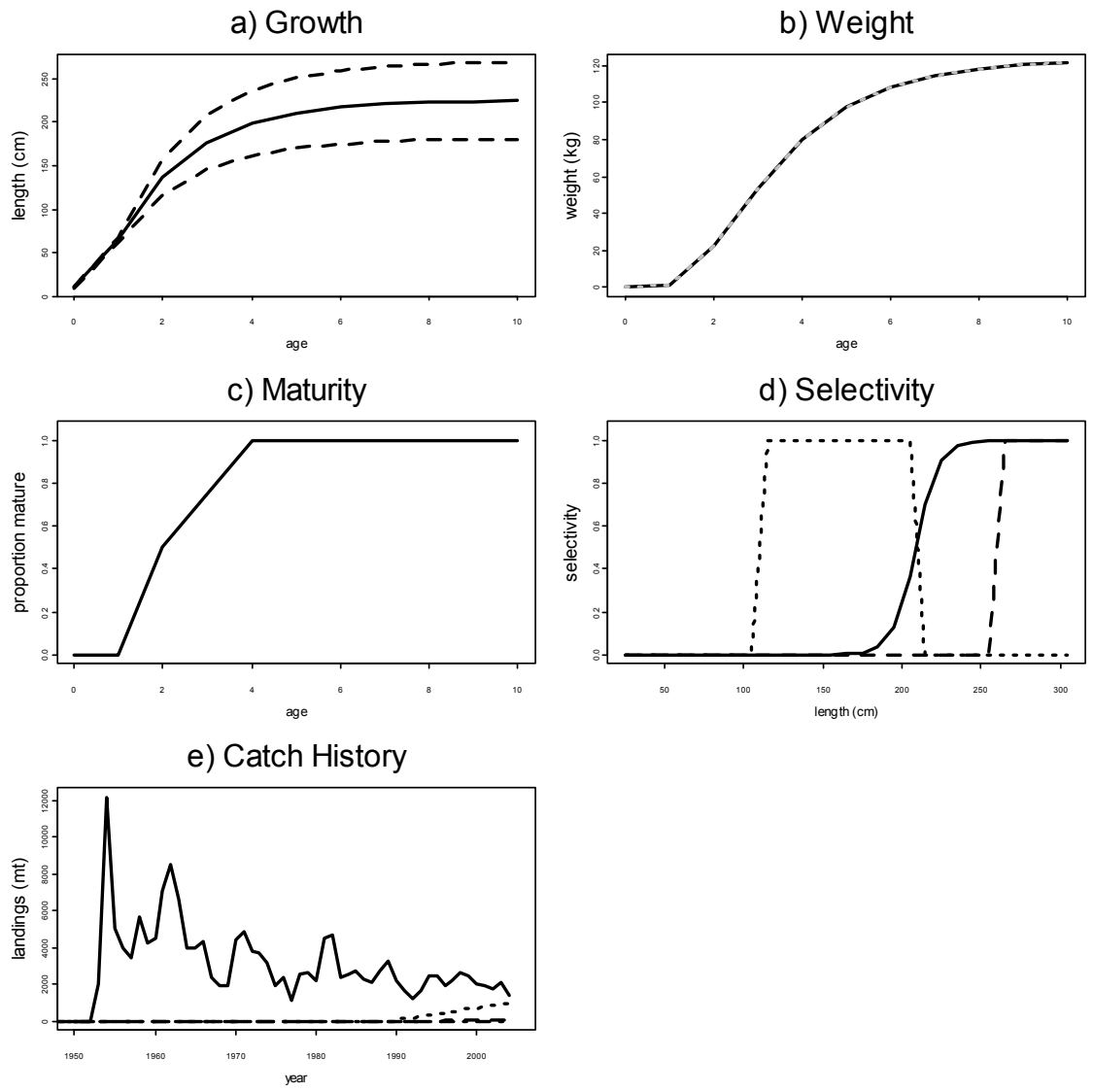

Figure 8.2: Biological and fishery-related parameters. Solid lines in Growth panel represent mean lengths-at-age in the middle of the year; dashed lines correspond to the 95% intervals of the distribution for length-at-age. Selectivity panel shows the commercial selectivity, which is asymptotic with length (solid line) and alternative specifications for the recreational fishery, depending on whether it is assumed to take young (dotted line) or old (dashed line) individuals. Catch history panel indicates the commercial catches (solid line) and alternative recreational catch histories (dashed and dotted lines), the latter increasing from zero over a period of 15 years to totals of 10 t, 100 t, or 1000t in 2004.

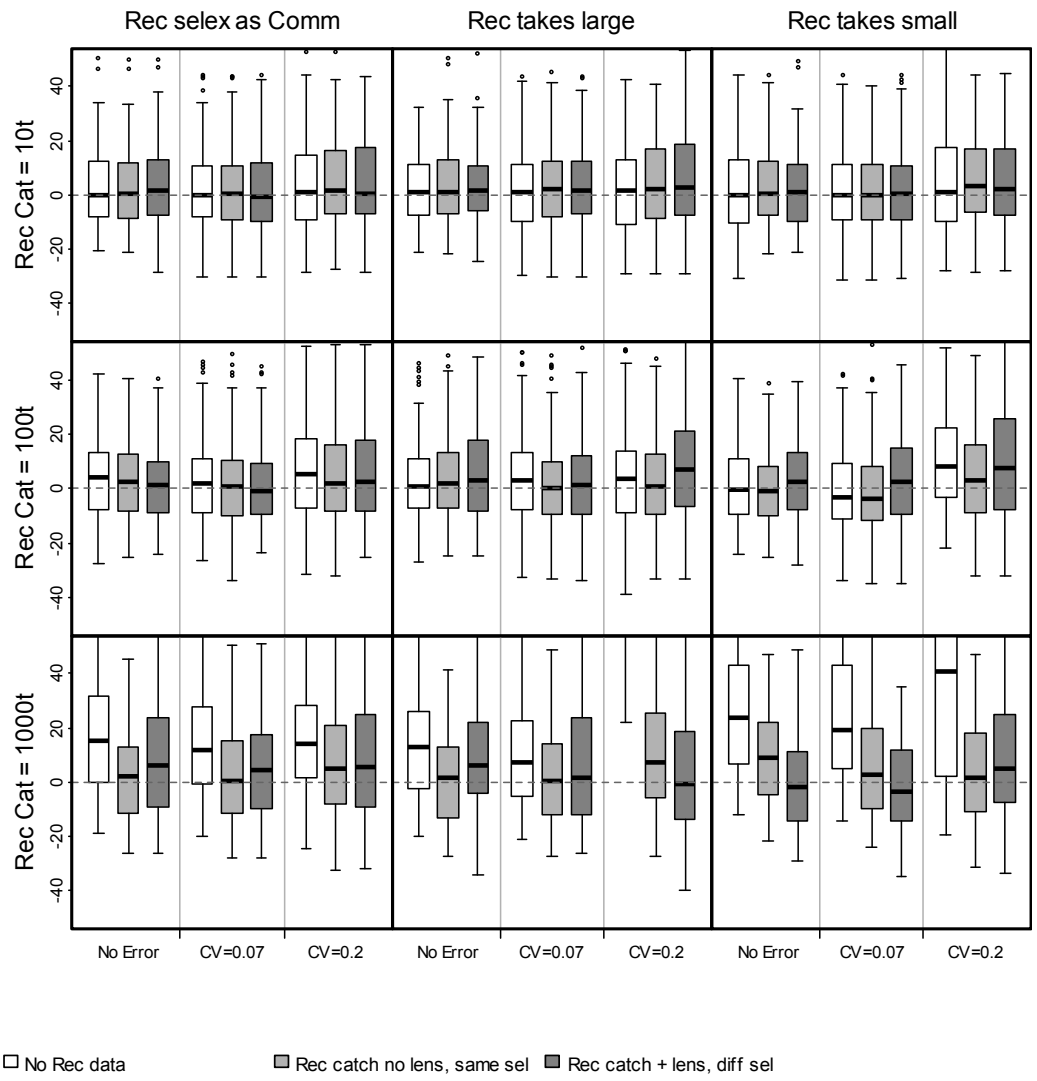

Figure 8.3: Distributions for the percent relative error of estimate (%REE) in the current spawning biomass for the striped marlin simulations. Rows are for different levels of true current recreational catch, main columns represent the different patterns for the true recreational selectivity. Sets of triplets within the main panels refer to the magnitude of observation error in the commercial catch data, and the different colour boxes refer to the 3 assessment methods. Box and whiskers summarise the results across simulations by showing the median (black line), central 50% (box), 95% (whiskers), and outliers (points). Horizontal dotted lines indicate an error of estimate of zero, i.e. that the estimate was the same as the true value.

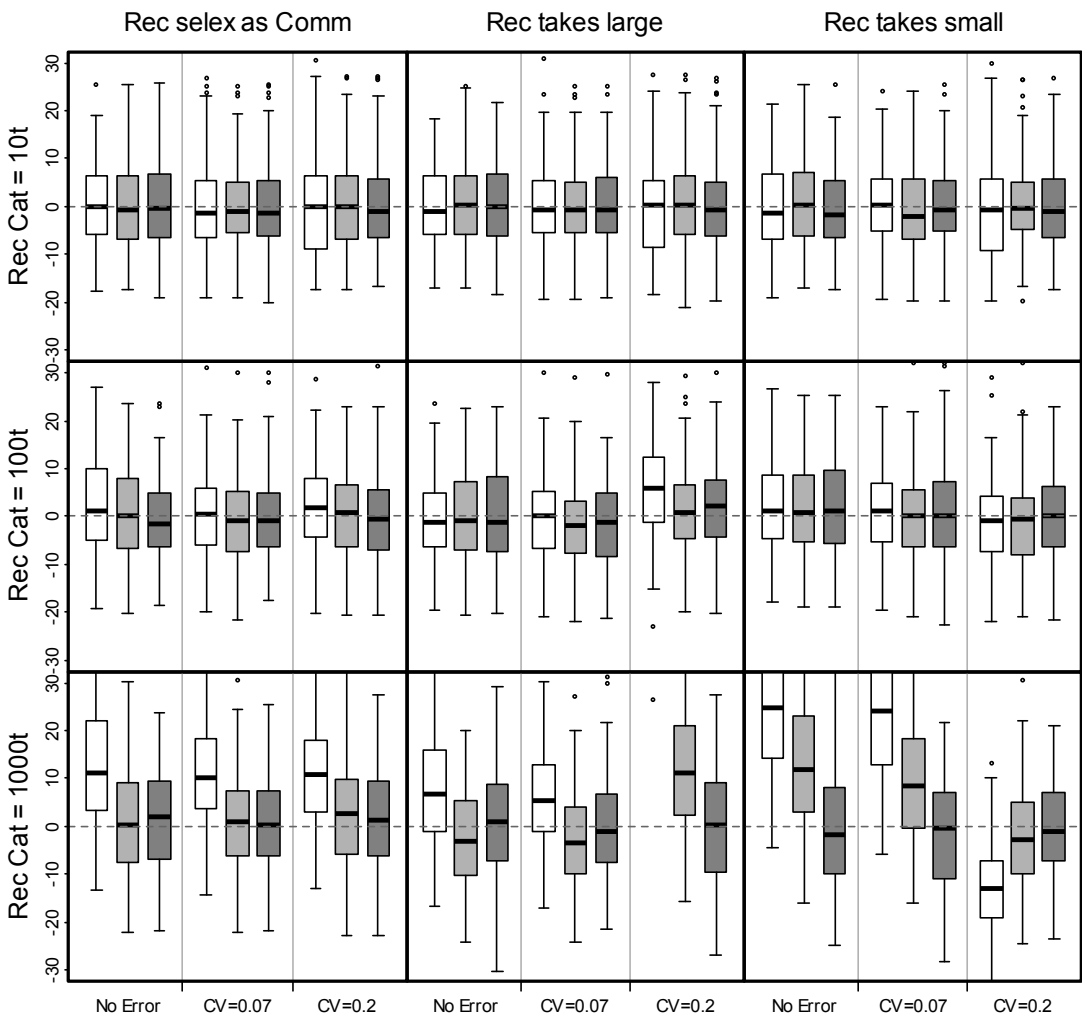

Figure 8.4: Distributions for the percent relative error of estimate (%REE) in the current depletion (current spawning biomass relative to unfished spawning biomass) for the striped marlin simulations. Rows are for different levels of true current recreational catch, main columns represent the different patterns for the true recreational selectivity. Sets of triplets within the main panels refer to the magnitude of observation error in the commercial catch data, and the different colour boxes refer to the 3 assessment methods. Box and whiskers summarise the results across simulations by showing the median (black line), central 50% (box), 95% (whiskers), and outliers (points). Horizontal dotted lines indicate an error of estimate of zero, i.e. that the estimate was the same as the true value.

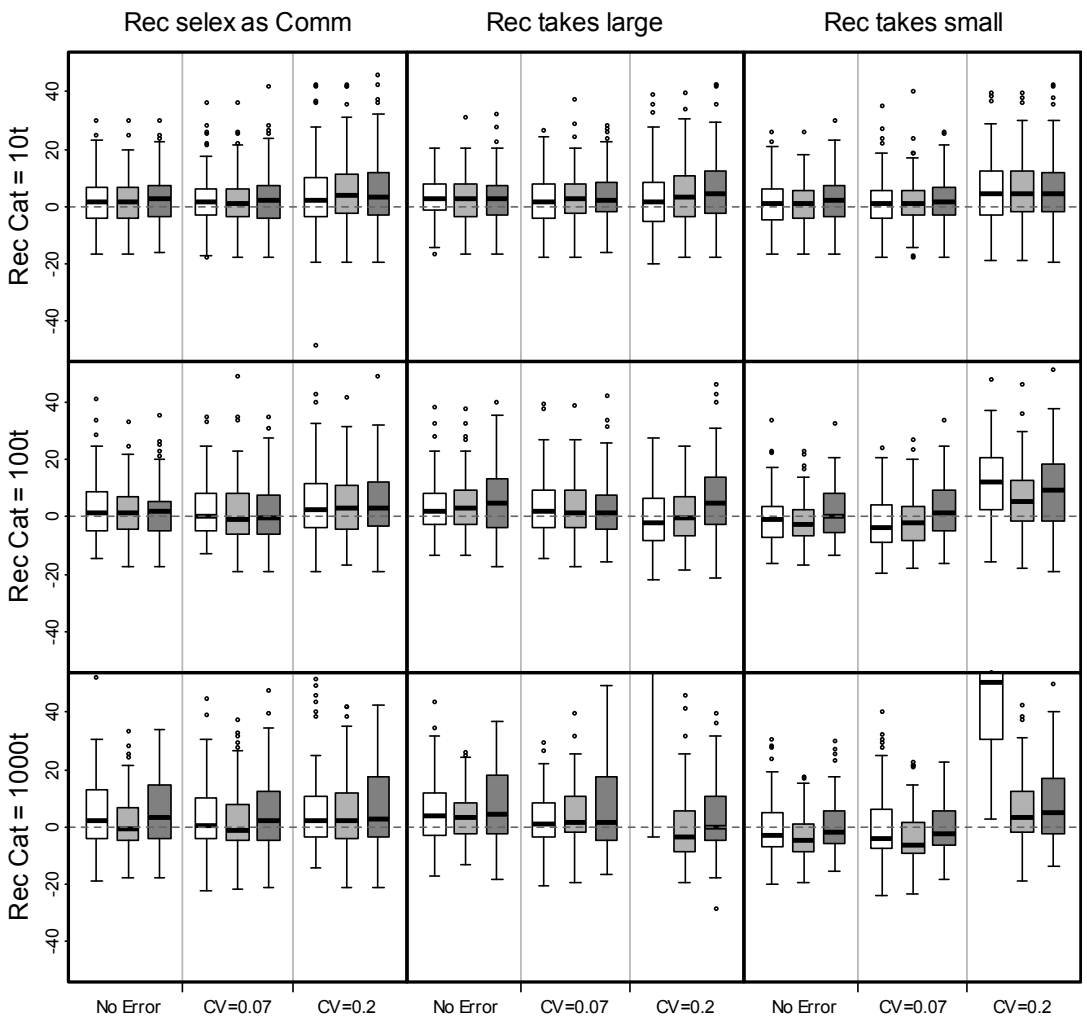

Figure 8.5: Distributions for the percent relative error of estimate (%REE) unfished spawning biomass for the striped marlin simulations. Rows are for different levels of true current recreational catch, main columns represent the different patterns for the true recreational selectivity. Sets of triplets within the main panels refer to the magnitude of observation error in the commercial catch data, and the different colour boxes refer to the 3 assessment methods. Box and whiskers summarise the results across simulations by showing the median (black line), central 50% (box), 95% (whiskers), and outliers (points). Horizontal dotted lines indicate an error of estimate of zero, i.e. that the estimate was the same as the true value.

8.4 Including data from recreational fisheries when applying the SESSF Tier 4 harvest control rule

Tier 4 analyses for data-poor SESSF stocks rely on standardised CPUE indices, which are generally derived at an aggregate basis, with the CPUE series used typically being from the fleet and/or region taking the majority of the catch, or which is best believed to represent changes in abundance of the stock. Little et al. (2009) described the Tier 4 HCR in detail, but essentially, the HCR operates by comparing the recent CPUE to that during a reference (target) period, and then calculates the RBC by scaling the average catch during the reference period depending on the value for the current CPUE relative to the reference period.

As the analysis is conducted on an aggregate basis on the dominant component of the catch, it is unlikely that CPUE from a recreational fishery would be used for most SESSF species. However, calculation of RBC requires accurate estimates of both current removals and, for Tier 4, those during the reference period. It is in determining these catch levels where data from recreational fishing would most appropriately be included, as this is also where additional sources of fishing mortality (discards, state catches) are accounted for.

Inclusion of recreational catch within a Tier 4 analysis may proceed as follows:

1. Addition of recreational catch during reference period to the reference catch, C*,
2. Calculation of RBC scaler based on standardised commercial CPUE value relative to the reference period,
3. Determine the RBC by multiplying the reference catch C* by the RBC scaler,
4. Applying the Tier 4 discount factor (reduces RBC by 15%),
5. Compute commercial RBC (TAC) by subtracting current recreational catch from RBC as well as the current levels of discard and state catches.

The impact of adding recreational fisheries data to the Tier 4 assessment will therefore likely depend on the trend in recreational catch over time, that is, the magnitude of current recreational catch relative to that during the reference period, and any change in the magnitude of the recreational catch relative to the total catch over these two times. This is because these catches would be added on before the analysis, and then removed following the analysis.

To illustrate the potential effects on the commercial RBC of including recreational data in Tier 4 analyses in this manner, we simulated Tier 4 analyses with recreational data using this framework, under a range of values for both the magnitude of reference period recreational catch, and the current recreational catch. As an example, this was applied to the results of the 2009 Tier 4 assessment for blue eye trevalla (*Hyperoglyphe antarctica*). The analyses were also conducted for a general case, over a large range of possible outcomes from the Tier 4 HCR that might result from standardisation of commercial CPUE (range of Tier 4 RBC scalers).

8.4.1 Example: Blue eye trevalla *(Hyperoglyphe antarctica)*

The 2009 Tier 4 assessment for blue eye trevalla (Haddon, 2009) resulted in a RBC scaler of 0.805 applied to the reference catch (1986-1995) C* of 667 t, giving an RBC (before application of the discount factor and removal of discards and state catches) of 536 t. After applying the 15% Tier 4 discount factor and then removing 36 t for state catches (data suggests zero discarding of blue eye), this resulted in a commercial RBC (effectively the TAC) of 419 t (A.F.M.A., 2010).

For the example simulations, we added a range of different levels of recreational catch to the reference catch of 667 t, applied the 2009 Tier 4 results (RBC scaler of 0.805), applied the 15% discount factor, subtracted the state catch, and then removed a range of values for the current recreational catch, to obtain values for the TAC when recreational catches were taken into account. The resulting outputs were then compared to the 419 t 2009 result, which does not include recreational data. The goal here was therefore to evaluate what the likely impact different levels of recreational catch would have on the Tier 4 results, rather than to identify what the actual recreational catch are.

The values for the blue eye trevalla TAC when including recreational catch are shown in Figure 8.6. Lower values for the TAC are associated with higher levels of recreational catch, and cases where the current recreational catch is higher than that during the reference period. The slope of the contours in Figure 8.6 is equivalent to the value of the RBC scaler. Figure 8.7 demonstrates the relative change to the 2009 assessment results, and shows that a 50 t current recreational catch of blue eye trevalla today versus 0 t during the reference period results in more than a 10% change in the TAC. Under a meta-rule within the current harvest strategy, annual TACs are only changed if the new calculated value results in more than a 10% change from the previous annual TAC.

The simulations are extended to results for a more general Tier 4 analysis by repeating the calculations for a range of possible values for the RBC scaler (Figure 8.8). The magnitude of recreational catch is expressed as a percentage of the commercial catch. Values of the RBC scaler less than 1 imply that the catch should decrease, and values greater than 1 suggest an increase. The contours show the greatest change in the TAC when including recreational catch over not including these catches occurs when the current recreational catch is higher than that during the reference period, when recreational catches are high compared to the commercial catch, and also when the result of the Tier 4 analysis suggests that the TAC should decrease as opposed to increase (Figure 8.8).

The results demonstrate that it is the trend over time in the recreational catch that is important in determining the impact of including these data on the recommended catch levels. This is because recreational catches are added to the reference catch and then subtracted from the resulting RBC. A recent increase in the level of recreational catch over that during the reference period would mean a lower TAC if recreational catch was included. While done for Tier 4, the results can also be extrapolated to the Tier 3 HCR, as the manner in which recreational catch would be incorporated into the HCR would be the same, despite the stock assessment analysis being different.

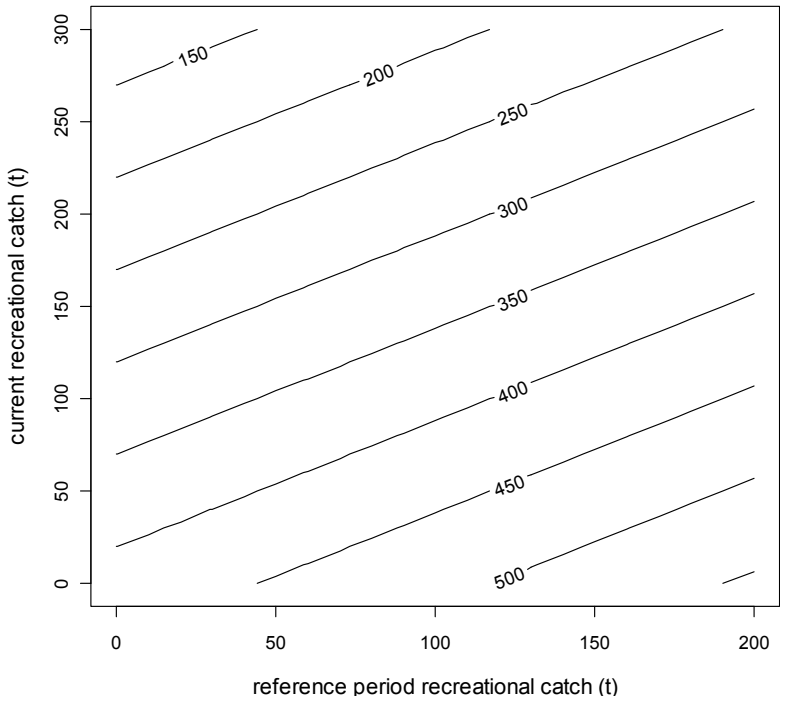

Figure 8.6: The commercial RBC (TAC) obtained when accounting for recreational catch in the 2009 Tier 4 analysis for blue eye trevalla (*Hyperoglyphe antarctica*), for different levels of historical and current recreational catches. The contour lines indicate the TAC obtained for the values of reference and current catch given on the axes.

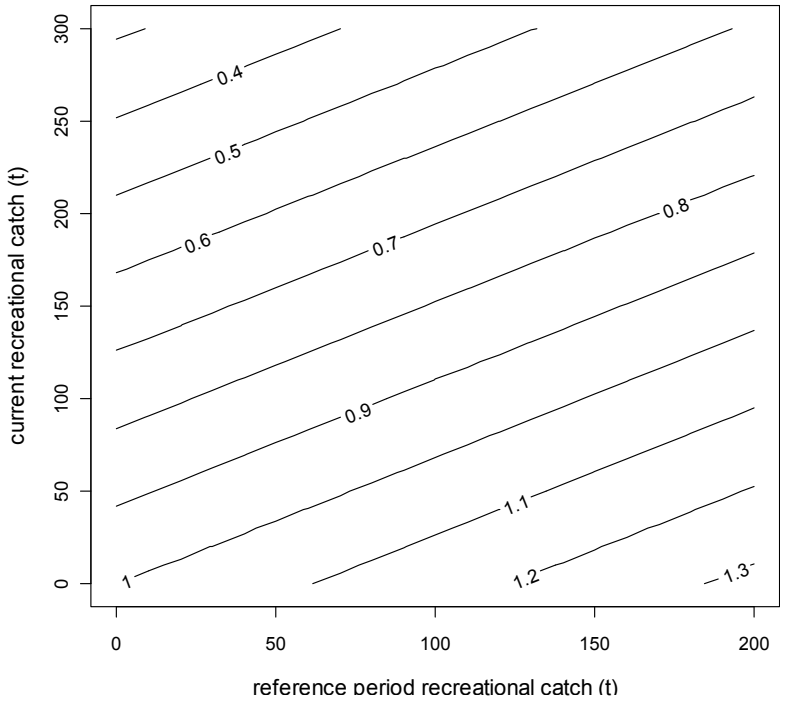

Figure 8.7: The commercial RBC (TAC) as a fraction of the 2009 stock assessment result for blue eye trevalla when accounting for different levels of recreational catch in the harvest control rule procedure.

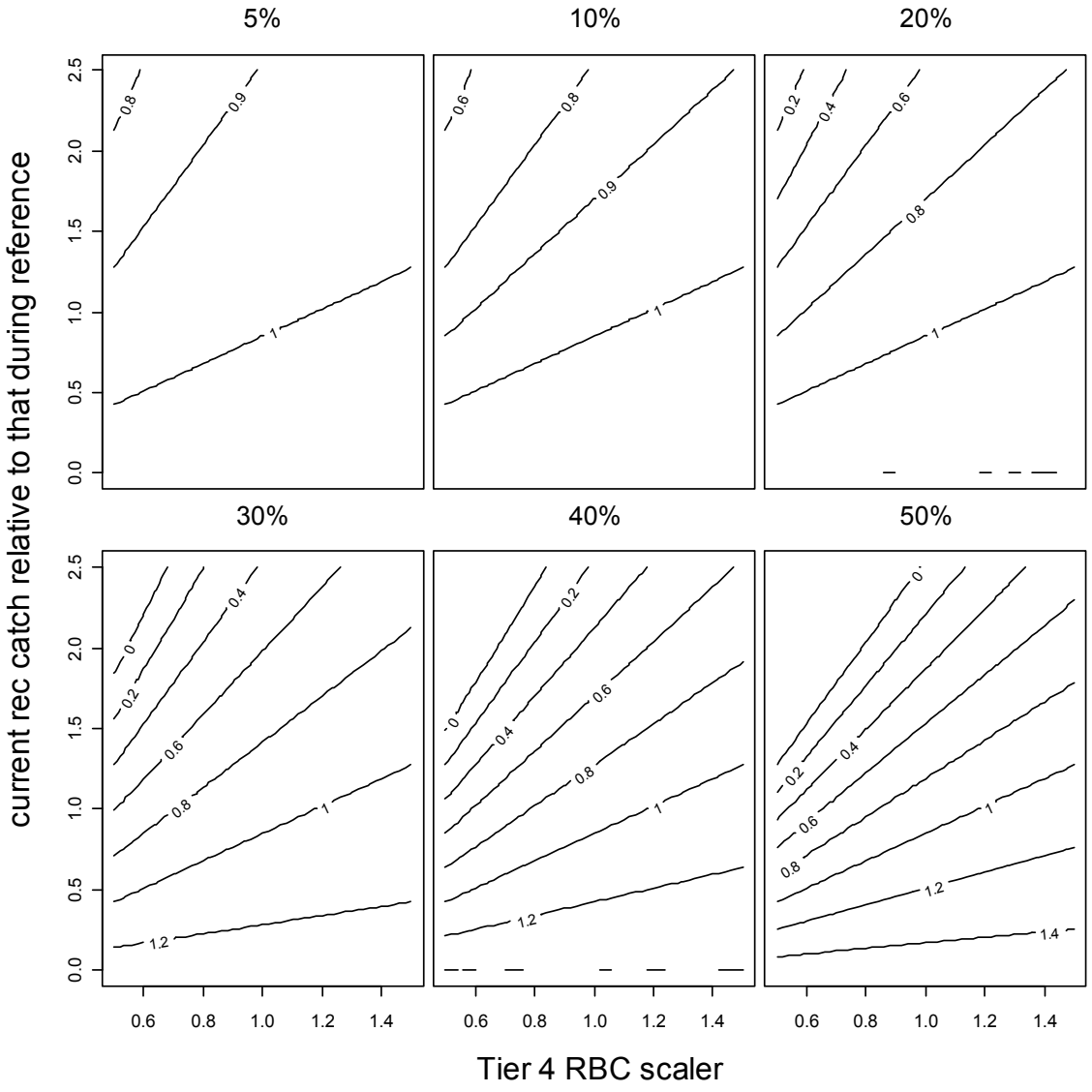

Figure 8.8: The relative change in the TAC (contour lines) obtained when including recreational catches in the Tier 4 assessment procedure versus when such information is ignored, for different levels of reference recreational catch (panels, shown as a percentage of the commercial catch), the level of current recreational catch compared to the reference level (y axis), and different results from the Tier 4 CPUE analysis (RBC scaler on the x axis, values less than 1 imply that the catch should decrease, values greater than 1 that it should increase).

8.5 Discussion

The impact of low levels of recreational catch on the population dynamics is within the uncertainty of the stock assessment even when these catches are ignored. Higher levels of recreational catch can result in biased estimates of current biomass and stock status relative to unfished conditions when these catches are not included in the assessment.

If the true selectivity for the recreational fishery is different from the commercial, then not having information on the age composition (here, via length compositions) results in poor performance, because selectivity must be assumed to be the same for both the recreational and the commercial fleets.

It is noted that the analyses presented here cover cases for a rather 'good' assessment, in that parameters determining biology, form of the stock-recruitment relationship, and so on are known correctly. In reality, there is of course uncertainty in these quantities, and these will further complicate the model's ability to estimate quantities accurately, such as current stock status. Removing this uncertainty, as in the simulations reported here, allows for exploration of model behaviour to the inclusion of recreational data and the dynamics of the recreational fishery, thus representing a best case for identifying the impacts and benefits associated with accounting for recreational catches. Additional work might investigate whether the patterns observed here remain when additional uncertainty associated with, for example, mis-specification of biological parameters is incorporated. It would also be of interest to examine how the development of the recreational fishery over time affects performance – the simulations assumed a recent linear increase in catch from zero – while potentially plausible, alternative scenarios about the manner in which the time series of recreational catches has evolved could be considered.

The data available for the assessment models in the simulations were fairly simplistic and included length composition data, which is typical of data from the commercial fishery. However, as mentioned previously Stock Synthesis can accommodate other data that may be more representative of recreational data but also provide (indirect) information on the age composition of the catch. Because of the need to estimate selectivity for recreational fishery (particularly when this is suspected to be different from commercial), recreational catch data should be augmented with a measure of the age composition of the recreational catch (e.g. length composition data). However, summaries of the length composition, such as mean length, or categorical length data would be helpful, and mean weight also provides a different context for providing such information (as a weight-length relationship is generally input into these models anyway, internal prediction of weights given the expected length composition is principally simple). Even a small effective sample size reduces bias. Given that the expected dilution of the effects of including recreational data, say from uncertainty in the commercial catch or uncertainty regarding biological parameters, will likely reduce the expected gains associated with collecting these data, relatively inexpensive data (e.g. lengths) is probably preferred over ages. As with commercial datasets, the challenge may lie with ensuring that such data are sufficiently representative of the fishery as a whole.

The simulations and examples illustrated in previous sections demonstrate that data from recreational fisheries can be readily incorporated into stock assessment of Commonwealth stocks, here for SESSF and ETBF species, across the range of methods employed for assessment, and translation of assessment results to management advice. There is a need in both fisheries to have a good understanding as to the role of recreational fisheries in contributing to the total of the quantity managed for (whether this be catch as in the case of determining the TAC, or effort). Having estimates of recreational catch is important when recreational catch is >10% of commercial catch, particularly if there has been a trend in the magnitude of recreational catch over time. The striped marlin simulations also demonstrate the importance of age structure information for the recreational catch (here coming from length frequency data), in order to estimate selectivity parameters, as assessment performance is degraded when the recreational fishery is focussed on a different component of the population to the commercial fleet without data to estimate this difference. The work here raises the following concluding points:

- Methods for including recreational data will vary by species and assessment method,
- Failure to account for recreational catches (or indeed any source of removals) will bias assessment results and impair harvest strategy performance,
- The majority of stock assessments and applications of harvest strategies applied to SESSF and ETBF are catch driven, although this is somewhat indirect in the case of effort-managed species,
- Consequently, quantification of removals (or effort) is of greatest importance, as it is required for both the stock assessment purposes and in harvest strategy application.
- Not including the recreational catch can be dangerous if:
    - Recreational catches are high, and
    - Recreational fishery selectivity is different from the commercial fishery.
- Data relating to the population component impacted by recreational fishing is also important (i.e. metrics of size frequency). These are necessary in order to estimate the selectivity of the recreational fishery.

9. AN ASSESSMENT OF THE USE OF BPC AERIAL SURVEILLANCE DATA FOR ESTIMATING RECREATIONAL FISHING EFFORT IN OFFSHORE WATERS

9.1 Introduction

Border Protection Command (BPC) – a division of the Australian Customs and Border Protection Service – conducts offshore surveillance flights as part of the Australian coastal protection strategy. These flights record all events observed during the flight, including all vessels sighted, and the time and location at which sighting is made. This includes offshore recreational fishing vessels. In this section, we investigate the possibility of using information on recreational fishing vessels collected by BPC to estimate recreational fishing effort in specific offshore Commonwealth fisheries.

The approach that may result in reasonably accurate estimates of recreational fishing effort can be defined in discrete stages. Initially, fishing effort would be measured in boat-days. However, this might be more finely calibrated at a later stage as information becomes available. The fishery of interest would need to be partitioned into separate *regions*, or strata, and effort estimated separately in each. There may be other ways of accommodating spatial variation in effort if partitioning the fishery into homogeneous regions that satisfy the criteria is impractical. This would require spatial terms in the model to allow for spatial inhomogeneity, which in turn would require some further developmental work to be undertaken. The strata would need to be chosen to satisfy a number of criteria. In particular, the strata should be small enough to ensure homogeneity with respect to recreational fishing effort, in the sense that if any section of it is surveyed the data can be regarded as a reliable sample for the region as a whole at that time. The strata should also be large enough to ensure that aerial surveillance flights visit the region reasonably frequently throughout the year.

Effort in boat-days would need to be modelled separately in each region. The most promising way to do this appears to be to use a discrete count model for the number of recreational fishing vessels sighted, which is described in Section 9.2. The drivers for the discrete model would be selected from a reasonably flexible long-term trend model. For example, if the study period extends beyond several years, seasonal terms to reflect seasonal influences on the fishing patterns, and local temporal adjustments to reflect differences between, week-days, weekends and long weekends need to be considered. Local adjustments would also be required to accommodate weather events that may influence recreational fishing, and diurnal variations in fishing effort, which is likely to be evident among fishers who target broadbill swordfish.

The unit of recreational fishing effort may be further refined if further information becomes available. For example, if a small onsite creel survey at boat ramps can provide some indication of the average hours fished per vessel in a region, which may be different for day or night fishing, then the fishing effort may be further calibrated to an estimate of the actual hours fished. Such an approach has been undertaken in New Zealand using chartered planes and onsite boat ramp surveys (Hartill et al., 2008).

The goal of the modelling approach was to allow for inevitable variations in sampling level for each region. The assumption underlying the modelling approach is that BPC sampling can be regarded as random with respect to recreational fishing vessels. This key assumption would need to be verified, with both internal and external evidence, before the approach could be used with confidence. Although BPC surveillance operational strategy is highly confidential, it should be possible to receive some assurance that this assumption was at least not systematically violated.

9.2 An example: Estimating foreign fishing vessel effort in BPC regions in Northern Australia

To illustrate the technology that anticipated to be appropriate for estimating recreational fishing effort, the fishing effort by foreign fishing vessels (FFVs) in and near the Australian EEZ was estimated for the period 1 June, 2006 to 30 June, 2007. The data used for this worked was derived from a CSIRO-led project with a slightly different, but related, objective (Griffiths et al., 2008).

9.2.1 Confidentiality issues

The data set is privileged and certain features of it could be considered sensitive. For this reason we only present the results here in the minimal detail, sufficient only to make the main points of the example. For example, no individual vessel information is shown, no fine locations or dates are shown, and the notional FFV fishing effort is only presented as rates, in boat-days per day per 100 grid cells.

9.2.2 BPC data and analysis

The features of the BPC data set are described below, though for confidentiality reasons, we provide only general details.

Events: For the purposes of this example, FFV sightings were treated as if they were recreational fishing vessels. If a vessel was sighted within a region during a day it was assumed to correspond to one boat-day of effort.

Study period: The data used consisted of all FFV events noted by BPC during the period 1 June, 2006 to 30 June, 2007.

Regions: BPC reports fishing events within a network of surveillance regions. For convenience in this example use these were used as if they were recreational fishing regions. For some regions this is a reasonable assumption, but some regions are much larger than would be considered homogeneous for recreational fishing, but may be reasonably homogeneous with respect to foreign fishing vessel effort to illustrate the modelling approach. Modelling was based on data collected from 16 regions in northern Australian waters where at least 50 FFV sightings were recorded during the study period. The spatial distribution of these regions is shown in Figure 9.1, while individual identification of regions to allow cross-referencing with the modelling results is shown in Figure 9.2.

