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Time-location sampling with capture-recapture to assess specialised recreational fisheries

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ABSTRACT

Specialisation in recreational fisheries has led to increasing diversification and segmentation of fishers into small 'hard-to-reach' populations that are inherently difficult and costly to sample using traditional methods. In this paper, we quantitatively assess, and expand upon, time-location sampling (TLS) for a specialised recreational sport fishery off eastern Australia using stratified random sampling of fishing tackle stores as aggregation points for fishers. Multiple TLS survey events facilitated the use of capture-recapture models to provide a minimum population size estimate of 3185 (SE 1338) fishers in the study region in 2010. Adopting a questionnaire with a long recall period (e.g. 12 months) may introduce biases in estimates of effort and catch from TLS. Therefore, these biases were corrected for using a 'benchmark' on-site survey, providing minimum estimates of effort and catch of 172,438 (SE 8440) angler hours and 4.7–31.4 (SE 2.6–6.8) t for six pelagic species, respectively, in the study region during 2010. TLS with capture-recapture is an efficient method for sampling hard-to-reach specialised fishers and may yield annual estimates of population size, effort and catch. Further research is needed to refine methods and develop systematic protocols that may be applied to a wide range of hard-to-reach populations, including recreational, artisanal and illegal fisheries.

1. Introduction

Recreational specialisation occurs in most sport and social activities whereby a continuum of participation behaviour exists, ranging from generalist to specialised participants (Bryan, 1977). Specialisation within a recreational community is often concomitant with increasing experience in a particular activity; however, it may also arise as new equipment or techniques allow more specialist participation (Ditton et al., 1992). Specialist participants often differ in preferences, motivations and attitudes to those of generalists, and may also place more value on a specific resource or experience (Bryan, 1977; Ditton et al., 1992; Scott and Shafer, 2001). These specialists often represent only a small component of the wider community; however, it is often vital that they are included in representative survey designs to allow for comprehensive and adaptive assessment and management (Ditton et al., 1992; Fisher, 1997).

Recreational fishing is a popular sport and leisure activity worldwide that is rapidly diversifying into several specialised subcomponents (Cooke and Cowx, 2004; Fisher, 1997). Affordability of sophisticated fishing technologies (e.g. electric fishing reels), improved transfer of knowledge (e.g. internet forums) and development of competitive fishing (e.g. fishing clubs and tournaments) has facilitated an increase in the specialisation of fishers and the overall fishing power of the recreational sector (Cooke and Cowx, 2004; Fisher, 1997; Griffiths et al., 2013; McPhee et al., 2002). Specialised fishers generally have more fishing experience (i.e. total years fishing) and often favour more challenging fishing methods (e.g. fly fishing) and target species (i.e. billfishes) whereby individual fish size and quality is more valued than number of fish caught (Bryan, 1977; Ditton et al., 1992; Fisher, 1997). Specialised recreational fisheries are also starting to interact with species that have traditionally only been commercially caught (e.g. tunas and swordfish). As such, there is an increasing need to quantify recreational catch for population assessment, resource allocation among competing sectors, and management (Cooke and Cowx, 2004; Griffiths et al., 2013; Zischke et al., 2012).

Despite the increasing importance of specialised recreational fisheries, they are poorly understood, mainly due to the difficulties in representatively sampling these relatively small populations of

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fishers (Griffiths et al., 2010b). Recreational fishing is undertaken by approximately 11.5% of the global population (Cooke and Cowx, 2004), and although specialised fishers may represent only a small percentage of the recreational fishing community, they may take the vast majority of the total recreational catch of some species (Griffiths et al., 2013; Zischke et al., 2012). Specialised recreational fisheries are often poorly represented in large-scale general recreational fishing surveys that commonly employ traditional survey methods such as general population telephone surveys. This is not only because these fishers are rare, but also because they utilise a range of fishing modes from various access points to the fishery (e.g. large vessels departing private marinas, land-based fishing etc.). Therefore, innovative approaches adapted from epidemiology and social sciences have been suggested as an alternative since they are designed to sample rare, hidden or 'hard-to-reach' populations (Griffiths et al., 2010b).

Time-location sampling (TLS) is one such method, which capitalises on the tendency of specific groups of people to aggregate at particular locations during certain times. TLS has been used to investigate recluse, stigmatised, 'hidden' and hard-to-reach populations such as drug users, HIV carriers and men who have sex with men (Muhib et al., 2001; Stueve et al., 2001; Watters and Biernacki, 1989). TLS increases sampling efficiency and stratified random sampling within a 'sampling universe' allows a probability-based sample to be obtained from the target population. Griffiths et al. (2013) recently undertook preliminary trials of TLS for accessing specialised recreational fishers and identified tackle stores as key aggregation points for fishers who represent the full spectrum of fishing modes, experience and avidity levels.

