Trail camera video systems: investigating their utility in interpreting patterns of marine, recreational trailer-boat fishers' access to an offshore Marine Park in differing weather conditions.

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Abstract

When monitoring marine recreational fishers at sub-bioregional scales - for example, those who are accessing a marine park - on-site sampling is often required. This poses various logistical challenges, such as the efficient timing of intercept interviews. Here we examine these challenges, combining trail cameras, CCTV, weather stations and interviews at boat ramps that bracket an offshore marine park. Trail camera results were similar to those from a CCTV system co-located at one of the boat ramps. Fishers' boat launches peaked early, but return times varied considerably by ramp and weather. Both the numbers of launches and trip durations were strongly responsive to good weather, particularly at ramps used for offshore fishing. Weather was a more important factor to predict the likelihood of intercept interview opportunities than holiday period, which may reflect changing dynamics in work culture and improvements in weather prediction. Interviewed fishers reported preferences to individual ramps over the fishing season and nearly all trips to the Marine Park were reported by fishers accessing just one ramp. The strong relationships between fishing, weather and ramp, observed by the trail camera and correlated with the weather station data, may allow for efficient targeting of intercept interviews.

Keywords: the human dimension, anglers, offshore fisheries, MPA, interviews, Marine Park, marine social science research, sensor array, weather, wildlife biology

Introduction

Marine recreational fishers are increasingly seen as important stakeholders not only for fisheries but also for the conservation of marine biodiversity (Pawson et al., 2008; Ihde et al., 2011; Productivity Commission, 2016; Monkman et al., 2018). Information needs on recreational fishing have strong overlaps between these two fields, with both Marine Protected Area (MPA) and fisheries managers interested in: a) reduction in any cumulative impacts on biodiversity, habitats or ecosystems, b) ecologically sustainable use of natural resources and c) ensuring worthwhile experiences for fishers (Director of National Parks, 2013; Mitchell et al., 2018). Both sets of managers also share an interest in effective compliance and communication (Read et al., 2011). To achieve these diverse objectives, understanding the behaviours of fishers is important; as fish and habitats are not usually managed, rather it is the behaviours of the people that are regulated (Fulton et al., 2011). The behaviours of fishers, however, tend not to be well understood (Jentoft, 2006; Fulton et al., 2011; Hunt et al., 2013; Gruby et al., 2016; Christie et al., 2017).

In 2012, the Australian government proclaimed a network of Australian Marine Parks (AMP), expanding its offshore (>3nm from the coast) reserve estate. The network amalgamated 33 previously declared Marine Parks with 27 new Parks, which now covers 3.1 million square kilometres (Hill et al., 2018) and mirrors international moves, expanding the global MPA estate into offshore waters (Watson et al., 2014; Christie et al., 2017; Jantke et al., 2018). These are mostly multiple-use parks and include zones accessible to recreational fishers (Director of National Parks, 2013) who are important stakeholders for both zoning designation (Lynch, 2006; Noble et al., 2019) and reviews (Martin et al., 2016; Cresswell et al., 2019).

Assessment of open-access recreational fisheries often requires sampling (McCluskey and Lewison, 2008) and depending on objectives and scale this can involve off-site, on-site or complementary survey methods (Venturelli et al., 2017; Flynn et al., 2018; Hyder et al., 2018). The choice of method depends on both survey objectives and the temporal and spatial scales of interest (Pollock et al., 1994; Hartill et al., 2012). In most States of Australia, data on recreational fisheries is available from off-site state-wide assessments (Lynch et al., 2019), which are designed to report at bio-regional scales (Henry and Lyle, 2003; Ryan et al., 2017). When finer spatial scale information is required, on-site methods are a more useful approach; for instance for performance assessment of MPA, which are generally within bio-regions (Smallwood et al., 2011; Smallwood et al., 2012a; Lynch, 2014).

For specialised recreational fisheries, on site methods may also be more appropriate, as broad scale surveys do not have the statistical power to accurately describe these niche components (Griffiths et al., 2010; Taylor et al., 2018). In Australia specialised offshore fishing appears to have increased over the last two decades (Evans et al. 2017) as have rapid uptakes in technology (echo-sounders, GPS, colour plotting) (West et al., 2015). As fishing gear has developed (e.g. electric reels), offshore targeted species have also expanded to include not only pelagic but also midwater and deeper species (Lowry and Murphy, 2003; Morton and Lyle, 2004; Tracey et al., 2013; Moore et al., 2015; Tracey et al., 2020).

One widely used on-site method is intercept interviews with fishers, either as they launch or return from fishing trips. This usually occurs at the access points to the fishery, such as boat ramps (Pollock et al., 1997; Hartill et al., 2011). Self-reporting, both to off-site and on-site surveys, is a common data collection method and fishers' recollections of their fishing location is often of particular interest to MPA managers (Scholz et al., 2011; Thiault et al., 2017). On-site interviews have several advantages over off-site methods, as they tend to have higher response rates (Hartill et al., 2012) and reduced recollection bias as the memories of the trip are still fresh (Tarrant et al., 1993; Roach et al., 1999; Ditton and Hunt, 2001). On-site methods can also be targeted to very small spatial and temporal scales and provide the opportunity for identification of the species harvested by trained interviewers or creel[1] clerks (Hartill and Edwards, 2015).

The major problem with on-site sampling is labour cost, as fishing often occurs outside of standard work hours and travel is involved (Pollock et al., 1994). It is therefore not surprising that sensor-based approaches are an emerging field to automate some aspects of data collection, with traffic counter (Steffe et al., 2008; van Poorten and Brydle, 2018) or imagery (Parnell et al., 2010; Hartill et al., 2016; Keller et al., 2016; Powers and Anson, 2016). Imagery is derived from various sources, which includes webcams, Close Circuit Television (CCTV) and panoramic cameras. Data from these sources is then analysed to produce direct estimations of fishing effort, high frequency effort metrics to track trends (Smallwood et al., 2012b; Hartill and Edwards, 2015; Hartill et al., 2016; Flynn et al., 2018), monitoring of compliance (Lancaster et al., 2017; Harasti et al., 2019), spatial distributions (Parnell et al., 2010) or differentiation between fisheries sectors (Wood et al., 2016). Sensor approaches can also either be direct observations or indirect measurements of fishing as participants pass access points. Often these methods use substantial camera or CCTV systems and various studies have found these to be reliable compared to other methods such as aerial counts, access point and bus route sampling (Smallwood et al., 2012b; Greenberg and Godin, 2015; van Poorten et al., 2015; Flynn et al., 2018; Stahr and Knudsen, 2018; Taylor et al., 2018).

Sensors can also be deployed concurrently to simultaneously record data at multiple sites (Hartill et al., 2016) and negate some issues with traditional interview applications of on-site probability sampling. Typically these traditional methods have low sampling rates that can, by chance, result in a biased sample of quiet or busy periods – given that factors such as weather (which is a random factor in many designs), seasonal availability of target species, events such as fishing tournaments or social media discussions about good fishing can all influence fisher behaviour (Martin et al., 2014; Hartill et

[1] A creel is a wicker basket traditionally used by anglers to hold their catch

al., 2016; Flynn et al., 2018; Giovos et al., 2018). The advantage of high frequency sampling with sensors is they allow for data capture of the complexity of localised fishing effort.

Analysis of sensor data can also allow for more efficient stratification of the clerk's sampling schedules. While considering the potential for bias, sampling can be weighted towards the peak times when fishers are entering or returning from the fishing grounds to minimise the times when creel clerks are at ramps during lulls in activity.

Sensors, however, cannot replace interviews for metrics such as catch or target species and they may not easily distinguish between fishers and other activity types (though see high resolution approaches such as Wood et al. (2016). These types of information are best collected by interviews. When used in conjunction, both sensor and interview approaches can provide complimentary information (Flynn et al., 2018). Sensors provide high-frequency and continuous quantitative metrics across 24 hours and 7 days a week to describe fisher behaviours (Edwards and Schindler, 2017), such as trends in effort over time and the timings when people enter and leave the fishery. They can also be deployed as arrays to simultaneously collect data. Interviews provide in-depth information both for sensor quality assurance, such as distinguishing the ratios of fishers to other boat activities (Flynn et al., 2018) and for metrics such as fishing target, catch and locations. Recent approaches have combined off-site monitoring, camera monitoring and low-intensity creel surveys to gain greater insight into recreational fishery dynamics (Hartill et al., 2019).