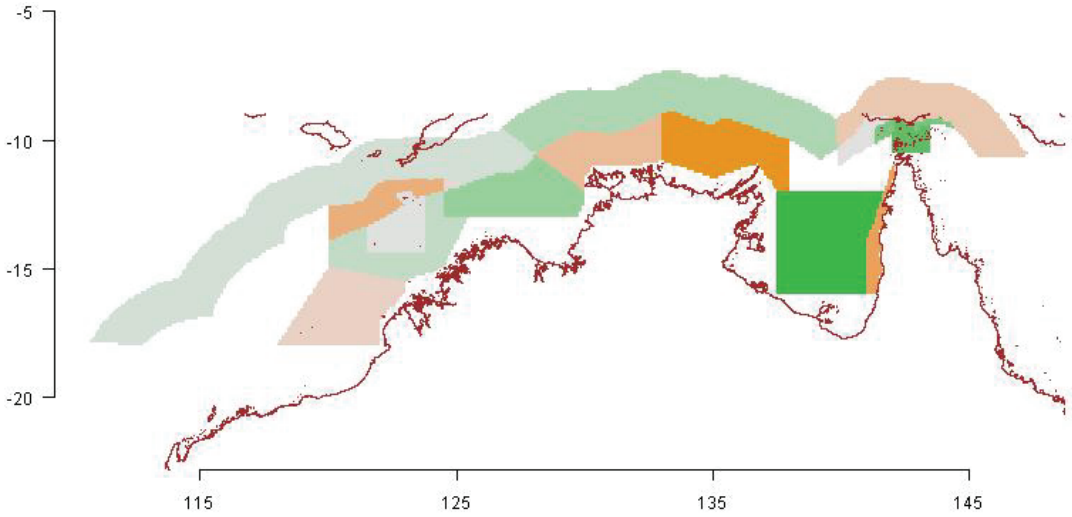

Figure 9.1: Aerial surveillance regions used by Border Protection Command in northern Australia for monitoring the activity of foreign fishing vessels within the Australian Exclusive Economic Zone.

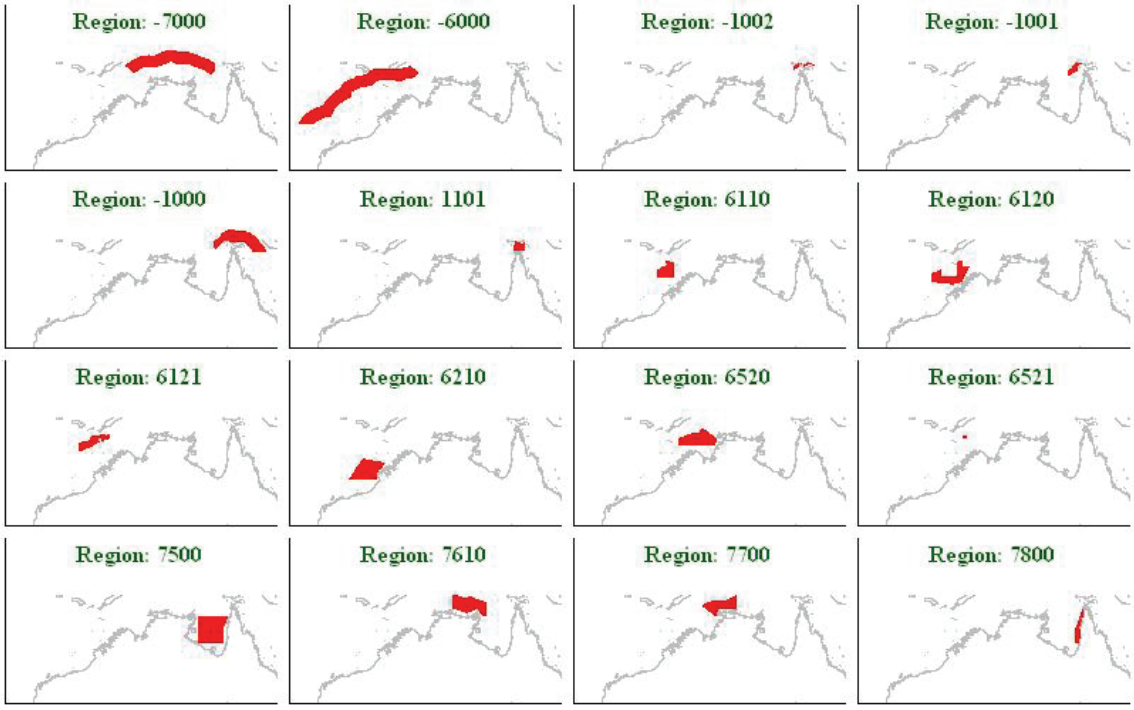

Figure 9.2: Border Protection Command's surveillance regions used for modelling the fishing effort of foreign fishing vessels, where a minimum of 50 FFV events was recorded for the surveillance period, 1 June 2006 to 30 June, 2007.

Driving variables: Since the study period was only 13 months, there was no possibility of estimating a long-term variation in FFV effort. Therefore, variations within the study period were modelled using a 'seasonal' term with an annual period, which was anticipated to be a term in any working model for actual recreational fisheries. For FFVs it was considered unlikely that any local adjustments for weekends or weather events would apply. Since most FFVs remain at sea for extended periods (Griffiths et al., 2008), it is also unlikely that diurnal effects could be detected in any model. For these reasons the example is a very simplified version of a realistic recreational fishing model in that it only contains the seasonal terms. This may be sufficient to assess whether the BPC data is adequate to estimate recreational fishing effort.

The modelling assumption made was that the number of FFVs, R, sighted on a day in a region has a Negative Binomial distribution taking the form,

$$R \sim \text{NB}(\mu,\theta) \quad \text{where} \quad \text{E}[R] = \mu \quad \text{and} \quad \text{Var}[\text{R}] = \mu + \mu^2 / \theta$$

For details on the Negative Binomial model fitting and prediction processes see Venables and Ripley (2002).

The mean μ is related to the temporal driver by,

$$\mu = A \, exp\,[f(t)]$$

where, A is the number of grid cells in the region inspected on any day, i.e. the area visited, t is the elapsed time, in days, since the start of the study period and $f(t)$ is a flexible periodic term allowing for seasonal variations.

For the purposes of this example, it is assumed that $f(t)$ is a truncated Fourier series with three sine and three cosine terms:

$$f(t) = \gamma_0 + \alpha_1 \cos(\phi) + \beta_1 \sin(\phi) + \alpha_2 \cos(2\phi) + \beta_2 \sin(2\phi) + \alpha_3 \cos(3\phi) + \beta_3 \sin(3\phi)$$

where, $\phi = 2\pi t / 365.25$ and t is the elapsed time, in days, since the start of the study period. The coefficients, γ_0, α_1, β_1, α_2, β_2, α_3, β_3 as well as the shape parameter, θ, are estimated from the data. Another common parameterisation of the Negative Binomial distribution uses the parameter $k = 1/\theta$. The parameterisation used here is the same as that in Venables and Ripley (2002).

9.2.3 Modelling rationale and model properties

If vessels travelled to random locations inside a region and moved independently of each other, the count, R, would be expected to follow a Poisson distribution. However, vessels commonly do not travel independently, and in many cases there is a tendency to travel in small, loosely connected convoys. The Negative Binomial has the Poisson distribution as a limiting case, in our parameterisation as $\theta \rightarrow \infty$. The parameter θ is then an indicator of 'clumpiness' in the distribution, in the sense that the smaller its value the more clumped the distribution. In practice, a value of $\theta > 5$ indicates a distribution that cannot easily be distinguished from the Poisson with real data. It should also be noted that both μ and θ are dimensionless quantities.

9.2.4 Results and Discussion

Estimates of the θ parameter

Estimates of the 'clumpiness' parameter, θ, and the standard errors of the estimates are shown in Table 9.1. In all cases, the estimate is quite low, indicating that the degree of clumpiness is much greater than for the Poisson distribution, which corresponds to independent random behaviour of the vessels. This is not surprising for FFVs and may be caused by a number of factors, such as favoured fishing areas within a region, or several vessels remaining within visual contact of each other for safety reasons. For the recreational fishing case, the Poisson distribution is also not likely to be adequate and therefore, some form of clumped distribution would need to be considered, with the Negative Binomial being the most likely candidate.

Table 9.1: Estimates of the 'clumpiness' parameter, θ, and their standard errors.

Region	$\hat{\theta}$	$SE\left(\hat{\theta}\right)$
-7000	0.0766	0.0127
-6000	0.8670	0.1550
-1002	0.1690	0.0111
-1001	0.1321	0.0352
-1000	0.0564	0.0080
1101	0.0891	0.0085
6110	0.9102	0.0893
6120	0.4160	0.0792
6121	0.4157	0.0752
6210	0.2653	0.0773
6520	0.2820	0.0417
6521	0.3440	0.1440
7500	0.3740	0.1100
7610	0.3391	0.0509
7700	1.1530	0.5390
7800	0.1300	0.0394

Coefficients and estimated daily effort

The numerical estimates of the coefficient parameters, γ_0, α_1, β_1, α_2, β_2, α_3, β_3 are of no great intrinsic interest and are not reported. It is important to note, however, that in no case was the seasonal effect as a whole non-significant. In other words, seasonal variations in daily effort patterns for FFVs were significant, and usually sizeable, in all 16 BPC regions.

Estimates of the seasonal components (i.e. $f(t) - \gamma_0$) with point-wise confidence intervals are shown in Figure 9.3. As these are in the log-scale it is difficult to appreciate their effect on the natural scale as variations in days of effort. However, it is apparent from the point-wise confidence intervals that the temporal changes are significant. In some cases it may have been possible to capture the seasonal signal with fewer than six terms in the truncated Fourier series, but it is unnecessary to trim the model in these cases.

Figure 9.4 shows the daily estimated FFV fishing effort, in boat-days, for a nominal 100 grid cells in each of six regions. It is clear that the model was able to capture the seasonal peaks in fishing effort, which are known to occur at different times in particular regions for a variety of reasons, but primarily weather. For example, in regions 6110, -6000 and 6521 near the Timor Box – where some traditional foreign fishing is permitted – the peak fishing activity is between July and September when the weather is relatively stable. In contrast, most fishing effort occurs in December to April in regions -1000, -1002 and 1101.

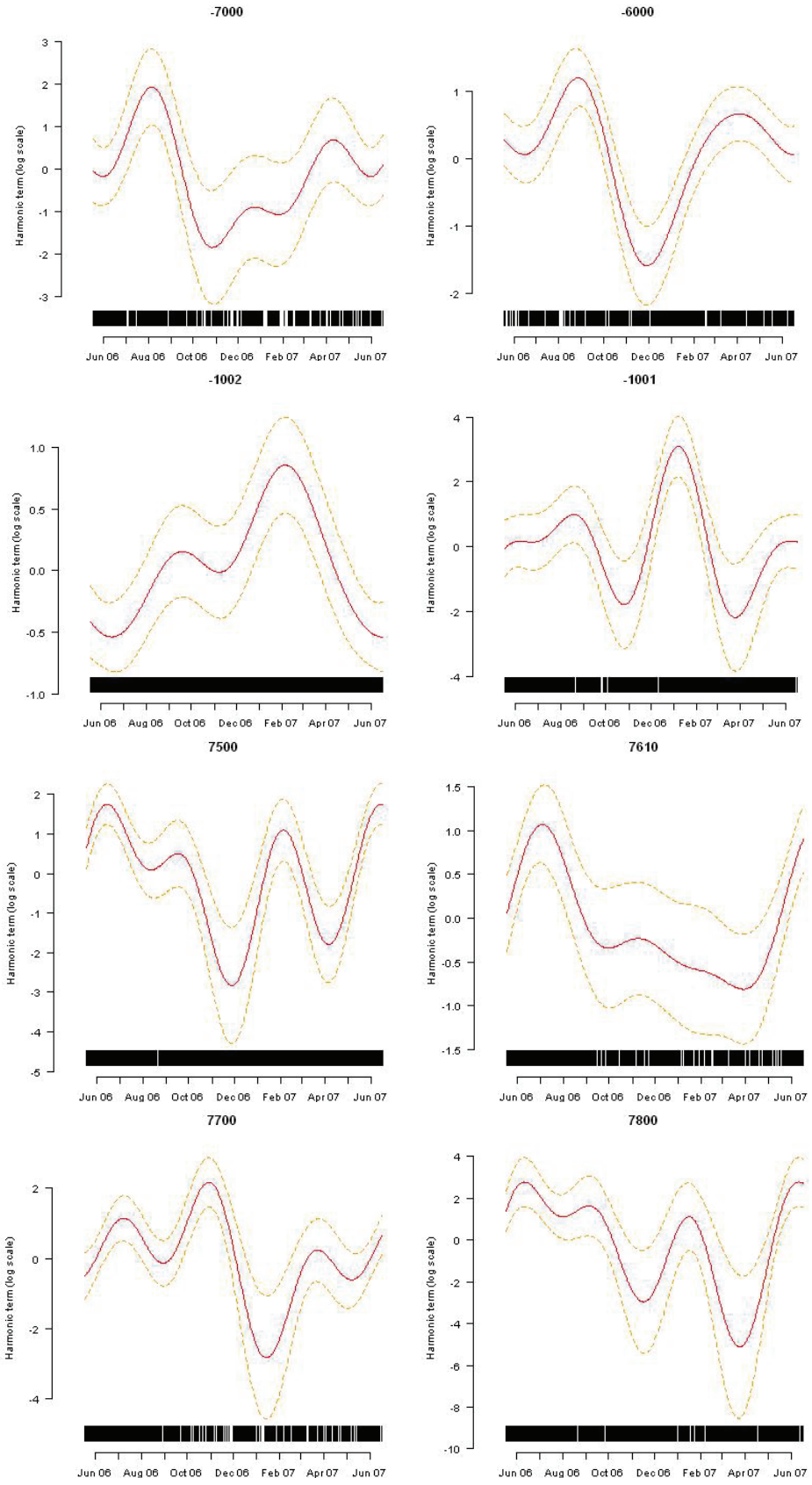

Figure 9.3: Predicted relative seasonal variation (using a log scale) in the fishing effort by foreign fishing vessels for eight Border Protection Command surveillance regions where at least 50 FFV sightings were recorded. Region number is shown above each panel. The fine white vertical lines at the base of each panel shows the times when flights did not survey the region.

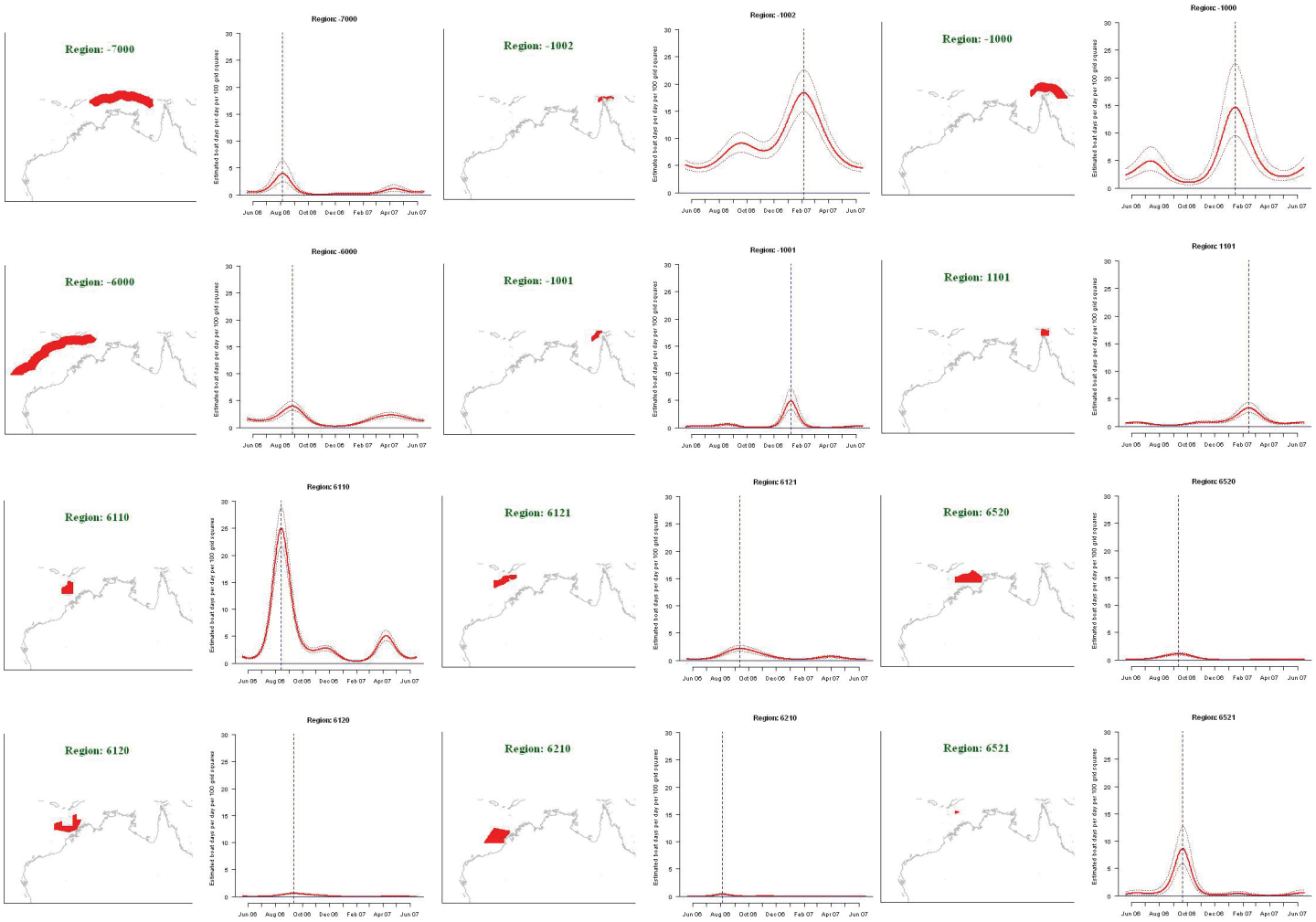

Figure 9.4: Estimated fishing effort (in boat-days) by foreign fishing vessels for a nominal 100 grid cells in each of the twelve regions, for the surveillance time of the study, 1 June, 2006 to 30 June, 2007. The vertical lines in each graph show the time of maximum FFV effort, or “peak season”. The error bars above and below the curve show are back-transformed intervals from adding or subtracting 1 standard error of the component estimate in the original log scale.

9.2.5 Application to recreational fisheries

The FFV effort model described in this section was based upon real data, which would be similar to the types of recreational fishing effort data that could be collected during BPC surveillance operations. However, the problems are substantially different in recreational fisheries. Below we note the main differences and suggest extensions to our modelling strategy that may accommodate them. Further work with real recreational fishing data would be needed to tune these models so that they operate satisfactorily in practice.

Time of day terms. Recreational fishing is anticipated to consist mostly of day-trips. This would make the effort pattern strongly diurnal, which was not a feature of the FFV case. To account for this, it may be sufficient to stratify the BPC visits to a region into night and day visits, with the night visits anticipated to show fewer vessels. Defining night and day strata would require care and consultation with recreational fishers belonging to the target population (e.g. swordfish fishers). The alternative is to adapt the model to include time-of-day on a more continuous basis. This is feasible, but would complicate the model and require further testing.

Weekday and weekend terms. The FFV case was not anticipated to show any substantial dependency on the day of the week and no allowance was made in the model for it. However, recreational fishing effort is likely to be considerably different between weekdays, weekends and long weekends. Extra terms can easily be included in the model to allow for these differences.

Weather effects. The model can allow weather effects, such as strong winds, to be accommodated. Whether this is done quantitatively using, for example, actual wind speed, or qualitatively using an indicator of "bad weather" would need to be considered carefully, but either could easily be incorporated into the basic model.

Homogeneity of spatial regions. We have noted above that if the effort assessment is done by partitioning the fishery into regions, then there is a requirement that such regions be reasonably uniform, or homogeneous, with respect to recreational fisher behaviour. In some cases this may not be easy to achieve *à priori*. Modifying the model to allow for spatial inhomogeneity would be possible, but would require some developmental work and testing. We recommend that using regions be considered as the simplest first step in developing the effort prediction model.

10. ADAPTING RESPONDENT-DRIVEN SAMPLING TO RECREATIONAL FISHERIES RESEARCH

10.1 Description of the RDS methodology

A recent extension of snowball sampling designed to minimise the bias caused by the non-random selection of seeds and reduce other forms of bias is Respondent-Driven Sampling (RDS) (Heckathorn, 1997;2002). RDS combines a modified form of snowball sampling that weights samples representing different groups within the target population (e.g. club members versus non-club members in a survey of gamefish anglers) to compensate for the non-random selection of subjects by modelling the recruitment process using Markov chain theory and biased-network theory (Heckathorn, 1997;2002). This is required due to the tendency of individuals to recruit individuals with similar characteristics as themselves, which can lead to oversampling of a particular group within the target population if their social network size differs to another group (Heckathorn, 2002).

RDS differs from snowball sampling in that respondents are not asked to identify other potential respondents to the researcher, but instead recruit them to the study themselves, thus efficiently and safely infiltrating the true population generally only accessible by insiders (Wejnert, 2009). This can significantly reduce masking bias and ethical issues associated with violation of subject confidentiality (Scott, 2008). A second difference between RDS and snowball sampling is that seeds do not need to be selected at random, but must simply be a member of the target population. In a population study in the United States, Heckathorn (2002) showed that the proportion of four different ethic groups in two replicate samples was identical regardless of whether the sampling began with all Hispanic seeds or all white seeds.

RDS works by a coupon system that starts by seeds being identified and rewarded for participating in the survey. The survey might be a recall survey whereby gamefish anglers are asked how many billfish they caught in a particular region in the past three months. The reward can be a nominal monetary amount or other types of incentives specific to the target population. Wejnert and Heckathorn (2008) recommend small incentives to reduce the suspicion of a ‘get rich quick’ scam. In fact, they found 20% of respondents did not collect their compensation, indicating motives for participation other than financial reward. The use of large financial incentives, coupled with the anonymity of subjects in RDS surveys, can encourage ineligible individuals to impersonate a eligible subjects, or attempt to participate in a study multiple times by using different identities. However the use of observable (e.g. scars, tattoos) and indirect (e.g. birth date, mother’s maiden name) indicators can be used to screen individuals before recruitment to a study (Heckathorn et al., 2001).

On recruitment to the study, the seed is given a small number of coupons (usually no more than 3) with a unique code and asked to give to them other eligible subjects. The seeds are informed they will be rewarded when a referred subject is recruited. The new subject then completes the survey and the researcher provides coupons to the respondent to recruit further subjects, and so on. Small coupon quotas allocated to each respondent have several advantages. Primarily, it allows development of robust and

long chains that eventually recruit a diversity of subjects (Salganik and Heckathorn, 2004), but also prevents the development of semi-professional recruiters who attempt to redeem the coupons intended to be passed on to their peers (Heckathorn, 1997).

An advantage of RDS is that the recruiters create 'group-mediated social control' (Heckathorn, 1990); a form of peer pressure strengthened by the desire of recruiters to redeem their reward. Therefore, non-response bias is often very low and also not skewed towards more affluent peers. This is because subjects that would not normally participate for financial gain often do so as a favour to their peer (Magnani et al., 2005).

The RDS coupon system provides an effective means to identify individuals while they still retain anonymity, which is one of the most powerful aspects for RDS to obtain survey responses that retain candor. However, this eliminates a researcher's ability to directly follow up on non-respondents to understand if their characteristics and attitudes differ to respondents. If non-response is likely to be an issue in a particular situation, the survey can be structure whereby respondents can be asked to provide specific information on individuals who refused to accept a coupon (see Johnston et al., 2008).

Most importantly, however, the RDS coupon system allows the relationships between a recruiter and his or her recruits – known as the recruiter's "degree" (Volz and Heckathorn, 2008) – to be mapped. This allows any in-group affiliation bias to be corrected by comparing the group membership of subjects in the final sample (e.g. club members or non-club members) to the group membership of seed subjects to assess whether recruitment was independent of the group membership of an individual. This degree of "homophily" is measured on a scale from -1 (no resemblance to the seed) to 1 (identical to the seed), while a value of zero indicates recruitment of a diversity of subjects (Heckathorn, 2002). Where homophily for a particular group (e.g. fishing club members) deviates from zero, sampling of this group must continue until homophily approaches zero.

RDS also overcomes 'differential recruitment' bias, whereby one group of subjects (e.g. fishing club members) may recruit a disproportionally higher number of subjects than another group (e.g. non-fishing club members). By obtaining each subject's network size (i.e. the total number of eligible peers a subject could give an RDS coupon to) during the survey, the ratio of subjects belonging to each group at each recruitment wave can be weighted according to their network size. Sampling continues until the proportion of each group comprising the cumulative sample stabilises and varies by less than 2% regardless of how many further waves are recruited (Heckathorn, 1997; Salganik and Heckathorn, 2004). This point of "equilibrium" is generally reached within six recruitment waves (Heckathorn, 2002).

Differential weighting of groups in the population with respect to their network sizes and differentially sampling groups with different homophily patterns is the fundamental advantage of RDS over other chain-referral methods, and qualifies this method as a probability-based sampling method (Heckathorn et al., 2002; Salganik and Heckathorn, 2004). The RDS recruitment process using a hypothetical recreational fishing survey example is described in Section 10.3 and is graphically represented in Figure 10.1.

An additional advantage of RDS is that survey costs are significantly lower than under probability-based sampling (e.g. telephone surveys based on a list frame), since the

respondents are responsible for contacting and recruiting further subjects. Freely available software, such as RDSAT (Volz et al., 2007), facilitates tracking of coupons, data management, and the final RDS analyses. With the increasing use of computers and online networks (e.g. 'chat' forums) in the recreational fishing sector, survey costs may be further reduced by recruiting subjects using semi-automated online approaches. A recent web-based application of RDS ("webRDS") (Wejnert and Heckathorn, 2008), showed that it was as effective as the traditional RDS and recruited respondents 20 times faster. However, further investigation of this approach is required to consider possible biases relating to the proportion of the target population that has access to a computer and the internet.

RDS may be the only statistically robust and cost-effective method for sampling specialised recreational fishers. However, RDS may serve as an inexpensive supplementary method for dual-frame survey designs (NRC, 2006). For example, RDS may be used to access out-of-frame licence holders in particular recreational fisheries, such as children or senior citizens, who may be exempt from holding a licence in some regions.

10.2 Application of RDS to recreational fisheries

The prevalence of rare or elusive components within recreational fisheries (e.g. sport fishers, fly fishers and spear fishers) presents fisheries researchers with an increasingly difficult problem of cost-effectively obtaining representative data from these hard-to-reach populations using probability-based sampling methods. The statistical grounding, cost-effectiveness and ease of implementation of respondent-driven sampling makes it an ideal alternative to traditional probability-based methods to representatively sample important minority groups within the recreational fisheries.

Nonetheless, before RDS can be confidently used by fisheries researchers the method requires validation since some populations of recreational anglers may have very different characteristics (e.g. network sizes, homophily, motivation to participate) to the types of hidden populations studied in epidemiology (e.g. illicit drug users). One validation method may be to compare the results of concurrent RDS and probability-based surveys – such as a telephone recall survey – on a reasonably small and spatially explicit recreational fishery that has a complete sampling frame (e.g. licence list). Comparisons should be made between the characteristics of respondents (e.g. avidity, age, ethnicity) but possibly most importantly, attempting to understand whether non-respondents have the same characteristics as respondents, since this can have a significant effect on catch and effort estimates (Tarrant et al., 1993; Fisher, 1996).

A further consideration is that while RDS may provide unbiased estimates for the target population (e.g. catch rates) after appropriate weighting, it does not directly estimate the population size for the target group and hence enable data expansion to obtain population totals. Therefore, a second method is required to estimate the size of the target population, with which the RDS estimates can be combined to estimate the population totals, which is often the most difficult problem in studying hidden populations (Cox and Shipley, 1997; Archibald et al., 2001). Although several methods may be employed to estimate population size (Williams et al., 2002), researchers are often required to choose from probability-based methods that are expensive and often inadequate for sampling hidden populations for the reasons discussed throughout this

paper. This conundrum may be cost-effectively circumvented by employing model-based methods that capitalise on the elements of RDS that make it a successful method for obtaining representative data from hard-to-reach populations.

To this end, we propose a complemented "RDS-Recapture" survey design for specialised recreational fisheries. In using this design to estimate the total catch of a species, representative catch rate data is collected using RDS, while the population estimate is simultaneously derived using mark-recapture sampling facilitated by fishers being 'marked' with a unique RDS coupon number. By completing an RDS survey at least three times (beginning with different seeds in each survey) and using a different coloured coupon in each survey, respondents can be asked if they had previously received a coupon of a colour specific to the previous survey. Fishers 'recaptured' in a subsequent survey can then be used to estimate population size using a range of mark-recapture models (see Williams et al., 2002). However, the capture probability of fishers is heterogeneous due to their varying network sizes and this covariate can be used in heterogeneity mark-recapture models such as the "Huggins Alho" model (Huggins, 1989; Alho, 1990) to estimate population size. Similar 'capture-recapture' methods have been used for estimating the population size of other hidden human populations such as illicit drug users (Hay, 2000), HIV carriers (Mastro et al., 1994) and the homeless (Dávid and Snijders, 2002).

Estimation of population size is obviously dependent upon recaptured individuals relinquishing their coupons. Fortunately, survey overburden of recaptured individuals – which would only occur if the population was extremely small – is not usually an issue simply because there should be sufficient tangible incentive (monetary or similar) and/or social pressure from respected peers for recaptured individuals to relinquish their coupons (Magnani et al., 2005).

10.3 A hypothetical example of using RDS to collect recreational catch and effort for southern bluefin tuna

In this hypothetical example, the researcher is interested in obtaining representative recreational catch and effort information of SBT in Tasmania, Australia in 2009. The researcher recognises that fishing club members and non-fishing club members have different characteristics (e.g. avidity, experience, fishing techniques) and needs to sample each group sufficiently in order to obtain data that is representative of the entire fishery.

For illustrative purposes, Figure 10.1 shows each subject that is recruited to the study has three potential peers (P1, P2, P3) – each with a selection probability of 1/3 – whom one of their two coupons can be given. Peers not receiving a coupon are shown as dashed circles and play no role in the study. Solid arrows indicate the transfer of a coupon from a recruited subject one of their peers. Each digit in the unique coupon code (shown in parentheses) identifies each recruiter in the recruitment process. Grey dashed lines (only three shown to reduce complexity of the figure) indicate the relinquishment of a coupon to the researcher, successful recruitment of the subject to the study, redemption of a reward and acceptance of two further coupons to give to the subject's peers.

To start the survey, the researcher finds an eligible subject (in this case, a fishing club member intercepted at a boat ramp) who fished for SBT in Tasmania during 2009. The researcher invites the fisher to participate in a recall survey where questions are asked regarding their fishing behaviour, catch and effort directed towards SBT, and the number of people the fisher knows who fish for SBT (i.e. the fisher's "degree"). On completion of the survey, the fisher is rewarded and given two coupons to give to two peers who also fished for SBT in Tasmania in 2009. It is explained to this "seed" subject that when each of the peers contact the researcher and successfully recruit to the survey, he/she will be rewarded again, as will the peer. When his/her peers contact the researcher and relinquish their coupon, they are rewarded and given two coupons each with a unique code - that relates to their recruiter- to give to their peer, and so on. The recruitment process continues in successive recruitment 'waves' until the sample reaches equilibrium (usually within 4-6 waves). This means that the ratio of fishing club to non-fishing club members remains stable regardless of how many further subjects are recruited.

At no stage is the identity of survey participants known, however, they are identified in the study by their unique coupon code. This allows a subject's network of recruiters and recruits to be mapped, facilitating differential weighting of fishing club or non-club members depending on their network sizes. Identification of individuals belonging to a particular group (e.g. fishing club member group) allows calculation of the homophily statistic for club and non-club members in order to determine whether the two groups recruited a diversity of subjects (homophily statistic ≈ 0) that are independent of the characteristics of the seed. If subjects from a particular group tend to recruit other subjects who are very similar or different to themselves (i.e. homophily values close to 1 and -1, respectively) further sampling of this group is required until homophily approaches zero in order to reduce in-group affiliation bias.

If snowball sampling was used in the study, the recruitment process would be similar to RDS, but without the use of coupons or incentives. Instead, the researcher obtains the names of potential subjects from each survey participant and contacts them directly. Violation of subject confidentiality, 'masking', 'volunteerism', 'differential recruitment' bias, and non-random seed selection are some of the issues that prevent snowball sampling from attaining a representative sample from the population.

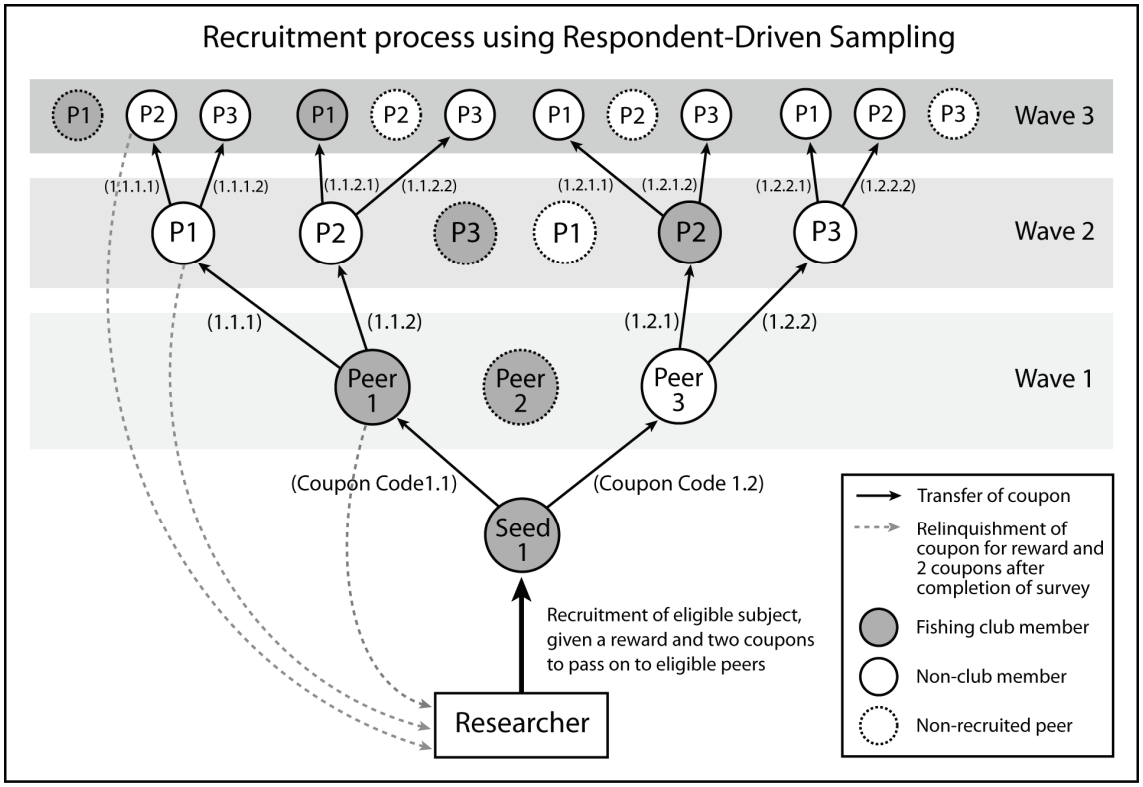

Figure 10.1: Diagrammatic representation of the recruitment process from a single “seed” subject using Respondent-Driven Sampling (RDS).

11. RECREATIONAL FISHING SURVEY OPTIONS FOR COMMONWEALTH FISHERIES – NATIONAL WORKSHOP 2

CSIRO hosted the second survey development workshop on 1 June, 2010 at the CSIRO's Cleveland laboratories. This was attended by representatives of key Commonwealth fishery stakeholder groups including DAFF, AFMA, BRS, Recfish Australia, Recfishing Research, and the CSIRO. The workshop participants and their affiliations are listed in Appendix 3. The objectives of the workshop were to:

1) Present the final results of statistical and cost-benefit analyses undertaken on the subset of survey methods recommended by participants at the National Recreational Methods Survey Workshop as a feasible monitoring tool for Commonwealth fisheries

2) Recommend a survey design for a long-term monitoring program for recreational fisheries in Commonwealth waters that can cost-effectively provide reliable estimates of the recreational catch of identified priority species

Workshop 2 began with a representative from each key stakeholder giving a brief presentation on the recreational fishing issues faced by their respective organisations, and how the present project may assist in addressing these issues. Results of exploratory modelling work and method developments (detailed in Sections 8, 9 and 10), and cost-benefit analyses for various survey types were then presented by project staff, followed by a final recommendation to the workshop group as to the most cost-effective methods for monitoring recreational fishing in Commonwealth waters. The workshop agenda is provided in Appendix 6.

11.1 Data requirements and fisheries management responsibilities

Establishing a clear outline of the jurisdictional arrangements for managing recreational fishing and the species these fishers target in Commonwealth waters allowed the group to focus on the most cost-effective methods for addressing the priority issues. A number of key points arose from the talks that helped participants understand both the political, statistical and logistical difficulties in monitoring recreational fishing in remote Commonwealth fisheries. These are summarised below.

DAFF has no interest in undertaking monitoring of recreational fishing in Commonwealth fisheries and suggest that this should be the responsibility of state fisheries agencies. However, it was acknowledged that there is a clear need for recreational fishing data at the Commonwealth level since DAFF has national and international obligations to account for all mortality sources in assessing the status of many species of growing conservation concern, particularly pelagic sharks (e.g. mako and thresher sharks) and SBT. DAFF is also in the process of renewing the National Plan of Action for Sharks, for which recreational fishing data will be a key requirement, especially in the case of mako and thresher sharks. It was expressed by DAFF that the primary reason that recreational fishing data has not been routinely collected in the past

at a national level is because the recreational fishery is difficult to define due to it having many sub-components. This has resulted in no single organisation being required to fund research or monitoring.

The need for recreational fishing data was recently recognised by Federal Agriculture, Fisheries and Forestry Minister Tony Burke, whose Recreational Fishing Advisory Committee (RFAC) recommended the gathering of up-to-date national data is required for effective fisheries management and development. The minister recently announced the funding of a major project to examine the social and economic characteristics of the gamefishing sector. This was due to the results of the NRFS not only becoming out of date but also because of the limited use of that data for Commonwealth-managed species, since the survey was not designed to provide high levels of precision for specialist/rare activities, such as fisheries for Commonwealth-managed species. DAFF expressed interest in facilitating the process of developing improved methodologies that can assist in providing high quality data relevant to Commonwealth-managed species and fisheries. It was suggested that a recreational fishing research strategy framework be established to scope the data requirements and determine suitable monitoring methods for recreational fishing. Many of these specific needs have been met by the current FRDC project and will allow resources to be diverted to specific areas of interest within the research strategy.

SBT was considered by DAFF to be the highest priority species with regards to understanding the recreational catch. The need for recreational fishing data has been driven by the EPBC Act 1999, with respect to export approval, which has been increasingly difficult to obtain given the declining population of SBT. Furthermore, DEWHA and the general public have also expressed growing concern with the lack of recreational fishing data relating to SBT in light of the species' current conservation status. Striped marlin is also a high priority species for DAFF as there are repeated issues faced each year with respect to resource allocation between the recreational and commercial sectors in the ETBF. DAFF expressed particular interest in the development of methods that are statistically robust, repeatable, inexpensive and able to connect with existing programs being run by state agencies in order to collect the required recreational catch and effort information for key Commonwealth-managed species.