Hard-to-reach populations often suffer from incomplete or non-existent sampling frames due to the elusiveness of individuals and the inability of large-scale registrars or networks to distinguish small, segmented groups. As such, survey results (i.e. recreational catch) cannot be extrapolated to the entire population since the population size is unknown. Novel methods from other scientific disciplines, such as respondent-driven sampling, snowball sampling and multi-stage sampling, have been combined with capture-recapture methods to estimate the size of hard-to-reach populations (Archibald et al., 2001; David and Snijders, 2002; Mastro et al., 1994; Tate and Hudgens, 2007). Recently, capture-recapture has been incorporated into fishing surveys, with a two-stage sampling design used to estimate participation rates of subsistence and recreational fishers in South Africa (Ellender et al., 2010). Therefore, multiple survey events may facilitate the use of capture-recapture models to estimate population size of specialised recreational fisheries (Griffiths et al., 2013; Pollock et al., 1990).

The recreational sport fishery off eastern Australia is a complex, multi-species fishery where specialised fishers use rod and reel and spear fishing methods to target large pelagic predators such as tunas and billfishes. Participation, effort and catch are temporally and spatially dynamic, as pelagic fish distributions are influenced by environmental factors such as changes in sea-surface temperature (SST) associated with the East-Australian Current (EAC; Lowry and Murphy, 2003; Zischke et al., 2012). The fishery spans multiple state and federal government jurisdictions; some of which have no licensing nor registrar system, resulting in an incomplete list of disparate participants. As such, few reliable estimates are available regarding participation rates, annual effort and species-specific catch in this fishery (Forbes et al., 2009; Lowry and Murphy, 2003; Steffe, 1996; Zischke et al., 2012). However, anecdotal information suggests that recreational catches may be as high as, or even exceed, those of commercial fisheries. This has resulted in conflict between the two sectors to over access 'rights' to some pelagic species such as striped marlin (Bromhead et al., 2004).

Recreational sport fishers off eastern Australia qualify as a hard-to-reach population. As such, this fishery was chosen for investigation using a TLS with capture-recapture complementary survey approach. The objective of this study was to build upon the methods of Griffiths et al. (2013) and refine TLS as a method to estimate recreational fishing effort and catch, and in particular, to extend the approach to incorporate estimates of fisher population size. The specific aims of the study were to: (1) assess the efficacy of using TLS with stratified random sampling to sample specialised sport fishers, (2) conduct multiple TLS surveys to assess the efficacy of capture-recapture methods for estimating population size of specialised sport fishers, (3) investigate the biases associated with a recall questionnaire by comparing fisher characteristics and estimates of effort, catch and catch rates to 'benchmark' estimates from a concurrent on-site survey (Zischke et al., 2012), and (4) provide preliminary estimates of catch and effort for the specialised recreational sport fishery in 2010.

2. Materials and methods

2.1. Study region

The study region spanned approximately 200 km of coastline near Brisbane, Queensland (Fig. 1). This region, extending from Maroochydore, Queensland to Tweed Heads, New South Wales, was selected as it represents a major population centre for eastern Australia, spans a federal and two state government jurisdictions and supports recreational and commercial fisheries for pelagic species. It also corresponds with the same study region as a concurrent on-site access point survey (APS) of the recreational sport fishery (Zischke et al., 2012), which will be used here as the 'benchmark' comparative study.

2.2. Survey design

Fishing tackle stores were used as sampling locations in this TLS survey. Prior to the survey, a pilot study was undertaken to collect descriptive information regarding tackle store visits and usage by both non-specialised recreational fishers and specialised sport fishers. Specific information regarding the number of tackle stores visited, frequency of visits and the proportion of fishing equipment purchased from tackle stores – as oppose to purchased via internet, mail order or second-hand – was collected from on-site surveys of fishers when they finished a fishing trip and returned to public boat-launching ramps. These data were used to investigate whether tackle stores represented suitable aggregation points, and to guide temporal stratification for TLS.

TLS was undertaken between February and April 2011 at 14 tackle stores throughout the study region (Fig. 1). These stores were chosen to encompass both generalist and specialist tackle stores and according to the likelihood of encountering sport fishers, which were determined by the pilot study and through liaison with store owners and managers. To increase sampling efficiency and to minimise length-of-stay bias, tackle stores were grouped into five bus routes, with one route selected on each survey day (Fig. 1; Pollock et al., 1994). The survey design was stratified by bus route, day type (low-traffic and high-traffic customer flow days) and month, with stratified random sampling used to select survey day. Day type was determined through liaison with store owners; low-traffic days were weekdays between 05:00 and 17:00 h and high-traffic days were weekends and Thursday late-night trade (i.e. 17:00–21:00 h). The first tackle store sampled and travel direction for the bus route were randomly selected for each survey day. The starting time for each bus-route depended on the trading hours of each tackle store and was randomly selected between 05:00 and 09:00 h for weekdays and weekends and fixed at 18:00 h for Thursday late-night trade. A sample weighting of 1:1 was assigned to day type (i.e. an equal number of low- and high-traffic days were sampled).