Over the last two decades trail cameras, which are cheap ($250 AUS per unit), remotely deployed, battery operated and automatically triggered camera traps, have become one of the most powerful tools for wildlife research (Cutler and Swann, 1999; Rovero et al., 2013; Cusack et al., 2015). Recreational fisheries researchers, however, have rarely used the key features of trail cameras commonly configured by wildlife biologists: a) simultaneous deployments into an array, b) passive infrared motion sensor to trigger the taking of a short video and c) invisible black infrared LED that allows for night time imagery without disturbing the behaviour of the subject. Crepuscular and nocturnal recreational fishing is important to understand as there can be high levels of night time effort (Taylor et al., 2018), which is often unaccounted for in other on-site fisheries assessments. Triggered action also constrains the post processing requirements that become unwieldy with large continuous imagery datasets (Parnell et al., 2010).

Triggered camera traps are similar conceptually to traffic counter approaches for the continuous recording of boat movements on ramps (van Poorten and Brydle, 2018) but may avoid double counts when people have multiple reversing attempts or vehicle movements are not associated with launching or retrieval of boats. An added data possibility with trail cameras compared to traffic counters are 'recaptures' or matched samples that can provide an additional metric of trip duration.

Recently, trail cameras have begun to be used as cheap time-lapse camera systems in recreational fisheries research. For instance to monitor fishing effort on a small reservoir (Stahr and Knudsen, 2018) or as a circulating array to assess compliance of coastal MPAs (Lancaster et al., 2017). Triggered still image have also been used to count fishing parties accessing wild trout fishery, either on foot along a trail (Hining and Rash, 2016) or to corroborate traffic counters (Simpson, 2018).

We assess, as a proof of concept study, if trail cameras arrays, when combined with weather data and limited on-site interviews can collect primary data that can be used by both fisheries and MPA management of spatially limited areas of interest. We scoped our study around offshore recreational fishing from trailer boats[2] of the offshore Freycinet Australian Marine Park (AMP). We did this by deploying an array of cameras at four major ramps used by the fishery along the East Coast of Tasmania that bracketed the Park. To cross validate our approach, at one ramp we also compared our trail camera's data, when deployed in their common wildlife biology configuration of a triggered trap, to a continuously recording CCTV system. At all ramps we conducted concurrent intercept interviews, to assess activities (recreational fishing or other) and to ask contextual questions, including the days

[2] Trailer boats are small offshore powered craft between 3m – 8m that are towed behind vehicles and are commonly used in Australia by the recreational fishery

fishing location, target and catch species as well as effort and locations fished across the East Coast study area during the previous three months. We also added a weather co-variate to our dataset drawn from the closest Australian Bureau of Meteorology (BoM) autonomous weather station to each ramp.

Our aims were to: a) understand the temporal pattern of ramp usage by fishers in trailer boats to efficiently stratify on-site, interview surveys, b) to compare our trail camera videos to CCTV footage and correlate with weather data, c) to provide proof of concept that trail cameras are useful for the collection of novel primary data that can be used in management and d) to better understand fisher's temporal and spatial distributions, targets and catch.

Methods

Site description

Recreational fishing is popular in Australia, compared to global norms (Arlinghaus et al., 2015; Hyder et al., 2018), and in the state of Tasmania there is an annual participation rate across the state's population of 24% (Lyle et al., 2019). The East Coast of Tasmania (Fig 1) provides many popular recreational fishing locations both for nearshore and offshore fishing via large trailer boats' (>5.0m in length)(Tracey et al., 2013).

The Freycinet Marine Park (FMP) is located on the East Coast of Tasmania (Fig. 1) and is a well-established part of the estate, having been initially zoned on 31st August 2007. Most of the FMP's 57,942 km^2 is zoned as International Union for Conservation of Nature (IUCN) protected area category II, which excludes both commercial and recreational fishing; but the entire section within 20-25 nautical miles (nm) of the coast is zoned as 'Recreational Use' (IUCN IV) or 'Multiple Use' (IUCN VI), which allows for recreational fishing (Director of National Parks, 2013). We chose this area for our proof of concept study as the FMP is well established, within a region popular with recreational fishers and is bracketed by four large ramps (St Helens, Bicheno, Swansea and Triabunna) which allow the launch of larger vessels required to access offshore fishing.

Sampling

We sampled immediately before and then across the Easter public holiday period in 2018. The Easter long weekend is a traditional fishing period (Lynch, 2006; Lynch, 2014; Lyle et al., 2019), coming towards the end of the peak of the southern Austral recreational fishing season. We choose this quiet and then busy period to trial the survivability of the gear, to see if the gear could capture data that would describe the expected variable of recreational fishing effort (low outside of the holidays and then high during the holiday period) and survey fishers about their fishing activities across the East Coast during the fishing season.

All four ramps were monitored with our array of trail cameras continuously and simultaneously, between 27th March to 2nd April 2018 (7 days). Each ramp's camera was configured to trigger from movement and collect short video clips of the launching and retrieval of trailer vessels. To provide supplementary and complementary data to our sensor data we scheduled intercept interviews across our four ramps, both for a morning and afternoon shift and across all day types (Weekday or Weekend/Holiday). We visited two ramps each day, one in the morning and the other in the afternoon. We conducted randomisations, without replacement, using a random number table to determine the visiting order for ramps and shift.

Trail cameras and CCTV

At each ramp, a Tasco trail camera (Model #119237) was swaged with 5mm steel cable onto existing infrastructure (Appendix A Supplementary Materials). A technical aim was to see if the trail cameras, when secured in this fashion, would survive in place, be stolen or vandalised. Cameras were mounted in public areas at choke points on the ramps where any cars that were reversing trailers would have to pass the camera within the maximum Passive Infra-Red (PIR) sensor's detection zone of 10m.

Cameras were placed at a height of 50-130cm off the ground that allowed for a side view; capturing the car's make, model and during daylight colour; trailer type and number of axles; and vessel type, markings and during daylight colour.

Video recording commenced instantaneously once the PIR was triggered, with the trail cameras programmed to capture time and date stamped 30 second videos. Colour video was captured during the day and black and white at night. Following video capture, a delay period of 59 seconds between the next motion activation was set, so single reversing trailers would not repeatedly trigger the sensor. Data was collected onto 32GB SanDisk SDHC cards and each camera was powered by 4 rechargeable batteries. Both the cards and the batteries were serviced in conjunction with the interviews.

At one site, Triabunna, a Hikvision closed circuit television (CCTV) system overlooks the ramp. This CCTV captures continuous video of the ramp and dock, which allowed us to cross validate our trail cameras recordings with this well-established sampling method. At this site we affixed our trail camera to the same pole that held up the CCTV. The CCTV footage was supplied via a link to an off-site storage facility into 5 sec to 5-minute-long mp3 files. These were stitched together using Adobe Premiere Pro into 24-hour files. The footage was time-stamped and then sped up, so 24 hours could be viewed in 4 minutes, which is a common method for reviewing CCTV footage for recreational fisheries. As remote video recording occurs without the consent of the subjects, we provide a detailed explanation of our ethics approval process in Appendix B. Supplementary materials.

Camera Analysis

For both camera systems, videos were reviewed, and time-stamped counts of trailer boat launches and retrievals were added to a database. A still image, for reference of car and boat colour and models (e.g. red Ford and white cabin cruiser) were taken for each launch and retrieval and, if possible, matched as recaptures to calculate a trip duration. Commercial vessels were also excluded from the dataset, where possible, if they could be recognised by their registration numbers.

Weather observations were downloaded from the closest Automatic weather stations (BOM, 2019) (Fig 1). We ranked boating weather condition, based on wind speeds, as: good (0-9.9km/hr), fair (10-19.9km/hr) and poor (>20km/hr) within four time periods across each 24 hours: 0300-0859, 0900-1459, 1500-2059, 2100-0259.

For the time of launch and the time of retrieval variables, we described the pattern assuming an inhomogeneous Poisson point process (Cressie, 1993) whose mean was allowed to vary with time-of-day, day-of-survey, weather conditions and day type (weekday or weekend/public holiday). The Poisson point process was fitted by first noticing that a number of events within a 15 minute time window will be distributed as a Poisson variable. This enabled the use of a Poisson generalised additive model (GAM; see Wood (2006). The spline defining the effect of the time-of-day covariate was constrained to be cyclic, so that the estimated pattern repeats without any 'jumps' in the response curve. Due to the small number of sampling days (7 in total), the spline defining the day-of-survey was limited to have 4 knot points. First order interactions with ramp, weather and day-type were also included in the model to see if the patterns varied between launching sites. Backwards selection was used to remove terms, from this full model, that did not explain a significant amount of variation (Neter et al., 1996). We tested spline and spline interaction terms, using likelihood ratio statistics (Wood, 2001), which provided estimated degrees of freedom and associated p values. To test non-spline or parametric terms we used standard tests of deviance. The same set of covariates and modelling approach was used for trip duration, but the gamma distribution was assumed for the stochastic model. To interpret the model, we produce predictions for 15-minute time blocks and plotted against covariates. Here the predictions are made whilst holding the values of the remaining covariates constant at their mean. We undertook multiple tests for three outcome variables (launches, retrivals and duration). Under an extreme Bonferroni correction this would mean that the critical value to control for type I errors was $p = 0.017$. We consider multiple testing is a potential type I error issue and limited sampling in our proof of concept study is a potential type II error issue. We adjusted our statistical interpretions to take into account these potential fasle positives and negatives.

