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Bridging the temporal gap: Continuous and cost-effective monitoring of dynamic recreational fisheries by web cameras and creel surveys

Bruce W. Hartill[a,*], George W. Payne[b], Nicola Rush[a], Richard Bian[a]

[a] National Institute of Water and Atmospheric Research, Private Bag 99940, Auckland1149, New Zealand
[b] National Institute of Water and Atmospheric Research, Private Bag 11-115, Hillcrest, Hamilton 3251, New Zealand

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ABSTRACT

We describe a cost effective method of continuously monitoring relative trends in recreational effort and harvest, based on web camera imagery and interview data provided by a concurrent low intensity creel survey. The number of boats returning to three boat ramps in separate regions on the north eastern coast of New Zealand's North Island fluctuated over a ten year period between 2004–05 and 2013–14. The most pronounced change occurred in the Hauraki Gulf, where most recreational fishing occurs. Web camera monitoring detected a 34% decline in the number of boats returning to one of the busiest ramps in the Hauraki Gulf over a three year period between 2011–12 and 2013–14, which was mirrored by a 58% decline in snapper catch rates over the same period. The combined result was a 71% decline in the weight of snapper landed annually at the monitored ramp over this three year period, which was far more rapid than anticipated given differences seen between harvest estimates provided by infrequent large scale surveys in the past. Trends in effort and harvest derived from data collected at a small number of ramps will only have utility, however, if they reflect trends in the wider fishery. The relative difference in snapper harvest estimates provided by aerial-access surveys of the entire Hauraki Gulf fishery in 2004–05 and 2011–12, closely matched the difference in the harvest landed at the high traffic ramp that was monitored in the Gulf during these years. This independent confirmation of relative trends inferred from combined web camera and creel survey monitoring at a small number of sites has further highlighted the need to continuously monitor recreational fisheries, which are potentially far more dynamic than previously thought. We discuss strategies that we have progressively developed to minimise the cost of monitoring these recreational fisheries and how they could be applied to continuously monitor recreational fisheries elsewhere.

1. Introduction

Recreational fishers account for a substantial proportion of the harvest taken from many fish stocks throughout the world (Coleman et al., 2004; Arlinghaus and Cooke, 2005), and fisheries managers have to account for all forms of harvest if they are to manage these resources sustainably (Ihde et al., 2011; Lewin et al., 2006). Commercial fishers in developed nations are usually required to comply with some form of catch reporting regime, but this is rarely the case for amateur fishers. This means that survey techniques are required to assess and estimate for levels of recreational harvest, which are usually expensive and onerous to maintain long term. Two examples of long term monitoring programmes are: America's Marine Recreational Information Programme (formerly the Marine Recreational Fishing Statistics Survey), which has provided recreational harvest estimates for most coastal states since 1979 (National Research Council, 2006); and a series of annual aerial-access surveys of fisheries in the Strait of Georgia and off Vancouver, which have been run by Canada's Department of Fisheries and Oceans since 1980 (English et al., 2002).

For most recreational fisheries, however, surveys are infrequent and the only means of inferring what has occurred between these surveys is some crude form of interpolation between, or extrapolation from, occasional harvest estimates (Zeller et al., 2015; Pauly and Zeller, 2016). This is especially concerning because levels of recreational harvesting are unpredictable, partially because they are usually poorly constrained by daily bag and size limits (Post et al., 2003; Van Poorten et al., 2013), and also because fishing catch and effort varies in response to dynamic environmental and social

* Corresponding author.
E-mail address: bruce.hartill@niwa.co.nz (B.W. Hartill).

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conditions operating interactively over a range of temporal scales (Heermann et al., 2013; Hunt et al., 2013).

Levels of recreational effort and harvesting are strongly influenced by diurnal, weekly, seasonal, and annual cycles (Bucher 2006; Smallwood et al., 2006; Stevenson and Millar, 2013). Higher levels of effort, and consequently catch, typically occur on weekends and public holidays (Smallwood et al., 2012; Bian and Hartill, 2015). Some fisheries are also subject to seasonal closures. In New Zealand, weather conditions are usually more conducive to fishing during the summer months, when several popular species spawn close inshore where they become more vulnerable to recreational fishers (Parsons et al., 2014). Non-cyclical inter-annual fluctuations between El Nino and La Nina conditions of varying degrees can also have a marked influence on levels of fishing effort and fisher success (Zúniga Flores et al., 2008). The combined effect of these influences can be highly unpredictable over a range of temporal scales.

Socio-economic influences on long term trends in fishing activity are also interactive and unpredictable to some degree. Population growth does not necessarily lead to greater fishing pressure, as demographically driven levels of fisher participation change over time (Sutton et al., 2009; Arlinghaus et al., 2015). Levels of disposable income and the availability of leisure time also vary over time, in response to prevailing and varying economic circumstances (Tseng et al., 2012). Changes in fishing technology can also have a pronounced impact on the level of fishing activity undertaken, and the degree of success associated with that effort (Lester et al., 2003). The number and range of leisure activities being pursued is also increasing, which can lead to a dissipation of marine recreational effort, away from recreational fishing.