AFMA clarified that it is responsible for the management of commercial fisheries beyond the three nautical mile state limits. AFMA has the ability to manage recreational fisheries, but only if this is specifically written into a management plan. However, AFMA has expressed no interest to doing so in future. AFMA has expressed a general interest in knowing the catch of recreationally-important species (especially striped marlin), but does not actively seek recreational catch data. AFMA is aware of the dramatic increase in recreational catch and directed effort for many Commonwealth-managed species. The increase in the recreational catch of SBT in particular was noted as likely to raise issues for AFMA at some point since there was no recreational fishery allocation in the 4015 t quota set in 2009 and the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has asked all signatory countries to report recreational catches. There was concern expressed by workshop participants that AFMA should be required to provide a recreational catch estimate of SBT under current Harvest Strategies, although it was clarified that this is not required for species such as SBT, that are managed by Regional Fisheries Management Organisations (RFMO).

The workshop group discussed the obvious need for another national recreational fishing survey. However, it was established that most of the respective state agencies are undertaking their own targeted surveys, and therefore, changing their current survey designs was considered unlikely to happen if additional funds were not made available by the Commonwealth government. There was also the ongoing concern that the national survey approach was not suitable for obtaining reliable catch estimates for Commonwealth-managed species, since they are usually 'rare event' captures within the general recreational fisheries. Both DAFF and AFMA representatives maintained that neither of their agencies should be responsible for running or funding recreational fishing monitoring programs, since the states have the responsibility of managing recreational fishing in Australia. Again, they expressed great interest in the key Commonwealth-managed species, but monitoring, even for these species too, should be coordinated with existing monitoring programs, and if possible, involve peak recreational fishing groups to reduce labour costs of surveys and increase the participation of recreational fishers.

Recfish Australia expressed the opinion that there is great need for recreational fishing data in Commonwealth waters. Historically, the need was for resource allocation of shared species, but now there is a growing need for data on SBT and sharks for reasons related to conservation. Recreational fishers want recognition for being pro-active in helping ensure the sustainability of their target species. The recent CSIRO-led project on the recreational catch of longtail tuna (Griffiths et al., 2010) was cited as a good example of such support, where recreational fishing organisations initiated the development of the project and directly contributed funds.

The idea of a recreational fishing permit for some Commonwealth-managed species, especially SBT, was raised. This could establish a complete list frame of fishers, so that traditional, but targeted telephone-diary surveys could be undertaken cost-effectively. It was agreed that this would be ideal, but unlikely to happen due to political and logistical issues and additional cost and compliance issues. The same issue was raised at workshop 1. The concept of a national recreational fishing register that would be free of charge to fishers was also raised. Again, political and funding issues were considered to be significant hurdles likely to prevent the register from being adopted, unless the idea was strongly supported and driven at the Commonwealth level. The quality of data from fishers required to have a permit was questioned, especially for SBT. In addition to compliance issues, there were concerns that fishers would become less cooperative with researchers if they were forced to buy a permit. An example was given regarding the apparent low compliance under the USA's Highly Migratory Species Permit that requires compulsory reporting of all landed tunas and billfish.

11.2 Cost-benefit analysis of monitoring survey options

11.2.1 Cost estimation procedure

Costs were estimated for each complemented survey design that could, in theory, obtain an estimate of the total recreational catch of specific Commonwealth-managed species. Although we focused on the survey methods recommended by participants in workshop

1, costs were calculated for a range of other survey types to provide a better understanding of the full range of survey costs. Definitions of complemented survey components are provided in Table 11.1.

Costing scenarios were based on obtaining an annual estimate of the catch of a single species within the ETBF. This fishery was chosen due to its large size and because this fishery currently has the highest interaction with recreational fishers. Labour costs were based on a CSIRO CSOF 3.1 for technical tasks and CSOF 5.1 for project leadership and statistical analyses. It is important to note that estimated labour costs were exclusive of on-costs.

Table 11.1: Definition of methods used to estimate the cost of complemented survey designs.

Survey type	Definition
Telephone survey	A single general population survey conducted by a market research company to intercept 1000 representative fishers.
Diary survey	A telephone survey used to recruit 1000 representative fishers to a 12-month diary survey where they would be expected to report catch, effort and other information for individual trips over a 12-month period. For the purposes of cost estimation, fishers are assumed to fish, on average, once per month.
Access point survey	An on-site survey at boat ramps conducted over 12 months, where one weekday and one day on a weekend is sampled on four occasions at nine access points along the east coast. It is likely that this sampling effort is inadequate, but useful for illustrating the relative cost of this method.
FFV	Cleaning and data preparation of BPC aerial surveillance data collected over a 12-month period and analysed using the CSIRO 'FFV' model. It is assumed that recreational fishing vessels could be accurately identified and recorded by BPC observers.
RDS Recall	A single survey using Respondent-Driven Sampling to obtain 1000 representative fishers who would be asked to recall catch, effort and other information over the previous 12 months. If this method is combined with a "Recapture" survey to estimate population size, the recall period would be 3-4 months depending on the number of RDS surveys undertaken.
RDS Diary	A single survey using Respondent-Driven Sampling to recruit 1000 representative fishers to a 12-month diary survey where they would be expected to report catch, effort and other information for individual trips over a 12-month period. For the purposes of cost estimation, fishers were assumed to fish, on average, once per month.
TLS Recall	A single survey using Time-Location Sampling at identified aggregation points specific to the target population and asking 1000 representative fishers to recall catch, effort and other information over the previous 12 months. If this method is combined with a "Recapture" survey to estimate population size, the recall period would be 3-4 months depending on the number of RDS surveys undertaken.
TLS Diary	A single survey using Time-Location Sampling at identified aggregation points specific to the target population to recruit 1000 representative fishers to a 12-month diary survey where they would be expected to report catch, effort and other information for individual trips over a 12-month period. For the purposes of cost estimation, fishers were assumed to fish, on average, once per month.
Recapture	Use of multiple RDS or TLS surveys where respondents are 'marked' in order for them to be identified in subsequent surveys, which allows an estimate of the total population size to be made. Respondents would be marked using the unique coupon codes in RDS or asked for unique information (e.g. full name, date of birth, home postcode) in TLS.

11.2.2 Results and workshop discussions regarding survey options and final recommendation

Results of the final estimated costs for complemented surveys that could potentially be used to estimate the total catch of a single Commonwealth-managed species in the ETBF are shown in Table 11.2, listed from left to right in ascending order of cost. Table 11.2 was presented to the workshop participants and the cost-benefits of each complemented survey were discussed. A summary of these discussions is provided below.

'FFV' model for estimating effort

The 'FFV' model had great potential for cost-effectively estimating instantaneous fishing effort from BPC surveillance data. It was demonstrated in Section 9 that the model is capable of providing reliable estimates of fishing effort, and is flexible enough to incorporate additional model terms to account for the behaviour of fishers targeting particular species. However, concerns were raised over potential inaccuracies that may arise in data with respect to recreational fishing effort. These mainly related to i) willingness of BPC to record recreational fishing vessels, ii) the ability of observers to correctly identify recreational fishing vessels and the types of fishing they are undertaking (e.g. fishing for game fish vs. demersal shelf slope species), iii) the inability to control aerial surveillance flight paths and the potential for incomplete coverage of a Commonwealth fishery of interest, and iv) ongoing access to the data should national security threats arise. It was recommended that further investigation of these issues be undertaken before the method could be seriously considered as a sampling method for recreational fisheries.

Access Point Surveys

The most expensive survey types involved an access point survey or a telephone survey. Access point surveys (normally conducted at launching ramps) have the distinct advantage of being able to interview fishers at the end of an individual trip. This allows high quality data to be collected on catch, effort and size composition of the catch where recall bias is minimised. However, labour costs are very high in order to adequately survey across all spatial and temporal strata. The workshop participants also agreed that irrespective of cost, it was unlikely that a representative sample could be obtained due to the inability of survey staff to access fishers who depart from marinas, private jetties or moorings. Furthermore, an access point survey would be inadequate for sampling specialised fishers who target some Commonwealth-managed species from the shore, such as silver trevally, longtail tuna, and warehou. In these instances, fishers would need to be sampled using a roving creel survey since they generally do not pass through prominent access points.

Telephone surveys

Telephone surveys have been cost-effectively used in general recreational fishing surveys to estimate the population size of active recreational fishers, as well as, to recruit fishers to diary surveys, where more detailed information can be collected for individual fishing trips over time. The workshop participants believed that a telephone

survey would clearly not be suitable to sample specialised recreational fishers who target Commonwealth species. This is due to the absence of a complete sampling frame for these fishers and their rarity within the general fishing community, which would result in general population telephone surveys being too costly to intercept a representative sample of these fishers. Even a basic telephone survey used to obtain 1000 specialised fishers would add around $180,000 to a survey, but there would be no assurance that the sample of fishers were actually representative of the entire population of specialised fishers. Even for general recreational fishing surveys, telephone surveys rarely yield a random sample from a population due to non-coverage of households and persons without landline telephones, non-response and non-contact issues, and an increasing refusal rate due to telemarketing saturation.

Diary surveys

Fisher diaries were regarded by the workshop participants as the most cost-effective means of collecting high resolution catch and effort data for individual fishing trips, where many potential biases (e.g. recall bias) can be greatly reduced. Recall bias in particular may be reduced further by having survey staff call respondents after a fishing trip to record their trip data. This personal contact ensures completeness of the trip data, but may also reduce the number of diarists exiting the program prematurely due to the burden of completing a diary after each fishing trip. However, maintaining contact with diarists and entry of data add a significant labour cost to these surveys. Furthermore, if diarists need to be recruited using a telephone survey, the significant issues of non-representativeness of the sample due to non-coverage and other factors are the same as when using a telephone survey to estimate population size. Diaries may be used to collect information on the size composition of the recreational catch, although there were initial concerns regarding the reliability of reported size estimates. However, the workshop participants agreed that the type of fisher who targets Commonwealth species is likely to be considered avid and experienced relative to the general recreational fisher. Therefore, it was suggested that diarists could be trained to measure the fish they retain or release, thereby providing more reliable size structure information for stock assessments. It was further suggested that diarists could also photograph fish, which fishers often do for rarer species such as SBT and billfish, which could then allow researchers to estimate fish lengths.

RDS and TLS surveys

Recall surveys (of individuals intercepted by using either RDS or TLS) were the least expensive designs that could, in theory, be used in tandem with a second method for estimating the fisher population size needed to estimate the total recreational catch for Commonwealth-managed species. However, the workshop participants agreed that a 12-month recall period is likely to be too long for fishers to recall accurate numbers of fish caught for some species such as striped marlin and blue eye trevalla, where several fish could be caught in a single fishing trip. However, the 12-month recall period is probably reasonable for more infrequently-caught species such as SBT, swordfish and mako sharks. There were also concerns that any type of recall survey could not provide reliable size composition of the catch, which may be required for stock assessments for some species as determined by modelling undertaken in Section 8. Apart from the level of accuracy in data reporting, the workshop participants also questioned the representativeness of surveyed fishers, as they would usually need to be recruited using a telephone survey. Importantly, though, if a representative sample of fishers could be obtained through RDS or TLS, then using a recall (or diary) survey would have more scientific merit.

The workshop participants agreed that TLS is a potentially cost-effective option for accessing specialised recreational fishers. However, there were some doubts regarding the representativeness of the sample if some fishers never visit aggregation points such as fishing tackle stores. This was acknowledged as a legitimate point that needs further investigation, although the recent national longtail tuna survey (see Griffiths et al., 2010) indicated that the vast majority of fishers from the target population are likely to visit a tackle store at some point during the year if the fishers are actively participating in the fishery. Although TLS can provide estimates of the catch of sampled fishers, a supplementary method is required to estimate the total fisher population size in order to in turn estimate the total recreational catch. The most cost-effective way to do this, in theory, would be to use mark-recapture in multiple TLS surveys. However, there were concerns over estimating population size using capture-recapture methods combined with TLS, since capture probabilities would be difficult to estimate where there are a large number of fishing tackle stores and only a subset could be sampled. Therefore, fishers visiting more than one store, and some that are not sampled, could severely bias selection probabilities compared to fishers who visit one store, which would result in imprecise population size estimates, and thus, estimates of the total recreational catch.

RDS-Recapture

Respondent-Driven Sampling was regarded by the workshop participants as probably one of the only methods that could be capable of accessing a representative sample of hard-to-reach specialised recreational fishers who target Commonwealth-managed species. It was also the most inexpensive method, even when conducted on multiple occasions with a "Recapture" design to estimate population size. The "RDS Diary-Recapture" complemented survey was not the least expensive survey option, but it was regarded by the workshop participants as the most cost-effective survey method for estimating the total recreational catch of Commonwealth-managed species. This survey would involve at least 3 RDS surveys to estimate the population size using mark-recapture methods, thereby negating the need for a separate expensive, and probably

unrepresentative, telephone survey to estimate the population size. During each survey, which would be separated by a few weeks, each respondent returning an RDS coupon would be asked to participate in a 12-month diary program.

The "RDS Recall-Recapture" complemented survey was considered to be the next most preferred survey method. Although the costs of this method were estimated to be less that half those of the RDS Diary-Recapture method, it was less preferred by workshop participants because size composition of the catch could not be reliably estimated. It is important to note that this would be the preferred method for species that are assessed using dynamic pool stock assessment models (e.g. blue eye trevalla, see Section 8), whereby only total catch or CPUE is required. This method also involves at least 3 separate RDS surveys whereby fishers are asked to recall their catch and effort over the previous 3-4 months, depending on the number of RDS surveys intended to be undertaken. This recall period was considered adequate for most fishers targeting Commonwealth species, since captures would be memorable, and therefore recall bias would be minimised over this period. Again, the multiple RDS surveys may allow for the fisher population size to be estimated using mark-recapture methods.

It is important to note that previous application of RDS to hard-to-reach populations in epidemiology (e.g. illicit drug uses, sex workers) has been within densely-populated cities, where individuals are socially connected and there is a high probability of RDS coupon transfer between individuals (Heckathorn, 1997;2002). In contrast, populations of recreational fishers who target Commonwealth-managed species are sparsely distributed across large spatial scales, and their social connectivity is unknown. As a result, the transfer of coupons between eligible fishers may take longer. In the worst case, the recruitment process may even break down before equilibrium is attained after the usual 4–6 recruitment wave. However, the proliferation of online fishing forums appears to be one of the main conduits for the exchange of information between fishers for these infrequently-caught species. Therefore, RDS may still be successful if coupon transfer and relinquishment can be accommodated for using online methods, as was demonstrated by Wejnert and Heckathorn (2008). Both RDS and the mark-recapture components of the RDS-Recapture complemented survey method therefore requires thorough testing in recreational fisheries before widespread application to Commonwealth-managed species, and particularly for species of significant conservation concern such as SBT.

Table 11.2: Estimated costs for undertaking an annual survey of the recreational catch and effort of a single species in the Eastern Tuna and Billfish Fishery using each complemented survey type. Methods for estimating catch and effort for a sample of recreational fishers are shown at the top, while methods for estimating the total population size of recreational fishers are shown below. A brief explanation of the time and tasks required for each survey are provided. Salary costs for a Principal Scientist (PS) and a statistician (ST) are represented by a level CSOF 5.1 in the CSIRO salary scale, while field and technical staff (TS) represent a CSOF 3.1.

Survey component	**RDS Recall + FFV**	**TLS Recall + FFV**	**RDS Recall + Recapture**	**TLS Recall + Recapture**	**RDS Diary + FFV**	**RDS Recall + Telephone**	**TLS Diary + FFV**	**RDS Diary + Recapture**	**Diary + Telephone**	**Diary + FFV**	**TLS Diary + Recapture**	**RDS Diary + Telephone**	**Access point survey + FFV**	**Access point survey + Telephone**
Survey design – 3 days for PS/ST	$915	$915	$915	$915	$915	$915	$915	$915	$915	$915	$915	$915	$915	$915
Scoping of sampling 'universe' – 5 days for TS	$982	$982	$982	$982	$982	$982	$982	$982			$982	$982	$982	$982
Sampling to intercept ~1000 sport fishers		$21,604		$64,812		$180,000	$21,604		$180,000	$180,000	$64,812	$180,000	$339,373	$519,373
RDS incentives - 7 seeds, 2 coupons @ $40	$40,000		$120,000		$40,000	$120,000		$120,000				$120,000		
FreeCall line for RDS recruitment	$10,500		$31,500		$10,500	$31,500		$31,500				$31,500		
Travel and accommodation	$2,100	$77,000	$6,300	$231,000	$2,100	$2,100	$77,000	$6,300			$231,000	$2,100	$604,800	$604,800
Diarist calls – 1 call/mth = 285 days of a TS		-		-	$55,973		$55,973	$55,973	$55,973	$55,973	$55,973	$55,973		-
Data entry (Screening survey) for a TS	$6,481	$6,481	$19,443	$19,443	$6,481	$6,481	$6,481	$19,443			$19,443	$19,443	$137,870	$137,870
Data entry (Diary survey) for a TS		-			$196,396		$196,396	$196,396	$196,396	$196,396	$196,396	$196,396		-
FFV' data cleaning & flight path calculation - 60 days	$11,780	$11,780			$11,780		$11,780			$11,780			$11,780	
Statistical analyses – 10 days of a ST	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049	$3,049
Total survey cost	**$75,807**	**$121,811**	**$182,189**	**$320,201**	**$328,176**	**$345,027**	**$374,180**	**$434,558**	**$436,333**	**$448,113**	**$572,570**	**$610,358**	**$1,098,769**	**$1,266,989**

12. BENEFITS AND ADOPTION

The increasing catch of Commonwealth-managed species by recreational fisheries highlights a growing need for reliable recreational catch estimates for stock assessment to ensure the biological sustainability of the populations, and for equitable sharing of resources between recreational and commercial fishing sectors. However, the diversification of the recreational fishery presents fisheries researchers with the increasingly difficult task of cost-effectively obtaining representative data from these hard-to-reach populations using traditional survey methods.

The primary benefit from this project has been the development of cost-effective methods that are specifically designed to representatively sample hard-to-reach populations of specialised recreational fishers. Respondent-Driven Sampling (RDS) in particular, is widely used in epidemiology and social sciences to survey rare or hidden populations within the wider community. This method should enable fisheries researchers to rapidly and cost-effectively obtain a representative sample of specialised recreational fishers.

However, previous epidemiological research employing RDS has largely focused on characterising the behaviour patterns among their target populations, rather than quantifying the absolute number of people within these hidden populations possessing those behavioural traits. In recreational fisheries research, quantification of the population of fishers is equally important as accessing a representative sample of subjects from the hidden population if the ultimate goal is to estimate the total recreational catch of a species. This project has developed an innovative and cost-effective extension of RDS called "RDS-Recapture". This complemented survey design uses multiple RDS surveys to obtain representative estimates of catch and effort from a hard-to-reach recreational fishing population – by use of a recall or diary survey – and incorporates a mark-recapture design to estimate the size of the population. Therefore, this approach may be capable of allowing the total catch of any given species caught by specialised recreational fishers.

Managers and researchers in Commonwealth and state fisheries agencies and recreational fishing groups are the main beneficiaries of this research. The statistical grounding, efficacy and relatively low cost of RDS provides researchers with an alternative to traditional probability-based methods for representatively sampling important but hard-to-reach components within recreational fisheries. This will allow researchers to cost-effectively obtain more reliable estimates of the total catch, and thus improve the quality and reliability of outcomes from stock assessments, as was demonstrated by scenario modelling in this project. This will in turn benefit fishery managers by having access to more reliable information on specialised recreational fisheries (e.g. SBT) and allow the most appropriate management measures to be implemented to ensure the biological sustainability of resources, allow equitable sharing of the resource among sectors, and fulfil state, national and international reporting obligations and legislative requirements.

13. FURTHER DEVELOPMENT

The primary objective of the current project was to develop innovative and cost-effective options for surveying recreational fishing in Commonwealth waters. Field testing of potentially useful survey methodologies developed or identified during the course of the project was beyond the scope and resources of the project. Nevertheless, this project was successful in developing specialised survey methods that could be tailored for specific Commonwealth fisheries/species and applied in cost-effective monitoring programs after testing. The methods regarded as having considerable potential for estimating the total recreational catch of Commonwealth-managed species were i) Respondent-Driven Sampling when combined with a supplementary method, such as mark-recapture, to estimate total population size of fishers, and ii) using BPC aerial surveillance data to estimate recreational fishing effort combined with a fisher diary program.

The potential efficacy and low cost of RDS compared to other methods considered in this study, point to it as the preferred method for further development. Although RDS has been widely used in epidemiology and social sciences, to our knowledge RDS has not previously been applied to fishery situations. Therefore, before RDS can be confidently used by fisheries researchers and managers, the method requires validation since some populations of recreational fishers may have different characteristics (e.g. network sizes, homophily, motivation to participate) to those of other hard-to-reach populations to which RDS has been successfully applied, such as illicit drug users and sex workers.

A possible method for validating the RDS method may be to compare the results of concurrent RDS and traditional probability-based surveys, such as a telephone recall survey, on a reasonably small and spatially explicit recreational fishery that has a complete sampling frame (e.g. a recreational fishing licence list). Comparisons may be made between the characteristics of respondents (e.g. avidity, age, ethnicity) but importantly, attempt to understand whether non-respondents have the same characteristics as respondents, since this can have a significant effect on catch and effort estimates.

A consideration for further development is that while RDS can provide unbiased catch rate estimates, it cannot directly estimate the population size of the target population. This, in turn, prevents the estimation of the total recreational catch. Therefore, it is recommended that the mark-recapture component of complemented “RDS-Recapture” survey design be developed further to overcome this problem. Because fishers are effectively ‘marked’ within an RDS survey by their coupon number, by completing an RDS survey multiple times, the proportion of fishers ‘recaptured’ in subsequent surveys may then be used to estimate population size using heterogeneous mark-recapture models that may be able to account for differential recapture probabilities of fishers based on their social network size.

14. CONCLUSION

The long-term sustainability of Commonwealth-managed species relies upon the implementation of effective management strategies that can control the total fishing mortality imposed upon these populations. Up until recent years, the total fishing mortality was assumed to be a direct result of commercial fisheries, since most Commonwealth-managed fish species are distributed in offshore waters that are largely inaccessible to most recreational fishers. However, in recent years there has been a marked increase in the number of specialised recreational fishers targeting these species. In some regions, this has resulted in conflict between the recreational and commercial fishing sectors over resource allocation for some shared species. More recently, apparent increases in recreational catches of SBT in Australia have raised concern among fishery managers, who have national and international obligations to report on all mortality sources for this species that currently carries a high international conservation status. Therefore, there is a need for representative recreational catch and effort data to be available for stock assessments, thereby guiding fishery managers to the most appropriate means for managing stocks and ensuring that reporting obligations be met.

Unfortunately, obtaining a reliable estimate of the total recreational catch of most Commonwealth-managed species presents considerable difficulties. This is because only a small minority of the recreational fishing community using specialised techniques engage in fishing activities that are likely to significantly interact with Commonwealth-managed species. Due to their rarity, the expense of sampling required to intercept these specialist fishers using traditional probability-based surveys (e.g. general telephone surveys or on-site access point surveys) is cost-prohibitive and unlikely to yield a representative sample.

In this project, the problem of how to sample hard-to-reach specialist recreational fishers was tackled by Australia's and New Zealand's leading scientists in the field of recreational fishing survey design. The project broke the traditional paradigm of attempting to intercept recreational fishers using random sampling and introduced innovative non-random approaches of infiltrating social networks to reach target populations of specialist recreational fishers. In particular, Respondent-Driven Sampling was identified as the most cost-effective method for accessing hard-to-reach specialist recreational fishers by using a dual incentive chain-referral recruitment process where fishers progressively recruit eligible peers to the study. This can result in the rapid and cost-effective penetration of hard-to-reach populations that are usually only accessible to insiders. Combined with a mark-recapture survey to estimate the population size of the target population, an "RDS-Recapture" complemented survey may allow for reliable estimation of the total recreational catch of Commonwealth-managed species. Although these methods require testing and validation of results before widespread application to recreational fishing in Commonwealth waters can be considered, they show enormous promise for aiding researchers to cost-effectively obtain representative data from even the most specialised recreational fisheries. This will allow fishery managers to more confidently implement measures that can ensure the biological sustainability of fished populations and allow equitable sharing of resources among all fishery stakeholders.

15. REFERENCES

A.F.M.A., 2007. *Commonwealth Fisheries Harvest Strategy: Policy and Guidelines*. Australian Fisheries Management Authority, Canberra.

A.F.M.A., 2009. *Eastern Tuna and Billfish Fishery (ETBF): management arrangements booklet. October 2009*. Australian Fisheries Management Authority, Canberra.

A.F.M.A., 2010. *Recommendations for total allowable catches for SESSF quota species for the 2010-2011 fishing year*. Australian Fisheries Management Authority, Canberra.

Aas, O., Haider, W., 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**, 940-950.

Abdul-Quader, A.S., Heckathorn, D.D., Mcknight, C., Bramson, H., Nemeth, C., Sabin, K., Gallagher, K., Des Jarlais, D.C., 2006. Effectiveness of respondent-driven sampling for recruiting drug users in New York city: Findings from a pilot study. *Journal of Urban Health-Bulletin of the New York Academy of Medicine* **83**, 459-476.

Alho, J.M., 1990. Logistic regression in capture-recapture models. *Biometrics* **46**, 623-635.

Allen, M.S., Tugend, K.I., Mann, M.J., 2003. Largemouth bass abundance and angler catch rates following a habitat enhancement project at Lake Kissimmee, Florida. *North American Journal of Fisheries Management* **23**, 845-855.

Anderson, L.E., Thompson, P.C., 1991. Development and implementation of the angler diary monitoring program for Great Bear Lake, Northwest Territories. In: Guthrie, D., Hoenig, J. M., Holliday, M., Jones, C. M., Mills, M. J., Moberly, S. A., Pollock, K. H., Talhelm, D. R. (Ed.), *Creel and Angler Surveys in Fisheries Management*. American Fisheries Society, Bethesda, Maryland.

Anon., 2006. Review of Recreational Fisheries Survey Methods. *Committee on the Review of Recreational Fisheries Survey Methods, National Research Council of the National Academies, The National Academies Press, Washington D. C.*

Archibald, C.P., Jayaraman, G.C., Major, C., Patrick, D.M., Houston, S.M., Sutherland, D., 2001. Estimating the size of hard-to-reach populations: a novel method using HIV testing data compared to other methods. *Aids* **15 (Suppl. 3)**, S41-S48.

Arlinghaus, R., Mehner, T., 2003. Characteristics of anglers living in the metropolitan area of Berlin (Germany): implications for urban fisheries management and research. *Proceedings of the 3rd World Recreational Fishing Conference 21–24 May 2002, Northern Territory, Australia. Fisheries Report* **67**, 117-120.

Arlinghaus, R., 2004. Recreational fisheries in Germany - a social and economic analysis. *Berichte des IGB* **18**, 1-160.

B.R.S., 2008. *Fishery status reports 2007: status of fish stocks managed by the Australian Government*. Bureau of Rural Sciences, Canberra.

Baharthah, T., Sumner, N.R., 2003. *Department of fisheries stakeholder survey 2002*. Fisheries Department of Western Australia, Perth.

Baker, M.S., Oeschger, I., 2009. Description and initial evaluation of a text message based reporting method for marine recreational anglers. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* **1**, 143-154.

Bangsund, D.A., Leistritz, F.L., 2003. Resident and nonresident hunter and angler expenditures, characteristics, and economic effects, North Dakota, 2001-2002.

Agribusiness & Applied Economics Report - Department of Agribusiness and Applied Economics, North Dakota State University **No. 507**, 129.

Barrett, R., 2006. Big fish off the rocks! Meeting the challenge. *Fishing World*, 8-12.

Beckley, L.E., Fennessy, S.T., Everett, B.I., 2008. Few fish but many fishers: a case study of shore-based recreational angling in a major South African estuarine port. *African Journal of Marine Science* **30**, 11-24.

Begg, G.A., O'neill, M.F., Cadrin, S.X., Bergenius, M.A.J., 2005. *Stock assessment of the Australian east coast spotted mackerel fishery*. CRC Reef Research Centre, Townsville, Australia, p. 159.

Bernard, D.R., Bingham, A.E., Alexandersdottir, M., 1998. Robust harvest estimates from on-site roving-access creel surveys. *Transactions of the American Fisheries Society* **127**, 481-495.

Biernacki, P., Waldorf, D., 1981. Snowball sampling - Problems and techniques of chain-referral sampling. *Sociological Methods and Research* **10**, 141-163.

Bjørkhaug, I., Hatløy, A., 2009. Utilization of respondent-driven sampling among a population of child workers in the diamond-mining sector of Sierra Leone. *Global Public Health* **4**, 96-109.

Bonney, F.R., 1987. *Maine's voluntary anglers: an assessment of the contribution of voluntary creel survey to Maine's fishery management program*. Maine Department of Inland Fish and Wildlife, Farmington.

Braccini, J.M., Walker, T.I., Conron, S., 2008. *Evaluation of effects of targeting breeding elephant fish by recreational fishers in Western Port. Draft Final report to Fisheries Revenue Allocation Committee*. Fisheries Research Brand: Queenscliff, Victoria, Australia, p. 59.

Bray, G.S., Schramm, H.L., 2001. Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool. *North American Journal of Fisheries Management* **21**, 606-615.

Bromhead, D., Pepperell, J., Wise, B., Findlay, J., 2004. *Striped marlin: biology and fisheries*. Bureau of Rural Sciences, Canberra.

Bryant, S., Jones, R., 1991. *Comparison of electrofishing and angler diary in evaluating largemouth bass size structure on Oak Hollow Lake.*, Federal Aid in Sport Fish Restoration project F-24–15. North Carolina Wildlife Resouces Commission, Division of Boating and Inland Fisheries, Raleigh.

Cahalan, J., 2006. Estimation of recreational dungeness crab harvest in puget sound, Washington using a telephone survey of harvesters. *Journal of Shellfish Research* **25**, 687-704.

Campbell, R., Prince, J., Davies, C., Kolody, D., Dowling, N., Ward, P., Mcloughlin, K., 2007. Development of an empirical-indicator based harvest strategy for the Australian Eastern Tuna and Billfish Fishery. *Meeting of the Western and Central Pacific Fisheries Commission, Document WCPFC-SC3-ME SWG/WP-4*.

Chen, R.J., Hunt, K.M., Ditton, R.B., 2003. Estimating the economic impacts of a trophy largemouth bass fishery: Issues and applications. *North American Journal of Fisheries Management* **23**, 835-844.

Cockcroft, A.C., Mackenzie, A.J., 1997. The recreational fishery for West Coast rock lobster *Jasus lalandii* in South Africa. *South African Journal of Marine Science* **18**, 75-84.

Coleman, A.P.M., West, L., 1999. FISHCOUNT: an innovative design for the collection of recreational fishing data. *Fisheries Centre Research Reports* **7**, 71-77.

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

Coleman, J.S., 1958. Relational analysis: the study of social organization with survey methods. *Human Organization* **17**, 28-36.

Comanducci, N., Driscoll, H., 2008. Applying a telephone/intercept methodology to measure the recreational blue crab fishery in New Jersey. *Journal of Shellfish Research* **27**, 998-998.

Conran, S., Coutin, P., 1998. *The recreational snapper catch from Port Phillip Bay: A pilot survey of the boat-based fishery 1994/95.* Marine and Freshwater Resources Institute, Queenscliff, Victoria, p. 23.

Conron, S., Bills, G., 2000. *A survey of the recreational shoreline fishery for black bream, Acanthopagrus butcheri, in the Gippsland Lakes 1995 and 1996*. Marine and Freshwater Resources Institute, Queenscliff, Australia.

Cook, A., 2008. Public opinion on freshwater issues and management in Canterbury. *Research Report - Agribusiness & Economics Research Unit, Lincoln University* **309**, 37.

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

Cope, J.M., Key, M., 2009. *Status of Cabezon (Scorpaenichthys marmoratus) in California and Oregon Waters as Assessed in 2009*. Pacific Fishery Management Council, Portland, Oregon.

Corbane, C., Marre, F., Petit, M., 2008. Using SPOT-5 HRG Data in Panchromatic Mode for Operational Detection of Small Ships in Tropical Area. *Sensors* **8**, 2959-2973.

Cowx, I.G., 1991. Catch effort sampling strategies: conclusions and recommendations for management. In: Cowx, I. G. (Ed.), *Catch Effort Sampling Strategies and their Application in Freshwater Fisheries Management*. Blackwell Scientific Publications, Oxford: Fishing News Books, pp. 404–414.

Cox, S., Shipley, M., 1997. Counting the uncatchable? An epidemiological method for counting drug misusers. *Social Psychiatry and Psychiatric Epidemiology* **32**, 19-23.

Dávid, B., Snijders, T.A.B., 2002. Estimating the size of the homeless population in Budapest, Hungary. *Quality and Quantity* **36**, 291-303.

Dempster, T., 2003. *Association of pelagic fish with floating structures: patterns, processes and ecological consequences*. School of Biological Sciences, Faculty of Science. University of Sydney, Sydney, pp. xi, 197 pp.

Ditton, R.B., 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.

Duda, M.D., De Michele, P.E., Allen, D., Harrison, B., Nash, V., Hayes, G., Self, R., Testerman, W., Zurawski, C.A., Lanier, A.J., Yoder, J., 2002. Attitudes of South Carolina youth towards aquatic resources and recreational fishing. *Proceedings of the Fifty-Sixth Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*, 421-433.

Erickson, B., 1979. Some problems of inference from chain data. *Sociological Methodology Research* **10**, 276-302.

Evans-Campbell, T., Lindhorst, T., Huang, B., Walters, K.L., 2006. Interpersonal violence in the lives of urban American Indian and Alaska native women:

Implications for health, mental health, and help-seeking. *American Journal of Public Health* **96**, 1416-1422.

Everett, B.I., Pradervand, P., Beckley, L.E., Mann, B.Q., Radebe, P.V., 2002. *Recreational fishing in two large South African ports*. Southern African Marine Science Symposium (SAMSS 2002): Currents Coasts Communities.

Faugier, J., Sargeant, M., 1997. Sampling hard to reach populations. *Journal of Advanced Nursing* **26**, 790-797.

Fay, G., Punt, A.E., Smith, A.D.M., 2009. Operating model specifications. In: Wayte, S. E. (Ed.), *Evaluation of new harvest strategies for SESSF species*. Australian Fisheries Management Authority, Canberra.

Ferrell, D., Sumpton, W., 1998. *Assessment of the fishery for snapper (Pagrus auratus) in Queensland and New South Wales*. Final report - FRDC Project 93/074. Queensland Department of Primary Industries, Brisbane, p. 143.

Ferrer Montano, O.J., Dibble, E.D., Jackson, D.C., Rundle, K.R., 2005. Angling assessment of the fisheries of Humacao Natural Reserve lagoon system, Puerto Rico. *Fisheries Research* **76**, 81-90.

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

Fournier, D.A., Hampton, J., Sibert, J.R., 1998. MULTIFAN-CL: a length-based, age-structured model for fisheries stock assessment, with application to South Pacific albacore, *Thunnus alalunga*. *Canadian Journal of Fisheries and Aquatic Sciences* **55**, 2105−2116.

Fraidenburg, Bargmann, 1982. Estimating boat-based fishing effort in a marine recreational fishery. *North American Journal of Fisheries Management* **2**, 351-358.

Fry, G.C., Griffiths, S.P., 2010. Population dynamics and stock status of cobia, *Rachycentron canadum*, caught in Australian recreational and commercial coastal fisheries. *Fisheries Management and Ecology* **17**, 231-239.

Gabelhouse, D.W., Willis, D.W., 1986. Biases and utility of angler catch data for assessing size structure and density of largemouth bass. *North American Journal of Fisheries Management* **6**, 481–489.

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

Goodman, L.A., 1961. Snowball sampling. *Annals of Mathematical Statistics* **32**, 148-170.

Gowing, L., Boyd, R., 2004. *2000-2001 National marine recreational fishing survey: rotational diarist recruitment survey*. (Unpublished report held by MFish, Wellington), p. 80.

Green, D., M., Schonhoff, B., J., Youngs, W.D., 1986. *The New York State bass study 1977–1980: use of angler collected data to determine population dynamics*. New York State Department of Environmental Conservation, Albany.

Greidanus, H., 2005. *Assessing the operationality of ship detection from space*. EURISY Symposium "New Space Services for Maritime Users: The Impact of Satellite Technology on Maritime Legislation", Paris, 21-23 Febr 2005., Paris.

Griffiths, S., Pepperell, J., Tonks, M., Sawynok, W., Olyott, L., Tickell, S., Zischke, M., Lynne, J., Burgess, J., Jones, E., Joyner, D., Makepeace, C., Moyle, K., 2010. *Biology, fisheries and status of longtail tuna (Thunnus tonggol), with special*

reference to recreational fisheries in Australian waters. FRDC Final Report 2008/058, CSIRO Marine and Atmospheric Research, Cleveland, Qld.

Griffiths, S.P., Fry, G.C., Van Der Velde, T.D., 2006. Population dynamics and fishery benefits of a large legal size of a pelagic sportfish, the Talang queenfish, *Scomberoides commersonnianus*, in northern Australia. *Fisheries Research* **82**, 74-86.

Griffiths, S.P., Pepperell, J.P., 2006. *A preliminary synopsis of existing recreational fisheries data sources and the potential for monitoring recreational fishing activities in Commonwealth fisheries*. AFMA Final Report R06/822. CSIRO Marine and Atmospheric Research, Cleveland.

Griffiths, S.P., Kuhnert, P.M., Venables, W.N., Blaber, S.J.M., 2007. Estimating abundance of pelagic fishes using gillnet catch data in data-limited fisheries: a Bayesian approach. *Canadian Journal of Fisheries and Aquatic Sciences* **64**, 1019-1033.

Griffiths, S.P., Edgar, S., Wang, Y.-G., Salini, J., 2008. *Calculating recent foreign fishing vessel numbers using established estimators based on Coastwatch surveillance and apprehension data. Final Report for Project 2007/836*. Final report to the Australian Fisheries Management Authority. CSIRO Marine and Atmospheric Research, Cleveland, Qld, p. 80.

Haddon, M., 2009. *TIER 4 Analyses 1986 - 2008. Technical report to Southern and Eastern Scalefish and Shark Fishery Resource Assessment Groups*.

Hall, K., Douglas, J., 2003. The use of creel surveys to answer fisheries management questions in Victoria, Australia. *Fishery Report - Department of Business, Industry & Resource Development, Northern Territory Government*, 55-58.

Hardie, D.C., Nagtegaal, D.A., Sturhahn, J., Hein, K., 2002. *Strait of Georgia and northern Vancouver Island sport fishery creel survey statistics for salmon and groundfish, 2000.*, Canadian manuscript report of Fisheries and Aquatic Sciences. 2608., p. 126.