Interviews

Clerks spent 3 hours at each ramp, awaiting the return of recreational fishers from boat trips, to conduct intercept interviews. After identifying ourselves one of our first questions was to ask the activity of the boat user. For non-fishing parties and commercial fishers, we noted their activity but then indicated that we were focused onto recreational fisheries and politely terminated the interview. Refusals were also noted.

Our survey questionnaire (Appendix C Supplementary Material) was wide ranging but, for this study, we only report on activity, target species, catch and small-scale spatial patterns of use. The scale of spatial resolution was set at a 5nm grid, as this scale when overlaid onto maps, resolved both the FMP zoning plan and key features such as coastal landmarks and the bathymetry of the continental shelf. Fishers were presented with A3 (297mm x 420mm) gridded maps and asked to mark both the locations of the day's fishing and the areas that they had fished during the previous fishing season, which we defined as the previous 3 months. Each mark was considered as presence absence data (0,1), plotted and then summed per grid square and colour co-ordinated based on the interview ramp. We also combined all plot data to generate a heat map of all reported distributions of fishing. While our figures show the boundaries of the FMP zoning plan, during data collection in the field we did not include this layer on our maps.

Results

Trail Camera versus CCTV

A total of 59 parties were approached for interview and only three were out of scope, hence we interpreted our camera data as a population of recreational fishers, though more interviews would be required to confirm this assumption.

When we compared the trail camera to the CCTV data, there was near identical numbers of totals for boats observed (Table 1). For both systems, more launches were observed than retrievals but there was a lower number of matches between launches and retrievals for the trail cameras. When we analysed comparable observations between CCTV and trail cameras for launches (Table 2a) and retrievals (2b) both cameras systems missed some launches or retrievals which were observed by the other system. Rates of missed observations were similar between systems for launches, but the CCTV camera was better at observing retrievals. The sub-sets of matched pairs of launches and retrievals, which provided a duration for the days fishing trip, when regressed between the two camera systems showed a near perfect agreement (R^2 = 0.99) (Fig. 2).

Trail Camera array

The array of 4 trail cameras observed 747 boat launches and 692 retrievals (Table 3) with a relatively equal share across most ramps (~200 boats), though Triabunna had around a quarter less activity. A total of 466 matches were made with more matches at Triabunna (89%) compared with the overall average (67%). We lost no cameras or data to theft or vandalism, through there was evidence of ineffective tampering at Triabunna. Although our data suggests Swansea had similar rates of use to St Helens, it has a new and old ramp and we only instrumented the new ramp, so we under-estimated total launches from this complex of ramps.

Launches were strongly associated with time-of-day (df = 20.52, $\chi2$ =83.16, $p < 0.001$) and peaked in the morning between 0600 -1000 (Fig. 3); though they continued across the day and into the early evening, there were no launches between 2000-0400. The number of boats launched was strongly associated with the day-of-survey, which included the popular recreational fishing period around the Easter long weekend public holiday, (df = 8.8, $\chi2$ = 72.87, $p < 0.001$). However, even if Bonferroni corrections were ignored, day type (i.e. weekend/public holiday versus weekday) only approached a statistical difference (df = 1, $\chi2$ =3.557, p = 0.059). Weather at launch, however, was strongly associated with the number of launches at all ramps (df = 2, $\chi2$ =27.44, P<0.001), with more launches when the weather was good compared to when conditions were fair or poor (Fig 4).

Figure 5a shows the predicted number of launches at each ramp every fifteen minutes across a modelled public holiday or weekend day, when the weather was good. Launches peaked in the mornings, though it is interesting to note a second, smaller, mode of launches in the late afternoon around 1600. At the large multi-lane ramps of St Helens and Swansea during periods of good weather there was a modelled predication of five launches every fifteen minutes and, although there are outliers, this corresponded well with the actual data. For example, on 31st March 2018 which was a public holiday with good weather, at the St Helens ramp between 0422 and 0837, there were 79 boats launched, or ~ 5 every fifteen minutes, but in the fifteen minutes between 0607-0622, there were 9 launches.

Maximum modelled numbers of launches appeared to differ for each ramp: St Helens 5.03 ± 0.65, Swansea 4.96 ±0.83, Triabunna 3.86 ± 0.74 and Bicheno 2.74 ± 0.36 but these differences, only approached significance if Bonferroni corrections are ignored (df = 3, $\chi2$ = 7.239, p = 0.065). When we plotted the predictive error estimates around launch numbers (Fig. 5b) the size of errors generally increased with means. While not statistically discernible with our current dataset there is a suggestion of more variability in launch numbers at ramps which accessed sheltered waterway (Swansea and Triabunna) compared to those that allowed direct access to offshore areas (St Helens and Bicheno).

When we parameterised the model for good weather on weekdays, peak launches at St Helens were 2 - 3.5 per fifteen minutes, this declined for weekdays and poor weather to only a peak of 1-2 per fifteen minutes. As there were no interactions between the ramps with day type or weather, the relative pattern of launches remained similar between ramp for the various parameterisations of the model by holiday period and weather. When we compared predictions of launches against observations with their matched covariate values, we found good agreement (Fig. S1) but with dispersion for both low and high rates of launches.

Generally, retrievals were more spread out across the day compared to launches (Fig. 3) and were a more complex behaviour. Most retrievals occurring between 0800 – 1800, but there was still a strong effect from time of day (df = 20.9, $\chi2$ = 138.7, $p < 0.001$), with very few late night and early morning retrievals. While there was a strong effect of the day-of-survey (df = 9.1, $\chi2$ = 47.4, $P < 0.001$) again, like launches, this was not associated with day type (holiday period vs non-holiday), either as a main effect (p=0.28) or as an interaction with ramps (p = 0.43). Weather was also again an important predictor for retrievals (df = 6, $\chi2$ = 56, $P < 0.001$).

There was a strong interaction with ramps and the numbers of returning boats (df = 20.87, $\chi2$ = 140.23, $P < 0.001$) and day-of-survey (df = 8.9, $\chi2$ =61.4, $p < 0.001$). Hence, the numbers of retrievals differed between ramps both within and between days. Two general patterns emerged, peaks of retrievals at the Swansea and Triabunna ramps and plateaus of retrievals at Bicheno and St Helens (Fig 6a-c). In good weather this return peak was especially high for Swansea around midday (Fig 6a). Retrievals also increasing at Triabunna as the weather on return deteriorated to fair conditions (Fig 6b). As conditions deteriorate further to poor weather, many more fishers returned to their launch ramps at St Helens and Bicheno with rates of returns five and three times higher in response to poor weather compared to good conditions (Fig. 6c). Bicheno, across all weather conditions, also continued to demonstrate the bi-model pattern that occurred for all ramps for launches.

Standard errors were linear in responses to numbers of retrieval in good weather. However, there was separation between fishers returning to the Swansea and Triabunna ramps, which had larger variability in their return times, compared to fishers returning to ramps of St Helens and Bicheno (Fig. 6d). Linearity was maintained in fair weather but both variability and separation between ramps diminished (Fig 6e), while in poor weather, errors diminished even further (Fig 6f).

The day-of-survey was associated with trip duration (df = 3.8, $\chi 2$, $p < 0.001$) but day type, even if Bonferroni corrections are ignored, only approached significance as a main effect (df = 1, F = 3.06, p = 0.08) and as an interaction with ramps (df = 3, F = 2.21, p=0.09). Weather had an association with trip duration (df = 2, F = 29.65, p< 0.001) and durations also differed between ramps (df = 3, F = 15.38, p< 0.001) with longer trips out of St Helens (Fig 7). However, there was no interactions between ramps and weather (p = 0.3), hence when the weather was good, all fishers tended to have longer trips and when poor, shorter trips.