The collective impact of the influences described above means that any inferences made from the interpolation or extrapolation of estimates provided by infrequent large scale surveys will be potentially misleading, because levels of recreational harvesting can vary substantially from year to year. What is needed is a cost effective method that would allow continuous monitoring of recreational fisheries to supplement expensive and infrequent broad scale surveys. Although creel survey methods are routinely used to monitor recreational fisheries (Wise et al., 2012; Lynch, 2014) the cumulative long term cost of these programmes can be considerable. Web cameras offer a cost effective means of continuously monitoring trends in effort (Wise and Fletcher, 2013; Van Poorten et al., 2015), but provide no information on landed catch.

We describe a method of monitoring long term trends in recreational effort and harvest which is based on the continuous collection of web camera imagery combined with low intensity creel survey interviewing. These methods have been progressively developed over a decade and are now used to monitor trends in recreational snapper (*Chrysophrys auratus*) harvesting on the north eastern coast of New Zealand's North Island, which has been far more variable than previously anticipated given estimates available from infrequent surveys of recreational fisheries in the past. We discuss lessons learnt from the development of this approach, including strategies to minimise the cost of continuously monitoring recreational fishers, which is necessary given their potentially dynamic nature.

2. Methods

2.1. Web camera systems

Web cameras have been used to continuously monitor the incidence of trailer boats returning to three high traffic boat ramps on the north eastern coast of New Zealand's North Island since 2005 (Fig. 1). This area supports New Zealand's largest recreational fishery, which is often broken down into three regions: the East Northland fishery, where landings have been monitored at the Waitangi boat ramp; the Hauraki Gulf fishery, where monitoring has focused on the boat ramp at Takapuna; and at the Sulphur Point boat ramp Bay of Plenty. Each web camera system is comprised of: a video camera overlooking the boat ramp, which transmits imagery to a nearby PC via a wireless link or ethernet cable; a PC frame grabber that captures a static image of the ramp, which is timestamped and temporally saved to the hard drive; and a modem that transmits batches of images to a secured central server.

Images of each ramp were recorded every 60 s, to provide a complete record of the traffic occurring on each day. Boating parties typically take at least 4–5 min to retrieve their boat, and it is highly unlikely that any of the boats returning to surveiled ramps escaped detection. Web cameras were only installed overlooking ramps that were well lit at night although relatively few boats were observed returning after dark.

The number of boats returning to a ramp on a day was counted manually, by viewing the 1440 min-by-minute images collected over a 24 h period. Standardized protocols were developed to ensure that all time lapse traffic imagery were interpreted in a consistent manner. Image Viewer 2 freeware (www.dimin.net) was used to play these images as a slide show, which could be paused and rewound as required. Only 15–20 min of viewing were usually required to obtain a reliable count of the number of trailer boats returning to a ramp during each 24 h period.

2.2. Optimising the image reading process

Although the interpretation of time lapsed imagery was far more economical than viewing continuous video footage, the effort required to monitor traffic at multiple ramps was still considerable, as 525,600 images of each ramp are recorded annually. Some form of temporal subsampling was therefore required to provide reliable estimates of the number of trailer boats retrieved annually at each site, in a more cost effective manner, with a reasonable level of precision.

Parametric simulations were used to determine an optimal level of temporal subsampling given a random stratified sampling design. The data used in these simulations were counts of trailer boats returning daily to the three boat ramps shown in Fig. 1, occurring over a twelve month period between the 25th of December 2004 and the 24th of December 2005. Short term camera system failures were experienced at two of the three ramps during this period, and daily boat count data were only used when it was concurrently available at all three ramps, to ensure inter-site comparability. Traffic counts from all three ramps were available on 349 of the 365 days assessed during this 12 month period.

Daily counts of boat retrievals were assigned their respective seasonal/day-type strata, which were based on combinations of seasonal (summer; October to April, and winter; May to September) and day-type (midweek work days vs weekends/public holidays days) stratum definitions. The timing of these seasonal strata coincides with the start and end of New Zealand's regulatory Fishing Year, which starts on 1 October and ends on 30 September the following year.

Summary boat count statistics were calculated for each temporal stratum, which were incorporated into an iterative random stratified precision estimator. An initial sample size of two days was allocated to each stratum and the overall level of precision obtained was recorded. The sample size of the temporal stratum with the highest variance in the previous iteration was then increased by one (representing a further days sampling) at each iteration. Coefficients of variation were calculated for each iteration, and these were plotted against the combined sample size across all strata,