Hart, A., 2002. *Southern Gulf Environmental Information program: Recreational Fishing Surveys - Pilot Study*. Trophia.

Hart, A.M., Walker, N.A., 2004. *Monitoring the recreational blue cod and sea perch fishery in the Kaikoura - North Canterbury area*. New Zealand Fisheries Assessment Report no. 45.

Hart, P.J.B., Reynolds, J.D., 2002. *Handbook of fish biology and fisheries*. Blackwell, Malden, MA.

Hartill, B., Vaughan, M., 2006. *Recreational marine harvest estimate for SNA 8: pilot survey results.*, Research Progess Report for Ministry of Fisheries research project REC200501. Objective 1. (Unpublished report held by MFish, Wellington), p. 19.

Hartill, B.W., Bian, R., Davies, N., 2008. *Review of recreational harvest estimates and approaches*. Research Progress Report, Ministry of Fisheries Research Project REC2004/06. National Institute of Water and Atmospheric Research.

Hay, G., 2000. Capture-recapture estimates of drug misuse in urban and non-urban settings in the north east of Scotland. *Addiction* **95** 1795-1803.

Heckathorn, D., Semaan, S., Broadhead, R., Hughes, J., 2002. Extensions of respondent-driven sampling: a new approach to the study of infection drug users aged 18-25. *AIDS and Behavior* **6**, 55-67.

Heckathorn, D.D., 1990. Collective sanctions and compliance norms: A formal theory of group-mediated social control. *American Sociological Review* **55**, 366-384.

Heckathorn, D.D., 1996. *Respondent-driven sampling: A new approach to the study of hidden populations*. XIth International Conference on AIDS. Univ Calif Press, Vancouver, Canada, pp. 174-199.

Heckathorn, D.D., 1997. Respondent-driven sampling: A new approach to the study of hidden populations. *Social Problems* **44**, 174-199.

Heckathorn, D.D., Broadhead, R.S., Sergeyev, B., 2001. A methodology for reducing respondent duplication and impersonation in samples of hidden populations. *Journal of Drug Issues* **31**, 543-564.

Heckathorn, D.D., 2002. Respondent-driven sampling II: deriving valid population estimates from chain-referral samples of hidden populations. *Social Problems* **49**, 11-34.

Henry, G.W., Lyle, J.M., 2003. *The National Recreational and Indigenous Fishing Survey. NSW Fisheries, Final Report Series No. 48. FRDC Project No. 99/158*. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, p. 188.

Higgs, J.B., 2003. Longitudinal survey suggests declining interest in recreational fishing. *Fishery Report - Department of Business, Industry & Resource Development, Northern Territory Government*, 135-137.

Higgs, J.B., Mcinnes, K.L., 2003. *2001 Biennial Recreational Fishing Survey of Queensland Residents*. Queensland Department of Primary Industries Brisbane Australia, p. 91.

Hoenig, J.M., Jones, C.M., Pollock, K.H., Robson, D.S., Wade, D.L., 1997. Calculation of catch rate and total catch in roving surveys of anglers. *Biometrics* **53**, 306-317.

Huggins, R.M., 1989. On the statistical analysis of capture experiments. *Biometrika* **76**, 133-140.

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

Johnston, L.G., Khanam, R., Reza, M., Khan, S.I., Banu, S., Alam, M.S., Rahman, M., Azim, T., 2008. The effectiveness of respondent driven sampling for recruiting males who have sex with males in Dhaka, Bangladesh. *AIDS and Behavior* **12**, 294-304.

Jones, K., 2009. *South Australian Recreational Fishing Survey 2007/08*. South Australian Fisheries Management Series Paper No 54, Primary Industries and Resources South Australia, Adelaide.

Kalvass, P.E., Geibel, J.J., 2006. California recreational abalone fishery catch and effort estimates for 2002 from a combined report card and telephone survey. *California Fish and Game* **92**, 157-171.

Kaplan, C.D., Korf, D., Sterk, C., 1987. Temporal and social contexts of heroin-using populations - An illustration of the snowball sampling technique. *Journal of Nervous and Mental Disease* **175**, 566-574.

Kearney, R.E., 1999. Evaluating recreational fishing: managing perceptions and/or reality. In: Pitcher, T. J. (Ed.), *Evaluating the benefits of recreational fishing*. Fisheries Centre Research Reports, Volume 7, Number 2, University of British Columbia, Vancouver, pp. 9-14.

Kelch, D., Lichtkoppler, F., Sohngen, B., Daigneault, A., 2006. The value of steelhead (Onchorhynchus mykiss) angling in Lake Erie tributaries. *Journal of Great Lakes Research* **32**, 424-433.

Kerr, S.J., Cholmondeley, R., 1992. *Results of an aerial creel survey on the Rideau and Cataraqui river systems, summer 1990.*, Ontario Ministry of Natural Resources, Kemptville, Ontario.

Killworth, P.D., Bernard, H.R., 1978. The reversal small-world experiment. *Social Networks* **1**, 159-192.

Klaer, N.L., Wayte, S.E., Punt, A.E., Little, L.R., Smith, A.D.M., Thomson, R.B., G.N., T., 2009. Simulation testing of alternative Tier 3 assessment methods and control rules for the SESSF. In: Wayte, S. E. (Ed.), *Evaluation of New Harvest Strategies for SESSF Species*. Australian Fisheries Management Authority, Canberra, pp. 42-70.

Kopf, R.K., Davie, P.S., Holdsworth, J.C., 2005. Size trend and population characteristics of striped marlin, *Tetrapturus audax*, caught in the New Zealand recreational fishery. *New Zealand Journal of Marine and Freshwater Research* **39**, 1145-1156.

Kuhnert, P.M., Martin, T.G., Mengersen, K., Possingham, H.P., 2005. Assessing the impacts of grazing levels on bird density in woodland habitat: a Bayesian approach using expert opinion. *Environmetrics* **16**, 717-747.

Langley, A., Molony, B., Bromhead, D., Yokawa, K., Wise, B., 2006. Stock assessment of striped marlin (*Tetrapturus audax*) in the southwest Pacific Ocean. *Meeting of the Western and Central Pacific Fisheries Commission, 7-18 August 2006, Manila, Philippines, Document WCPFC-SC2-2006/SA WP-6*.

Leigh, G.M., O'neill, M.L., 2003. *Stock assessment of the Queensland-New South Wales tailor fishery (Pomatomus saltatrix)*. Queensland Department of Primary Industries and Fisheries, Southern Fisheries Centre, Deception Bay

Little, L.R., Wayte, S.E., Tuck, G.N., Thomson, R.B., Smith, A.D.M., Klaer, N.L., Punt, A.E., Haddon, M., 2009. Testing an alternative Tier 4 control rule and CPUE reference points for the SESSF. In: Wayte, S. E. (Ed.), *Evaluation of new harvest strategies for SESSF species*. Australian Fisheries Management Authority, Canberra, pp. 98-112.

Lockwood, R.N., Peck, J., Oelfke, J., 2001. Survey of angling in Lake Superior waters at Isle Royale National Park, 1998. *North American Journal of Fisheries Management* **21**, 471-481.

Lowry, M., Murphy, J., 2003. Monitoring the recreational gamefish fishery off south-eastern Australia. *Marine and Freshwater Research* **54**, 425-434.

Lowry, M., Steffe, A., Williams, D., 2006. Relationships between bait collection, bait type and catch: A comparison of the NSW trailer-boat and gamefish-tournament fisheries. *Fisheries Research* **78**, 266-275.

Lowry, M., Williams, D., Metti, Y., 2007. Lunar landings - Relationship between lunar phase and catch rates for an Australian gamefish-tournament fishery. *Fisheries Research* **88**, 15-23.

Lyle, J.M., 2005. *2000/01 Survey of Recreational Fishing in Tasmania*. Technical Report Series. No. 24, pp. 97. Tasmanian Aquaculture and Fisheries Institute.

Lyle, J.M., Morton, A.J., 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**, 703-713.

Magnani, R., Sabin, K., Saidel, T., Heckathorn, D., 2005. Review of sampling hard-to-reach and hidden populations for HIV surveillance. *Aids* **19**, S67-S72.

Malseed, B.E., Sumner, N.R., Williamson, P.C., 2000. *A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998*. Fisheries Research Report. Western Australia Fisheries Department, pp. 1-36.

Malseed, B.E., Sumner, N.R., 2001. *A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99*. Fisheries Research Report No. 127, 2001. Fisheries Research Division, WA Marine Research Laboratories.

Malvestuto, S.P., 1996. Sampling the recreational creel. In: Murphy, B. R., Willis, D. W. (Eds.), *Fisheries Techniques*. American Fisheries Society, Bethesda, Maryland, pp. 591-624.

Mann, B.Q., Mcdonald, A.M., Sauer, W.H.H., Hecht, T., 2003. Evaluation of participation in and management of the Transkei shore linefishery. *African Journal of Marine Science* **25**, 79-97.

Mastro, T.D., Kitayaporn, D., Weniger, B.G., Vanichseni, S., Laosunthorn, V., Uneklabh, T., Uneklabh, C., Choopanya, K., Limpakarnjanarat, K., 1994. Estimating the number of HIV-infected injection drug users in Bangkok: a capture-recapture method. *American Journal of Public Health* **84**, 1094-1099.

Mateo, I., 2004. Survey of resident participation in recreational fisheries activities in the US Virgin Islands. *Proceedings of the Fifty-Fifth Annual Gulf and Caribbean Fisheries Institute*, 205-222.

Mccarthy, M.A., Masters, P., 2005. Profiting from prior information in Bayesian analyses of ecological data. *Journal of Applied Ecology* **42**, 1012-1019.

Mcclanahan, D.R., Hansen, M.J., 2005. *A statewide mail survey to estimate 2000/2001 angler catch, harvest, and effort in Wisconsin*. Wisconsin Department of Natural Resources, Madison, p. 48

Mcglennon, D., 1992. Recreational boatfishing: The 1990-91 metropolitan survey. *Safish* **4**, 4-10.

Mcglennon, D., Kinloch, M.A., 1997. Evaluation of the bus-route creel survey method in a large Australian marine recreational fishery - II. Pilot surveys and optimal sampling allocation. *Fisheries Research* **33**, 89-99.

Mcglennon, D., 1999. *Monitoring recreational fishing and boating*. SARDI Int. Rept. No. 76. South Australian Research and Development Institute, p. 13.

Mcinnes, K.L., 2003. 2004 Biennial Recreational Fishing Telephone Survey of Queensland Residents. *Queensland Department of Primary Industries Publication Q106010, ISSN 0727-6273, Brisbane Australia, pp. 72.*

Mcphee, D.P., Leadbitter, D., Skilleter, G.A., 2002. Swallowing the bait: Is recreational fishing ecologically sustainable? *Pacific Conservation Biology* **8**, 41-50.

Melville-Smith, R., Anderton, S.M., 2000. Western rock lobster mail surveys of licensed recreational fishers 1986/87 to 1998/99. *Fisheries Research Report* **122**, 1-39.

Methot, R.D., 2009. *User manual for Stock Synthesis: Model version 3.02B*. NOAA Fisheries, Seattle, Washington.

Mitchell, R.W.D., Baba, O., Jackson, G., Isshiki, T., 2008. Comparing management of recreational Pagrus fisheries in Shark Bay (Australia) and Sagami Bay (Japan): Conventional catch controls versus stock enhancement. *Marine Policy* **32**, 27-37.

Morales-Nin, B., Moranta, J., Garcia, C., Tugores, M.P., Grau, A.M., Riera, F., Cerda, M., 2005. The recreational fishery off Majorca Island (western Mediterranean): some implications for coastal resource management. *Ices Journal of Marine Science* **62**, 727-739.

Morton, A.J., Lyle, J.M., 2003. Preliminary assessment of the recreational gamefish fishery in Tasmania, with particular reference to southern blue tuna. *Tasmanian Aquaculture and Fisheries Institute Technical Report Series* **21**, 30.

Muhib, F.B., Lin, L.S., Stueve, A., Miller, R.L., Ford, W.L., Johnson, W.D., Smith, P.J., 2001. A venue-based method for sampling hard-to-reach populations. *Public Health Reports* **116**, 216-222.

Murray-Jones, S., Steffe, A.S., 2000. A comparison between the commercial and recreational fisheries of the surf clam, *Donax deltoides*. *Fisheries Research* **44**, 219-233.

N.R.C., 2006. *Review of recreational fisheries survey methods*. National Research Council, National Academy Press, Washington, D.C., USA.

Newman, M.E.J., 2003. Ego-centered networks and the ripple effect. *Social Networks* **25**, 83-95.

Newman, S.P., Rasmussen, P.W., Andrews, L.M., 1997. Comparison of a stratified, instantaneous count creel survey with a complete mandatory creel census on Escanaba Lake, Wisconsin. *North American Journal of Fisheries Management* **17**, 321–330.

Nrc, 2006. *Review of recreational fisheries survey methods*. National Research Council, National Academy Press, Washington, D.C., USA.

O'neill, M.F., 2000. *Fishery assessment of the Burnett River, Maroochy River, and Pumicestone Passage*. Queensland Department of Primary Industries and Fisheries, p. 112.

Park, T., 2006. *Fishcare Volunteer Survey: Summary of data collected*. Fisheries Final Report Series No. 85. NSW Department of Primary Industries, p. 41.

Peachey, A., 1998. An economic valuation of water based recreation in the Great Barrier Reef marine park. *Australian Parks & Recreation* **34**, 14-16.

Penn, J.W., 2003. *State of the fisheries report 2002/2003*. Western Australian Department of Fisheries, p. 235.

Pepperell, J.G., 1994a. Dispersal and homing of black marlin in the southwest Pacific: 25 years of recreational tagging. In: Kleiber, P., Rasmussen, R. (Eds.), *Proceedings of the 45th Annual Tuna Conference, May 23–26, 1994*. National Marine Fisheries Service (SWFSC), La Jolla, p. 105.

Pepperell, J.G., 1994b. The value of game fishing. *Bluewater Fishing, Game Fishing Association of Australia*, 12-13.

Pepperell, J.G., Dominion, 1996. *Reconciling Australian recreational fishing surveys with particular reference to New South Wales. Report to the NSW Recreational Saltwater Fishing Trust*. Pepperell Research & Consulting and Dominion Consulting Pty Ltd,.

Platt, L., Wall, M., Rhodes, T., Judd, A., Hickman, M., Johnston, L.G., Renton, A., Bobrova, N., Sarang, A., 2006. Methods to recruit hard-to-reach groups: Comparing two chain referral sampling methods of recruiting injecting drug users across nine studies in Russia and Estonia. *Journal of Urban Health-Bulletin of the New York Academy of Medicine* **83**, I39-I53.

Pollock, K.H., Jones, C.M., Brown, T.L., 1994. Angler survey methods and their implications in fisheries management. *American Fisheries Society Special Publication 25*, 371.

Pollock, K.H., Hoenig, J.M., Jones, C.M., Robson, D.S., Greene, C.J., 1997. Catch rate estimation for roving and access point surveys. *North American Journal of Fisheries Management* **17**, 11-19.

Post, J.R., Sullivan, M., Cox, P., Lester, N.P., Walters, C.J., Parkinson, E.A., Paul, A.J., Jackson, L., Shuter, B.J., 2002. Canada's recreational fishery: The invisible collapse? *Fisheries* **27**, 6-17.

Prentice, J.A., Farquhar, B.W., Whitworth, W.E., 1995. Comparison of volunteer angler–supplied fisheries catch and population structure data with traditional data. *Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies (1993)* **47**, 666–678.

Prior, S.P., 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.

Rangel, M.O., Erzini, K., 2007. An assessment of catches and harvest of recreational shore angling in the north of Portugal. *Fisheries Management and Ecology* **14**, 343-352.

Rapoport, A., 1957. Contribution to the theory of random and biased nets. *Bulletin of Mathematical Biophysics* **19**, 257-277.

Reid, D.D., Montgomery, S.S., 2005. Creel survey based estimation of recreational harvest of penaeid prawns in four southeastern Australian estuaries and comparison with commercial catches. *Fisheries Research* **74**, 169-185.

Roach, B., Trail, J., Boyle, K., 1999. Comparing 1994 Angler Catch and Harvest Rates from On–site and Mail Surveys on Selected Maine Lakes. *North American Journal of Fisheries Management* **19**, 203–208.

Robson, D.S., 1991. *The roving creel survey*. In: Guthrie, D.s (Ed.), Creel and angler surveys in fisheries management : proceedings of the International Symposium and Workshop on Creel and Angler Surveys in Fisheries Management, held at Houston, Texas, USA, 26-31 March 1990, Houston, Texas, USA, pp. 19-24.

Ryan, K., Morison, A.K., Conron, S., 2009. *Evaluating methods of obtaining total catch estimates for individual Victorian bay and inlet recreational fisheries*. FRDC Final Report 2003/047, Department of Primary Industries, Queenscliff.

Salganik, M.J., Heckathorn, D.D., 2004. Sampling and estimation in hidden populations using respondent driven sampling. *Sociological Methodology* **34**, 193-239.

Sawynok, B., 2005. CapReef. Capricorn reef monitoring program. A community-based monitoring program for the Great Barrier Reef in central Queensland. *Unpublished report, pp. 65.*

Scholten, S.J., 2003. *Aerial Effort Surveys of the Winter Lake Trout Fishery in Thunder Bay District for 1999 and 2001.*, Ontario Ministry of Natural Resources, Thunder Bay, Ontario, p. 26.

Scott, G., 2008. "They got their program, and I got mine": A cautionary tale concerning the ethical implications of using respondent-driven sampling to study injection drug users. *International Journal of Drug Policy* **19**, 42-51.

Sharp, W.C., Bertelsen, R.D., Leeworthy, V.R., 2005. Long-term trends in the recreational lobster fishery of Florida, United States: landings, effort, and implications for management. *New Zealand Journal of Marine and Freshwater Research* **39**, 733-747.

Smallwood, C.B., Beckley, L.E., Sumner, N.R., 2006. Shore-based recreational angling in the Rottnest Island Reserve, Western Australia: Spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* **12**, 238-251.

Smallwood, C.B., Sumner, N.R., 2007. *A 12 month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002-03*. Fisheries Research Report. Fisheries Western Australia pp. 1-56.

Smith, A.D.M., Smith, D.C., 2005. *A harvest strategy framework for the SESSF. Report to the Australian Fisheries Management Authority*. CSIRO Marine Research, Hobart.

Smith, A.D.M., Smith, D.C., Tuck, G.N., Klaer, N., Punt, A.E., Knuckey, I., Prince, J., Morison, A., Kloser, R., Haddon, M., Wayte, S., Day, J., Fay, G., Pribac, F., Fuller, M., Taylor, B., Little, L.R., 2008. Experience in implementing harvest strategies in Australia's south-eastern fisheries. *Fisheries Research* **94**, 373-379.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Tarlinton, B.E., Gordon, G.N.G., Grinberg, A., 1996. An assessment of the impact of offshore recreational fishing in NSW waters on the management of commercial fisheries. *FRDC Project no. 94/053*, 139.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Barrett, G.P., Gray, C.A., 2005a. An assessment of changes in the daytime, boat-based, recreational fishery of the Tuross Lake estuary following the establishment of a 'Recreational Fishing Haven'. *NSW Department of Primary Industries Fisheries Final Report Series* **81**, 70.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Gray, C.C., 2005b. An assessment of changes in the daytime recreational fishery of Lake Macquarie following the establishment of a 'Recreational Fishing Haven'. *NSW Department of Primary Industries Fisheries Final Report Series* **79**, 9-103.

Steffe, A.S., Murphy, J.J., Reid, D.D., 2008. Supplemented access point sampling designs: A cost-effective way of improving the accuracy and precision of fishing effort and harvest estimates derived from recreational fishing surveys. *North American Journal of Fisheries Management* **28**, 1001-1008.

Stueve, A., O'donnell, L.N., Duran, R., San, D.A., Blome, J., 2001. Time-space sampling in minority communities: Results with young Latino men who have sex with men. *American Journal of Public Health* **91**, 922-926.

Sumner, N.R., Williamson, P.C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. *Fisheries Research Report* **117**, 52.

Sumner, N.R., Willimson, P.C., Malseed, B.E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. *Fisheries WA Research Report* **139**.

Sun, C.Y., Pokharel, S., Jones, W.D., Grado, S.C., Grebner, D.L., 2007. Extent of recreational incidents and determinants of liability insurance coverage for hunters and anglers in Mississippi. *Southern Journal of Applied Forestry* **31**, 151-158.

Sutton, S.G., 2005. Factors influencing boater satisfaction in Australia's Great Barrier Reef Marine Park. *Tourism in Marine Environments* **2**, 13-22.

Sutton, S.G., 2006a. Understanding recreational fishers' participation in public consultation programs. *Human Dimensions of Wildlife* **11**, 329-341.

Sutton, S.G., 2006b. *An Assessment of the Social Characteristics of Queensland's Recreational Fishers*. CRC Reef Research Centre Technical Report No 65. CRC Reef Research Centre, Townsville.

Sylvester, T., 1996. *A comparison of the Hauraki Gulf recreational snapper catch between the aerial / interview survey and the telephone / diary survey*. (Unpublished report held by MFish, Wellington), p. 32.

Sztramko, L.K., Dunlop, W.I., Powell, S.W., Sutherland, R.G., 1991. *Applications benefits of an angler diary program on Lake Erie*. In: Guthrie, D., Hoenig, J. M., Holliday, M., Jones, C. M., Mills, M. J., Moberly, S. A., Pollock, K. H., Talhelm,

D. R.s (Eds.), Creel and angler surveys in fisheries management. American Fisheries Society, Symposium 12, Bethesda, Maryland, pp. 520–528.

Tarrant, M.A., Manfredo, M.J., Bayley, P.B., Hess, R., 1993. Effects of Recall Bias and Nonresponse Bias on Self-Report Estimates of Angling Participation. *North American Journal of Fisheries Management* **13**, 217-222.

Teirney, L.D., Kilner, A.R., Millar, R.B., Bradford, E., Bell, J.D., 1997. *Estimation of Recreational Harvests from 1991–92 to 1993–1994.*, New Zealand Fisheries Assessment Research Document 97/15. New Zealand Fisheries, p. 43.

Thayer, S.A., 2005. *Michigan Department of Natural Resources Disheries Division Research Theme Assessment - Human Dimensions of Aquatics and Fisheries Management*. Internal Report.

Thomson, C.J., 1991. *Effects of the avidity bias on survey estimates of fishing effort and economic value*. American Fisheries Society Symposium, pp. 356-366.

Thunberg, E., 1999. Marine recreational fishing participation in the Northeast USA, 2000-2025. *Evaluating the benefits of recreational fisheries* **7**, 143-149.

Vandevalk, A.J., Forney, J.L., Jackson, J.R., Rudstam, L.G., Brooking, T.E., Krueger, S.D., 2005. Angler catch rates and catchability of walleyes in Oneida Lake, New York. *North American Journal of Fisheries Management* **25**, 1441-1447.

Venables, W.N., Ripley, B.D., 2002. *Modern Applied Statistics with S, 4th edition*. Springer-Verlag, New York.

Volstad, J., H., Pollock, K.H., Richkus, W.A., 2006. Comparing and combining effort and catch estimates from aerial-access designs as applied to a large-scale angler survey in the delaware river. *North American Journal of Fisheries Management* **26**, 727-741.

Volz, E., Wejnert, C., Deganii, I., Heckathorn, D.D., 2007. *Respondent-Driven Sampling Analysis Tool (RDSAT), Version 6.0.1*. Cornell University, Ithaca, NY.

Volz, E., Heckathorn, D.D., 2008. Probability-based estimation theory for respondent-driven sampling. *Journal of Official Statistics* **24**, 79-97.

Wade, D.L., Jones, C.M., Robson, D.S., Pollock, K.H., 1991. Computer simulation techniques to assess bias in the roving-creel-survey estimator. *American Fisheries Society Symposium* **12**, 40-46.

Wang, J.C., Carlson, R.G., Falck, R.S., Siegal, H.A., Rahman, A., Li, L.N., 2005. Respondent-driven sampling to recruit MDMA users: a methodological assessment. *Drug and Alcohol Dependence* **78**, 147-157.

Watters, J.K., Biernacki, P., 1989. Targeted Sampling: Options for the study of hidden populations. *Social Problems* **36**, 416-430.

Weithman, A.S., Haverland, P., 1991. Comparability of data collected by telephone and roving creel surveys. *Creel and Angler Surveys in Fisheries Management* **12**, 67-73.

Wejnert, C., Heckathorn, D.D., 2008. Web-based network sampling: Efficiency and efficacy of respondent-driven sampling for online research. *Sociological Methods and Research* **37**, 105-134.

Wejnert, C., 2009. An empirical test of respondent-driven sampling: Point estimates, variance, measures of degree, and out-of-equilibrium data. *Sociological Methodology* **39**, 73-116.

West, R.J., Gordon, G.N.G., 1994. Commercial and recreational harvest of fish from two Australian coastal rivers. *Australian Journal of Marine and Freshwater Research* **45**, 1259-1279.

Whitehead, J.C., Clifford, W.B., Hoban, T.J., 2001. Willingness to pay for a saltwater recreational fishing license: a comparison of angler groups. *Marine Resource Economics* **16**, 177-194.

Wilberg, M., Humphrey, J., 2008. *A creel survey for early spring fisheries of Maryland's Chesapeake Bay tributaries*. Progress report to Maryland Department of Natural Resources.

Willems, J.C., Iguchi, M.Y., Lidz, V., Bux, D.A.J., 1997. Change in drug-using networks of injecting drug users during methadone treatment: a pilot study using snowball recruitment and intensive interviews. *Substance Use and Misue* **32**, 1539-1554.

Williams, B.K., Nichols, J.D., Conroy, M.J., 2002. *Analysis and management of animal populations: modeling, estimation, and decision making*. Academic Press, San Diego, California.

Williams, D.L., 2003. *Data derived from the gamefish fishery and its utility in assessing size composition and movements of yellowfin tuna in eastern Australian waters*. Working paper YFT-6, 16th meeting of the standing committee on tuna and billfish, Mooloolaba, Australia, 9-16 July 2003, p. 19.

Williams, E.H., 2002. The effects of unaccounted discards and misspecified natural mortality on harvest policies based on estimates of spawners per recruit. *North American Journal of Fisheries Management* **22**, 311-325.

Williamson, P.C., Sumner, N.R., Malseed, B.E., 2006. *A 12-month survey of recreational fishing in the Pilbara region of Western Australia during 1999-2000*. Fisheries WA Research Report No. 153. Fisheries Western Australia.

Zeller, D., Darcy, M., Booth, S., Lowe, M.K., Martell, S., 2008. What about recreational catch?: Potential impact on stock assessment for Hawaii's bottomfish fisheries. *Fisheries Research* **91**, 88-97.

16. APPENDICES

16.1 Appendix 1

Intellectual property

None arising.

16.2 Appendix 2

Annotated bibliography of references included in the global literature review of recreational fishing survey methods

ANGOLA

Potts, W.M., Childs, A.R., Sauer, W.H.H., Duarte, A.D.C., 2009. Characteristics and economic contribution of a developing recreational fishery in southern Angola. *Fisheries Management and Ecology* **16**, 14-20.
Country: ANGOLA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point creel surveys used to estimate total effort and catch.

AUSTRALIA

Braccini, J.M., Walker, T.I., Conron, S., 2008. Evaluation of effects of targeting breeding elephant fish by recreational fishers in Western Port. Draft Final report to Fisheries Revenue Allocation Committee. Fisheries Research Brand: Queenscliff, Victoria, Australia, p. 59.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route survey and charter boat logbooks were used to estimate catch, effort and size composition.

Malseed, B.E., Sumner, N.R., 2001. A 12-month survey of recreational fishing in the Peel-Harvey Estuary of Western Australia during 1998-99. *Fisheries Research Report* **127**. Fisheries Research Division, WA Marine Research Laboratories.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route and roving creel surveys were used to estimate catch and effort for shore and boat based fishers.

Malseed, B.E., Sumner, N.R., Williamson, P.C., 2000. A 12-month survey of recreational fishing in the Leschenault Estuary of Western Australia during 1998. *Fisheries Research Report 1035-4549*. Western Australia Fisheries Department, p. 36.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route and roving creel surveys were used to estimate catch and effort for shore and boat based fishers.

Steffe, A.S., Macbeth, W.G., Muthy, J.J., 2007. Status of the recreational fisheries in two Australian coastal estuaries following large fish-kill events. *Fisheries Research* **85**, 258-269.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving-roving survey used to estimate catch and effort for shore-based fishers and a roving-access point survey to estimate catch and effort for boat-based fishers.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Gray, C.C., 2005a. An assessment of changes in the daytime recreational fishery of Lake Macquarie following the establishment of a 'Recreational Fishing Haven'. *NSW Department of Primary Industries Fisheries Final Report Series*. p. 103.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving-roving survey used to estimate catch and effort for shore-based fishers and a roving-access point survey to estimate catch and effort for boat-based fishers.

Steffe, A.S., Murphy, J.J., Chapman, D.J.B., G.P., Gray, C.A., 2005b. An assessment of changes in the daytime, boat-based, recreational fishery of the Tuross Lake estuary following the establishment of a 'Recreational Fishing Haven. *NSW Department of Primary Industries Fisheries Final Report Series*, Cronulla, p. 70.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:**

Coutin, P.C., Conron, S., MacDonald, C.M,. 1995. The day-time recreational fishery in Port Phillip Bay 1989-94. *Victorian Fisheries Research Institute Technical Report*. Victorian Fisheries Research Institute, Queenscliff.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** On-site creel surveys and aerial surveys used to estimate catch and effort.

Griffin, R.K., 1993. The Recreational Fishery for Barramundi (*Lates calcarifer*) in the Mary River, Northern Territory 1986-1992. *Fishery Report No. 30*. Fisheries Division, Northern Territory Department of Primary Industry and Fisheries, p. 16.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Access point (boat ramps, roadside interviews) and roving creel surveys were used to estimate catch, effort and harvest for barramundi from several water bodies in the Northern Territory.

Conron, S., Coutin, P.C., 1995. *Survey of the recreational fishery in the Gippsland Lakes 1995. Progress Report No. 1.* Victorian Fisheries Research Institute, Queenscliff.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** On-site creel surveys and aerial surveys used to estimate catch and effort.

Department of Fisheries WA, Western Australia West Coast Boat Phone Diary Survey. **Country:** AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Multiple telephone interviews to anglers who use a diary (as a memory prompt) to collect catch and effort from boat based fishers (2005/06).

Griffiths, S.P., 2008. Recreational catch and effort in a unique land-based pelagic game fish fishery in eastern Australia. *Australian Society for Fish Biology Conference Poster.*
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel and electronic diaries used to estimate effort and catch rates for gamefish and baitfish species.

Morton, A.J., Lyle, J.M., 2003. Preliminary assessment of the recreational gamefish fishery in Tasmania, with particular reference to southern blue fin tuna. *Technical Report Series* **21**. Tasmanian Aquaculture and Fisheries Institute, Taroona, Tas., p. 30.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Onsite surveys and charter boat log books used to estimate catch and effort of southern bluefin tuna and other gamefish species.

Smallwood, C.B., Sumner, N.R., 2007. A 12 month survey of recreational estuarine fishing in the South Coast bioregion of Western Australia during 2002-03. *Fisheries Research Report*. Fisheries Western Australia p. 56.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route, roving creel surveys and a census was used to estimate effort and catch from trailer boats, shore-based fishers and from houseboats.

Sumner, N.R., 2008. An assessment of the finfish catch by recreational fishers, tour operators, commercial lobster fishers and commercial wetline fishers from the Houtman Abrolhos Islands during 2006. *Fisheries Research Report* **175***,* Department of Fisheries, Western Australia p. 32.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel and access point surveys, diaries and aerial surveys were used in combination to estimate catch and effort for recreational fishers.

Sumner, N.R., Malseed, B.E., 2004. Quantification of changes in recreational catch and effort on blue swimmer crabs in Cockburn Sound and Geographe Bay. Fisheries Research Report No. 147. Department of Fisheries, Western Australia, p. 48.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route and roving creel surveys were used to estimate catch and effort for boat-based and shore-based crabbers.

Sumner, N.R., Williamson, P.C., 1999. A 12-month survey of coastal recreational boat fishing between Augusta and Kalbarri on the west coast of Western Australia during 1996-97. *Fisheries Research Report 1035-4549*. Western Australian Department of Fisheries, p. 52.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route survey used to estimate catch and effort for trailer boats; access point surveys used to estimate catch and effort for non-trailered boats.

Sumner, N.R., Willimson, P.C., Malseed, B.E., 2002. A 12-month survey of recreational fishing in the Gascoyne bioregion of Western Australia during 1998-99. *Fisheries WA Research Report*. Western Australian Department of Fisheries.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route surveys and roving creel surveys used to estimate catch and effort.

Williamson, P.C., Sumner, N.R., Malseed, B.E., 2006. A 12-month survey of recreational fishing in the Pilbara region of Western Australia during 1999-2000. *Fisheries WA Research Report* **153**. Fisheries Western Australia.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route and roving creel surveys used to estimate boat-based and shore-based (and boats launched from beaches) angler catch and effort.

Department of Primary Industries and Water, Tasmanian Recreational Scallop Fishery Survey. Hobart.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone survey for effort and distribution of effort; dive transects for abundance. Surveys began in 2005.

Related publications:

Tracey, S.R., Lyle, J.M., 2008. *Survey of the 2007 Tasmanian recreational scallop fishery*. TAFI Internal Report. p. 28.

Fisheries Victoria, (1998-present). Victorian Angler Fishing Diary Program.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Angler diaries and access point creel surveys used to estimate catch and effort.

Sawynok, W., 2005. CapReef. Capricorn reef monitoring program. A community-based monitoring program for the Great Barrier Reef in central Queensland. *Unpublished report*, p. 65.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Access point surveys and counts of boat trailers at boat ramps with traffic counting machines are used to estimate catch and effort.

Department of Fisheries WA, Western Australia Marron Recreational Fishery.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Logbook and telephone surveys used to estimate participation, catch rate, total landings, fishing method, catch composition, sex ratio and size composition. Surveys conducted annually since 2000.

Department of Fisheries WA, Western Australia Abalone Phone Diary Survey.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone-diary survey used to estimate recreational catch and effort from license holders. Multiple interviews by phone to collect data; diary used as a memory prompt.

Primary Industries Research Victoria, Pilot Telephone Diary Survey to Develop Ways of Estimating Victorian Recreational Fishing Catches. Queenscliff, Victoria.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Off-site telephone diary survey used to estimate catch and effort in Victoria's coastal marine waters.

Venema, S., Boxall, V., Ward, T.M., 2003. *Survey of recreational rock lobster fishing in South Australia during 2001/02*. South Australian Research and Development Institute (SARDI) p. 42.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone and diary survey used to estimate catch and effort.

Department of Regional Development Primary Industry Fisheries and Resources, Recreational Fishing Survey 2009-10.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone-diary-access point survey used to estimate catch and effort for Northern Territory residents, visitors and tourists.

Department of Fisheries WA, Western Australia Rock Lobster Phone Diary Survey.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone-diary survey: monthly phone ups to collect catch and effort data from recreational rock lobster license holders using diaries as memory prompts.

Lyle, J.M., Morton, A.J., 2004. Survey of the 2002/03 Tasmanian recreational rock lobster and abalone fisheries. *TAFI Technical Report 22*. Tasmanian Aquaculture and Fisheries Institute, Hobart, Tasmania, p. 32.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** A telephone-diary survey was used to estimate participation, fishing effort and catch for Tasmanian recreational rock lobster and abalone.

New South Wales Department of Primary Industries, New South Wales Gamefish Tournament Monitoring Programme.

Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Uses the gamefish fishery framework (mandatory radio reporting system) and on-site post-fishing interviews to estimate catch and effort from club- based gamefishing in NSW.

Related publications:

Park, T., 2007. NSW Gamefish Tournament Monitoring - Angling Research Tournament Monitoring Program. *Fisheries Final Report Series, 94*, NSW Department of Primary Industries, Cronulla Fisheries Research Centre, Cronulla, NSW, Australia.

Lowry, M., Murphy, J., 2003. Monitoring the recreational gamefish fishery off south-eastern Australia. *Marine and Freshwater Research* **54**, 425-434.

Steffe, A.S., Murphy, J.J., Chapman, D.J., Tarlinton, B.E., Gordon, G.N.G., Grinberg, A., 1996. *An assessment of the impact of offshore recreational fishing in NSW waters on the management of commercial fisheries*. FRDC Project no. 94/053, p. 139.

Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Used on-site surveys to estimate trailer boat catch and effort at selected sites; logbook (visual boat counts of different categories) returning from sea at selected sites; charter boat logbook data for catch and effort from the Sydney region.

Tasmanian Aquaculture and Fisheries Institute (TAFI), Tasmanian Recreational Rock Lobster and Abalone Fisheries Surveys.

Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone-diary surveys used to estimate participation, catch and effort by region and method. Survey conducted biannually since 2000/01.

Related publications:

Lyle, J. M., Morton, A. J., Forward, J., 2005. Characterising the recreational fishery for southern rock lobster, *Jasus edwardsii*, in Tasmania. *New Zealand Journal of Marine and Freshwater Research* **39**, 703-714.

Lyle, J. M., 2008. Tasmanian recreational rock lobster and abalone fisheries - 2006/07 fishing season. *TAFI Internal Report*. p. 26.

Tasmanian Aquaculture and Fisheries Institute (TAFI), 2007/08. Tasmanian State-wide Recreational Fishing Surveys.

Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** General population telephone survey followed by a telephone-diary survey with limited onsite surveys.

Coleman, A.P.M., West, L., 1999. FISHCOUNT: an innovative design for the collection of recreational fishing data. *Fisheries Centre Research Reports* 7, 71-77.

Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone surveys, face to face interviews and 'memory jogger' diaries were used to estimate catch and effort for Northern Territory (Australia) residents, visitors and tourists.

Queensland Department of Primary Industries and Fisheries, 1996-2005. Recreational Fishing Information System (RFISH) – Queensland Recreational Fishing Volunteer Diary Program.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone survey to establish participation rate and an offsite diary with a quarterly telephone followup interview to estimate catch rates.

Related publications:

Higgs, J.B., McInnes, K.L., 2003. 2001 Biennial Recreational Fishing Survey of Queensland Residents. Queensland Department of Primary Industries Brisbane Australia, p. 91.

McInnes, K.L., 2006. *2004 Biennial Recreational Fishing Telephone Survey of Queensland Residents*. Queensland Dept. of Primary Industries and Fisheries, Brisbane Australia.

Department of Employment Economic Development and Innovation (DEEDI), 2007-present. Recreational Fishing Information System (RFISH) – Queensland Recreational Fishing Volunteer Diary Program.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Initial telephone survey to establish participation rate and an offsite diary. The recruitment method for volunteer dairies is different to the 1996-2005 method.