Interviews

We had 5 'soft' refusals (e.g. one fisher had fallen into the water and was too cold to interview) but no 'hard' or protest refusals to interviews, leaving a responding sample of 51 recreational fishing parties, which were evenly distributed between ramps. Many parties, across all ramps, targeted benthic fish (flatheads), which include both a nearshore and deeper species (Table 4 and Table S1). Diversity of targets was highest at St Helens and Bicheno with fishers targeting not only nearshore but deeper water species.

There was separation of the spatial distributions of fishing locations by ramps (Fig. 8), with no individual grids fished by parties originating from separate ramps. One pair of grids targeted by fishers launching from neighbouring ramps abutted just north of Triabunna. Only those fishers launching from the Bicheno ramp reported offshore fishing of the FMP, and they only fished zones that remain open to recreational fishing. All fishing out of Swansea and Triabunna was nearshore, while some offshore fishing (>3nm) occurred out of St Helens. Fishers who were seeking southern rock lobster (*Jasus edwardsii*), which include divers and those using traps (pots) targeted coastal reefs; flathead fishers target both demersal soft sediment inshore/coastal waters (< 50 m) probably for one species (*Platycephalus bassensis*) and deeper on-shelf waters (50-150m) for another (*Neoplatycephalus richardsoni)* (Table 4). Offshore (demersal) fishers reported targeting the deepwater shelf edge/break reefs (<300m) for striped trumpeter (*Latris lineata*) and demersal slope (400m +) for blue eye trevalla (*Hyperoglyphe antarctica*).

Recollections by fishers of their past season were that, across the study area, they tended to only access waters adjacent to the ramp that they were being interviewed on (Fig. 9), suggesting a preference for familiar ramps and their associated fishing grounds. Fishers launching from both Bicheno and St Helens indicated that they have fished offshore locations earlier in the season, including the FMP, as did, to a lesser extent those departing from the Swansea and Triabunna ramps. When all spatial data was combined (Study period + previous 3 months of the fishing season) (Fig. 10) hot spots of activity occurred in the 5nm grids closest to all ramps, except for Swansea, which had a hotspot on the far side of the bay across from the ramp. Fishing was widespread along the entire coastline, with only 2 x 5nm coastal blocks reported as unfished. Fishing was reported to have occurred in grid blocks as far as 30nm out to sea.

Discussion

To investigate a marine, trailer-boat recreational fishery (MRF) bracketing an offshore MPA, we deployed an array of trail cameras, configured in a similar way to methods developed by wildlife biologists. In conjunction with our array, we also examined our target MRF with the more traditional fisheries methods of on-site intercept interviews and correlated with weather observations. This novel approach produced results that may be of interest not only to MPA practitioners but also more generally for the efficient targeting of on-site sampling for management of niche recreational fisheries (Griffiths et al., 2010; Zischke et al., 2012).

The trail cameras performed well, observing trailer boat movements on ramps, with close agreement between numbers of launches and retrievals and comparative CCTV footage. The trail camera footage also allowed for a subset (~67%) of launches to be matched to retrievals and in one case, at the Triabunna ramp, matches were as high as 89%. We suspect that differences in matching rates between ramps was due to our relative inexperience in optimally setting up trail cameras to detect trailer boat retrievals. Retrievals in particular appear to be missed due to cars travelling more quickly when moving off the ramp, especially in busy periods, than when reversing down the ramp. At the ramp with the best matching rate (Triabunna) our camera placement providing a clear view of the boat trailers at a point where they were travelling slowly on the ramp. Better consideration of this type of field craft would benefit future deployment of trail cameras on boat ramps.

Trail cameras are widely used in wildlife research and there are various concerns around best sampling designs, such as the number of sampling sites, spatial arrangement, sampling duration and biases in species detection from sampling only a limited set of potential habitat features (Rovero et al., 2013; Cusack et al., 2015). These biases may not be as important for observing large trailer boats, due to the small number of suitable ramps to launch these vessels. This limitation of suitable 'habitat' results in known bottlenecks with extensive queuing at popular ramps (Flynn et al., 2018).

To optimise intercept survey sampling through stratification (Pollock et al., 1994; Pollock et al., 1997; Jones and Pollock, 2012) our sensor data suggests launch times peaked across short periods (0600 - 1000), increased with good weather and showed little difference in patterns between ramps. Retrievals, which are the most common time to initiate intercept surveys, were, however, a much more complex behaviour. In our study, interview survey timing could have been best optimised by stratification by weather and ramp, with a division in return times between fishers using ramps that access offshore areas (St Helens and Bicheno) and those for sheltered water (Swansea and Triabunna). Fishers using the offshore access ramps stayed out longer in good weather and displayed a plateau of returns across the day, while fishers launching into sheltered waters tended to have peak returns around midday. As the weather deteriorated trailer boat fishers using the offshore accessing ramps tended to head back to the shore in larger numbers. Depending on the objectives of intercept interviews (i.e. research, compliance, communication) having flexibility within the clerk's scheduling to tailor shifts based on weather observations and the characterisation of the ramp, may be a design consideration for future surveys.

We hypothesised with our design, based on well-established methods and local field studies (Pollock et al., 1994; Lynch, 2006; Jones and Pollock, 2012; Flynn et al., 2018) that day type (weekend and public holidays vs weekdays) would be the most important factor for estimation. We were surprised that this was not the case, rather we found that weather was the more important factor. This is not to say the day type is not important, our sample size of days surveyed was small and if multiple comparison issues were ignored, day type approached significance for launches and trip durations. We suspect that this lack of significance is probably a type II error. Weather, however, had a very large effect and was highly significant even with our limited sampling and Bonferroni corrections.

While the impact of weather on recreational fisheries has been considered in response to climate change (Townhill et al., 2019), weather conditions are typically considered a random factor in sampling designs. Fisheries field survey methodologies were developed in post-WWII industrialised economies and there may be a changing dynamic in the influence of weather on recreational fishing. In the last two decades, there has been significant expansion of flexible working arrangements (FWAs) (Ryser et al., 2016; Bessa and Tomlinson, 2017; Wheatley, 2017). These have particularly benefited men (Wheatley, 2017), who have higher participation rates in recreational fishing compared to women (Henry and Lyle, 2003; Brownscombe et al., 2014; Gaynor et al., 2016). With more flexibility in men's workplaces, good weather conditions can now be better targeted for fishing. To aid targeting, recreationally fisher also now have access to more accurate long range weather reports that are downscaled to local conditions (e.g. MetEye - http://www.bom.gov.au/australia/meteye/).

While sensors provide a method to investigate the complexity of fisher behaviours, they have several drawbacks. Our trail camera approaches could estimate trip duration, by matching pairs of launches and retrievals, but this required labour intensive post-processing. Simpler traffic counter approaches avoid post-processing for determining launches and retrieval but do not allow for the estimation of duration (van Poorten and Brydle, 2018). An intriguing outcome of our analysis, however, was how sensitive return times and trip durations were to weather and ramp.

Autonomous weather stations are ubiquitous in many high-income nations, producing web harvestable data streams. By combining local weather data with ramp sensors, a cost-effective method for modelling daily effort in near real time to the ramp scale may be possible. Trail cameras and interviews could be used for ramp characterisation and quality control, but simpler counters could then determine the number of parties entering the fishery. Local weather station data could then be used to predict average daily trip duration (see supplementary material Appendix D) and the numbers of launches and daily average trip durations could then be used to estimate fishing effort. More sampling and model development would be required to determine if this method was viable. These types of fine scaled information, however, are increasingly important to marine park managers, who often manage areas at scales that cannot be resolved by common off-site, bio-regional methods for assessments of recreational fisheries (Lynch et al., 2019).

The recreational fishers we interviewed indicated widespread use of fishing grounds along Tasmania's East Coast. Use was particularly high close to the ramps, a pattern which corresponds to observed declines in targeted fish size and abundance near access points (Stuart-Smith et al., 2008). Except for one party at the Swansea ramp, who indicated that they targeted the FMP earlier in the season, all reported activity in the park originated from fishers interviewed on the Bicheno ramp. This pattern of fishers returning to their preferred fishing grounds across the season was common across our interviews. For the FMP, the ramp at Bicheno appears to be the preferred access points for entry into the park by trailer boat fishers across the region. The limited number of regional boat ramps that can access offshore areas may be common across the AMP system. This could mean that a limited number of access points could be monitored to capture much of the systems trailer boat recreational fishery.

The number of fishers interviewed who accessed offshore area grids across our survey period was relatively small compared to those fishing nearshore, which is consistent with larger scale surveys (Lyle et al., 2019). Our camera data, however, provided context on the population size of fishers from which we drew our interviews, suggesting that we interviewed less than 6% of fishing parties across our study period. Offshore fishing was also concentrated at certain ramps (Tracey et al., 2013) and suggests, like other fisheries (Fulton et al., 2011), fisher behaviour is predictable.

Fishers launching from Swansea and Triabunna were mostly targeting nearshore species, while those interviewed on the St Helens and Bicheno ramps reported targeting a more diverse suite of species, habitats and depths. This included shelf and slope bathymetry between 400-1000m, where they fished for deeper water species, such as blue eye trevalla (*Hyperoglyphe antarctica*). This bathymetry and habitat remain open to recreational fishing across the East Coast, including the FMP. Avoidance of heavily recreationally fished areas is a common planning strategy in Australian MPA design (Lynch, 2006; Lynch, 2008; Devillers et al., 2015), where recreational fisher engagement in MPA planning processes is often sought to maximize voluntary compliance and manageability (Read et al., 2011).

While trail camera data gives a more comprehensive evaluation of activity on the boat ramp, the real power of the approach was to combine various sensor inputs with interviews. This allows not only for statistically derived insights from the modelled sensor data to be cross validated against activity (fishing vs non-fishing and nearshore vs offshore) but also for the collection of catch information and recollections of the spatial distributions of the fishing trip locations. The low cost of trail camera sensors means loss of gear is not crippling and at least across our study sites, the swaging and padlock security prevented theft. Multiple sensors can be bought and deployed simultaneously and as it is a triggered system, post processing is reduced compared to CCTV footage. Further experimental work, such as comparing different delay times before triggers and optimising camera locations based on vehicle velocities on the ramp, would build further confidence in this promising research application. More widespread spatial and temporal replication would also be of interest to test the generalities of our results and develop better models.

Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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References

Arlinghaus, R., Tillner, R., and Bork, M. 2015. Explaining participation rates in recreational fishing across industrialised countries. Fisheries Management and Ecology, 22: 45-55.

Bessa, I., and Tomlinson, J. 2017. Established, accelerated and emergent themes in flexible work research. Journal of Industrial Relations, 59: 153-169.

BOM 2019. Climate and oceans data and analysis. *In* Australian Bureau of Meteorology climate data services

Brownscombe, J. W., Bower, S. D., Bowden, W., Nowell, L., Midwood, J. D., Johnson, N., and Cooke, S. J. 2014. Canadian Recreational Fisheries: 35 Years of Social, Biological, and Economic Dynamics from a National Survey. Fisheries, 39: 251-260.

Christie, P., Bennett, N. J., Gray, N. J., 'Aulani Wilhelm, T., Lewis, N. a., Parks, J., Ban, N. C., et al. 2017. Why people matter in ocean governance: Incorporating human dimensions into large-scale marine protected areas. Marine Policy, 84: 273-284.

Cressie, N. 1993. Statistics for Spatial Data*,* Wiley-Interscience, New York.

Cresswell, A. K., Langlois, T. J., Wilson, S. K., Claudet, J., Thomson, D. P., Renton, M., Fulton, C. J., et al. 2019. Disentangling the response of fishes to recreational fishing over 30 years within a fringing coral reef reserve network. Biological Conservation, 237: 514-524.

Cusack, J. J., Dickman, A. J., Rowcliffe, J. M., Carbone, C., Macdonald, D. W., and Coulson, T. 2015. Random versus Game Trail-Based Camera Trap Placement Strategy for Monitoring Terrestrial Mammal Communities. PLoS ONE, 10: e0126373.

Cutler, T. L., and Swann, D. E. 1999. Using Remote Photography in Wildlife Ecology: A Review. Wildlife Society Bulletin (1973-2006), 27: 571-581.

Devillers, R., Pressey, R. L., Grech, A., Kittinger, J. N., Edgar, G. J., Ward, T., and Watson, R. 2015. Reinventing residual reserves in the sea: are we favouring ease of establishment over need for protection? Aquatic Conservation: Marine and Freshwater Ecosystems, 25: 480-504.

Director of National Parks. 2013. South-east Commonwealth Marine Reserves Network management plan 2013-23. 109 pp.

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

Edwards, J., and Schindler, E. 2017. A Video Monitoring System to Evaluate Ocean Recreational Fishing Effort in Astoria, Oregon. 31 pp.

Flynn, D. J. H., Lynch, T. P., Barrett, N. S., Wong, L. S. C., Devine, C., and Hughes, D. 2018. Gigapixel big data movies provide cost-effective seascape scale direct measurements of open-access coastal human use such as recreational fisheries. Ecology and Evolution, 8: 9372-9383.

Fulton, E. A., Smith, A. D. M., Smith, D. C., and van Putten, I. E. 2011. Human behaviour: the key source of uncertainty in fisheries management. Fish and Fisheries, 12: 2-17.

Gaynor, A., Frawley, J., and Schwerdtner Máñez, K. 2016. 'Slim female records the same old story': Newspapers, gender, and recreational fishing in Australia, 1957–2000. Geoforum, 77: 114-123.

Giovos, I., Keramidas, I., Antoniou, C., Deidun, A., Font, T., Kleitou, P., Lloret, J., et al. 2018. Identifying recreational fisheries in the Mediterranean Sea through social media. Fisheries Management and Ecology, 25: 287-295.

Greenberg, S., and Godin, T. 2015. A Tool Supporting the Extraction of Angling Effort Data from Remote Camera Images. Fisheries, 40: 276-287.

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.

Gruby, R. L., Gray, N. J., Campbell, L. M., and Acton, L. 2016. Toward a Social Science Research Agenda for Large Marine Protected Areas. Conservation Letters, 9: 153-163.

Harasti, D., Davis, T. R., Jordan, A., Erskine, L., and Moltschaniwskyj, N. 2019. Illegal recreational fishing causes a decline in a fishery targeted species (Snapper: Chrysophrys auratus) within a remote no-take marine protected area. PLoS ONE, 14: e0209926.

Hartill, B. W., Cryer, M., Lyle, J. M., Rees, E. B., Ryan, K. L., Steffe, A. S., Taylor, S. M., et al. 2012. Scale- and Context-Dependent Selection of Recreational Harvest Estimation Methods: The Australasian Experience. North American Journal of Fisheries Management, 32: 109-123.

Hartill, B. W., and Edwards, C. T. T. 2015. Comparison of recreational harvest estimates provided by onsite and offsite surveys: detecting bias and corroborating estimates. Canadian Journal of Fisheries and Aquatic Sciences, 72: 1379-1389.

Hartill, B. W., Payne, G. W., Rush, N., and Bian, R. 2016. Bridging the temporal gap: Continuous and cost-effective monitoring of dynamic recreational fisheries by web cameras and creel surveys. Fisheries Research, 183: 488-497.

Hartill, B. W., Taylor, S. M., Keller, K., and Weltersbach, M. S. 2019. Digital camera monitoring of recreational fishing effort: Applications and challenges. Fish and Fisheries, 0: 1-12.

Hartill, B. W., Watson, T. G., and Bian, R. 2011. Refining and Applying a Maximum-Count Aerial-Access Survey Design to Estimate the Harvest Taken from New Zealand's Largest Recreational Fishery. North American Journal of Fisheries Management, 31: 1197-1210.

Henry, G. W., and Lyle, J. M. 2003. National recreational and indigenous fishing survey. ICES Document Project No. 1999/158. 188 pp.

Hill, N. A., Barrett, N., Ford, J. H., Peel, D., Foster, S., Lawrence, E., Monk, J., et al. 2018. Developing indicators and a baseline for monitoring demersal fish in data-poor, offshore Marine Parks using probabilistic sampling. Ecological Indicators, 89: 610-621.

Hining, K. J., and Rash, J. M. 2016. Use of Trail Cameras to Assess Angler Use of Two Remote Trout Streams in North Carolina. Journal of the Southeastern Association of Fish and Wildlife Agencies, 3: 89-96.

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

Hyder, K., Weltersbach, M. S., Armstrong, M., Ferter, K., Townhill, B., Ahvonen, A., Arlinghaus, R., et al. 2018. Recreational sea fishing in Europe in a global context—Participation rates, fishing effort, expenditure, and implications for monitoring and assessment. Fish and Fisheries, 19: 225-243.

Ihde, T. F., Wilberg, M. J., Loewensteiner, D. A., Secor, D. H., and Miller, T. J. 2011. The increasing importance of marine recreational fishing in the US: Challenges for management. Fisheries Research, 108: 268-276.

Jantke, K., Jones, K. R., Allan, J. R., Chauvenet, A. L. M., Watson, J. E. M., and Possingham, H. P. 2018. Poor ecological representation by an expensive reserve system: Evaluating 35 years of marine protected area expansion. Conservation Letters, 11: e12584.