Primary Industries and Resources South Australia (PIRSA), South Australia Recreational Fishing Surveys.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone screening survey to estimate participation rates; telephone-diary survey to estimate catch rates, on-site interview survey of marine waters to collect size composition of key species; recreational fishing logbooks for size composition of key species. The same methodology was used for the 200/01 and 2007/08 state-wide surveys.

Henry, G.W., Lyle, J.M., 2003. *The national recreational and indigenous fishing survey*. Final Report to Fisheries Research and Development Corporation Project No. 1999/158, Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, p. 188.
Country: AUST; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone-diary survey primarily used to determine fishing participation rate and to quantify catch and effort.

Slade, A.J., 1994. An investigation into long term trends of catches in four south Australian recreational angling clubs. Thesis, Australian Maritime College.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Angling club records were used to examine trends in catch rate and average fish weight for multiple species. These parameters may be used as indicators of relative abundance.

Rimmer, M.A., Russel, D.J., 1998. Survival of stocked Barramundi, *Lates calcarifer* (Bloch), in a coastal river system in far far northern Queensland, Australia. *Bulletin of Marine Science* **62**, 325-335.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Voluntary angler catch cards used to estimate catch and effort.

Gartside, D.F., Harrison, B., Ryan, B.L., 1999. An evaluation of the use of fishing club records in the management of marine recreational fisheries. *Fisheries Research* **41**, 47-61.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Fishing club records used to examine changes in total catch, catch seasonality, effort and catch rate for all species combined and for selected species.

New South Wales Department of Primary Industries, New South Wales Saltwater Tournament-Angling Catch/Effort Data.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Catch cards (Catch-card-angler-return-system (CARS)) used to estimate catch and effort, size and species composition for NSW recreational fishing tournament-based angling.
Programme began in 2001 and finished in 2006.

Related publications:

Williams, D.L. Scandol, J.P., 2008. Review of NSW recreational fishing tournament-based monitoring methods and datasets. NSW Department of Primary Industries - *Fisheries Final Report Series No. 99*, p. 83.

Van Der Walt, B., Faragher, R.A., Harris, J., 2005. Comparative Angler Catches of Australian Bass (*Macquaria novemaculeata*) in Three Major River Systems in New South Wales, Australia. *Asian Fisheries Science* **18**, 175-193.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards used by competition anglers to estimate catch and effort for Australian Bass.

New South Wales Department of Primary Industries, New South Wales Freshwater Tournament-Angling Catch/Effort Data.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards (Catch-card-angler-return-system (CARS)) used to estimate catch and effort, size and species composition for NSW recreational fishing tournament-based angling. Various regions

sampled at different times: 1988-1992, NSW eastern-drainage rivers only; 1993-1994, NSW eastern-drainage rivers and Lake Mulwala (Murray River); 1994-2007, eastern-drainage rivers, western drainage rivers and freshwater impoundments; 2007-present, eastern-drainage rivers and impoundments, and Lake Mulwala.

Related publications or reports:

Williams, D.L. Scandol, J.P., 2008. Review of NSW recreational fishing tournament-based monitoring methods and datasets. NSW Department of Primary Industries - *Fisheries Final Report Series No. 99*, p. 83.

New South Wales Department of Primary Industries, New South Wales Department of Primary Iindustries Game Fish Tagging Program.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Tag cards are completed offsite to obtain information on the biology and exploitation of game fish

Primary Industries and Resources South Australia (PIRSA), Draft Management Plan for Charter Boat Fishing in South Australia.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Logbooks are used to estimate catch and effort for recreational fishing on charter boats. It is mandatory for all licence holders in the charter boat fishery to have logbook which they are required to fill out daily for each charter trip undertaken, and submitted each month to SARDI Aquatic Sciences.

Queensland Department of Primary Industries and Fisheries, 1993-present. Queensland Charter Fishing Logbook Program-Queensland Commercial Fishing Tour Logbooks.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Logbooks used to monitor catch of individual species using total catch or some form of effort such as number of days fished, number of boats accessing the fishery or catch rate.

Related publications:

Sumpton, W., Petitt, J., 2005. *Preliminary assessment of Rocky Reef Fisheries in southern Queensland with emphasis on the Gold Coast charter boat fishery for snapper*. DPI&F, Brisbane, Australia.

South Australia Managed Recreational Charter Boat Fishery, South Australian Research and Development Institute (SARDI) Aquatic Sciences.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Logbooks used to record catch and effort for each licence holder per trip. Programme began in 2005.

Related publications:

Knight, M., Doonan, A., Tsolos, A., 2007. The South Australian Charter Boat Fishery. *SARDI Research Report Series* **239**. p. 56.

Department of Fisheries WA, Recreational Angler Program - Western Australia Angler's Log Book
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Log book (per angler) used to collect data on regional and seasonal catch composition (including discards), by all recreational methods; also use log book catch rates as a relative index of abundance for key species. Program began in 2004.

Related publications:

Smith, K. Hammond, M., Brown, J., 2007. A summary of data collected by the Angler's Daily Log Book and Fishing Tournament Monitoring Programs in 2004-2006. *Western Australia Fisheries Occasional Publication* **40**.

Department of Regional Development Primary Industry Fisheries and Resources (DRDPIFR), 1994-present. Fishing Tour Operator Log Return Program.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Daily log books submitted monthly to provide data on numbers of fishers, methods used, kept and released catch in numbers by species, fishing effort and target species.

Related publications:

Hall, P., Dysart, K., 2007. Fishing Tour Operator Status Report 2006. pp. 141-145. In Fisheries Status Reports 2006. Department of Primary Indusrty, Fisheries and Mines. *Fishery Report* **87**. p. 162.

New South Wales Department of Primary Industries, New South Wales Charter Fishing Logbook Programme.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Catch cards (Catch-card-angler-return-system (CARS)) used to estimate catch, effort, by species and fishing methods, used for resource management, resource allocation, stock assessment and compliance. Programme began in 2000.

Related publications:

Williams, D.L. Scandol, J.P., 2008. Review of NSW recreational fishing tournament-based monitoring methods and datasets. NSW Department of Primary Industries - *Fisheries Final Report Series* **99**. p. 83.

Bucher, D.J., 2006. Spatial and temporal patterns of recreational angling effort in a warm-temperate Australian estuary. *Australian Geographical Studies* **44**, 87-94.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Used on-site progressive count method to estimate angling effort.

Hart, A., 2002. *Southern Gulf Environmental Information program: Recreational Fishing Surveys - Pilot Study*. Australian Centre for Freshwater Research. p. 17.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to estimate harvest rates of the principal target species in the Karumba recreational fishery.

Knuckey, I.A., Hudson, R., Conron, S., Smith, D.C., 1997. Melbourne Docklands-Recreational Fishery and Aquatic Ecosystem Project. Report to the Docklands Authority, Marine and Freshwater Resources Institute, Queenscliff.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to estimate catch and effort.

McGlennon, D., Branden, K., 1995. Comparison of catch and effort of marine recreational anglers fishing on artificial reefs and natural seabed in Gulf St Vincent, South Australia. *Bulletin of Marine Science* **57**, 922-922.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to estimate utilization, catch composition and catch rates of anglers fishing over artificial tire reefs and adjacent natural seabed sites.

Murray-Jones, S., Steffe, A.S., 2000. A comparison between the commercial and recreational fisheries of the surf clam, *Donax deltoides*. *Fisheries Research* **44**, 219-233.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** On-site bus route survey used to estimate recreational catch and effort of pipis.

O'Neill, M.F., 2000. *Fishery assessment of the Burnett River, Maroochy River, and Pumicestone Passage*. Report QO099012. Queensland Department of Primary Industries and Fisheries, p. 112.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:**

Prior, S.P., 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.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Used a roving creel survey to identify spatial and temporal patterns of fishing.

Smallwood, C.B., Beckley, L.E., Sumner, N.R., 2006. Shore-based recreational angling in the Rottnest Island Reserve, Western Australia: Spatial and temporal distribution of catch and fishing effort. *Pacific Conservation Biology* **12**, 238-251.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to

determine composition and size distribution of the catch and to estimate total effort, total catch and catch rates.

Steffe, A.S., Murphy, J.J., Reid, D.D., 2008. Supplemented access point sampling designs: A cost-effective way of improving the accuracy and precision of fishing effort and harvest estimates derived from recreational fishing surveys. *North American Journal of Fisheries Management* **28**, 1001-1008.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point survey (with auxiliary data provided by a traffic counting machine) is used to estimate catch and effort. Catch and effort comparisons are made between the traditional access point survey (without auxiliary data) and the supplemented access point survey (with auxiliary data).

Sumpton, W., 2000. *Assessing the recreational fishery for the blue swimmer crab in Moreton Bay*. Department of Primary Industries, Queensland.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point survey used to gain a better understanding of size structure and recreational catch in Moreton Bay.

Inland Fisheries Service, Publications.
http://www.ifs.tas.gov.au/ifs/fisherymanagement/publications
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for numerous lakes, rivers and lagoons (70): Including Arthurs Lake, Geat Lake, Brady's Lake, Lake Binney, Tungatinah Lagoon, River Derwent, Bronte Lagoon, Four Springs Lake, Wooda Lake, Brushy Lagoon, Lake Burbury, Penstock Lagoon, Little Pine Lagoon, Meadowbank Lake, Brumbys Creek, South Esk River, Macquarie River, Mersey River, Huon River, Tyenna River, Meander River, St Patricks River, Leven River, Tooms Lake, Lea Lake, Dee Lake, Binney Lake, Ada Lake, Barrington Lake, Craigbourne Lake, Ecko Lake. Information from annual reports.

West, L.D., Pepperell, J.G., Waugh, G., 1996. *Ord River Fishing Survey*. A Report to the East Kimberley Recreational Fishing Committee. Kewagama Research, September.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:**

Conron, S., Bills, G., 2000. A survey of the recreational shoreline fishery for black bream, *Acanthopagrus butcheri*, in the Gippsland Lakes 1995 and 1996. Marine and Freshwater Resources Institute, *MAFRI Report* **30**, Queenscliff, Australia.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to estimate black bream catch and effort for shoreline anglers during the peak fishing season.

West, R.J., Gordon, G.N.G., 1994. Commercial and recreational harvest of fish from two Australian coastal rivers. *Australian Journal of Marine and Freshwater Research* **45**, 1259-1279.

Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys were used to estimate harvest

Fisheries Victoria, (1993-2008). Freshwater Fisheries Research Program - Victorian Freshwater Creel Surveys.
Country: AUST; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** *Creel surveys used to estimate catch, effort and angler profile for numerous Victorian water bodies (16): Eildon Pondage, Mid-Goullburn River, Lake Bullen Merri, Lake Dartmouth, Lake Hume, Lake Modewarre, Lake Mohoan, Lake Purrumbete, Lake Wendouree, Loddon River, Macalister River, Murray River (South Australia to Toolybuc, Toolybuc to Torrumbarry, Yarrawonga to Torrumbarry), Rubicon River, Upper Merri/Hopkins River.

Blackweir, D.G., Beckley, L.E., 2004. *Beach usage patterns along the Perth metropolitan coastline during shark surveillance flights in summer 2003/04*. School of Environmental Science, Murdoch University, p. 122.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Aerial survey was used to estimate the human usage of 43 beaches along 143 km of coastline; including fishing activity.

Conron, S., Coutin, P., 1998. *The recreational snapper catch from Port Phillip Bay: A pilot survey of the boat-based fishery 1994/95*. Marine and Freshwater Resources Institute, Queenscliff, Victoria, p. 23.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Bus route survey used to estimate catch and effort for snapper in Port Phillip Bay.

Kinloch, M.A., McGlennon, D., Nicoll, G., Pike, P.G., 1997. Evaluation of the bus-route creel survey method in a large Australian marine recreational fishery: I. Survey design. *Fisheries Research* **33**, 101-121.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access points were monitored to provide an estimate of total daily fishing effort which was used as baseline data to compare with model simulated estimates.

McGlennon, D., Kinloch, M.A., 1997. Evaluation of the bus-route creel survey method in a large Australian marine recreational fishery - II. Pilot surveys and optimal sampling allocation. *Fisheries Research* **33**, 89-99.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Bus route survey used to investigate spatial and temporal characteristics of fishing effort and also its effectiveness in estimating catch rates.

Queensland Department of Primary Industries and Fisheries, (2007-2008). Recreational Fishing Information System (RFISH) – Queensland Recreational Fishing Boat Ramp Survey Program.

Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Bus route creel surveys used to estimate regional catch and effort from boat based anglers.

Rotherham, D., 2004. Fisheries biology, ecology and recreational harvesting of ghost shrimp (*Trypaea australiensis*) in south-eastern Australia. Ph.D Thesis, Earth and Environmental Sciences. University of Wollongong.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point creel surveys used to estimate catch and effort.

Lynch, T.P., 2006. Incorporation of recreational fishing effort into design of marine protected areas. *Conservation Biology* **20**, 1466-1476.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Used an on-water randomly stratified roving design to measure fishing effort. The study site covered an area of approx 143 km^2.

Reid, D.D., Montgomery, S.S., 2005. Creel survey based estimation of recreational harvest of penaeid prawns in four southeastern Australian estuaries and comparison with commercial catches. *Fisheries Research* **74**, 169-185.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys were used to quantify the catch of penaeid prawns in NSW.

Fisheries Victoria, Marine and Estuarine Fin Fisheries Monitoring Program - Victorian On-site Recreational Fisheries Surveys.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to estimate catch, effort, size and age composition data for long term fishery monitoring and stock assessment. Regions covered include, Gippsland Lakes, Western Port, Port Phillip Bay. These surveys began in 1995.

OLFISH Web Data Logger. http://www.olfish-data-logger.com
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** INTERNET; **Survey Objective:** Internet web page for recreational anglers to enter their catch and effort (currently in a trial period).

Department of Fisheries WA, Western Australia Rock Lobster Survey.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** MAIL; **Survey Objective:** Mail survey conducted at the end of each fishing season to estimate participation rates, catch and effort. Surveys conducted since 1986.

Related publications:

de Lestang, S., Melville-Smith, R., Thomson, A., Rossbach, M., 2007. West Coast Rock Lobster Fishery Staus Report. In: *State of the Fisheries Report 2006/07*, Fletcher, W.J., Santoro, K. (Eds), Department of Fisheries, Western Australia, pp. 15-25.

Melville-Smith, R., Anderton, S.M., 2000. Western rock lobster mail surveys of licensed recreational fishers 1986/87 to 1998/99. *Fisheries WA Fisheries Research Report* **122**. p. 39.

Department of Fisheries WA, Western Australia Recreational Freshwater Fishery.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone survey to estimate participation, catch rate, total landings, fishing method, catch composition, sex ratio and size composition. Surveys conducted annually since 2000.

Department of Fisheries WA, Western Australia Southwest Freshwater Angling Phone Recall Survey.
Country: AUST; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone recall survey (single interview) conducted annually to estimate catch and effort from recreational southwest freshwater angling license holders.

Department of Fisheries WA, Western Australia Abalone Phone Recall Survey, 2007.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Telephone recall survey (single interview) used to estimate catch and effort from a stratified random sample of recreational abalone license holders.

Department of Fisheries WA, Western Australia Recreational Marron Phone Recall Survey.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone recall survey (single interview) conducted annually and used to estimate catch and effort for recreational marron license holders.

Related publications:

de Graaf, M., Baharthah, T., 2007. Licensed Recreational Marron Fishery Status Report. In: *State of the Fisheries Report 2006/07*, Fletcher, W.J., Santoro, K. (Eds), Department of Fisheries, Western Australia, pp. 265-268.

Department of Fisheries WA, Western Australia Department of Fisheries Community Survey.
Country: AUST; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** Telephone recall surveys (single interview) used to estimate participation in recreational fishing in the previous 12 months. Surveys have been conducted annually since 1996 by various agencies.

Kewagama Research, 2002. *National Survey of Bait and Burley use by Recreational Fishers Report to Biosecurity Australia*. AFFA, Canberra.
Country: AUST; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** Telephone survey used to

estimate the number of resident Australians (over the age of 5) who went recreational fishing in the 12 months prior to the study; number of recreational fishers using aquatic animals as bait/berley; the quantities of 10 bait types used in the previous 12 months (by acquisition source, purchase form, location and season of usage).

BRAZIL

Pereira, J.M.A., Petrere Junior, M., Ribeiro Filho, R.A., 2008. Angling sport fishing in Lobo-Broa reservoir (Itirapina, SP, Brazil). *Brazilian Journal of Biology* **68**, 721-731.

Country: BRAZIL; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort.

CANADA

Kristmanson, J.D., 1999. Angler Effort and Catch in the Shuswap River Chinook Salmon Sport Fisheries, 1996. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* **2489**. Fisheries and Oceans Canada, Delta, British Columbia, p. 19.

Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** River sections and a lake surveyed to estimate effort and harvest for these water bodies. Access-roving survey was used for the river sections and an access point survey was used for the lake.

Palermo, V., Thompson, A.S., 2000. Angler Effort and Catch in the 1998 Sport Fishery of the Capilano and Squamish Rivers. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* **2529**. Fisheries and Oceans Canada, Science Branch, Pacific Region, Delta, British Columbia, p. 29.

Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Roving and access point surveys (for Capilano River) and roving creel surveys (for Squamish River) to estimate effort, harvest and release of Coho salmon.

Kerr, S.J., Cholmondeley, R., 1992. *Results of an aerial creel survey on the Rideau and Cataraqui river systems, summer 1990*. Ontario Ministry of Natural Resources, Kemptville, Ontario.

Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial and on-site creel surveys used to estimate catch and effort.

Lirette, M.G., 1991. Angler Harvest of Lake Char, Kokanee and Rainbow Trout from Bridge Lake, 1990. *Fisheries Technical Circular* **92**. Ministry of Environment, Lands and Parks Fisheries Branch, Williams Lake, British Columbia.

Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point (at resorts) surveys used to estimate harvest and effort for three target species. Lake Bridge has a surface area of 3397 acres.

Morten, K.L., 1999. A survey of Bulkley River Steelhead Anglers in 1998. *Skeena Fisheries Report* **SK-119**. Report by the Cascadia Natural Resource Consulting, Smithers, B. C. for Fisheries Branch, British Columbia Ministry of Environment, Lands and Parks, Smithers, B. C.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial counts of anglers (effort) and on-site roving creel surveys (catch and effort) were used to estimate catch, effort and collect demographic and angling method data. Sampling stratification was different from the previous year's survey.

Morten, K.L., Parken, C.K., 1998. A survey of Bulkley River steelhead anglers during the Classified Waters Period of 1997. Skeena Fisheries Report SK-43. Report by the Cascadia Natural Resource Consulting, Smithers, B. C. for Fisheries Branch, British Columbia Ministry of Environment, Lands and Parks, Smithers, B. C.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial counts of anglers (effort) and on-site roving creel surveys (catch and effort) were used to estimate catch, effort and collect demographic and angling method data.

Tallman, D.C., 2008. *2007 Creel Survey of the Squamish River Watershed Recreational Fishery*. A report to the Pacific Salmon Foundation, Canadian National Railway Company and the Squamish River Watershed Society, Vancouver, B.C.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Roving, access point and aerial surveys were used to estimate the catch and effort of various salmon species.

Vandenbroeck, J., 2004. 2003 open water creel survey of the Pipestone, Burditt, and Despair chain of lakes. *Fort Frances District Report Series No. 61*. Ontario Ministry of Natural Resources, p. 73.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial-creel survey used to estimate catch and effort for 10 lakes.

Parkinson, E.A., 1990. An evaluation of adaptive management and minimal sampling as techniques for optimising rainbow trout stocking rates. *Fishery Management Report* **96**, Province of British Columbia, p. 14.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Describes the Small Lakes Index Management (SLIM) program that used aerial-creel surveys to estimate catch rates and to collect fish size, fish age and growth rate data. The SLIM aerial boat count covered approximately 400 lakes annually to provide standardised effort estimates throughout the summer (open water) fishing season.

Schubert, N.D., 1995. Angler Effort and Catch in Four Fraser River Chinook Salmon Sport Fisheries, 1994, and a Retrospective on Nine Years of Upper Fraser River Sport Fishery Management and Assessment. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* **2275**. Department of Fisheries and Oceans, Science Branch, New Westminster, British Columbia.

Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Various methods were used to sample the four rivers: Lower and Middle Shuswap River (Roving-access point), Mabel Lake (access point) and Thompson River (complete census). These various methods were used to estimate effort and catch for Chinook salmon.

Duffy, M., Mosindy, T., 2001. *1988-1999 Lake of the Woods Muskie Angler Diary Surveys. Aquatics Update 2001-1*. Ontario Ministry of Natural Resources, Northwest Science and Technology, p. 6.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Angler diaries used by volunteers to estimate effort, catch and catch rates.

Fruetel, M., 1998. The Squeers Lake experimental winter fishery: Evaluating the status of lake trout from creel survey data. *NWST Technical Report TR-116*. Ontario Ministry of Natural Resources, Northwest Science and Technology, Thunder Bay, Ontario, p. 13.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Angler diary is used to record data on effort catch and harvest. This is a limited entry fishery. Anglers must report to a creel agent daily before they begin fishing so they can be assigned a diary. Diaries must be returned to the creel agent at the completion of fishing for that day.

MacLennan, D., 1996. Changes in the muskellunge fishery and population of Lake St Clair after and increase in the minimum size limit. pp. 19-27 In: Kerr, S.J., Oliver, C.H. (Eds.) *Managing Muskies in the 90's.*
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Diary survey used to monitor catch and effort of muskellunge sport fishing.

Sztramko, L.M., Dunlop, W.I., Powell, S.W., Sutherland, R.G., 1991. Applications and benefits of an angler diary program on Lake Erie. *American Fisheries Symposium* **12**, 520-528.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Logbooks used by inland charter boat operators to record catch and effort.

Ontario Ministry of Natural Resources, 2009. The Algonquin Park Interior Lakes Fishing Survey Algonquin Fisheries Assessment Unit, Whitney, Ontario, p. 5.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** A pocket-sized form (daily record) used by anglers to record effort, catch and harvest. Forms returned to access points, permit boxes, mailed or emailed. 103 water bodies have been surveyed (185 lakes, 8 rivers) since 2006.

Stronks, T.R., 1994. Lake Simcoe Angler Diary Program, 1990-1993. Lake Simcoe Fisheries Assessment Unit Report 1994-1. Ontario Ministry of Natural Resources.

Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Angler diaries used to estimate catch and effort.

Anderson, L.E., Thompson, P.C., 1991. Development and implementation of the angler diary monitoring program for Great Bear Lake, Northwest Territories. pp. 457-475, In: Guthrie, D., Hoenig, J. M., Holliday, M., Jones, C. M., Mills, M. J., Moberly, S. A., Pollock, K. H., Talhelm, D. R. (Eds), *Creel and angler surveys in fisheries management*. American Fisheries Society, Bethesda, Maryland.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Diaries distributed by five commercial sportfishing lodges to estimate angler effort, catch and harvest for multiple species.

Department of Fisheries and Oceans (DFO), Charter Boat/Lodge Logbook Program.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Voluntary logbooks are used by independent charter boats and charter boats associated with lodges to record effort and catch. Logbook program began in 1992.

Bowlby, J.N., Daniel, M.E., 2000. A Survey of Rainbow Trout Anglers at the Ganaraska River during Spring 1999. Lake Ontario Fish Communities and Fisheries: 1999 Annual Report of the Lake Ontario Management Unit Section. Ontario Ministry of Natural Resources, Niagra-on-the-Lake, Ontario, p. 5.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey along 22 sites; angler counts along the route with interviews at specific sites (5) to estimate effort catch and harvest. Survey conducted over approximately 25 km of river section.

de Leeuw, A.D., 1991. Babine Lake Creel Survey at Fulton and Pinkut creeks, May - June, 1990. *Skeena Fisheries Report No. SK-78*. British Columbia Environment, Fisheries Branch, Smithers, B.C., p. 8.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Instantaneous counts and creel interviews used to estimate catch and effort for rainbow trout.

Stanfield, L., Stoneman, M., Cope, L., 1998. The Wilmot Creek 1994 creel survey and population assessment report. Great Lakes Salmonid Unit, Ontario Ministry of Natural Resources, Picton.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort.

Zimmerman, T., Kardash, L., 2002. *Results of Ground Creel Surveys Completed in 2001*. Final Report.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** On-site creel surveys used to estimate catch and effort for 4 lakes.

Amtstaetter, F., 2006. Changes in the Winter Fishery of Greenwater Lake Following a Reduction in Fishing Season Length. Aquatics Update 2006-1. Ontario Ministry of Natural Resources, Northwest Science and Information, Thunder Bay, Ontario, p. 2.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel survey results (from multiple years) used to investigate changes in effort and harvest weight.

Kristmanson, J., Armstrong, K., 2001. Walleye Rotational Fishing Experimental Management Project: Summary and Analysis of Data Collected from 1989 to 1998. NEST Technical Report TR-042. Ontario Ministry of Natural Resources, Northeast Science and Technology South Porcupine, Ontario.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys were used with an activity count at the start of the sampling period before moving on to interview anglers. Effort, catch, harvest and species targeted were recorded.

van Ogtrop, A., 2000. Lake Nipigon Angler Surveys 1993 to 1999. *NWST Technical Report TR-129*. Ontario Ministry of Natural Resources, Lake Nipigon Fisheries Assessment Unit, p. 10.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to estimate effort and harvest.

Mosindy, T., 2008. *Lake of the Woods North/Central Winter Creel Surveys: 2006-07. Aquatics Update 2008-1*. Ontario Ministry of Natural Resources, Northwest Science and Information, p. 12.
Country: CANADA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey used to estimate effort, harvest, age and size composition of harvest and catch rates.

Kerr, S.J., 1992. Results of an aerial survey of lake trout and splake fisheries in Divisions 9, 10, and 29. Ontario Ministry of Natural Resources, Eastern Region, Kempville, Ontario, p. 18 **Country:** CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Aerial survey.

Kerr, S.J., 1999. *A survey of twelve winter fisheries in Lanark County during the winter of 1998-99.* Southcentral Sciences Sections, Ontario Ministry of Natural Resources, Kemptville, Ontario, p. 12.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Aerial surveys used to estimate fishing effort.

Kerr, S.J., Cholmondeley, R., 1998. *A survey of angling activity on a set of inland lakes in southeastern Ontario during the winter of 1997-98*. Ontario Ministry of Natural Resources, Kemptville, Ontario.

Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Aerial survey

Shaw, W., Jordan, C., Hein, K., 2006. Halibut Length-Weight Data from the Southern British Columbia Recreational Fishery, 2000-2004. *Canadian Data Report of Fisheries and Aquatic Sciences* **1173**. Fisheries and Oceans Canada, Science Branch, Pacific Region, Pacific Biological Station, Nanaimo, British Columbia, p. 19.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys to provide monthly and annual catch and release estimates for all species.

Scholten, S.J., 2003. Aerial Effort Surveys of the Winter Lake Trout Fishery in Thunder Bay District for 1999 and 2001. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, p. 26.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Aerial survey to estimate fishing effort.

Selinger, W., Lowman, D., Kaufman, S., Malette, M., 2006. *The Status of Lake Trout Populations in Northeastern Ontario (2000-2005)*. Unpublished Draft Internal Report. Ontario Ministry of Natural Resources, p. 65.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Aerial surveys were used to assess the angling pressure on 679 northestern Ontario lakes between 2001 and 2003.

Department of Fisheries and Oceans (DFO), 2006. *Survey of Recreational Fishing 2005*. Economic Analysis and Statistics, Policy Sector, Ottowa, Ontario.
Country: CANADA; **Geographic Scale:** NATION; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** MAIL; **Survey Objective:** Mail survey of licenced fishers used to provide data on fisher demographics, participation, economics and harvest estimates. These surveys are conducted every five years and began in 1975.

BriLev Consulting Inc., 2008. *2007 Survey of the Recreational Cod Fishery of Newfoundland and Labrador*. Final Report.
Country: CANADA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Telephone survey (random sample of households) to estimate post-season catch and effort in the recreational cod fishery.

ENGLAND

Cappell, R., Lawrence, K., 2004. *Sea angling and the fishing industry*. Nautilus Consultants Final Report for Invest in Fish South West, Work Package 10, p. 118.
Country: ENGLAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Face to face interviews at shore angling marks, angling competitions and in tackle shops; telephone survey of randomly selected members of the National Federation of Sea Anglers (NFSA). These survey methods combined provided information on demographics,

expenditure, species targeted and caught (catch levels, return rates and trends) and their opinions on various potential management strategies.

Smith, P.A., 2002. The relationship between stock and catch and the effect of bait on catch as determined for a UK recreational catch and release fishery. *Fisheries Management and Ecology* **9**, 261-266.
Country: ENGLAND; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate effort and catch.

Lappalainen, A., Hilden, M., Leinonen, K., 1994. Acidification and Recreational Fisheries in Finland: A Mail Survey of Potential Impacts. *Environmental Management* **18**, 831-840.
Country: FINLAND; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** MAIL; **Survey Objective:** Mail survey used to determine national recreational fishing characteristics including participation rates.

FRANCE

Herfaut, J., 2008. Combining telephone and on-site surveys for the estimation of catches and expenditures by recreational fishers: the pilot study of French recreational fisheries.
Country: FRANCE; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telephone and on-site creel surveys used to estimate catch and effort.

Gerdeaux, D., Janjua, M.Y., 2009. Contribution of obligatory and voluntary fisheries statistics to the knowledge of whitefish population in Lake Annecy (France). *Fisheries Research* **96**, 6-10.
Country: FRANCE; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** A notebook is used by recreational anglers to record the total number and weight of species caught.

GERMANY

Dorow, M., Arlinghaus, R., 2008. Generating Biological, Sociological and Economic Insights into Angler Populations with a Large-Scale Survey. Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Department of Biology and Ecology of Fishes, Berlin, p. 151.
Country: GERMANY; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Telepnone-diary-mail survey used to estimate catches and determine various human dimensions of anglers for the federal state of Meckenburg-Vorpommern.

Zimmerman, C., Schultz, N., Hammer, C., How much cod is removed from the western Baltic Sea by recreational fishers?
Country: GERMANY; **Geographic Scale:** NATION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** A 3 year pilot study used questionnaires mailed to angling license holders and on-site creel interviews to estimate catch and effort of cod.

JAPAN

Ando, D., Miyakoshi, Y., Takeuchi, K., Nagat, M., Sato, T., Yanai, S., Kitada, S., 2002. Estimates of numbers of juvenile masu salmon Oncorhynchus masou caught by recreational anglers in an urban stream. *Nippon Suisan Gakkaishi* **68**, 52-60.
Country: JAPAN; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Used questionnnaires and interviews to estimate the catch of juvenile masu salmon (*Oncorhynchus masou*).

Matsuishi, T., Narita, A., Ueda, H., 2002. Population assessment of sockeye salmon Oncorhynchus nerka caught by recreational angling and commercial fishery in Lake Toya, Japan. *Fisheries Science* **68**, 1205-1211.
Country: JAPAN; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Used a mail survey and access point survey to estimate the catch and effort of sockeye salmon.

Kitada, S., Tezuka, K., 2002. Longitudinal logbook survey designs for estimating recreational fishery catch, with application to ayu (*Plecoglosssus altivelis*). *Fishery Bulletin* **100**, 648-648.
Country: JAPAN; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Logbooks used to estimate the annual ayu catch by recreational anglers.

Miyakoshi, Y., Koyama, T., Aoyama, T., Sakakibara, S., Kitada, S., 2004. Estimates of numbers of masu salmon caught by recreational fishermen in the coastal area off Iburi, Hokkaido, Japan. *Fisheries Science* **70**, 87-93.
Country: JAPAN; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Used logbooks to record number of anglers and catch of masu salmon for each angler from party boats per fishing day

Mitchell, R.W.D., Baba, O., Jackson, G., Isshiki, T., 2008. Comparing management of recreational *Pagrus* fisheries in Shark Bay (Australia) and Sagami Bay (Japan): Conventional catch controls versus stock enhancement. *Marine Policy* **32**, 27-37.
Country: JAPAN; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:**

Kitamura, S., Ikuta, K., Shikama, T., Nakamura, H., 2004. The present condition of recreational fisheries in the Yukawa River surveyed by a questionnaire to anglers. *Bulletin of Fisheries Research Agency* **12**, 1-9.
Country: JAPAN; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used on-site questionnaires to estimate catch rates of trout (*Salvelinus fontinalis*) for three fishing methods: fly, lure and bait. Response rate was low for this study (7.25%).

LESOTHO

Westerlund, L., 1994. Fisheries Monitoring Survey at Sebaboleng Dam, Maseru Town, Lesotho. *ALCOM Field Document* **30**. Aquaculture for Local Community Development Programme (ALCOM).

Country: LESOTHO; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel survey used to estimate catch and effort.

MOZAMBIQUE

Weyl, O.L.F., 2008. Rapid invasion of a subtropical lake fishery in central Mozambique by Nile tilapia, Oreochromis niloticus (Pisces: Cichlidae). *Aquatic Conservation-Marine and Freshwater Ecosystems* **18**, 839-851.

Country: MOZAMBIQUE; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Used access surveys and roving creel surveys to estimate catch and effort from shore based and boat based gill net fishers and anglers

NAMIBIA

Kirchner, C.H., Beyer, J.E., 1999. Estimation of total catch of silver kob Argyrosomus inodorus by recreational shore-anglers in Namibia using a roving-roving creel survey. *South African Journal of Marine Science* **21**, 191-199.

Country: NAMIBIA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving-roving survey used to estimate catch and effort.

NEW ZEALAND

Department of Conservation, 1991. *How many fish are caught at Taupo?* Target Taupo. Special edition 1, Turangi: New Zealand Department of Conservation.

Country: NEW ZEALAND; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial and access point surveys used to estimate catch and effort for the Taupo trout fishery.

Davey, N.K., Hartill, B., Cairney, D.J., Cole, R.G., 2008. Characterisation of the Malborough Sounds recreational fishery and associated blue cod and snapper harvest estimates. New Zealand Fisheries Assessment Report 2008/31. p. 63.

Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point survey used to estimate catch and effort. Problem with this survey in that many fishing boats in the survey region did not return to the surveyed boat ramps.

Hart, A.M., Walker, N.A., 2004. Monitoring the recreational blue cod and sea perch fishery in the Kaikoura - North Canterbury area. *New Zealand Fisheries Assessment Report* **45**. p. 30.

Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Bus route surveys and charter boat logbooks were used to examine changes in catch rates and sizes of blue cod (*Parapercias colias*) and sea perch (*Helicolenus percoides*).

Hartill, B., Bian, R., Armiger, H., Vaughan, M., Rush, N., 2007b. *Recreational marine harvest estimates of snapper, kahawai and kingfish in QMA 1 in 2004-05*. New Zealand Fisheries Assessment Report 2007/26, p. 44.
Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point surveys and diaries to estimate catch and effort for three regions (East Northland, the Hauraki Gulf and the Bay of Plenty).

Hartill, B., Vaughan, M., 2006. *Recreational marine harvest estimate for SNA 8: pilot survey results*. Unpublished report held by MFish, Wellington. Research Progress Report for Ministry of Fisheries research project REC200501. p. 19.
Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point pilot survey used to determine the relative level of snapper catch taken by shore based fishing methods.

Hartill, B., Vaughan, M., Rush, N., 2008b. *Recreational harvest estimate for SNA 8 in 2006-07*. Research Progress Report for Ministry of Fisheries Programme REC200501. 42 p.
Country: NEW ZEALAND **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Charter boat catches surveyed by voluntary logbook; private vessel catches surveyed by aerial-access point; shore based angler catches were accounted for by scaling up estimates of aerial-access point survey associated with the previous year's pilot study.

Hartill, B., Watson, T., Cryer, M., Armiger, H., 2007c. *Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf in 2003-04*. New Zealand Fisheries Assessment Report 2007/25. p. 55.
Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point surveys and diaries to estimate catch and effort.

Sylvester, T., 1996. *A comparison of the Hauraki Gulf recreational snapper catch between the aerial/interview survey and the telephone/diary survey*. Unpublished report held by MFish, Wellington. p. 32.
Country: NEW ZEALAND; **Geographic Scale:** REGION **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial and access point surveys used to estimate catch and effort. Used as a comparison of estimates from concurrent telephone diary estimate from the same fishery.

Teirney, L.D., Kilner, A.R., Millar, R.B., Bradford, E., Bell, J.D., 1997. Estimation of Recreational Harvests from 1991–92 to 1993–1994. *New Zealand Fisheries Assessment Research Document 97/15*. New Zealand Fisheries, p. 43.
Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone/ diary surveys used to estimate catch and effort of all species for three regions in the MAF fisheries (South, Central, North). 3 annual regional surveys are recognised.

Bradford, E., Booth, J.D., Tapsell, E., Ellery, P., Mackay, K.A., 2001. *Results of the marine recreational fishing survey at the Maketu Taiapure, 1999-2001*. New Zealand Fisheries Assessment Report 2001/56, p. 61.
Country: NEW ZEALAND; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Fishing activity counts (effort) from observation points and on-site creel surveys (harvest) were used to estimate total harvest.

Boyd, R.O., Gowing, L., Reilly, J.L., 2004. *2000-2001 National marine recreational fishing survey: diary results and harvest estimates*. Unpublished Report held by MFish, Wellington. 81 p.
Country: NEW ZEALAND; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone diary survey used to estimate catch and effort. Different from previous year's survey as it used mean fish weights derived from a national boat ramp survey in 2000.

Boyd, R.O., Reilly, J.L., 2004. *1999/2000 National marine recreational fishing survey: harvest estimates.* Unpublished Report held by MFish, Wellington. 84 p.
Country: NEW ZEALAND; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone diary survey used to estimate catch and effort.

Bradford, E., 1998. *Harvest estimates from the 1996 national marine recreational fishing surveys*. New Zealand Fisheries Assessment Research Document 98/16, p. 27.
Country: NEW ZEALAND; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone diary survey to estimate recreational harvest.

Cole, R., Horn, P.L., Davey, N., Bradley, A., 2006. *An assessment of the recreational catch of scallops and dredge oysters in the Golden Bay and Tasman Bay sections of the Southern Scallop Fishery (SCA7) for the 2003-04 fishing season*. New Zealand Fisheries Assessment Report 2006/10.
Country: NEW ZEALAND; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to estimate harvest.

Hartill, B., Bian, R., Davies, N., 2008a. *Review of recreational harvest estimates and approaches*. Research Progress Report Ministry of Fisheries Research Project REC2004/06 National Institute of Water and Atmospheric Research, p. 54.
Country: NEW ZEALAND; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys used to provide harvest estimates for scallops and rock lobster taken from the north eastern coast of the Coromandel peninsular.

Hartill, B.W., Cryer, M., Morrison, M.A., 2005. Estimates of biomass, sustainable yield, and harvest: neither necessary nor sufficient for the management of non-commercial urban intertidal shellfish fisheries. *Fisheries Research* **71**, 209-222.

Country: NEW ZEALAND; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Instantaneous counts of non-commercial fishers gathering shellfish (effort) combined with catch rate data from interviewed harvesters allowed a total estimate of shellfish harvest for several species.

Hartill, B., Payne, G., Reddish, L., Vaughan, M., Spong, K., Buckthought, D., 2007a. *Monitoring recreational fishing effort in QMA 1*. Final Research Report prepared for Ministry of Fisheries research project REC200506, Objective 1. National Institute of Water and Atmospheric Research, p. 17.

Country: NEW ZEALAND; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Images obtained from web cameras, based at boat ramps, are used to monitor levels of marine recreational fishing effort.

Hartill, B., Blackwell, R., Bradford, E., 1998. Estimation of mean fish weights from the recreational catch landed at boat ramps in 1996. *NIWA Technical Report* 31, p. 40.

Country: NEW ZEALAND; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point survey (boat ramps) to estimate catch (particularly mean fish weights).

PHILIPPINES

Maypa, A.P., Russ, G.R., Alcala, A.C., Calumpong, H.P., 2001. Long-term trends in yield and catch rates of the coral reef fishery at Apo Island, central Philippines. *Proceedings of the 6th Indo-Pacific Fish Conference*. CSIRO Publishing, pp. 207-213.

Country: PHILIPPINES; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Used a roving creel survey to estimate long-term trends of fish yields, catch composition and catch rates at Apo Island

PORTUGAL

Rangel, M.O., Erzini, K., 2007. An assessment of catches and harvest of recreational shore angling in the north of Portugal. *Fisheries Management and Ecology* **14**, 343-352.

Country: PORTUGAL; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Used roving creel surveys to estimate effort, catch and catch rate for recreational shore angling in the Atlantic Ocean between Moledo and Aveiro.

Marta, P., Bochechas, J., Collares-Pereira, M.J., 2001. Importance of recreational fisheries in the Guadiana River Basin in Portugal. *Fisheries Management and Ecology* **8**, 345-354.

Country: PORTUGAL; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Interview questionnaire used to estimate fishing participation and catch.

PUERTO RICO

Ferrer Montano, O.J., Dibble, E.D., Jackson, D.C., Rundle, K.R., 2005. Angling assessment of the fisheries of Humacao Natural Reserve lagoon system, Puerto Rico. *Fisheries Research* **76**, 81-90.
Country: PUERTO RICO; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey used to estimate fishing effort and catch composition.

SOUTH AFRICA

Beckley, L.E., Fennessy, S.T., Everett, B.I., 2008. Few fish but many fishers: a case study of shore-based recreational angling in a major South African estuarine port. *African Journal of Marine Science* **30**, 24.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel surveys and interview questionnaires to estimate catch and effort.

Baird, D., Marais, J.F.K., Daniel, C., 1996. Exploitation and conservation of angling fish in two South African estuaries. *Aquatic Conservation-Marine and Freshwater Ecosystems* **6**, 319-330.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Creel surveys and catch records from club competitions are used to estimate effort, catch and catch rates.

Everett, B.I., Pradervand, P., Beckley, L.E., Mann, B.Q., Radebe, P.V., 2002. *Recreational fishing in two large South African ports*. Southern African Marine Science Symposium (SAMSS 2002): Currents Coasts Communities. 2002.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel and access point surveys were used to estimate catch and effort, and collect socio-economic data.

Guastella, L.A.M., 1994. A quantitative assessment of recreational angling in Duban Harbor, South Africa. *South African Journal of Marine Science* **14**, 187-203.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Used diary records and roving creel surveys to estimate angler catch rates and catch per species.

Mann, B.Q., James, N.C., Beckley, L.E., 2002. An assessment of the recreational fishery in the St Lucia estuarine system, Kwazulu-Natal, South Africa. *South African Journal of Marine Science* **24**, 263-279.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Used catch cards and on-site counts at access points to estimate catch composition, catch rates and seasonality of catches by recreational anglers

Mann, B.Q., McDonald, A.M., Sauer, W.H.H., Hecht, T., 2003. Evaluation of participation in and management of the Transkei shore linefishery. *African Journal of Marine Science* **25**, 79-97.

Country: SOUTH AFRICA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel and aerial surveys were used to quantify fishing effort.

Brouwer, S.L., Buxton, C.D., 2002. Catch and effort of the shore and skiboat linefisheries along the South African Eastern Cape Coast. *South African Journal of Marine Science* **24**, 341-354.
Country: SOUTH AFRICA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Roving creel and access point surveys were used to estimate catch and effort in the Eastern Cape shore and skiboat linefisheries.

Mann, B.Q., Scott, G.M., Mann-Lang, J.B., Brouwer, S.L., Lamberth, S.J., Sauer, W.H.H., Erasmus, C., 1997. An evaluation of participation in and management of the South African spearfishery. *South African Journal of Marine Science* **18**, 179-193.
Country: SOUTH AFRICA; **Geographic Scale:** NATION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Used catch cards, postal questionnaire and creel surveys to estimate catch and effort.

Everett, B.I., Fennessy, S.T., 2007. Assessment of recreational boat-angling in a large estuarine embayment in KwaZulu-Natal, South Africa. *African Journal of Marine Science* **29**, 411-422.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys were used to collect effort, catch and socio-economic data from the recreational estuarine boat-fishery in Richards Bay Harbour on the east coast of South Africa.

Hutchings, K., Clarke, B.M., Atkinson, L.J., Attwood, C.G., 2008. Evidence of recovery of the linefishery in the Berg River Estuary, Western Cape, South Africa, subsequent to closure of commercial gillnetting. *African Journal of Marine Science* **30**, 507-517.
Country: SOUTH AFRICA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to estimate catch and effort.

Fennessy, S.T., McDonald, A.M., Mann, B.Q., Everett, B.I., 2003. An assessment of the recreational and commercial skiboat fishery in the Transkei. *African Journal of Marine Science* **25**, 61-78.
Country: SOUTH AFRICA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Access point surveys were used to estimate catch and effort for recreational and commercial skiboat fishers.

Pradervand, P., Baird, D., 2002. Assessment of the recreational linefishery in selected Eastern Cape estuaries: Trends in catches and effort. *South African Journal of Marine Science* **24**, 87-101.

Country: SOUTH AFRICA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Using roving creel surveys to estimate catch and effort data on shore and boat based linefisheries.

SPAIN

Morales-Nin, B., Moranta, J., Garcia, C., Tugores, M.P., Grau, A.M., Riera, F., Cerda, M., 2005. The recreational fishery off Majorca Island (western Mediterranean): some implications for coastal resource management. *ICES Journal of Marine Science* **62**, 727-739.

Country: SPAIN; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone survey, on-site personal interviews, voluntary logbooks and records from recreational fishing competitions were used to estimate numbers of recreational anglers, their habits, effort and catch.

SWEDEN

Anon., 2005. Fishing 2005 - A study of Swedes' recreational fishing. *Fiskeriverket Informerar* **10**.

Country: SWEDEN; **Geographic Scale:** NATION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** MAIL; **Survey Objective:** Postal questionnaire used to estimate national fishing participation, total catch and harvest.

UNITES STATES OF AMERICA

Cahalan, J., 2006. Estimation of recreational Dungeness crab harvest in Puget Sound, Washington using a telephone survey of harvesters. *Journal of Shellfish Research* **25**, 687-704.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone survey used to sample recreational fishers which have mandatory catch cards. In season sampling is required to assess regional harvest in relation to quotas.

Finley, B.L., Iannuzzi, T.J., Wilson, N.D., Kinnell, J.C., Craven, V.A., Lemeshow, S., Teaf, C.M., Calabrese, E.J., Kostecki, P.T., 2003. The Passaic River Creel/Angler Survey: Expert panel review, findings, and recommendations. *Human and Ecological Risk Assessment* **9**, 829-855.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Boat based counts of anglers for effort and land based interviews for effort, catch and demographics.

Anon., 2006. *Draft Englebright Lake Creel Su*rvey. Technical Report, June 2006. California Department of Water Resources, p. 6.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Questionnaires and creel surveys used to estimate in general terms, the number, species and size of fish caught and retained by anglers. Authors note survey was not designed to provide a rigorous assessment of number of anglers and catch rates. The lake has a surface area of 815 acres and a shoreline of 24 miles.

Markham, J.L., 2005. *Interim Report: Lake Erie Tributary Creel Survey, Fall 2003-Spring 2004*. New York State Department of Environmental Conservation, Division of Fish, Wildlife and Marine Resources, Albany, New York, p. 29.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Used a roving-roving survey design where creel agents were required to conduct angler counts and interviews.

Normandeau Associates, University of Idaho, Agricultural Enterprises Inc, (1999). *Sport Fishery Use and Value on the Unimpounded Snake River above Lewiston, Idaho, Phase II Report: Part 1 Reservoir Sport Fishery During 1997*. Preliminary Draft Document Report prepared for Department of the Army, Corps of Engineers, Walla Walla, Washington, Drumore, Pennsylvania.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point survey used to assess angler use of a 48 km unimpounded reach of the Snake River. Collected data on angling effort, catch, harvest, fishing method, residence, vistor status and species preference.

Osterhoudt, S.R., Swanson, J.E., Johnson, D.R., Gasper, J.R., Gallucci, V.F., Miller, M., 2004. *Sport fishery information for managing Glacier Bay National Park and Reserve. Vol. 2: A survey of fishing license holders entering Glacier Bay on private vessel permits*. Technical Report NPS/PWRUW/NRTR-2005-01. National Park Service, Pacific West Region, Protected Area Social Research Unit, University of Washington, Seattle.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Mail/ telephone survey used to estimate effort and catch for licensed anglers aboard private vessels in Glacier Bay.

Keleher, C.J., 1996. *Utah Lake Creel Survey Annual Report Based on 1996 Season*. Utah Division of Wildlife Resources, Central Regions Office Springville, Utah.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Access point surveys used to estimate catch and effort and aerial surveys to estimate total effort.

Krueger, S.D., Jackson, J.R., VanDe Valk, A.J., Rudstam, L.G., 2009. *The Oneida Lake Creel Survey, 2002-2007*. Final Report, New York Federal Aid in Sport Fish Restoration, Study 2, Job 1, Grant F-56-R: Warmwater Fisheries. Cornell University Biological Field Station, Bridgeport, New York, p. 89.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial-roving startified random sampling design to estimate catch and effort for walleye, yellow perch and other species.

O'bara, J., 1999. Econimic Benefits and Value of a Localised and Seasonal Walleye Fishery. In: Pitcher, T.J. (Ed.), *Fisheries Centre Research Reports*. The Fisheries Centre, University of British Columbia, Vancouver, British Columbia, pp. 124-129.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Roving-roving survey used to estimate the catch and effort of walleye from two 13km river sections.

Shirley, K., 1998. *Norfork Lake Creel Survey*. Arkansas game and Fish Commission.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial pressure counts and on-site roving creel surveys to estimate effort and catch. Norfork Lake covers an area of 89 square km.

Sloane, M.B., Cunningham, K.K., Wethington, M.C., 2008. *Status of the San Juan Tailwater Fishery*. New Mexico Department of Game and Fish, Fisheries Management Division.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Angler pressure counts at various sites along the river combined with completed trip creel surveys to estimate catch and effort.

Bishop, D.L., Penney-Sabia, M.E., 2004. *2004 Salmon River Creel Survey*. NYSDEC Lake Ontario Annual Report 2004, Section 10. New York Department of Environmental Conservation, Cortland, New York, p. 14.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Used a roving-access point survey to estimate angler catch, effort and harvest for trout and salmon species.

Guillory, V., 1998. A survey of the recreational blue crab fishery in Terrebonne Parish, Louisiana. *Journal of Shellfish Research* **17**, 543-549.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Various methods were used to measure catch and effort for four district fishing modes- roving creel survey to intercept land-based crabbers; access point survey of recreational shrimp trawlers; mail surveys of licenced saltwater anglers and recreational crab trappers.

Hardie, D.C., Nagtegaal, D.A., Sturhahn, J., Hein, K., 2002. Strait of Georgia and northern Vancouver Island sport fishery creel survey statistics for salmon and groundfish, 2000., *Canadian manuscript report of Fisheries and Aquatic Sciences* **2608**. p. 126.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Aerial-access point surveys used to provide catch and effort statistics for the Strait of Georgia and Northern Vancouver Island tidal sport fishery for each month, statistical area and by individual species.

Wilberg, M., Humphrey, J., 2008. *A creel survey for early spring fisheries of Maryland's Chesapeake Bay Tributaries*. Progress Report to Maryland Department of Natural Resources.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Hybrid bus route-roving creel survey used to estimate catch and effort.

Connelly, N.A., Kuehn, D., Brown, T.L., Knuth, B.A., 2002. 1996 Angler Effort and Expenditures on New York's Great Lakes Waters.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Used mail surveys and follow-up telephone survey of non-respondents to estimate angler use on New York's Great Lakes waters.

Lewynski, V.A., Olmsted, W.R., 1990. *Angler use and catch surveys of the lower Skeena, Zymoetz (Copper), Kispiox and Bulkley River steelhead fisheries, 1989*. Report by ESL Environmental Sciences Limited, Vancouver, B. C. for Fisheries Branch, B. C. Ministry of Environment, Lands and Parks, Victoria, B.C.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial-roving creel surveys used to estimate catch and effort.

Lockwood, R.N., Peck, J., Oelfke, J., 2001. Survey of angling in Lake Superior waters at Isle Royale National Park, 1998. *North American Journal of Fisheries Management* **21**, 471-481.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** On-site creel and aerial surveys used to estimate effort, sport catch and harvest and residency of noncharter boats. The surface area of water in the Isle Royale National Park is 438,400 acres.

McCullough, R.D., Einhouse, D.W., 1999. *Lake Ontario - Eastern Basin Creel Survey, 1998*. NYSDEC Special Report. New York Department of Environmental Conservation Watertown, New York, p. 19.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Access point and aerial survey to estimate effort, catch and harvest rates of smallmouth bass

McCullough, R.D., Einhouse, D.W., 2003. *Eastern Basin of Lake Ontario Creel Survey, 2003*. NYSDEC Lake Ontario Annual Report 2003, Section 22. New York Department of Environmental Conservation, Watertown, New York, p. 8.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Access point and aerial survey to estimate effort, catch and harvest rates of the warmwater fishing season May-September 2003. The survey covered an area of 256,000 acres.

Volstad, J.H., Richkus, W.A., Miller, J., Lupine, A., Dew, J., 2003. *Delaware River Creel Survey 2002*. Final Report, Volume 1. Prepared for Robert Lorantas, Pennsylvania Fish and Boat Commission. Versar, Inc., Columbia, M.D, p. 42.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Access point survey used in conjunction with an aerial effort survey was used to estimate effort, catch and harvest of American shad, hickory shad, river herring, striped bass, and other species targeted by anglers in the Delaware River.

Comanducci, N., Driscoll, H., 2008. Applying a telephone/intercept methodology to measure the recreational blue crab fishery in New Jersey. *Journal of Shellfish Research* **27**, 998-998.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone and creel surveys are used to estimate catch and effort.

Limibird, B., 2000. *Lake Dardanelle Creel Survey*. Unpublished Report. Arkansas Game and Fish Commission.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** Aerial fishing pressure counts and on-site creel surveys to estimate effort and catch over a 3 year period. Lake Dardanelle has a surface area of 40,000 acres.

Mudre, J., 1989. *Recreational Fishing Survey of the District of Columbia Waters: 1989*. American Fisheries Society. International Science and Technology, Inc.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Used roving creel and mail surveys to provide data on angling effort, catch and harvest, species preference, fish consumption, angler demographics and angling expenditures for both shoreline and boat anglers.

Pacific States Marine Fisheries Commission - Recreational Fisheries Information Network (RecFIN), Washington Department of Fish and Wildlife (Ocean Sampling Program).
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Creel surveys (catch) and counts of vessels leaving and entering main access sites (effort) are used to estimate total ocean recreational effort and catch by boat type (charter and private), port, catch area, and trip type (primary target species).

Pacific States Marine Fisheries Commission - Recreational Fisheries Information Network (RecFIN), Ocean Recreational Boat Survey (ORBS). Viewed 03/08 2009,**Country:** USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** The ORBS project estimates the ocean effort, catch, and catch rates from private boat and charter boats. Anglers are interviewed at boat ramps, moorages, and charter docks for catch rate data. Charter boat effort in most ports is estimated by contacting each charter office for their count of boat trips by trip type i.e. salmon fishing, bottomfish fishing, tuna fishing, etc. Effort information for private boat trips is primarily obtained through boat counts by ODFW samplers of bar crossings.

QuanTech Inc., Large Pelagics Survey. http://www.quantech.com/lps.htm
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone and access point surveys are used to estimate catch and effort for large pelagic species (e.g., tunas, billfishes, swordfish, sharks, wahoo, dolphinfish, and amberjack) in the offshore waters from Maine through Virginia. Survey has been conducted since 1992.

Washington Department of Fish and Wildlife, Puget Sound Sampling Program.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Telephone and creel surveys used to estimate catch and effort. Sampling began in 2000.

Kalvass, P.E., Geibel, J.J., 2006. California recreational abalone fishery catch and effort estimates for 2002 from a combined report card and telephone survey. *California Fish and Game* **92**, 157-171.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Catch cards and telephone survey (used to measure non-response) to estimate catch and effort for the recreational abalone fishery.

McClanahan, D.R., Hansen, M.J., 2005. A statewide mail survey to estimate 2000/2001 angler catch, harvest, and effort in Wisconsin. Fisheries Management Report 151. Wisconsin Department of Natural Resources, Madison, p. 48.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** COMPL; **Survey Objective:** A mail-mail survey and comparisons with creel survey data was used to estimate and correct for bias - angler catch, harvest and effort for Wisconson's inland lakes and rivers.

2001 Pacific Coast Cooperative, Party Charter Phone Survey. http://www.recfin.org/pcps.html
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** To obtain survey catch estimates, party/charterboat fishing-effort estimates were combined with catch-per-trip estimates from the MRFSS dockside intercept survey.

Muffley, B., Lurig, L., Mahnke, G.N., Driscoll, H., 2007. *Survey of New Jersey's Blue Crab, Callinectes sapidus, Recreational Fishery, Year 1 - Delaware Bay*. New Jersey Department of Environmental Protection, Division of Science, Research and Technology.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Used a telephone and on-site creel survey to estimate monthly effort and harvest by various gear types.

California Department of Fish and Game, California Recreational Fisheries Survey. http://www.dfg.ca.gov/marine/crfs.asp
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** On-site creel and telephone surveys are used to estimate catch and effort of marine finfish for six geographic regions on a monthly basis.

Pacific States Marine Fisheries Commission - Recreational Fisheries Information Network (RecFIN), (1999). Oregon Shore and Estuary Boat Survey (ODFW-SEB. http://www.recfin.org/cntrbtrs.htm
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Access point and

telephone surveys used to estimate catch and effort for recreational anglers that fish man made structures, beaches and banks and from private and rental boats.

Office of Science and Technology, Marine Recreational Fisheries Statistics Survey (MRFSS). http://www.st.nmfs.noaa.gov/st1/recreational/index.html
Country: USA; **Geographic Scale:** NATION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** COMPL; **Survey Objective:** Complemented survey approach that included telephone surveys of fishing effort and access-site intercept surveys of angler catch.

U.S. Department of the Interior, 2006. *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*. http://www.census.gov/prod/2008pubs/fhw06-nat.pdf
Country: USA; **Geographic Scale:** NATION; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** COMPL; **Survey Objective:** Used telephone and door-door surveys to estimate numbers of anglers; how often they participate, and their expenditures.

Van De Valk, A.J., 2003. *Factors Affecting Angler Catch Rates in Oneida Lake, New York*. Final Report, Cornell University, Ithaca, New York.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Used angler dairy program between 1994 and 1998 to estimate catch and effort.

Kerr, S.J., 1996. *A summary of Muskies Canada Inc. angler log information, 1979-1994*. Ontario Ministry of Natural Resources Kemptvill, Ontario: Science and Technology Transfer Unit. p. 107.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Diaries used to estimate catch and effort of muskellunge from 77 Ontario water bodies.

Pennsylvania Fish and Boat Commission, Raytown Lake Angler Log. http://www.fish.state.pa.us/newsreleases/2006/raystown_logbook.pdf
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Angler logbooks used to estimate annual catch and effort.

Connelly, N.A., Knuth, B.A., 1999. Using diaries to examine children's fishing patterns. *North American Journal of Fisheries Management* **19**, 1103-1107.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Diaries used to estimate children's fishing participation in central and western New York.

Pennsylvania Fish and Boat Commission, Delaware River and Estuary, Eastern Pennsylvania, Angler Logbook Summary for 2005 and 2006. http://www.fish.state.pa.us/images/fisheries/afm/2008/5x07_15delaware.htm
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** DIARY; **Survey Objective:** Angler Logbooks used to estimate catch, harvest and effort throughout the Delaware River Basin.

Pacific States Marine Fisheries Commission - Recreational Fisheries Information Network (RecFIN), Pacific-Indian Ocean Billfish Angler Survey. http://www.recfin.org/cntrbtrs.htm
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Voluntary annual survey response catch cards are mailed to National Marine Fisheries Service (NMFS) reporting recreational catch and effort of Billfish in southern Californian waters.

Washington Department of Fish and Wildlife, Shellfish Regulations: Dungeness Crab Catch Record Card. http://wdfw.wa.gov/fish/shelfish/crabreg/crc.htm
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** MAR; **Survey Method:** DIARY; **Survey Objective:** Catch cards used to estimate seasonal catch and effort. Reporting of catch cards can be via mail or online.

Idaho Fish and Game, Fishing Report Card Program, Southeast Region. http://fishandgame.idaho.gov/apps/releases/view.cfm?NewsID=4458
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** As a supplement to creel surveys use voluntary catch cards to estimate catch and effort; determine where stocking efforts may need to be increased; assist in identifying where amenities (parking, boat ramps etc) need to be provided.

Washington Department of Fish and Wildlife, Voluntary Trip Report (VTR) Program. http://wdfw.wa.gov/fishing/vtr/index.html
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards used to record daily catch of Chinook or Coho salmon in selective areas of the Strait of Juan de Fuca and Puget Sound.

Bray, G.S., Schramm, H.L., 2001. Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool. *North American Journal of Fisheries Management* **21**, 606-615.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Statewide volunteer angler diary program used to determine if angler diaries can provide useful catch and effort data for management of the principal sport fishes in waters throughout Mississippi.

Arkansas Game and Fish Commission, 2009. *Black Bass Program Report & Arkansas Tournament Information Program (ATIP) Results 2006*. http://www.agfc.com/!userfiles/pdfs/fisheries/BBP/BlackBassReport2006.pdf
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards used to estimate bass catch and effort from tournaments. Catch card details can be returned via website or mail.

Tennesse Wildlife Resources Agency, 2004. *B.I.T.E Bass Information from Tournament Entries*. 2004 Annual Report, Nashville, Tennessee.

Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards used to record tournament effort and catch.

Younk, J.A., Cook, M.F., 1992. *Applications of an Angler Diary for Muskellunge Esox masquinongy*. Minnesota Department of Natural Resources, Investigational Report 420.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Diary program used to estimate effort and catch.

Younk, J.A., Pereira, D.L., 2007. An examination of Minnesota's muskellunge waters. *Environmental Biology of Fishes* **79**, 125-136.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Used trap net assessments and angler diary surveys to compare native and introduced (stocked) waters by examining catch rates, size of fish caught, and angler success.

Ferencak, J., 2009. *Illinois Muskie Creel Project 1987-2008*. Final Report. Illinois Department of Natural Resources.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** DIARY; **Survey Objective:** Catch cards are used to record catch and effort of muskies on at least 59 water bodies. Catch cards details can be mailed in or reported on a web page.

Ball, R., 2005. *The 2002 Recreational use survey of the West Fork White River in Central Indiana*. Fisheries Section, Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, p. 22.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route survey designed to estimate recreational use of the study area including angler effort and catch rates.

Bettoli, P.W., 2002. *Creel Survey of the Recreational Fishery of the North Fork of the Holston River*. A Final Report Submitted to Tennessee Wildlife Resources Agency, p. 11.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey used to estimate angler effort and harvest rates.

Bettoli, P.W., 2007. *Surveys of the Trout Fisheries in the Watauga River and South Fork of the Holston River*. A Final Report Submitted to Tennessee Wildlife Resources Agency, p. 41.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey used to estimate angler effort and harvest rates.

Christianson, J., Berquist, J., 1998. Spirit Lake Creel Survey, 1997/1998. Iowa Department of Natural Resources, Spirit Lake, Dickinson County, Iowa.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate angling pressure, harvest (species composition by number and weight), catch rates, species preference and distance travelled to fish.

Colorado Division of Wildlife, Fishery Survey Summaries. http://wildlife.state.co.us
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** *Creel surveys used to estimate catch and effort for numerous lakes and reservoirs (9): Rampart Reservoir, Nichols Reservoir, Trinidad Reservoir, Spinney Mountain Reservoir, Brush Hollow Reservoir, Arkansas River, John Martin Reservoir, Gunnison River, Blue Mesa Reservoir.

Dunaway, D.O., Fleischman, S.J., 1996. *Surveys of the Sockeye Salmon Sport Fishery in the Upper Kvichak River, Alaskaa, 1995*. Fisheries Data Series No. 96-18. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, Anchorage, Alaska, p. 54.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel survey used to estimate effort, catch and harvest.

Idaho Fish and Game, Regional Fishing Information. http://fishandgame.idaho.gov/cms/fish/reports
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for numerous reservoirs, lakes and rivers (7): Boise River, Island Park Reservoir, Bear Lake, Redfish Lake, Teton River, Coeur d'alene Lake, Snake River.

Indiana Department of Natural Resources, Fishing Research & Management Notes Archives.http://www.in.gov/dnr/fishwild/3511.htm
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for numerous lakes and reservoirs (13): Bear Lake, Eagle Creek Reservoir, Eel River (Bus route survey), Hardy Lake, Huntingburg Lake (1992, 1997), Lake Michigan, Robinson Lake, Saddle Lake, Shakamak Lakes, West Boggs Creek Reservoir, Mississinewa Reservoir, Salamonie Reservoir.

Isermann, D.A., Willis, D.W., Lucchesi, D.O., Blackwell, B.G., 2005. Seasonal Harvest, Exploitation, Size Selectivity, and Catch Preferences Associated with Winter Yellow Perch Anglers on South Dakota Lakes. *North American Journal of Fisheries Management* **25**, 827-840.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to evaluated harvest patterns, exploitation, size selectivity, and angler catch preferences associated with winter fisheries for yellow perch *Perca flavescens* (i.e. ice fishing) on South Dakota lakes.

Keniry, P., Carmichael, R.W., Hoffnagle, T.L., 2004. Chinook Salmon Recreational Fishery Creel Survey on Lookingglass Creek for the 2001 Run Year. Oregon Department of Fish and Wildlife, Fish Research and Development, Northeast

Region, La Grande, Oregon, p. 15 **Country:** USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys primarily used to estimate angler effort, harvest and catch rate of Chinook salmon.

Minnesota Department of Natural Resources, 2009. *Fisheries Area Offices*. http://www.dnr.state.mn.us/areas/fisheries/index.html
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for numerous lakes for several areas: Montrose-Clearwater lake (winter/summer), Buffalo Lake (winter/summer), Pulaski Lake; Walker-Leech Lake; Lake Superior.

Pennsylvania Fish and Boat Commission, Biologist Reports. http://pfbc.state.pa.us/Biologist_Reports/Biologist_Reports.htm
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for several lakes (5): Lake Erie, Presque Isle Bay, Harvey's Lake, Susquehanna River-Juniata River, Delaware River.

Schramm, H.L., Arey, S.D., Miko, D.A., 1998. Angler Perceptions of Fishing Success and the Effect of On-site Catch Rate Information. *Human Dimensions of Wildlife* **3**, 1-10.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used roving creel surveys to estimate catch rates.

Schultz, R.D., Schneider, G.L., 1999. Consequences of an Exceptional Ice-Fishing Season on White Bass in Cheney and Glen Elder Reservoirs, Kansas. *Transactions of the Kansas Academy of Science*. Kansas Academy of Science, pp. 107-116.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort of white bass for two reservoirs during the 1985 ice-fishing season. Cheney reservoir covers and area of approx 38 square km; Glen Elder Reservoir covers an area of approx 50 square km.

Van De Valk, A.J., Rudstam, L.G., 2001. Evolution of the Oneida Lake Fishery. *Clearwaters, Winter 2001* **31**.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel survey used to estimate catch and effort.

Virgina Department of Game and Inland Fisheries, 2009. Virginia Lakes. http://www.dgif.virginia.gov/fishing/waterbodies/?type=1
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to monitor catch and effort for numerous reservoirs, lakes and rivers (15): North Fork of Pound Reservoir, Laurel Bed Lake, James River, Rappahannock River, Smith Mountain Lake,

Briery Creek Lake, Lake Frederick, Upper New River, Chickahominy River, Douthat Lake, Swan Lake, John W. Flannagan Reservoir, Lake Orange, Chesdin Reervoir, Lake Gaston

Woller, H., Baldwin, C., Polacek, M., Knuttgen, K., Caromile, S., Jackson, C., 2004. *Banks Lake Fish Survey, September 2000*. Technical Report. Washington Department of Fish and Wildlife, Fish Program, Science Division, p. 62.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used creel surveys to estimate seasonal catch and effort.

Gasper, J.R., Gallucci, V.F., Miller, M.L., Swanson, J., Soiseth, C., Johnson, D.R., 2005. Sportfishing catch and harvest of Pacific halibut (Hippoglossus stenolepis) in Glacier Bay National Park. *Fisheries Assessment and Management in Data-Limited Situations* **21**, 339-355.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Creel surveys (access point) used to estimate catch, harvest and effort from charter and private marine anglers as boats returned to homeports at the completion of fishing trips.

Kahiapo, J., Kimberly Smith, M., 1994. *Shoreline Creel Survey of Hilo Bay Hawaii: 1985-1990*. Technical Report 94-02. Department of Land and Natural Resources, Division of Aquatic Resources, State of Hawaii, p. 31.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to gather data relating to changes in catch rates, species composition and fish size before and after the closure of Hilo Harbor to gillnetting in June, 1987.

Meyer, C.G., 2007. The impacts of spear and other recreational fishers on a small permanent Marine Protected Area and adjacent pulse fished area. *Fisheries Research* **84**, 301-307.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to estimate catch and effort.

Palsson, W.A., 1991. Using Creel Surveys to Evaluate Angler Success in Discret Fisheries. In: Guthrie, D., Hoenig, J.M., Holliday, M., Jones, C.M., Mills, M.J., Moberly, S.A., Pollock, K.H., Talhelm, D.R. (Eds). *Creel and angler surveys in fisheries management*. American Fisheries Society, Bethesda, Maryland, pp. 139-154.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** The catch and effort of two spatially and temporally discrete fisheries were determined by similar survey design. Effort derived from effort counts from shore-based positions and catch rates estimated from access point surveys at boat ramps.

Allen, M.S., Tugend, K.I., Mann, M.J., 2003. Largemouth bass abundance and angler catch rates following a habitat enhancement project at Lake Kissimmee, Florida. *North American Journal of Fisheries Management* **23**, 845-855.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Roving creel surveys used to estimate catch rate data for largemouth bass. This study did not conduct the creel surveys but used historical creel survey data collected by the FWC (K. McDaniel, FWC, unpublished data). Lake Kissimmee covers an area of 141 square km.

Bister, T.J., Brice, M.W., 2008. *2007 Survey Report, Lake Monticello*. Statewide Freshwater Fisheries Monitoring and Management Program, Texas Parks and Wildlife, Marshall, Texas, p. 23.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Access point creel survey used to assess angler use, catch and harvest primarily for the main sport fish species. Lake Monticello is an 8 square km impoundment.

Hallberg, J.E., Bingham, A.E., 1997. The 1996 Delta Clearwater River Creel Survey. Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, Anchorage, Alaska, p. 16.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Access point survey used to describe the age and length compositions of the Arctic grayling harvest.

Hampton, T., 2003. Laurel Bed Lake Angler Survey 2002 Summary Report. Virginia Department of Game & Inland Fisheries. http://www.dgif.virginia.gov/fishing/waterbodies/reports/2002%20Laurel%20Bed%20Lake.pdf
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to provide data on angler effort, species preference, catch, harvest and economics.

Kenyon, R., Murray, C., 2001. A review of the Lake Erie and Presque Isle Bay Yellow Perch Sport Angling Fisheries, 1997-2001. Pennsylvania Fish and Boat Commission, Division of Research, Lake Erie Research Unit, p. 19, Fairview, Pennsylvania.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route survey (Lake Erie Boat Angler Survey (LEBAS) started 1996), also in report mentions creel survey in 1993 to estimate catch and effort for yellow perch.

Kozlowski, G.E., 1999. *Fall Trout Stocking Program Angler Survey 1993-1994*. New York State Department of Environmental Conservation, Division of Fish and Wildlife, p. 38.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Angler interviews conducted at ponds to estimate catch and effort.

Nebraska Game and Parks Commission, 2009. *Fish Sampling Program*. http://www.ngpc.state.ne.us/fishing/programs/sampling/sampling.asp
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Uses access point surveys to

monitor fish populations for a number of water bodies (20): Box Butte Reservoir, Davis Creek Reservoir, Elwood Reservoir, Harlan County Reservoir, Johnson Lake, Lake Minatare, Sherman Reservoir, Stagecoach, Walnut Creek, Widwood Reservoir, Willow Creek, Calamus, Enders Reservoir, Lake Maloney, Lewis and Clark, Medicine Creek, Merritt, Pawnee, Red Willow Reservoir, Swanson Reservoir.

Nelson, J.E., 2003. *Onion River, Sheboygan County, WBIC # 51200, Trout Creel Survey - 2003*. Final Report.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used random stratified creel surveys to estimate angler pressure, catch and harvest on the Onion River.

Quinn, J., 2001. *Characteristics of Bowfishing Tournaments in Arkansas*. Arkansas Game and Fish Commission, Little Rock, Arkansas.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used a hand out survey to assess the harvest and harvest rate of fish from bowfishing tournaments in Arkansas.

Rasmussen, P.W., Unmuth, J.M.L., Lyons, J., Van Dyck, G., 1994. A Creel Survey of the Lower Wisconsin River, 1990-1991. *Research Report* **160**. Wisconsin Department of Natural Resources, Madison, Wisconsin, p. 36.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route survey used to estimate effort, catch and catch rates.

Texas Parks and Wildlife, 2008. *Lake Survey Reports*. http://www.tpwd.state.tx.us/publications/pwdpubs/lake_survey
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Access point or roving creel surveys used to monitor fish populations for a number of Texas lakes and reservoirs (58): Alan Henry Reservoir, Amistad Reservoir, Amon G. Carter Reservoir, Aquilla Reservoir, Lake Arrowhead, Lake Athens, Austin Reservoir, Averhoff Reservoir, Lake Bardwell, Bastrop Reservoir, Lake Bob Sandlin, Bonham City Reservoir, Brandy Branch Reservoir, Victor Braunig Reservoir, Bridgeport Reservoir, Lake Bryan, Buchanan Reservoir, Caddo Lake, Cedar Creek Reservoir, Choke Canyon Reservoir, Lake Conroe, Lake Cypress Springs, Diversion Reservoir, Eagle Mountain Reservoir, Lake Fairfield, Falcon Reservoir, Fayette County Reservoir, Lake Fork Reservoir, Fort Phantom Hill Reservoir, Georgetown Reservoir, Gibbons Creek Reservoir, Gilmer Reservoir, Granger Reservoir, Lake Houston, Kirby Reservoir, Kurth Reservoir, Limestone Reservoir, Livingston Reservoir, Lone Star Lake, Meredith Reservoir, Lake Monticello, Lake Murvaul, Lake Nacogdoches, Nasworthy Reservoir, O.H. Ivie Reservoir, Lake Palestine, Pinkstone Reservoir, Possum Kingdom Reservoir, Ray Hubbard Reservoir, Richland Chambers Reservoir, Sam Rayburn Reservoir, Toledo Bend Reservoir, Lake Tyler East, Lake Tyler West, Waco Reservoir, Walter E. Long Reservoir, Lake Welsh, Wichita Reservoir.

Wooldridge, S.J., 1998. Creel survey comparison of all anglers vs. hook-and-line anglers, Lake Ouachita, Arkansas. Arkansas Game and Fish Commission, Hot Springs, Arkansas.
http://www.sdafs.org/meetings/98sdafs/reservor/wooldge.htm
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel survey used to compare spear fishing pressure and harvest with "all angler" pressure and harvest for this 160 square km reservoir.

Malvestuto, S., Black, W.P., 2002. Tennessee Reservoir Creel Survey: 2001 Results. Report No. 02-10. Tennessee Wildlife Resources Agency. p. 195.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate catch and effort for numerous reservoirs.

Tennesse Wildlife Resources Agency, Angler surveys.
http://www.tennessee.gov/twra/fish/Reservoir/AngSurv.html
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to estimate angler expenditure, catch and effort for a number of lakes, rivers and reservoirs (17): Holston River (south and north fork), Watauga River, Hiwassee River, Normandy Tailwater, Tims Ford Tailwater, Dale Hollow Tailwater, Norris Tailwater, Center Hill Tailwater, Kentucky Lake, Boone, J. Percy Priest, Pickwick, Cherokee, Douglas, Chickamauga.

Related publications or reports:

Fiss, F.C., Churchhill, T.N. 2003. *Tennessee Smallmouth Bass Management Plan*. Fisheries Management Division, Tennessee Wildlife Resources Agency, Nashville, Tennessee. http://www.tennessee.gov/twra/fish/SMBPLAN/SMBPLAN%20final.pdf

Ward, M., 2008. *Completion Report: Lake Superior Spring Creel Survey 2008*. Completion Report F-29-R(P)-28. Minnesota Department of Natural Resources, Division of Fisheries, p. 24.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Stratified random creel survey used annually on 17 streams along the Minnesota shore since 1992, from mid-April through late-May to estimate the catch and effort of rainbow trout.

Wooldridge, S.J., Hobbs, B., 2007. *Lake Ouachita, Montgomery and Garland Counties, 2006 Annual Fish Population Sampling Report*. Arkansas Game and Fish Commission.
Country: USA; **Geographic Scale:** LOC; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to provide data on growth rates, fishing pressure, angler catch and harvest.

Condo, B., Bettoli, P.W., 2000. *Survey of the recreational fishery in the Duck River*. Fishery Report 02-22. Tennessee Wildlife Resources Agency.

Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route survey used to estimate angler species preference, effort, catch harvest and economic impact on a 240km stretch of the Duck River.

Hoffman, K., 2005. *2004 Recreational Use Survey of the West Fork White River*. Indiana Department of Natural Resources, Fisheries Section, Indianapolis, Indiana, p. 24.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route survey used to estimate effort, catch and harvest.