Jentoft, S. 2006. Beyond fisheries management: The Phronetic dimension. Marine Policy, 30: 671-680.

Jones, C. M., and Pollock, K. H. 2012. Recreational angler survey methods: estimation of effort, harvest, and released catch. *In* Fisheries Techniqes, 3rd edn. Ed. by A. Zale, D. L. Parrish, and T. M. Sutton. American Fisheries Society, Maryland USA.

Keller, K., Steffe, A. S., Lowry, M., Murphy, J. J., and Suthers, I. M. 2016. Monitoring boat-based recreational fishing effort at a nearshore artificial reef with a shore-based camera. Fisheries Research, 181: 84-92.

Lancaster, D., Dearden, P., Haggarty, D. R., Volpe, J. P., and Ban, N. C. 2017. Effectiveness of shore-based remote camera monitoring for quantifying recreational fisher compliance in marine conservation areas. Aquatic Conservation: Marine and Freshwater Ecosystems, 27: 804-813.

Lowry, M., and Murphy, J. 2003. Monitoring the recreational gamefish fishery off south-eastern Australia. Marine and Freshwater Research, 54: 425-434.
Lyle, J. M., Stark, K. E., Ewing, G. P., and Tracey, S. R. 2019. 2017-18 Survey of recreational fishing in Tasmania. 123 pp.
Lynch, T. P. 2006. Incorporation of Recreational Fishing Effort into Design of Marine Protected Areas

Incorporación del Esfuerzo de Pesca Recreativa en el Diseño de Áreas Marinas Protegidas. Conservation Biology, 20: 1466-1476.
Lynch, T. P. 2008. The Difference between Spatial and Temporal Variation in Recreational Fisheries for Planning of Marine Protected Areas: Response to Steffe. Conservation Biology, 22: 486-491.
Lynch, T. P. 2014. A decadal time-series of recreational fishing effort collected during and after implementation of a multiple use marine park shows high inter-annual but low spatial variability. Fisheries Research, 151: 85-90.
Lynch, T. P., Smallwood, C. B., Ochwada-Doyle, F. A., Lyle, J., Williams, J., Ryan, K. L., Devine, C., et al. 2019. A cross continental scale comparison of Australian offshore recreational fisheries research and its applications to Marine Park and fisheries management. ICES Journal of Marine Science.
Martin, C. L., Momtaz, S., Jordan, A., and Moltschaniwskyj, N. A. 2016. Exploring recreational fishers' perceptions, attitudes, and support towards a multiple-use marine protected area six years after implementation. Marine Policy, 73: 138-145.
Martin, D. R., Chizinski, C. J., Eskridge, K. M., and Pope, K. L. 2014. Using posts to an online social network to assess fishing effort. Fisheries Research, 157: 24-27.
McCluskey, S. M., and Lewison, R. L. 2008. Quantifying fishing effort: a synthesis of current methods and their applications. Fish and Fisheries, 9: 188-200.
Mitchell, J. D., McLean, D. L., Collin, S. P., Taylor, S., Jackson, G., Fisher, R., and Langlois, T. J. 2018. Quantifying shark depredation in a recreational fishery in the Ningaloo Marine Park and Exmouth Gulf, Western Australia. Marine Ecology Progress Series, 587: 141-157.
Monkman, G. G., Kaiser, M. J., and Hyder, K. 2018. Heterogeneous public and local knowledge provides a qualitative indicator of coastal use by marine recreational fishers. Journal of Environmental Management, 228: 495-505.
Moore, A., Hall, K., Giri, K., Tracey, S., Penrose, L., Hansen, S., and et. al. 2015. Developing robust and cost-effective methods for estimating the national recreational catch of Southern Bluefin Tuna in Australia. ICES Document 2012/022.20. 123 pp.
Morton, A. J., and Lyle, J. M. 2004. Preliminary assessment of the recreational gamefish fishery in Tasmania, with particular reference to Southern Bluefin Tuna, Tasmanian Aquaculture and Fisheries Institute.
Neter, J., Kutner, M. H., Nachtsheim, C. J., and Wasserman, W. 1996 Applied Linear Statistical Models, Irwin.
Noble, M. M., Harasti, D., Pittock, J., and Doran, B. 2019. Linking the social to the ecological using GIS methods in marine spatial planning and management to support resilience: A review. Marine Policy, 108: 103657.
Parnell, P. E., Dayton, P. K., Fisher, R. A., Loarie, C. C., and Darrow, R. D. 2010. Spatial patterns of fishing effort off San Diego: implications for zonal management and ecosystem function. Ecological Applications, 20: 2203-2222.
Pawson, M. G., Glenn, H., and Padda, G. 2008. The definition of marine recreational fishing in Europe. Marine Policy, 32: 339-350.
Pollock, K. H., Hoenig, J. M., Jones, C. M., Robson, D. S., and Greene, C. J. 1997. Catch Rate Estimation for Roving and Access Point Surveys. North American Journal of Fisheries Management, 17: 11-19.
Pollock, K. H., Jones, C. M., and Brown, T. L. 1994. Angler survey methods and their applications in fisheries management, American Fisheries Society.

Powers, S. P., and Anson, K. 2016. Estimating Recreational Effort in the Gulf of Mexico Red Snapper Fishery Using Boat Ramp Cameras: Reduction in Federal Season Length Does Not Proportionally Reduce Catch. North American Journal of Fisheries Management, 36: 1156-1166.

Productivity Commission. 2016. Marine Fisheries and Aquaculture, Final Report,. 81. 43 pp.

Read, A. D., West, R. J., Haste, M., and Jordan, A. 2011. Optimizing voluntary compliance in marine protected areas: A comparison of recreational fisher and enforcement officer perspectives using multi-criteria analysis. Journal of Environmental Management, 92: 2558-2567.

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

Rovero, F., Zimmermann, F., Berzi, D., and Meek, P. 2013. "Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. Hystrix, the Italian Journal of Mammalogy, 24: 148-156.

Ryan, K. L., Hall, N. G., Lai, E. K., Smallwood, C. B., Taylor, S. M., and Wise, B. S. 2017. Statewide survey of boat-based recreational fishing in Western Australia 2015/16. ICES Document No. 287. 205 pp.

Ryser, L., Markey, S., and Halseth, G. 2016. The workers' perspective: The impacts of long distance labour commuting in a northern Canadian small town. The Extractive Industries and Society, 3: 594-605.

Scholz, A. J., Steinbeck, C., Kruse, S. A., Mertens, M., and Silverman, H. 2011. Incorporation of Spatial and Economic Analyses of Human-Use Data in the Design of Marine Protected Areas. Conservation Biology, 25: 485-492.

Simpson, G. 2018. Use of a Public Fishing Area Determined by Vehicle Counters with Verification by Trail Cameras. Natural Resources, 9: 188-197.

Smallwood, C. B., Beckley, L. E., and Moore, S. A. 2012a. Influence of Zoning and Habitats on the Spatial Distribution of Recreational Activities in a Multiple-Use Marine Park. Coastal Management, 40: 381-400.

Smallwood, C. B., Beckley, L. E., Moore, S. A., and Kobryn, H. T. 2011. Assessing patterns of recreational use in large marine parks: A case study from Ningaloo Marine Park, Australia. Ocean & Coastal Management, 54: 330-340.

Smallwood, C. B., Pollock, K. H., Wise, B. S., Hall, N. G., and Gaughan, D. J. 2012b. Expanding Aerial-Roving Surveys to Include Counts of Shore-Based Recreational Fishers from Remotely Operated Cameras: Benefits, Limitations, and Cost Effectiveness. North American Journal of Fisheries Management, 32: 1265-1276.

Stahr, K. J., and Knudsen, R. L. 2018. Evaluating the Efficacy of Using Time-Lapse Cameras to Assess Angling Use: An Example from a High-Use Metropolitan Reservoir in Arizona. North American Journal of Fisheries Management, 38: 327-333.

Steffe, A. S., Murphy, J. J., and 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.

Stuart-Smith, R. D., Barrett, N. S., Crawford, C. M., Frusher, S. D., Stevenson, D. G., and Edgar, G. J. 2008. Spatial patterns in impacts of fishing on temperate rocky reefs: Are fish abundance and mean size related to proximity to fisher access points? Journal of Experimental Marine Biology and Ecology, 365: 116-125.

Tarrant, M. A., Manfredo, M. J., Bayley, P. B., and 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.

Taylor, S. M., Blight, S. J., Desfosses, C. J., Steffe, A. S., Ryan, K. L., Denham, A. M., Wise, B. S., et al. 2018. Thermographic cameras reveal high levels of crepuscular and nocturnal shore-based recreational fishing effort in an Australian estuary. ICES Journal of Marine Science: fsy066-fsy066.

Thiault, L., Collin, A., Chlous, F., Gelcich, S., and Claudet, J. 2017. Combining participatory and socioeconomic approaches to map fishing effort in small-scale fisheries. PLoS ONE, 12: e0176862.

Townhill, B. L., Radford, Z., Pecl, G., van Putten, I., Pinnegar, J. K., and Hyder, K. 2019. Marine recreational fishing and the implications of climate change. Fish and Fisheries, 20: 977-992.

Tracey, S., Lyle, J. M., Ewing, G., Hartmann, K., and Mapleston, A. 2013. Offshore recreational fishing in Tasmania 2011/12. 94 pp.

Tracey, S. R., Lyle, J. M., Stark, K. E., Gray, S., Moore, A., Twiname, S., and Wotherspoon, S. 2020. National Survey of Recreational Fishing for Southern Bluefin Tuna in Australia 2018/19. 124 pp.

van Poorten, B. T., and Brydle, S. 2018. Estimating fishing effort from remote traffic counters: Opportunities and challenges. Fisheries Research, 204: 231-238.

van Poorten, B. T., Carruthers, T. R., Ward, H. G. M., and Varkey, D. A. 2015. Imputing recreational angling effort from time-lapse cameras using an hierarchical Bayesian model. Fisheries Research, 172: 265-273.

Venturelli, P. A., Hyder, K., and Skov, C. 2017. Angler apps as a source of recreational fisheries data: opportunities, challenges and proposed standards. Fish and Fisheries, 18: 578-595.

Watson, J. E. M., Dudley, N., Segan, D. B., and Hockings, M. 2014. The performance and potential of protected areas. Nature, 515: 67.

West, L. D., Stark, K. E., Murphy, J. J., Lyle, J. M., and Ochwada-Doyle, F. A. 2015. Survey of Recreational Fishing in New South Wales and the ACT, 2013/2014. 149. 150 pp.

Wheatley, D. 2017. Employee satisfaction and use of flexible working arrangements. Work, Employment and Society, 31: 567-585.

Wood, G., Lynch, T. P., Devine, C., Keller, K., and Figueira, W. 2016. High-resolution photo-mosaic time-series imagery for monitoring human use of an artificial reef. Ecology and Evolution, 6: 6963-6968.

Wood, S. 2006. Generalized Additive Models: An Introduction with R Chapman and Hall.

Wood, S. N. 2001. Partially specified ecological models. Ecological Monographs, 71: 1-25.

Zischke, M. T., Griffiths, S. P., and Tibbetts, I. R. 2012. Catch and effort from a specialised recreational pelagic sport fishery off eastern Australia. Fisheries Research, 127–128: 61-72.

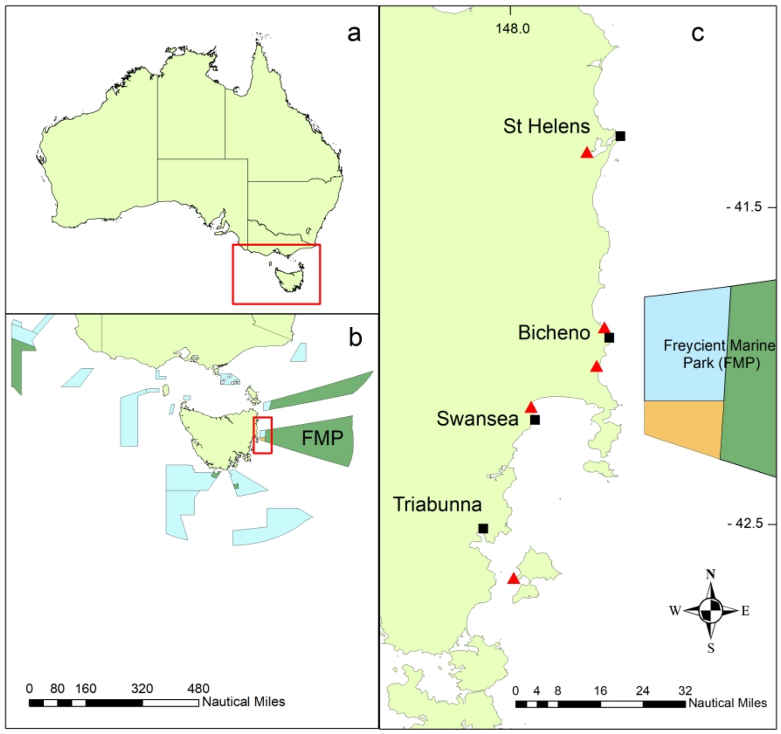

Figure 1 a) Australia with state boundaries, the island state of Tasmania is enclosed in a red box, b) the South East Network of Australia Marine Parks, including the Freycinet Australian Marine Park (FMP), the East Coast of Tasmania study site is within a red box, c) the study site with the location of ramps (■), closest weather stations (��) and the zoning of the FMP. 'No-take' or International Union for Conservation of Nature (IUCN) protected area category II is coloured dark green, 'Recreational Use' (IUCN IV) is orange and 'Multiple Use' (IUCN VI) is blue.

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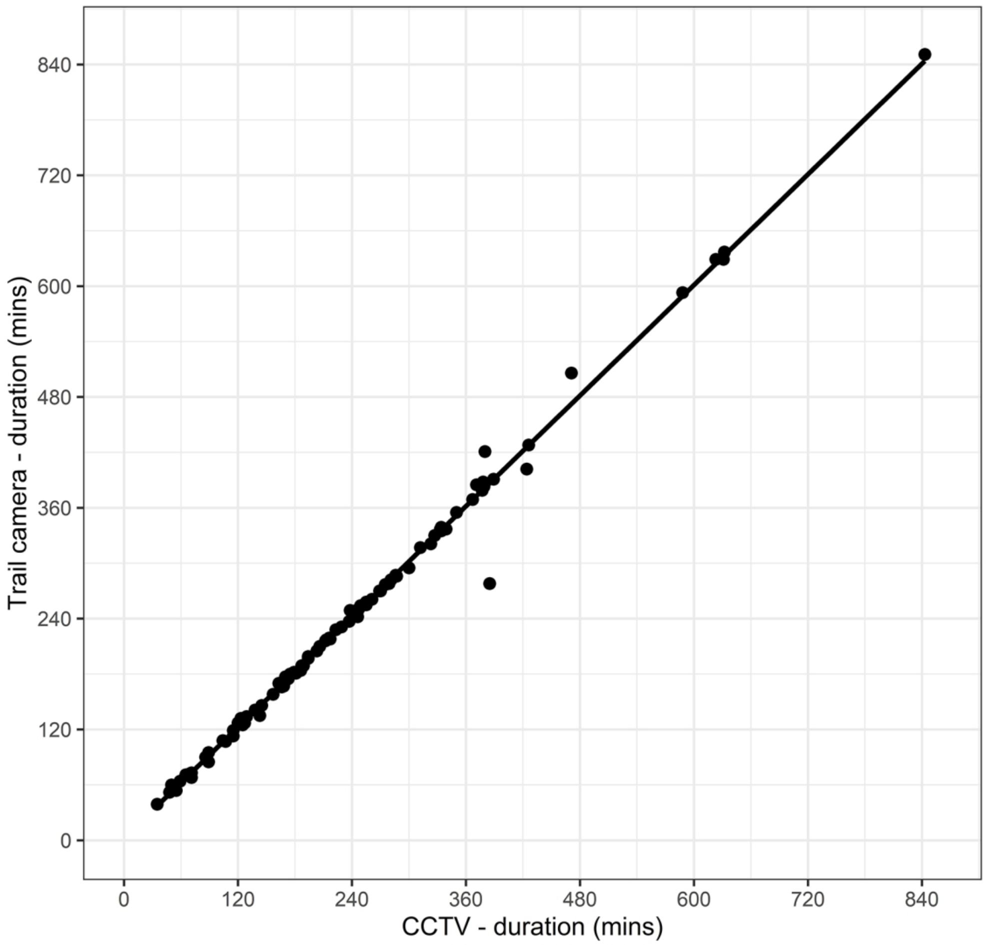


Figure 2. Comparison of estimated trailer boat trip durations between observations made by a CCTV camera and those made by a trail camera at the Triabunna boat ramp.