Pacific States Marine Fisheries Commission - Recreational Fisheries Information Network (RecFIN), Central California Marine Sportfish Project (Commercial Passenger Fishing Vessel (CPFV) Survey). http://www.recfin.org/cntrbtrs.htm
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Fishery technicians , supplied by the Pacific States Marine Fisheries Commission under contract with the California Department of Game and Fish, and project biologists conducted on-board sampling of catches from Commercial Passenger Fishing Vessels (CPFVs). This survey aimed to record catch and effort data primarily for rockfish and lingcod.

Toller, W., O'Sullivan, C., Gomez, C., 2005. *Survey of Fishing Tournaments in the U.S. Virgin Islands, October 1, 2000 to September 30, 2005*. Division of Fish and Wildlife, Frederiksted, St. Croix, US Virgin Islands, p. 54.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** INTERC; **Survey Objective:** Interviews of vessel captains (or anglers) in conjunction with port-based sampling of landings to collect recreational catch and effort.

New York State Department of Environmental Conservation, Beaver Kill Watershed Trout Study. New Paltz.
http://www.wildtroutstreams.com/NYReports/2002beaverkillrpt.pdf
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Creel surveys used to gather data on catch and distribution of trout.

Snook, V.A., Dieterman, D.J., 2006. *A Roving Creel Survey of Selected Southeast Minnesota Trout Streams - 2005*. Minnesota Department of Natural Resources, Division of Fish and Wildlife.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Used a 'bus route' creel survey to estimate catch rates, harvest rates and angler satisfaction.

Lott, J., Hanten, R., Potter, K., 2004. *Annual Fish Population and Angler Use, Harvest and Preferences Surveys on Lake Sharpe, South Dakota, 2003*. Annual Report No. 04-15. Missouri River Fisheries Center, South Dakota Dept. of Game, Fish and Parks, Pierre, South Dakota, p. 61.

Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route creel survey used to estimate angler catch, harvest, and release rates, along with information on mean party size, mean angler day length, angler residency, angler age distribution, annual local economic impact of the sport fishery, effects of regulations and other management activities, size structure of fish in the harvest, angler preference, attitude and satisfaction information. Lake Sharpe covers an area of 25000 ha.

Sorensen, J., 2004. *Annual Fish Population and Angler Use, Harvest and Preferences Surveys on Lake Francis Case, South Dakota, 2003*. Progress Report No. 04-19. American Creek Fisheries Station, South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, p. 57.

Country: USA; **Geographic Scale:** REGION; **Survey Duration:** ONGOING; **Water Type:** FW; **Survey Method:** INTERC; **Survey Objective:** Bus route creel survey used to estimate angler catch, harvest, and release rates, along with information on mean party size, mean angler day length, angler residency, and angler age distribution. Total fish catch, harvest and release estimates were calculated by multiplying the pressure estimate (angler hours) by the estimated catch, harvest, or release rate (fish per angler hour). Lake Francis Case covers an area of 32000 hectares.

Maryland Department of Natural Resources, 2009. Maryland Volunteer Angler Surveys. http://www.dnr.state.md.us/fisheries/survey/vasurvey.html

Country: USA; **Geographic Scale:** STATE; **Survey Duration:** ONGOING; **Water Type:** BOTH; **Survey Method:** INTERNET; **Survey Objective:** Can use internet or mail surveys to collect catch and effort data for both marine and freshwater species.

Henry, S.D., Barkley, S.W., Johnson, R.L., 2005. Exploitation of nile tilapia in a closed-system public fishing reservoir in northern Arkansas. *North American Journal of Fisheries Management* **25**, 853-860.

Country: USA; **Geographic Scale:** LOC; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** MAIL; **Survey Objective:** A mail-in reward tag study was used to estimate the harvest and effort associated with Nile tilapia compared to other species.

Low, R.A., 2002. Survey of the South Carolina Shrimp Baiting Fishery. *Data Report* **39**. Office of Fisheries Management, Marine Resources Division, South Carolina Department of Natural Resources, Charleston, South Carolina, p. 16.

Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** MAIL; **Survey Objective:** Used a post-season mailout survey to determine total participation, total effort in numbers of trips, total catch and effort and catch by shrimping area.

Sharp, W.C., Bertelsen, R.D., Leeworthy, V.R., 2005. Long-term trends in the recreational lobster fishery of Florida, United States: landings, effort, and implications for management. *New Zealand Journal of Marine and Freshwater Research* **39**, 733-747.

Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** MAR; **Survey Method:** MAIL; **Survey Objective:** Mail surveys used to estimate spatially explicit landings and fishing effort.

Gigliotti, L., 2004. *Fishing in South Dakota - 2003, Fishing Activity, Harvest and Angler Opinion Survey.* Report to Survey Participants, South Dakota Game, Fish & Parks, p. 4.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** MAIL; **Survey Objective:** Using mail surveys to estimate total statewide fishing activity and harvest

Lilieholm, R.J., Krannich, R.S., Tessema, M.E., 2006. *2005 Utah Angler Survey*. Utah Division of Wildlife Resources, Logan.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** MAIL; **Survey Objective:** Mail survey used to provide estimates of angling activity and harvest levels across the state and at selected specific locations.

Jennings, C.A., 1992. Survey of non-charter boat recreational fishing in the United-States Virgin-Islands. *Bulletin of Marine Science* **50**, 342-351.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Telephone survey to estimate catch and effort for the recreational non-charter boat fishery around the Virgin Islands in 1986.

Mateo, I., 2002. Survey of resident participation in recreational fisheries activities in the US Virgin Islands. In: Creswell, R.L. (Ed.), *55th Annual Meeting of the Gulf-and-Caribbean-Fisheries-Institute*. Gulf Caribbean Fisheries Inst Gcfi, Xel Ha, MEXICO, pp. 205-222.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Telephone surveys used to estimate fishing participation, catch and effort.

Byers, T.F., 1999. 1998 *Recreational Fishing Survey of The District of Columbia Project Performance Report F-2-R-13*. Government of the District of Columbia, Department of Health, Environmental Health Administration, Fisheries and Wildlife Division, Washington.
Country: USA; **Geographic Scale:** REGION; **Survey Duration:** >1YR; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** Telephone survey used to provide data on angling effort, catch and harvest, species preference, fish consumption, angler demographics and angling expenditures for both shoreline and boat anglers.

Responsive Management, 2005a. *South Carolina Saltwater anglers' Participation in and Satisfaction with Saltwater Fishing and Opinions on Saltwater Fisheries Management*. South Carolina Department of Natural Resources, Marine Resources Division, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** To determine saltwater anglers' participation in fishing and shellfishing and their opinions towards saltwater fisheries management.

Responsive Management, 2005b. *South Carolina Saltwater anglers' opinions on the Red Drum Fishery*. South Carolina Department of Natural Resources, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Telephone survey of licenced resident saltwater anglers to determine opinions on and participation in red drum fishing in South Carolina.

Responsive Management, 2006. *South Carolina Saltwater Anglers' Participation in Saltwater Recreational Fishing and Opinions on a Precautionary Approach to Managing Marine Finfish Resources*. South Carolina Department of Natural Resources, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** MAR; **Survey Method:** TELE; **Survey Objective:** Determine saltwater anglers' participation in saltwater recreational fishing and their opinions on managing marine finfish resources.

Michael, P.J., 2004. *A 2002 survey of resident freshwater anglers in Washington State and comparisons to the 1994 and 1988 surveys*. Washington Department of Fish and Wildlife, Fish Program, Fish Management Division.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone survey to determine the activities and preferences of resident licensed anglers from the previous 12 months.

Responsive Management, 2003. *New Jersey Angler's Participation in Fishing, Harvest Success, and Opinions on Fishing Regulations*. New Jersey Division of Fish and Wildlife, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone survey to determine anglers' participation, harvest success, and opinions on fishing regulations in New Jersey.

Responsive Management, 2004a. *South Carolina Fishing Licence Holders' Opinions on and Attitudes Towards Freshwater Fisheries Management and the South Carolina Department of Natural Resources*. South Carolina Department of Natural Resources, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Determine licensed anglers' participation in fishing and their attitudes toward and opinions on fisheries management and the DNR.

Responsive Management, 2008. Washington Angler Survey. Washington Department of Fish and Wildlife, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Determine Washington resident freshwater anglers' participation in fishing, the species they most commonly fish for and the species most preferred, and their opinions on various regulations and Department efforts.

Responsive Management, 2004b. *Resident Participation in Freshwater and Saltwater Sport Fishing in Georgia*. Georgia Department of Natural Resources, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** Telephone survey to determine the number of resident anglers participating in freshwater and saltwater sport fishing within the previous 12 months.

Responsive Management, 2004c. *New Hampshire Angler Survey, Resident Angler's Participation in and Satisfaction with Fishing and Their Opinions on Fishing Issues*. New Hampshire Fish and Game Department, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** Determine New Hampshire resident anglers' participation in fishing, their satisfaction with it, license-purchasing and fishing behaviours, and likelihood to purchase licenses at different prices.

Responsive Management, 2007. *Oregon's 2006 Angler Preference Survey of Annually Licensed Resident Anglers*. Oregon Department of Fish and Wildlife, Harrisonburg, Virginia.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** <1YR; **Water Type:** BOTH; **Survey Method:** TELE; **Survey Objective:** To determine licensed anglers' participation in fishing in Oregon, their motivations for fishing and constraints to fishing participation, and their opinions on various fishing regulations and fisheries management strategies.

Stephens, B., Jakus, J., Fly, J.M., 2001. *Fall 2000 REAL database fishing survey results*. Human Dimensions Research Lab, University of Tennessee Agriculture Institute, Knoxville.
Country: USA; **Geographic Scale:** STATE; **Survey Duration:** >1YR; **Water Type:** FW; **Survey Method:** TELE; **Survey Objective:** Telephone surveys (1995-2000) used to estimate fishing participation, species targeted, catch and harvest for streams and reservoirs by resident Tennessee anglers.

16.3 Appendix 3

Project staff

Shane Griffiths (CSIRO Marine and Atmospheric Research)
Julian Pepperell (Pepperell Research)
Mark Tonks (CSIRO Marine and Atmospheric Research)
Bill Sawynok (Infofish Services)
Len Olyott (Recfish Australia)
Evan Jones (Queensland Game Fish Association)

Workshop 1 participants

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Len Olyott (Recfish Australia)
Mark Tonks (CSIRO Marine and Atmospheric Research)
Gavin Fay (CSIRO Marine and Atmospheric Research)
You-Gan Wang (CSIRO Mathematics, Informatics and Statistics)
Bill Sawynok (Fisheries Research Development Corporation)
Jeremy Lyle (Tasmanian Aquaculture and Fisheries Institute)
Josh Fielding (Australian Fisheries Management Authority)
Phil Sahlqvist (Bureau of Rural Sciences)
Ken Pollock (Murdoch University)
Bruce Hartill (National Institute of Water and Atmospheric Research, NZ)
Aldo Steffe (Industry and Investment NSW)
Danielle Ghosn (Industry and Investment NSW)
Steve Taylor (Queensland Department of Primary Industries and Fisheries)
Jonathan Staunton-Smith (Queensland Department of Primary Industries and Fisheries)
Murray MacDonald (Victorian Department of Primary Industries)
Karina Ryan (Victorian Department of Primary Industries)
Brent Wise (Department of Fisheries Western Australia)
HockSeng Lee (Northern Territory Department of Regional Development, Primary Industries, Fisheries and Resources)
Keith Jones (South Australian Research and Development Institute)
Mitchell Zischke (University of Queensland)
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Michael Mihajlov (Australian Land-based Anglers Association)
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Ken Pollock (Murdoch University)
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Matthew Daniel (Australian Fisheries Management Authority)
Elizabetta Morello (CSIRO Marine and Atmospheric Research)
Steve Edgar (CSIRO Marine and Atmospheric Research)

16.4 Appendix 4

Peer-reviewed publications arising from the project

1) Griffiths, S.P., Pollock, K.H., Lyle, J.M., Pepperell, J.G., Tonks, M.L. and Sawynok, W. (2010) Following the chain to elusive anglers. *Fish and Fisheries* **11**, 220-228.

16.5 Appendix 5

Program and associated materials for workshop 1

Includes workshop agenda, presentation abstracts, and relevant background documentation on survey types, Commonwealth fisheries management areas and their principal target and bycatch species.

Developing innovative and cost-effective tools for monitoring recreational fishing in Commonwealth fisheries

Monitoring Methods Development Workshop 1

4-5 November 2009

CSIRO Marine and Atmospheric Research Laboratories

Workshop facilitator: Julian Pepperell

Day 1

8.45 Tea and coffee

Overview of Recreational Fisheries and Management Needs in Australia

9.00	Shane Griffiths (CSIRO)	*Welcome address, OHS, and attendee introductions*
9.15	Josh Fielding (AFMA)	*Recreational fisheries catch monitoring - an AFMA perspective*
9.30	Bill Sawynok (FRDC)	*Recfishing Research – FRDC Investment*
9.45	Len Olyott (Recfish)	*Data Needs vs. Data Wants – time for a change in focus*
10.00	Phil Sahlqvist (BRS)	*A BRS perspective on priorities for monitoring recreational fishing in Commonwealth fisheries*
10.15	Julian Pepperell (PR)	*Prioritisation of Commonwealth fisheries and species requiring monitoring for recreational fishing interactions*
10.30	Gavin Fay (CSIRO)	*Including data from recreational fisheries in Commonwealth stock assessments*
10.45	Mark Tonks (CSIRO)	*A global review of traditional and innovative methods for estimating catch and effort in recreational fisheries*

11.00 **Morning Tea**

Case Studies of Recreational Fishing Surveys

11.30	Aldo Steffe (NSW)	*Recreational Fishing Surveys in New South Wales – why we do them and how we use the data*
11.45	Steve Taylor (QDPI&F)	*An overview of monitoring and assessment of recreational fishing in Queensland*
12.00	Karina Ryan (VIC DPI)	*Evaluation of methods of obtaining annual catch estimates for individual Victorian bay and inlet recreational fisheries*
12.15	Brent Wise (WA)	*Recreational surveys in Western Australia*
12.30	HockSeng Lee (NT)	*Large-scale Assessment of Recreational Fisheries in the Northern Territory – 1995 to 2009*
12.45	Evan Jones (QGFA)	*QGFA Logbook Program - a framework of data collection, self monitoring and model for information supporting co-management arrangements*
1.00	**Lunch**	

Specialised Recreational Fishing Survey Designs

1.45	Bruce Hartill (NIWA - NZ)	*Horses for New Zealand courses: how the development of the aerial access method has progressed our ability to assess harvests from large scale recreational fisheries*
2.05	Jeremy Lyle (TAFI)	*Understanding the gamefish fishery of Tasmania with particular reference to southern bluefin tuna*
2.20	Keith Jones (SARDI)	*Commonwealth managed fish species caught by SA resident recreational fishers in South Australia – comparing two survey methods to estimate their catches*
2.35	Danielle Ghosn (NSW)	*Gamefish Tournament Monitoring in NSW: Can this historical dataset be integrated into stock assessments?*
2.50	**Afternoon Tea**	

Innovative and Cost-effective Recreational Fishing Survey Options

3.20	Ken Pollock (Murdoch)	*Uses of dual frame sampling in recreational fishing surveys*
3.35	Bill Sawynok (FRDC)	*Community monitoring*
3.50	Andy Bodsworth (Olfish)	*The Olfish Recreational Fishing Data Logger - an overview*
4.05	You-Gan Wang (CSIRO)	*Use of BPC Surveillance data to estimate illegal foreign fishing effort in northern Australia: a potential approach to quantify recreational fishing effort in remote Commonwealth waters*
4.20	Julian Pepperell (PR)	*"Time-location sampling" to representatively sample hard-to-reach gamefish anglers*
4.35	Shane Griffiths (CSIRO)	*Catching the uncatchable: potential use of Respondent-Driven Sampling to obtain unbiased samples and population estimates for specialised recreational fisheries that lack a complete sampling frame*

Which Fisheries and Species Really Need Monitoring?

5.05 Build matrix of Commonwealth fisheries & species of interest and methods used by recreational fishers (e.g. boat-based, land-based, spear fishers etc) in order to choose potential survey methods

5.30 End of Day 1

Day 2

8.45 Tea and coffee

Discussion of Survey Methods and Issues for Monitoring Catch and Effort

9.00 Survey options and potential issues for estimating **effort** in each fishery

- List all methods that could be used in each fishery

- Discuss major biases or issues that need to be addressed in each fishery

9.45 - Breakout groups report back to the workshop

10.00 Options and issues for estimating **catch rates** in each fishery

- List all methods that could be used in each fishery

- Discuss major biases or issues that need to be addressed in each fishery

10.45 - Breakout groups report back to the workshop

11.00 Morning Tea

Discussion of Extensions to Existing Survey Designs to Improve Cost-effectiveness

11.30 - Existing attempts at monitoring recreational fishing in Commonwealth fisheries

- National Recreational fishing register to develop sampling frame

- Explore 'patchwork' options to link with ongoing state surveys

- Rank the most statistically robust survey options then rank by cost-effectiveness

12.45 Lunch

Post-workshop Method Evaluation and Testing

1.30 - Issues to explore to evaluate recommended methods (e.g. a phone survey for effort may only work with a complete sampling frame)

- Identify available datasets suitable for preliminary methods testing

- Cost-effective ideas for preliminary method testing (e.g. longtail online vs phone survey)

2.30 Recap, agree on choice of methods, and way forward to workshop 2

3.00 End of Workshop

Project Objectives

1. Undertake a comprehensive review of the global literature relating to the existing methods used to monitor recreational fishing, which may be transferable to Commonwealth fisheries

2. Develop innovative operational and statistical tools for collecting, integrating and analysing recreational fisheries data, for the purpose of integration into stock assessment and to support resource allocation in Commonwealth fisheries

3. Recommend a cost-effective and statistically robust long-term recreational fisheries monitoring program for Commonwealth fisheries

Goals of the workshop

1. To facilitate an exchange of the latest information between state, Commonwealth fisheries research and management agencies and fishery stakeholders relating to recreational fishing research including new survey approaches and technologies, issues and remedies identified for existing surveys

2. To identify the Commonwealth fisheries and species that have the highest interactions with recreational fisheries and prioritise their importance for monitoring

3. Recommend survey options for a long-term monitoring program for recreational fisheries in Commonwealth waters that can cost-effectively provide reliable estimates of the recreational catch of identified priority species

Supporting documents:

1. Recreational fisheries data requirements (Griffiths and Pepperell, 2006)

2. Global literature review of recreational fishing survey methods (Tonks *et al*.)

3. Respondent-Driven Sampling – Submitted Manuscript (Griffiths *et al*.)

Abstracts of oral presentations given at the workshop

Recreational fisheries catch monitoring – an AFMA perspective

Josh Fielding – Australian Fisheries Management Authority

Email: joshua.fielding@afma.gov.au

In managing Commonwealth fisheries, the Fisheries Management Act 1991 (the Act) requires that AFMA pursues multiple objectives including; cost-effective and efficient management; maximise the net economic benefit to the community; and ensuring the ecological sustainability of stocks. Clearly, in pursuing these objectives AFMA must consider all sources of fishing mortality, including recreational catch.

Under the Act, AFMA only has jurisdiction of recreational fishing, if it is written into a fisheries management plan. To date this has not occurred and recreational management has remained with the states. Understanding mortality to fish stocks from all sources, including the recreational sector, is important in sustainably managing a fishery.

It would be beneficial to the management of stocks if both the levels of and trends in recreational catch were better understood. Particularly as there are some fisheries where there is a high level of interaction between recreational and commercial fishers.

Australia also has international obligations to abide by in terms of catch of highly migratory fish stocks. Under some Regional Fisheries Management Organisations Australia is required to provide estimates of recreational catch.

Recfishing Research – FRDC Investment

Bill Sawynok – Infofish Services

Email: bill@info-fish.net

The current Recfishing Research project ends in June 2010. A new proposal has been submitted to FRDC to extend its life for another 3 years. It is proposed that FRDC use Recfishing Research to a greater extent in dealing with recreational fishing RDE. It is also likely that Recfishing Research will work closely with the federal Minister's Recreational Fishing Advisory Committee in the implementation of the Recreational Fishing Industry Development Strategy.

Data Needs vs. Data Wants – time for a change in focus

Len Olyott – Recfish Australia

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For a long time now, the recreational sector has been campaigning for the ongoing, long term collection of recreational fishing data from all Australian recreational fishers.

The most significant challenge to data collection has been jurisdictional where each state or territory identifies priority needs for data collection to support policy and management. The lack of comprehensive, national statistics is a frustration for peak industry bodies at both the national and state/territory level. Only one national survey was attempted in 2001 and the data from that survey are now dated and of limited use.

For Commonwealth waters, the situation is particularly challenging since no jurisdiction feels duty bound to consider recreational fishers. As a result, collection of even the simplest catch and effort data is not a priority for fisheries management agencies.

The time has come for recreational fishers to take responsibility for their own data collection programs. Advances in technology mean that Internet and other electronic media based survey instruments can now be cost-effectively deployed. Use of novel statistical methods with appropriate guidance from experts means that the industry can now deliver statistically robust data which can withstand peer review.

Recreational fishers and management agencies need to work in partnership to deliver recreational fishing data that are relevant and useful to the ongoing sustainable development of our fisheries.

A BRS perspective on priorities for monitoring recreational fishing in Commonwealth fisheries

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The Commonwealth's need for data and analysis related to recreational fisheries will be discussed in terms of stock assessment, socioeconomic assessment and other information required for policy development, particularly related to issues of resource sharing. Recent investigations of options for data collection will be discussed in the areas of economic valuation, social assessment, and community-government partnerships in fishery monitoring.

Prioritisation of Commonwealth fisheries and species to be monitored for recreational fishing interactions in Commonwealth waters

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Recreational fishing is a popular sport and social activity in Australia. Increasing population growth, tourism-based fishing and 'technology creep' have contributed to increasing recreational catches for some species; to the extent where the commercial catch is exceeded. Increasing affluence of recreational fishers, competition for inshore fishing grounds and improved technologies have contributed to an increase in recreational fishers travelling further to target Commonwealth-managed species such as billfishes, tunas, shelf/slope and reef species. However, the recreational fishing effort and impact on these species is poorly known. The purpose of this talk is to: 1) identify the Commonwealth fisheries where the interaction with recreational fisheries is highest, 2) prioritise species for a long-term recreational fishing monitoring program in Commonwealth waters and 3) identify the issues that need to be considered when choosing an appropriate survey approach.

Our review of the scientific literature and recreational fishing association records revealed that 1164 taxa from 247 families were caught by recreational fishers in Australia. Of these, 245 were considered to be of commercial importance in 20 of 21 Commonwealth fisheries. The fisheries having the highest number of interactions with recreationally-important species were SET (133 taxa), GHT (132), CSF (101) GAB (89), ECT and WDW (both 74). The fisheries with the fewest number of interactions were SCA (0), SBT (2), SQJ (5), and NWS (9). Species from three broad categories are recommended for inclusion in a long-term monitoring program of recreational fishing in Commonwealth fisheries. These include: 1) Pelagic fishes: tunas, billfishes, mackerels, and sharks (ECT, HSS, SBT, SPF, TSF, WTF), 2) Demersal slope and shelf species: a large number of species representing trevallies, snapper, elephantfish, gummy shark, flatheads, trevallas, warehous, gemfish, morwongs, trumpeters and barracouta (ECD, GAB, GHT, HST, NWS, SET, WDW), and 3) Tropical reef species: a large number of species representing including tropical emperors and snappers, coral trouts and cods, and amberjacks (CSF, NPF, NWS, TSF).

The final design of a monitoring program for recreational fishing in Commonwealth fisheries needs careful thought. Recreational fishers who target Commonwealth-managed species represent a minority of the general recreational fishing community, and a high proportion of their catch is not landed (i.e. tagged and/or released). Consequently, targeted sampling of these fishers is required to gather information on species and size composition of the catch, CPUE and total effort for inclusion in stock assessments.

Including data from recreational fisheries in Commonwealth stock assessments

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Data from recreational fisheries can be readily incorporated into stock assessment of Commonwealth stocks. However, the methods for and value of doing this will vary depending on the species, the assessment method, and type of management employed. I will briefly review the currently applied stock assessment methods in the southern and eastern shark and scalefish (SESSF) and eastern tuna and billfish (ETBF) fisheries, along with applications of the harvest strategy policy in these fisheries, with the purpose of indicating where data from recreational fishing can fit in to the process.

Methods for stock assessment of stocks within the SESSF and ETBF are typically determined by the types and quality of data available. The majority of stock assessments and applications of harvest strategies are catch driven, either as a result of needing to accurately account for removals in a population dynamics model, or applying the results of a data-poor stock indicator (such as recent trend in catch rates) to an estimate of current catch in order to determine suitable management action.

Full quantitative stock assessments typically fit statistical catch at age models to a variety of data sources, and are sufficiently flexible to incorporate a suite of data types from multiple fishing fleets, including data such as catch in numbers, estimates of mean length or weight, that may be more readily available from recreational data than, say the results of intensive logbook sampling, or length and age frequencies. However, less data intensive assessment methods may also gain value from the inclusion of representative recreational fisheries data when evaluating the impact of different fishing fleets on fish stocks, and subsequent translation to management response.

A global review of traditional and innovative methods for estimating catch and effort in recreational fisheries

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A global review of the various methods used to estimate recreational fishing catch and effort was undertaken. A brief overview of traditional survey methods is provided (on-site, off-site and complemented), including their advantages and disadvantages. Second, a summary is provided as to how the various recreational fishing survey methods have been applied globally, particularly in relation to spatial and temporal scales. Third, new cost-effective methods are discussed with respect to their usefulness for estimating recreational catch and/ or effort; some of which are currently in use and others that are theoretically applicable, yet untested in fisheries. Finally, examples of large scale marine surveys applied in the US are discussed with reference to estimating the catch and effort of large migratory pelagic species.

Recreational Fishing Surveys in New South Wales – why we do them and how we use the data

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Recreational fishing surveys can generate a variety of data that can be used by fisheries agencies to develop robust management plans to ensure the sustainable use of fisheries resources. Recreational fisheries data can be used to: (1) enhance stock assessments; (2) assess resource allocation issues: (3) assess the status of fish stocks and fisheries at various spatial scales; (4) monitor trends and changing patterns of fishing pressure, catch rates and total catches within and among fisheries through time; (5) measure the success (or otherwise) of management initiatives (e.g. Marine Park zoning); (6) assess environmental and anthropogenic impacts on fishers and fisheries; (7) monitor changes in the species composition of catches and the size structure of harvested fish populations; (8) describe the behaviour and perceptions of fishers (e.g. participation rates, targeting, avidity, economic expenditure, motivations and attitudes about resource management); NSW DPI has conducted a variety of off-site and on-site surveys over the past 20 years. The survey objectives and the spatial scale of survey coverage have greatly influenced the choice of survey methods used. A brief description of some previous and current surveys will be provided.

An overview of monitoring and assessment of recreational fishing in Queensland

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The role of Queensland Primary Industries and Fisheries (QPIF) Recreational fishing in Queensland is very popular with over 700 000 Queensland residents going fishing every year. This recreational fishing activity has developed substantial social and economic value within the state. Recreational fishers also harvest a large number of fish and crustaceans and for some fish such as snapper and tailor, the recreational catch far exceeds the commercial catch. In order to manage fish stocks on a sustainable basis, accurate estimates of recreational catch are required. The primary aim of QPIF's recreational fishing surveys is to provide accurate and precise recreational catch estimates (harvest and release) to fisheries managers, recreational fishers and for stock assessment.

Past monitoring Fisheries Long Term Monitoring Program which commenced in 1999 monitors biological characteristics of major recreationally important species throughout Queensland and provides inputs to comprehensive stock assessments. Between 1996 and 2005, QPIF delivered four state-wide catch and effort surveys using a telephone-12 month diary approach (known as the RFish surveys). The RFish surveys provided precise catch estimates for numerous commonly caught species and provided a good time-series of recreational catch, estimated using a consistent methodology. They also provided important information on the recreational participation rate.

These surveys were enhanced by complementary social surveys undertaken in the Great Barrier Reef region by James Cook University social scientists. In addition, QPIF participated in the National Recreational and Indigenous Fishing Survey (NRIFS) undertaken in 2000-2001 using a technique derived from that used in the NT Fishcount 96.

QPIF's recent recreational fishing survey efforts have focussed in southeast Queensland to field test regional scale survey strategies and provide more accurate and timely estimates of catch and effort for key southeast Queensland species. In 2007-2008, an access point bus-route method was trialled providing estimates of fishing effort and harvest and release by fishers launching from public boat ramps and the report will be available on our website before the end of 2009.

Current and future activities In 2010 a state-wide recreational fishing survey will commence. This survey will provide:
o Recreational fishing participation rate
o Accurate catch estimates for at least the top 15 recreationally caught species (state-wide and regional)
o Harvest and release, along with motives for release

The results of this survey will provide the first state-wide recreational catch estimates since a broad range of new management measures have been implemented (Great Sandy Marine Park zoning, rezoning of Moreton Bay Marine Park, East Coast Inshore Finfish Fishery management changes). Ongoing access point surveys collect representative length data and otoliths for aging key inshore demersal and pelagic species from recreational fishers.

Other current monitoring activities include the development of a cost-effective survey tool to monitor the recreational catch of rocky reef species and continuation of the Keen Angler Program as part of the Long Term Monitoring Program and the online Recreational Fishing Diary Program.

Issues The sheer geographical size of Queensland, diversity of species caught and the heterogeneous fishing characteristics of Queensland residents make designing state-wide recreational fishing surveys particularly challenging. The lack of a registration system to identify recreational fishers also makes it logistically difficult and expensive to quantify recreational catch and effort. Queensland Primary Industries and Fisheries will continue to optimize its state-wide and regional recreational fishing survey activities and work closely with stakeholders, other States and research organizations to ensure that it delivers comprehensive and accurate recreational catch estimates cost-effectively.

Evaluation of methods of obtaining annual catch estimates for individual Victorian bay and inlet recreational fisheries

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Project objectives:

1. Review survey methods used in the past to estimate total annual catches of key species in Victorian marine and estuarine recreational fisheries,

2. From the results of past surveys statistically assess the costs and sampling requirements of different survey methods for providing unbiased estimates of total recreational catch and effort, with acceptable precision,

3. Conduct a workshop to evaluate alternative angler survey methods,

4. Develop a cost-effective survey design that would, if possible, provide annual estimates of recreational catch for main recreational fisheries,

5. Trial the recommended design,

6. Review the success of the pilot survey at a second workshop and recommend a final survey design.

Project outcomes:

An innovative survey design was adopted for a phone-diary survey of coastal Victoria in 2006/07. The Recreational Fishing License database was used as the sampling frame in the screening survey. Consequently each call contacted a fisher with most anglers happy to talk about their fishing. This reduced sample costs, increased response rates and reduced non-response bias. Sampling from the Recreational Fishing License database also allowed disproportionate stratification (over-sampling) of avid anglers. This increased the number of fishing events and improved precision. A concurrent on-site survey to address bias in the sampling frame identified that the in-scope and out-of-scope anglers had similar catch rates, and potential bias from non-representation was minimal.

Recreational surveys in Western Australia

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During 2008/09, 603,000 Western Australians participated in recreational fishing with approximately 56% of these fishing in the West Coast Bioregion centred round the capital city Perth and several of the State's largest regional centres (Bunbury, Busselton and Geraldton). In Western Australia recreational fishing licences are required to fish for rock lobster, abalone and marron and to participate in freshwater angling and netting. During 2008/09 there were 61,385 varying combinations of recreational licences granted. A total of 28% of licences were granted and renewed on the Internet. Currently in Western Australia there is no license required for marine angling, which makes up the majority of recreational effort, however in March 2010, a new boat fishing licence will be introduced.

The large Western Australian coastline (20,781 km) remains a challenge to the collection of recreational catch and effort within the state. Furthermore the rapid northern regional development will both change the distribution and increase the total recreational catch and effort, particularly in this region of the state. In this context the challenge is the level of sampling and stratification required to survey a widely spread population. The lack of a registration or licensing system to easily identify shore-based recreational anglers also makes it logistically difficult to estimate total state catch and effort. The implementation of Integrated Fisheries Management (IFM) formalises sectoral allocation of sustainable fish resources between competing recreational and commercial fishers within the broad context of Ecologically Sustainable Development.

Major priorities for research are estimates of catch and effort in key recreational fisheries including west coast scalefish, abalone, rock lobster, marron, freshwater finfish and aquatic tour operator (charter) fisheries. In addition there is ongoing collection of age samples of key recreational species especially in areas where there is no commercial fishing that may be used as inputs to determine the stock status of these species. Monitoring strategies for the collection of ongoing research information from recreational fisheries include a number of survey methods run simultaneously. These methods include creel, telephone, compliance contacts, fisheries volunteer interviews, angler volunteer logbooks and remote technologies such as cameras and road counters. Outcomes are cost effectiveness methods to estimate catch and effort.

Large-scale Assessment of Recreational Fisheries in the Northern Territory – 1995 to 2009

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Fishcount 95 represented the first comprehensive assessment of recreational fishing in the Northern Territory and provided valuable information on participation, catch and effort, fishing-related expenditure and the opinions/awareness of resident fishers. Limited information was also collected for fishers from interstate and overseas. After refinement of the telephone-diary survey methodology used in this study, a major national survey of recreational fishing was conducted in 2000/01 (NRFS), conforming to the second large-scale assessment. By design, interstate visitors were routinely covered by the NRFS and confirmed that the NT had the highest level of 'imported' fishing activity of all states (around 30% of recreational catch and effort in the Territory). Indigenous fishing activity was also assessed in a separate study component. The third territory-wide assessment is currently being conducted through a telephone-diary survey of residents and in the absence of a repeat of the NRFS, cost-effective assessment of the visitor component has been a major challenge. After extensive 'mining' of the NRFS database, a program of on-site surveys is being conducted at various boat ramps and accommodation establishments across the Territory. Despite temporal and spatial coverage limitations, these on-site surveys will assess visitor catch and effort for eight key catchments, identified as fisheries management priorities. After this project, potential areas of improvement for future survey will be explored.

QGFA Logbook Program - a framework of data collection, self monitoring and model for information supporting co-management arrangements

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The QGFA logbook program has now been in operation for 14 years. The organisational and club points system supports a model that encourages self reporting. What are the advantages and pitfalls? Where to from here?

Horses for New Zealand courses: how the development of the aerial access method has progressed our ability to assess harvests from large scale recreational fisheries

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The first concerted attempts to estimate recreational harvests in New Zealand followed self reported telephone diary methods similar to those used in the RFISH surveys in Queensland. The most recent of these surveys, in 2001, produced harvest estimates which were clearly implausible. A detailed examination of the data collected in these surveys led to the abandonment of this approach. An alternative on-site method was required which could be used to cost effectively estimate boat based harvests along coastlines in excess of 1000 km. We have developed a form of Aerial-Access survey which combines aerial counts made at the time of peak fishing effort with catch census data collected at a subsample of available ramps. Rigorous reviews of four surveys have led to the conclusion that, this method can be used to provide plausible harvest estimates for many key fisheries, and this is now the harvest estimation method of choice in New Zealand.

It is recognised, however, that not all forms of fishing effort are assessable from the air. A dual method programme is proposed for 2011–12, whereby the results from an aerial-access survey will be used to validate/calibrate estimates obtained from a telephone-diary survey which is capable of providing harvest estimates for all fisheries, and not just those that are assessable from the air. This telephone diary survey will be based on the methods currently used in Australia, which are thought to minimise many sources of bias. This proposal appears to be the first attempt to independently, concurrently and rigorously compare the results of a large scale off-site survey with those collected via an on-site method of a similar scale.

Understanding the gamefish fishery of Tasmania with particular reference to southern bluefin tuna

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The gamefish fishery is a small but specialised component of the overall recreational fishery that is socially and economically very significant. Assessing catch and effort and other values of this fishery are particularly important in the context of the management of southern bluefin tuna. There have been several surveys employing different methodologies that have provided information on the fishery; the strengths and weaknesses of each will be discussed briefly along with a consideration of alternative options to improve reliability in estimates and survey coverage.

Commonwealth managed fish species caught by SA resident recreational fishers in South Australia – comparing two survey methods to estimate their catches

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South Australian recreational fishers have access to a number of Commonwealth managed finfish species that also have state-regulated minimum size and/or personal daily bag and boat limits. These species include bight redfish/nannygai, gummy/school sharks, gemfish, barracouta, ling, blue-eye trevalla and the tunas (southern bluefin, yellowfin and albacore). Catch information (total, harvested and released numbers) by recreational fishers are available from two independent sources: Firstly, comprehensive state-wide surveys of the entire SA recreational fishery in 2000/01 and 2007/08, using the phone-diary survey method. Secondly, since 2005, compulsory trip logbook data have been collected from the licence-managed recreational charter boat fishery in SA marine waters. The merits of both survey methods in providing catch estimates with associated levels of precision and the potential for their validation are discussed.

Gamefish Tournament Monitoring in NSW: Can this historical dataset be integrated into stock assessments?

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Club-based gamefishing is a relatively organised sector of the recreational fishery. Their organisational structure involves the recording of both catch and effort information through their mandatory radio schedule reporting system (Scheds). Scientific monitoring of gamefish tournaments was initiated in 1993/94 using this system as a basis for data collection. This was considered to be a cost-effective method to collect long-term spatial catch and effort information for this fishery because of the difficulties of accessing fishers who target gamefish species using traditional survey techniques. It was recognised, however, that Scheds can not provide complete information on targeting practices or the catch of species which are not associated with competition points (such as fish that are either kept for food or used as bait). An on-site post-fishing interview component was therefore incorporated into the monitoring regime. These data represent one of very few historical datasets for the east coast recreational gamefish fishery. The need to evaluate this monitoring program with the objective of incorporating this historical data set into formal stock assessment processes will be discussed. Future work needs to be focussed on appropriate documentation and analysis to identify the strengths and weaknesses of this dataset for the management of fish stocks that are primary target species of this fishery.

Uses of dual frame sampling in recreational fishing surveys

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The existence of a complete list frame of recreational anglers makes implementation of sample surveys much more efficient in practice. Unfortunately this is often not true and here I discuss how to use ideas of dual frame sampling when only an incomplete list of anglers is available. The general idea is that one can combine two samples from two different frames together to achieve complete coverage of a population of interest. The costs of the sampling in the different frames may be very different and optimal allocation rules can be developed. The theory has been well developed and applied widely in many areas of application but not in recreational fisheries. Here I will present the key ideas of the approach and then speculate about how it could be used in different ways in recreational fisheries. One possible application is in a telephone survey where one could use a partial list frame of anglers combined with random digit dialling of the general population to get at anglers not on the list frame. Another possible application to specialized recreational fisheries (say large pelagics like marlin) would be to build a partial list of anglers based on membership lists in fishing clubs and take a sample from that list. Then augment this by some other method such as using Respondent-Driven Sampling (a form of "snowball sampling") for the non-club members.

Community monitoring

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When undertaking community monitoring in fisheries it is necessary to develop new approaches to collecting data, especially when using volunteers. CapReef has been a program set up in Central Queensland that collected data over the past 4 years using a mix of volunteer and paid effort. What are the best ways of developing community monitoring programs?

The Olfish Recreational Fishing Data Logger - an overview

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High-quality recreational catch and effort information is difficult and expensive to obtain. The lack of this information continues to complicate the management of a range of recreational fisheries within Australia. This comes at a time of increasing community and regulatory interest in cost effective and efficient management of individual fish stocks, and the broader marine environment.

Olfish Australia has developed an online recreational fishing logbook (the Olfish Data Logger) that allows quick and efficient entry of detailed recreational fishing information by anglers. It is based on a commercial fishing version developed in recent years by Dr Ian Knuckey and Dr Amos Barkai of OLRAC Pty Ltd. The commercial fishing version is popular because it is easy to use and cost effective, and offers a powerful capability to improve fishing and business outcomes. It also enables cost effective and efficient catch and effort data collection for science and management.

The recreational version offers similar potential however faces some unique challenges, principally with respect to data quality. Sources of bias that may undermine data quality are likely to include: not all active anglers have easy access to the internet, or are internet savvy; participation costs (money and/or time) associated with data entry influencing the quality of data entered; anglers may not be interested in entering their data without a strong incentive; anglers may be concerned that their data may be used inappropriately - i.e. to justify additional management controls (bag or size limits), and/or reduced access to the resource through spatial closures or marine Park Sanctuary Zones.

In a more positive light, and assuming data bias issues can be understood and managed, the data logger and the site's software interface has some significant benefits:

• It has been designed to help anglers improve their success and the quality of their fishing experiences by building a personal database of key angling information and success factors, including relationships between variables like tides, gear used, and water temperatures.
• It is based on proven internet based software currently used to collect and analyse commercial fishing catch and effort data within Australia and internationally, and is ready to use;
• It provides a very cost effective and simple data collection platform to collect near real time data in a common format over very large spatial scales;
• In time it may generate higher levels of engagement from anglers in the processes of data collection and management, and may improve their understanding and stewardship of recreational fishing impacts.

In March 2009, a one month live trial of the Olfish DL was successfully conducted in WA. Angler feedback from the trial was positive and has been used to improve the ease of use and functionality of the DL. Olfish is currently making final changes to the software with a view to further user trials and initial implementation early in 2010.

Use of BPC Surveillance data to estimate illegal foreign fishing effort in northern Australia: a potential approach for recreational fisheries

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In survey sampling, we often collect data in a biased way due to logistical reasons or budgetary constraints. We consider population estimation from data when sampling is biased and quantification of bias in sampling is difficult. Sampling recreational fishing vessels in remote areas in Commonwealth waters is both difficult and expensive. BPC undertakes routine surveillance flights on most days around Australia to the extent of the EEZ, where all vessel types, including recreational vessels, are recorded. This data has been critical for the estimation of fishing effort by illegal foreign fishing vessels in northern Australia that target shark for their valuable fins. We propose use of these data as a cost-effective means to estimate the fishing effort by recreational fishers in Commonwealth waters. There are, however, potential biases in the survey method because "high risk" regions where illegal activity is highest (e.g. northern Australia) are more frequently surveyed. A simple grid-based estimation methodology is described to overcome a number of issues for obtaining reliable estimates of the FFV numbers, which can similarly be applied to the recreational fishing fleet in Commonwealth waters.

"Time-Location Sampling" to representatively sample hard-to-reach gamefish anglers

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Obtaining representative samples from rare or minority populations is difficult and expensive using probabilistic survey methods. There are several specialised components of the recreational fishing community that are physically to locate in the absence of a complete sampling frame (e.g. gamefish anglers). Time-Location Sampling (TLS) is a non-probabilistic sampling method commonly used in epidemiology and social sciences that capitalises on the fact that some rare populations tend to gather at specific locations at particular times, such as intravenous drug users at 'shooting galleries, sex workers on street corners and 'red light' districts, and homeless persons at shelters. In an attempt to representatively survey gamefish anglers, a preliminary trial of TLS was undertaken using tackle store customers to account for both the club and non-club anglers. Although the method was successful in cost-effectively obtaining a reasonable sample size of anglers, several sources of bias are likely to occur if many anglers buy their tackle over the internet or overseas. The primary problem with the method is that it only provides data on catch rates, and so other methods are required to estimate population size in order to estimate total catch.

Catching the uncatchable: Potential use of Respondent-Driven Sampling to obtain unbiased samples and population estimates for specialised recreational fisheries that lack a complete sampling frame

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Increasing population size of coastal cities, availability, affordability and improvements of boats, searching technologies (GPS, sonar, etc) and fishing tackle (e.g. electric reels), have resulted in increased efficiency and diversification of the recreational fishing sector. Specialised recreational fisheries have developed for many species that have traditionally been commercial targets in Commonwealth fisheries (e.g. swordfish, blue eye trevalla, etc) which, in some cases, has led to conflict between commercial and recreational sectors. As a result, there is a critical need to obtain robust estimates of the recreational catch for inclusion in stock assessments and to ensure resources are sustainably harvested and shared equitably among stakeholders.

However, obtaining unbiased estimates of catch and effort is problematic for specialised recreational fisheries that typically lack a complete sampling frame (e.g. fishing licence). Traditional probability-based sampling methods (e.g. creel or telephone surveys) are expensive and often inadequate for obtaining representative data from small hard-to-reach components within recreational fisheries (e.g. the gamefish fishery) that probably account for the majority of the catch for some species.

Researchers in epidemiology and social sciences routinely survey rare, 'hidden' or hard-to-reach populations within the general community (e.g. HIV carriers, sex workers, illicit drug users) by penetration of social networks rather than by interception of individuals. The method of using Respondent-Driven Sampling (RDS) a form of chain-referral (or 'snowball') sampling, is introduced as a cost-effective means of obtaining an unbiased sample of fishers from elusive specialised recreational fisheries that lack a sampling frame. By undertaking a capture-recapture survey within the RDS survey, it is demonstrated how the population size can also be estimated using heterogeneous mark-recapture models, and thus, allowing the total recreational harvest to be estimated for these small specialised fisheries.

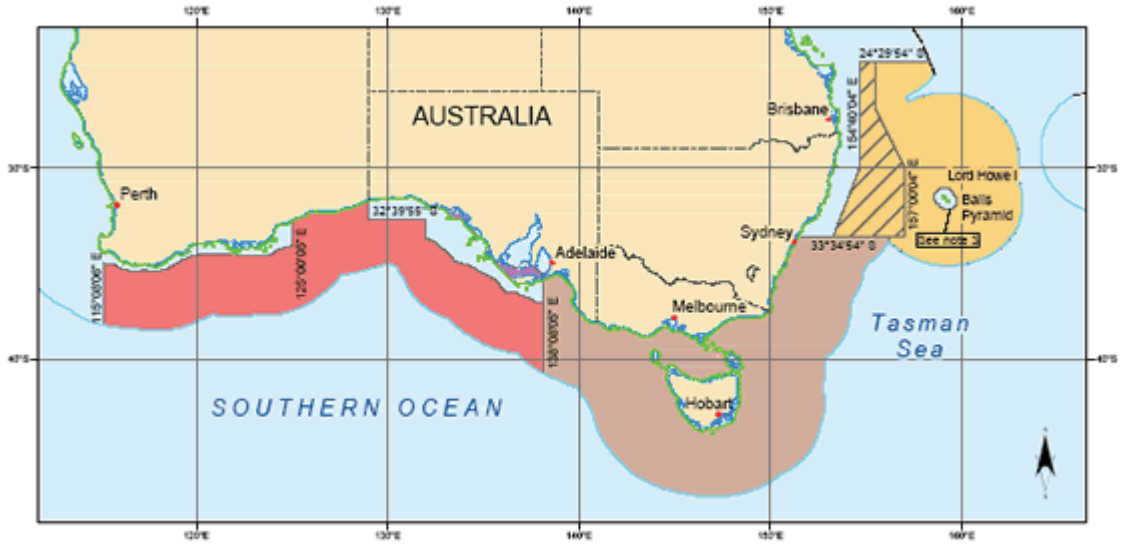
Commonwealth fisheries and their primary target and bycatch species
(Fishery maps courtesy of AFMA – www.afma.gov.au)

Coral Sea Fishery (CSF)

Principal Species

- Alfonsino
- Flame Snapper
- Gemfish (minor)
- Hapuku
- Bass Groper
- Longfinned bullseye
- Redbait (mixed)
- Temperate basses & rockcods
- Bar Rockcod
- Blacktip shark (mixed)
- Blue-eye Trevalla
- Paddletail Seabream
- Rosy Snapper
- Ruby Snapper
- Scalloped Hammerhead
- Tiger Shark
- Whitetip Reef Shark
- Grass Emperor
- Pelagic morid and eucla cods
- Purple Rockcod
- Red Emperor
- Redthroat Emperor
- Spotcheek Emperor

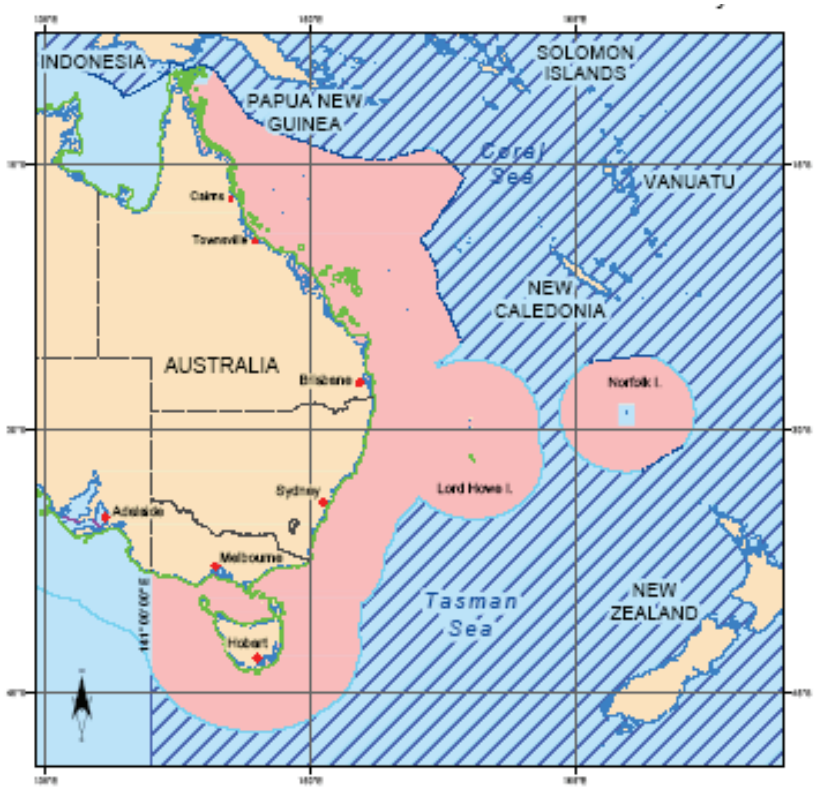
East Coast Deepwater Trawl Fishery (ECD) (shaded in orange)



Principal Species

- Alfonsino
- Blue-eye Trevalla
- Orange Roughy

Eastern Tuna and Billfish Fishery (ECT)



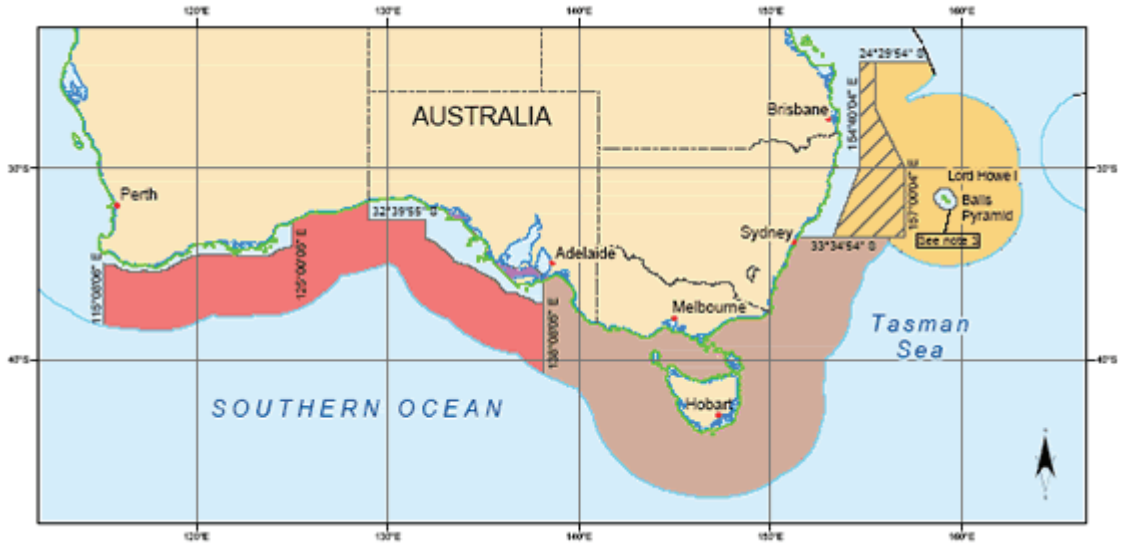
Principal Species

- Broadbill swordfish
- Yellowfin tuna
- Bigeye tuna
- Albacore tuna
- Longtail tuna
- Striped marlin

Bycatch

- Ray's bream (pomfret)
- Rudderfish
- Dolphinfish
- Black oilfish
- Skipjack tuna
- Wahoo
- Shortfin mako
- Shortbill spearfish
- Moonfish
- Oilfish
- Bronze whaler
- Blue shark
- Hammerhead shark
- Oceanic whitetip shark
- Lancet fish
- Tiger shark
- Blacktip sharks
- Northern bluefin tuna
- Indo-Pacific sailfish

Great Australian Bight Trawl Fishery (GAB) (shaded in red)



Principal Species

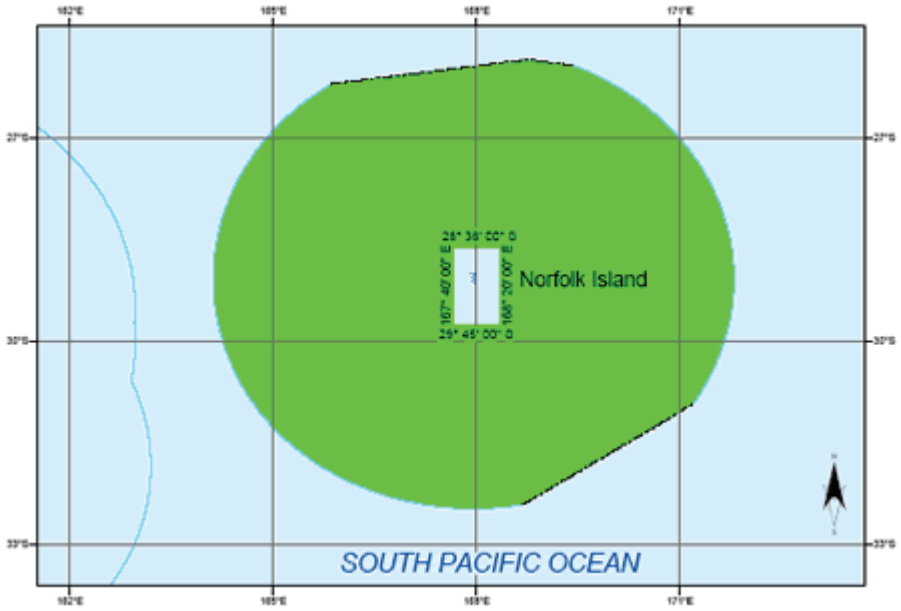
- Alfonsino
- Deepwater flatheads (5 species)
- Blue-eye trevalla
- Pink ling
- Gemfish
- Hapuku and Bass Groper
- Blue Grenadier
- Orange roughy
- Oreo dories

Gillnet, Hook and Trap Fishery (GHT)

Principal Species

- Blue-eye trevalla
- Pink ling
- Gummy shark

Norfolk Island Fishery (NFO)



Norfolk Island Offshore Demersal Finfish Fishery (NIODFF) – currently no commercial fishing
The Norfolk Island Inshore Fishery - currently no commercial fishing

- Island residents target trumpeter (*Lethrinus miniatus*)

Northern Prawn Fishery (NPF)

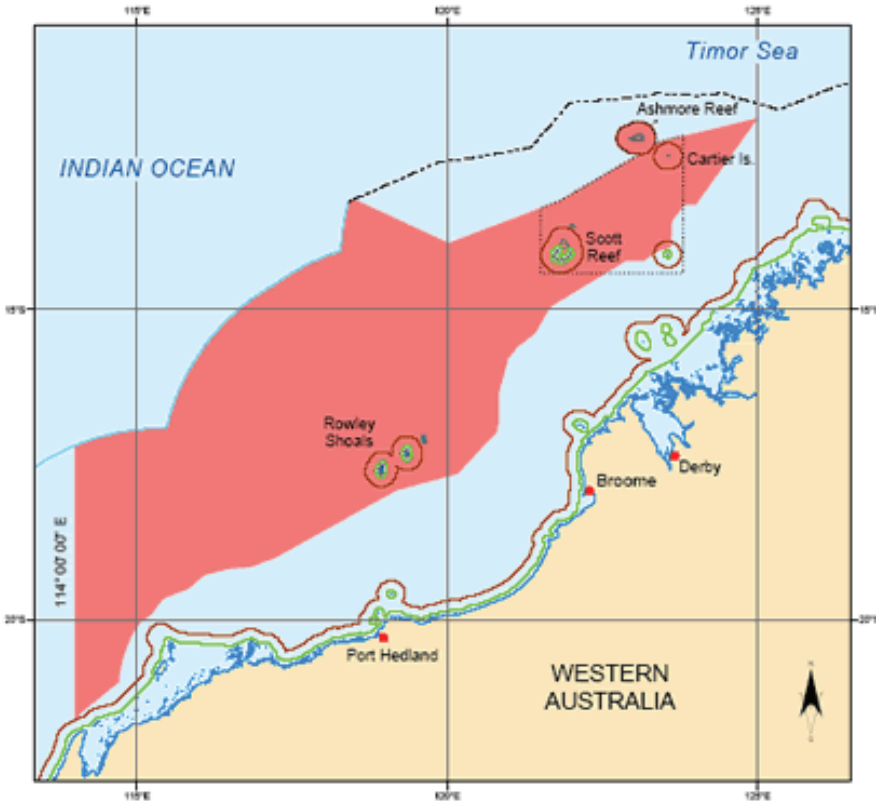
Principal Species

- Tiger, Banana and Endeavour prawns

Bycatch species

- all Lethrinidae
- Grey mackerel
- Gold band snapper
- all serranidae
- Longtail tuna
- Spanish mackerel
- Saddle tail snapper
- Red snapper
- Red emperor

North West Slope Trawl Fishery (NWS)



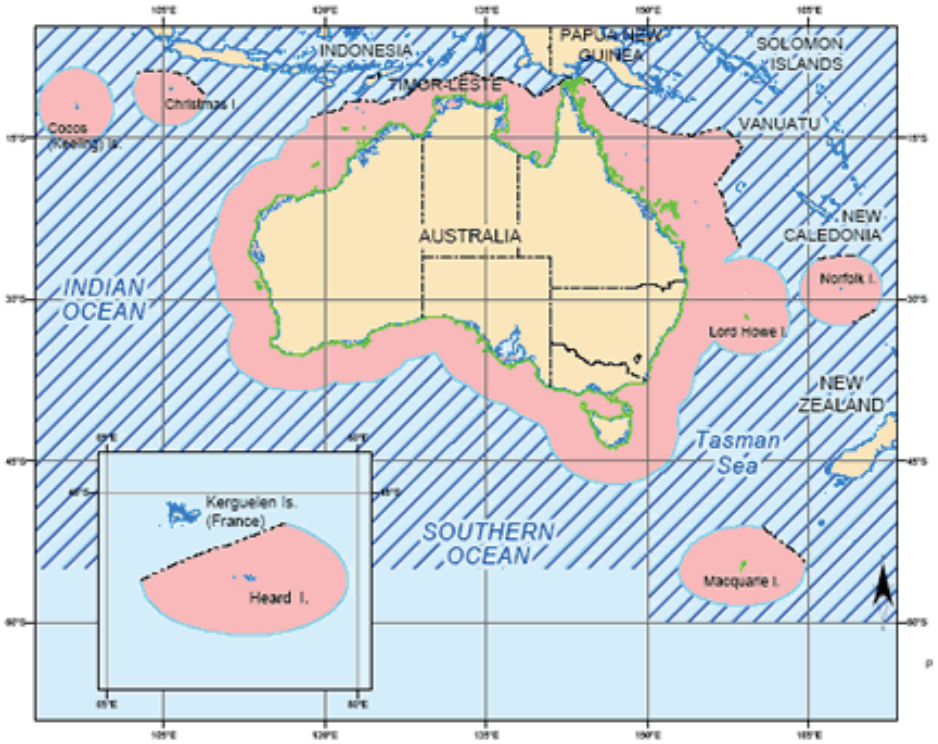
Principal Species

- Scampi and deepwater prawn

Bycatch

- Gummy Shark
- Sandbar Shark
- Tiger Shark
- Blacktip sharks
- Dogfishes
- Stingray
- Ghost shark
- Ogilbys Ghost Shark
- Elephantfish
- Eel
- Cucumber Fish - Montigue Mullet
- Lantern fishers
- Coffinfish
- Whiptail - Rattail
- Redfish
- Dealfish
- Red Gurnard
- Jack Mackerel
- Sea Bass
- Sea Bream/Deepsea Snapper
- Stargazer

Southern Bluefin Tuna Fishery (SBT)



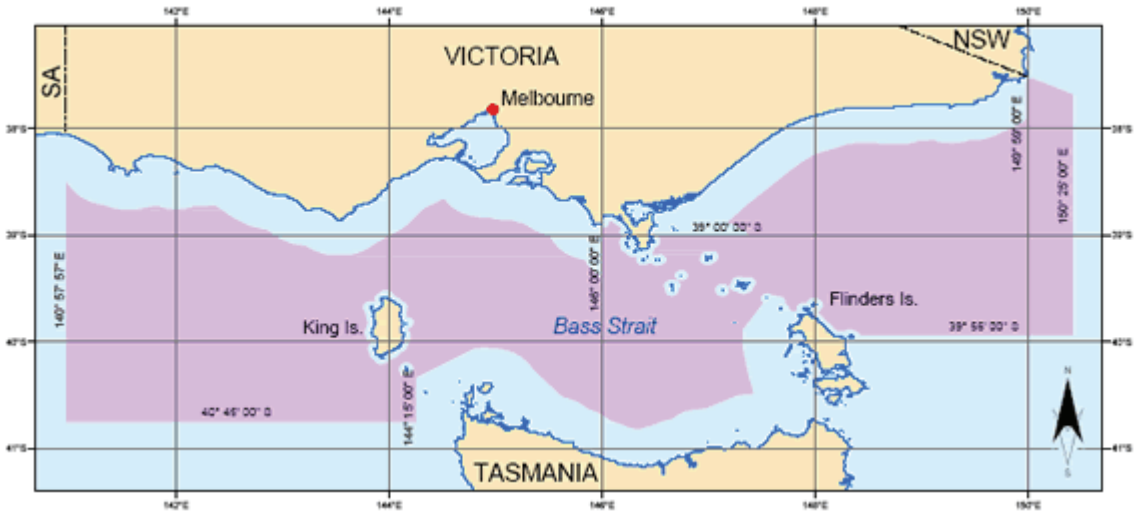
Principal Species

- Southern bluefin tuna

Bycatch

- Skipjack
- Albacore

Bass Strait Central Zone Scallop Fishery (SCA)



Principal Species

- Commercial scallops (*Pecten fumatus*)

Bycatch

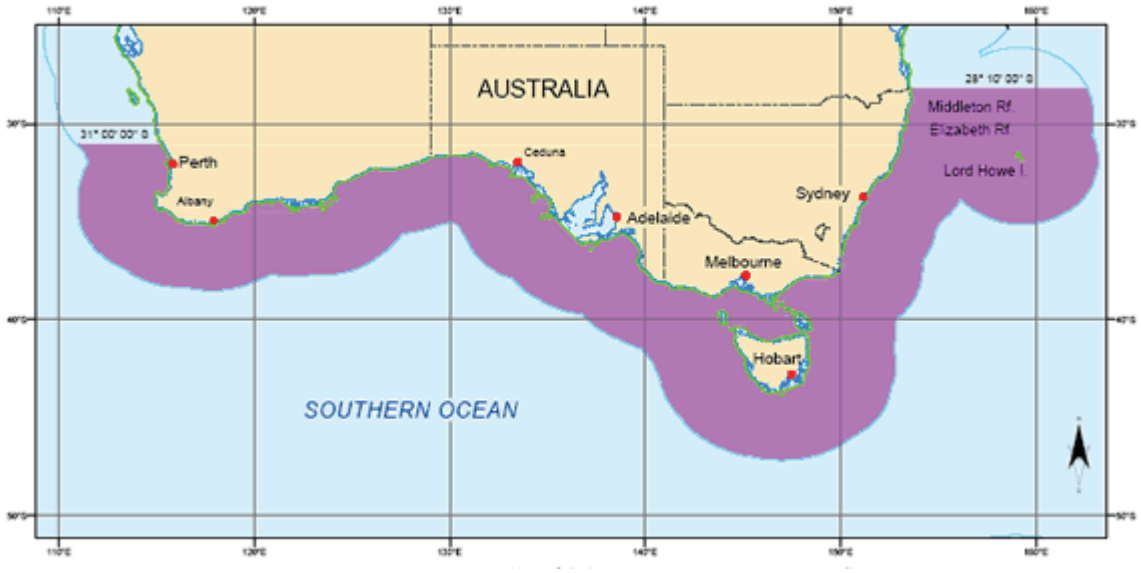
- Flathead (minor)
- Flounder (minor)

South East Trawl Fishery (SET) (shaded in brown)

Principal Species

- Blue eye trevalla
- Blue grenadier
- Blue warehou
- Elephant fish
- Flathead
- Gemfish (East and West)
- Gummy shark
- Jackass morwong
- John dory
- Ling
- Mirror dory
- Ocean perch
- Silver trevally
- Spotted warehou
- Smooth dory
- Ribaldo cod
- Oreo dories
- Deepwater sharks

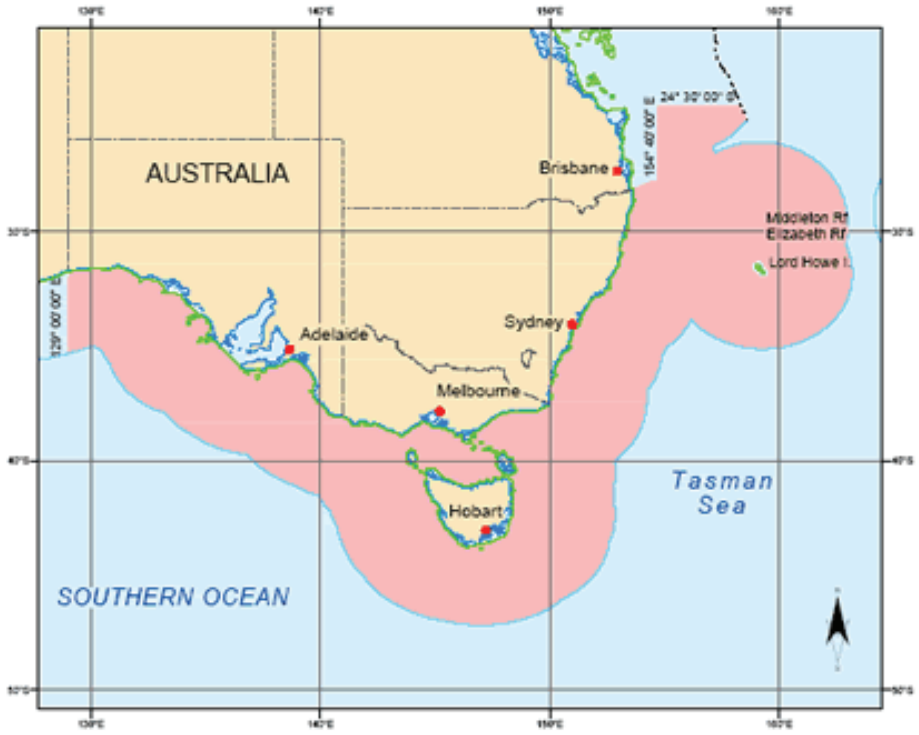
Small Pelagic Fishery (SPF)



Principal Species

- Blue mackerel
- Jack mackerel
- Yellowtail scad
- Redbait

Southern Squid Fishery (SQJ)



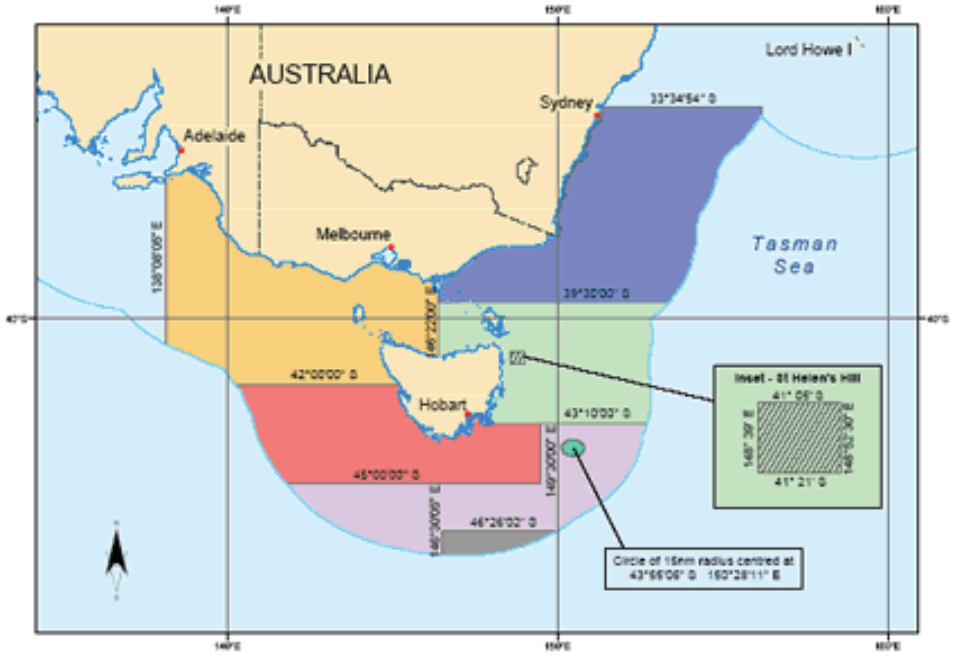
Principal Species

- Arrow squid

Bycatch

- Blue shark (minor)
- Barracouta (minor)

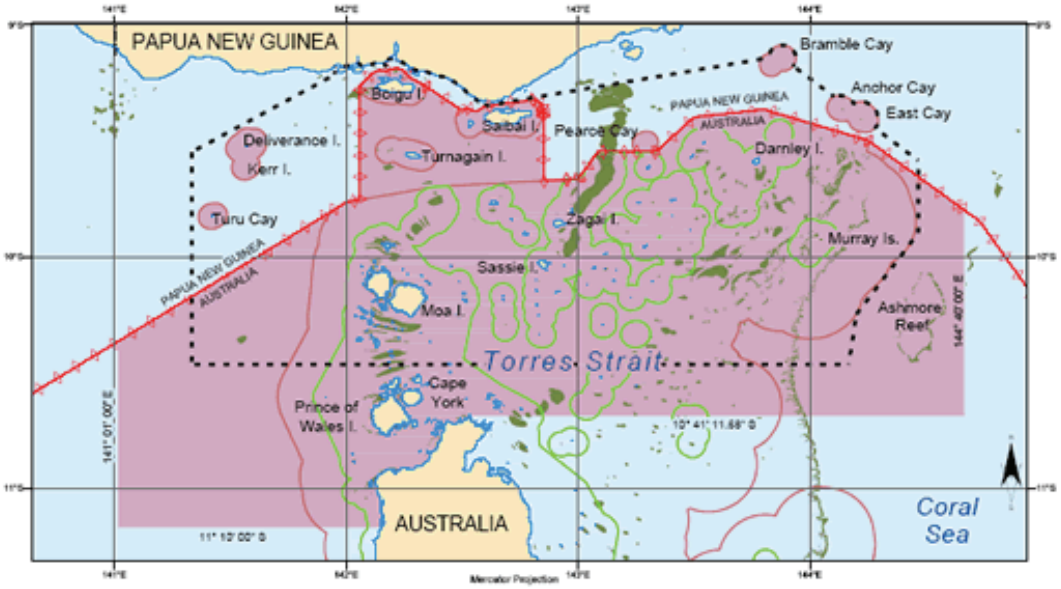
South Tasman Rise Fishery (STR) (shaded in grey)



Principal Species

- Orange roughy
- Oreo dory

Torres Strait Rock Lobster, Spanish Mackerel and Reef Line Fishery (TSF) and **Torres Strait Prawn Fishery (TSP)**



Principal Species

- Rock lobster
- Spanish mackerel
- Prawn
- Coral trout
- Lutjanus spp. (Red Emporer)
- Lethrinus spp. (Spangled Emporer)
- Rock cods
- Maori wrasse
- Black kingfish
- Trevally
- Barramundi fishery also exists within the Torres Strait Finfish Fishery but is limited to the territorial waters adjacent to the six Australian islands in the north west of Torres Strait near the Papua New Guinea coast: Saibai, Boigu, Moimi, Kaumag, Aubusi and Dauan

Western Deepwater Trawl Fishery (WDW)

Principal Species

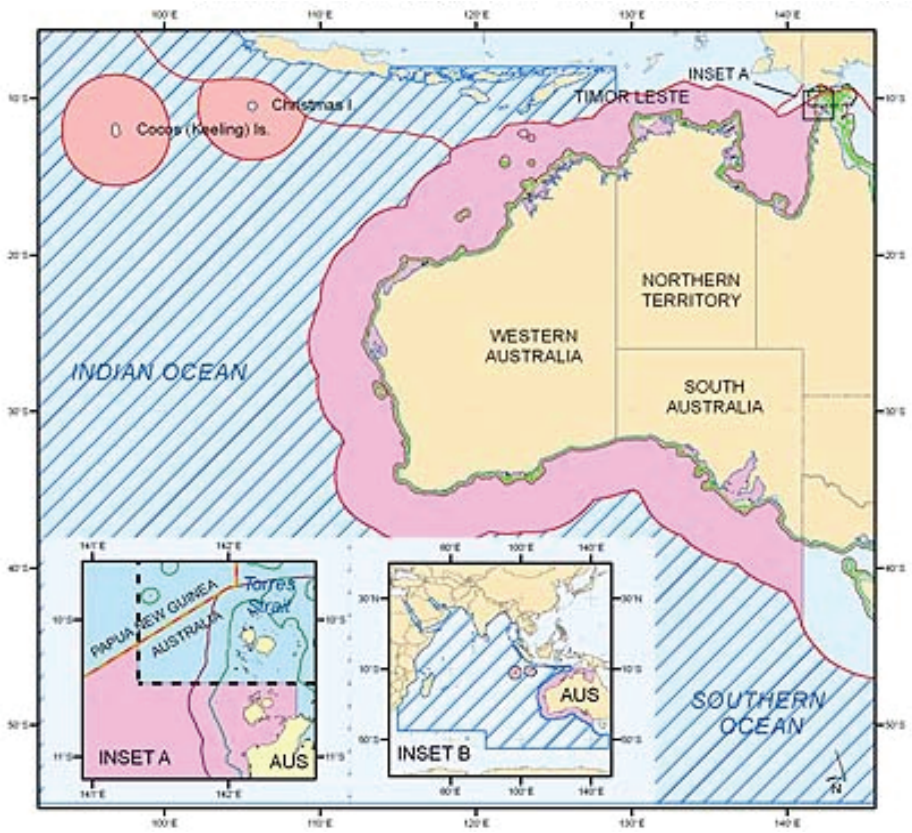
Southern Regions (generally deeper waters 300->700m)
- Orange roughy
- Oreo dory
- Big spine boarfish
- Alfonsino
- Mirror dory
- Gemfish
- Deepwater flathead

Northern Regions (shallower 200-400m)
- Ruby snapper
- Tang's snapper
- Apsiline snappers
- Sea bream (Lethrinidae)

Bycatch

- Poorly understood

Western Tuna and Billfish Fishery (WTF)



Principal Species

- Broadbill swordfish
- Yellowfin tuna
- Bigeye tuna
- Albacore tuna
- Longtail tuna

Bycatch

- Blue sharks
- Crocodile sharks
- Lancetfish
- Dolphinfish
- Escolar
- Oilfish
- Rudderfish

16.6 Appendix 6

Agenda for Workshop 2

Final Recommendations for a recreational fishing monitoring program in Commonwealth waters, 1 June 2010, CSIRO Cleveland Laboratories

Developing innovative and cost-effective tools for monitoring recreational fishing in Commonwealth fisheries

Recreational Fishing Monitoring Methods Workshop 2

1 June 2010

CSIRO Marine and Atmospheric Research, Cleveland Laboratories

Project Principal Investigator: Dr Shane Griffiths

Chair: Dr Julian Pepperell

8.45	Tea and coffee	
9.00	Rodrigo Bustamante (CSIRO)	*Welcome address, OHS, and attendee introductions*
9.15	Bruce Wallner (DAFF)	*Recreational fisheries monitoring - a DAFF perspective*
9.30	Matt Daniel (AFMA)	*Recreational fisheries monitoring - an AFMA perspective*
9.45	Len Olyott (Recfish Australia)	*The need for recreational fishing data from Commonwealth waters*
10.00	Julian Pepperell (PR)	*Outcomes of Workshop 1 - Prioritisation of Commonwealth fisheries/species requiring monitoring & feasible survey methods*
10.30		**MORNING TEA**
10.45	Gavin Fay (CSIRO)	*Including data from recreational fisheries in Commonwealth stock assessments*
11.15	Bill Venables (CSIRO)	*Assessment of Recreational Fishing Effort: A technique using aerial surveillance*
11.45	Shane Griffiths (CSIRO)	*Sampling 'hard-to-reach' recreational fishers using Respondent-Driven Sampling and Time-Location Sampling*

12.15	Shane Griffiths (CSIRO)	*Cost estimates of monitoring options and recommended final monitoring program*
12.30		**LUNCH**
1.00	Discussion	*Which methods will realistically work? Is further method development required first? Where to from here? Who is responsible for running and funding a monitoring program?*
2.00	**End of Workshop**	

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