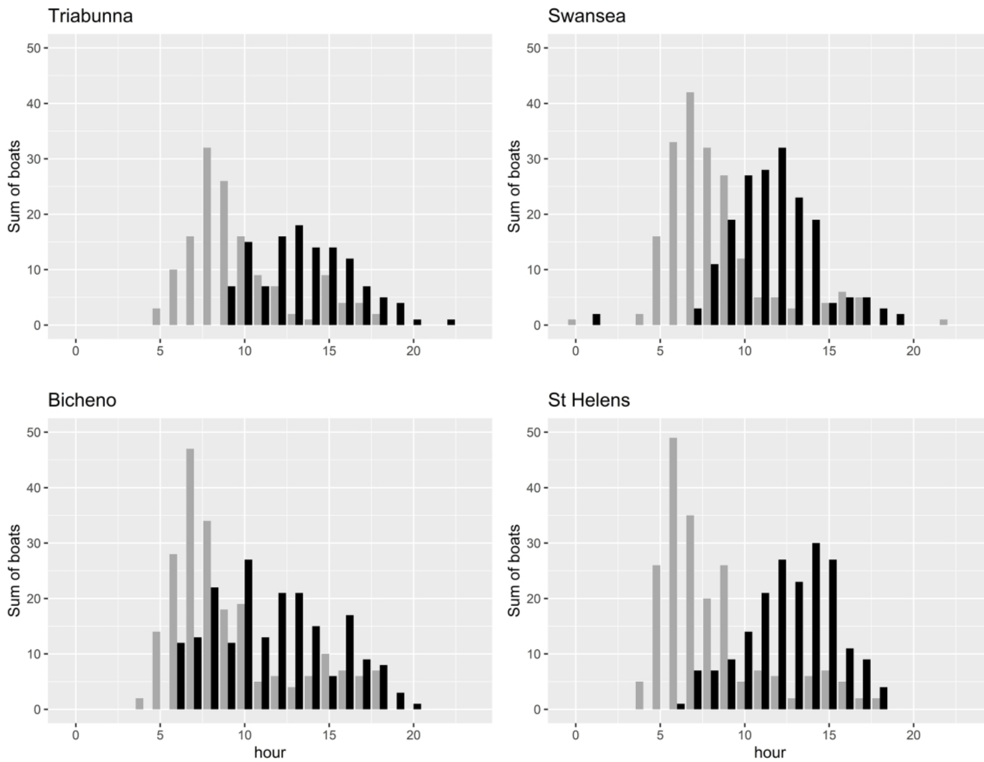
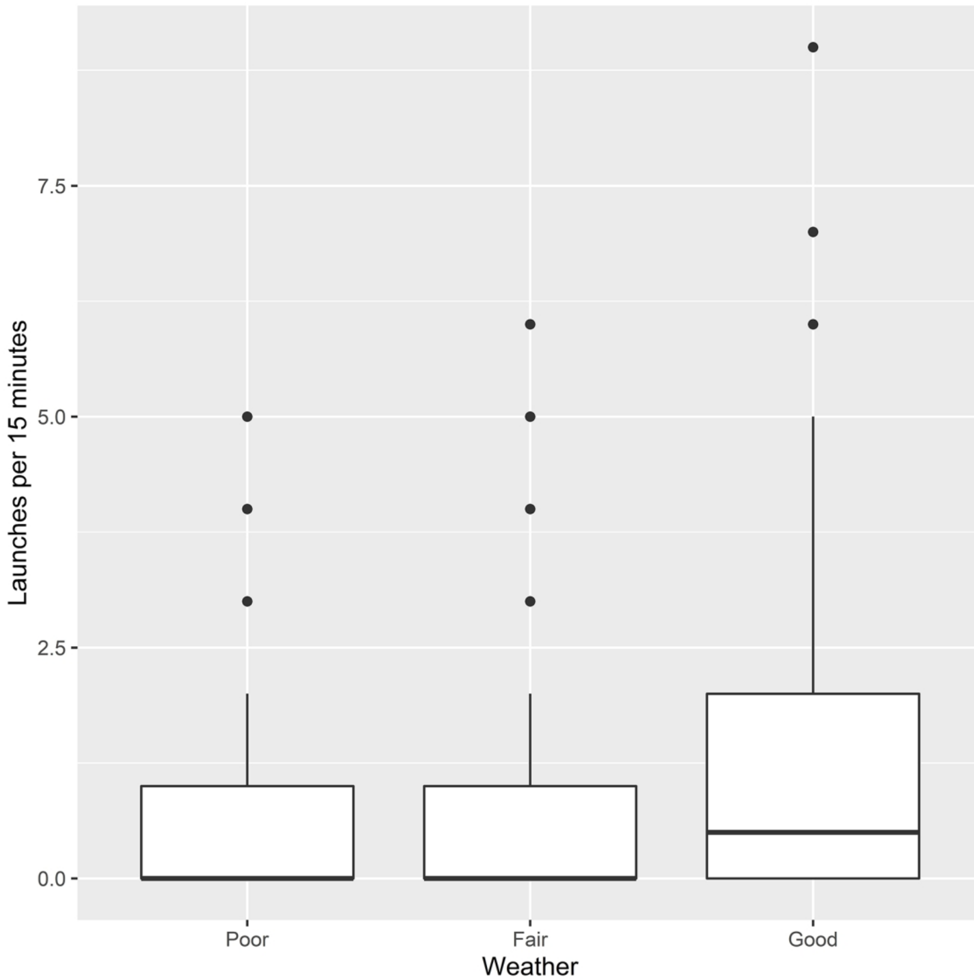


Figure 3. Hourly cumulative frequencies of launches (grey) and retrievals (black) of trailer boats observed via trail cameras at four ramps on Tasmania’s East Coast.



Distributions of trailer boat launches per hour, observed between the peak times of 0600-1000, in three different wind weather conditions for fishing: Poor > 20 km/h, Fair 10-20 km/h and Good 0-10 km/h.

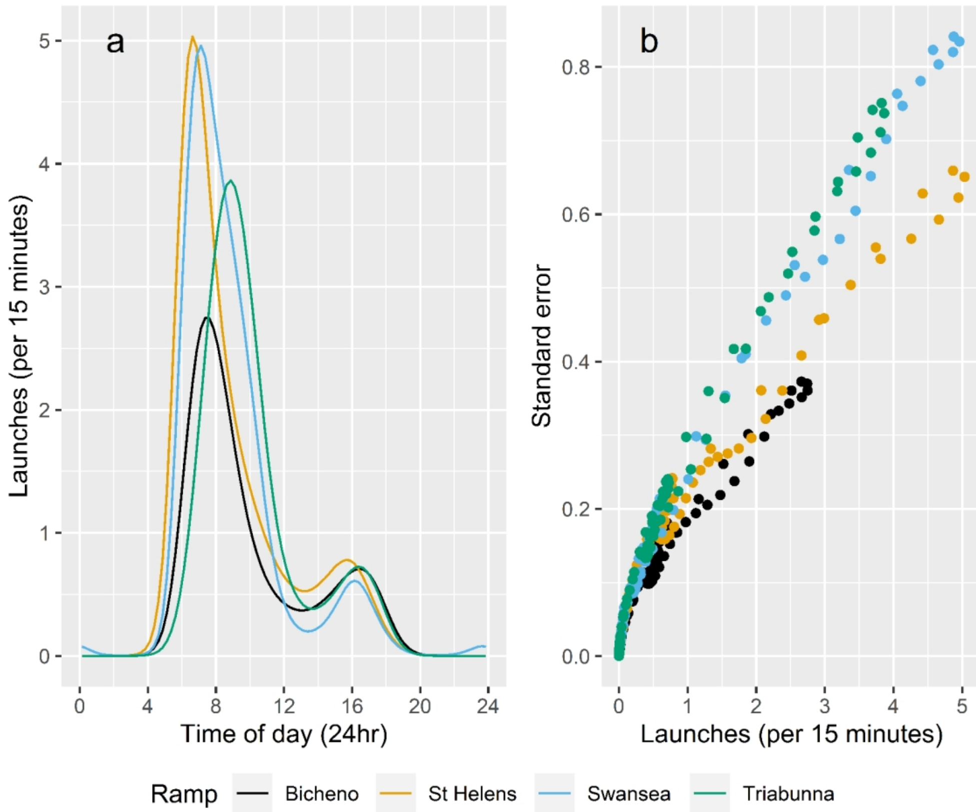


Figure 5. Predictive model of the a) timing and number of recreational fishing boat launches at four ramps on Tasmania's East Coast on weekends/public holidays during good weather conditions and b) the associated standard errors.

152x127mm (300 x 300 DPI)

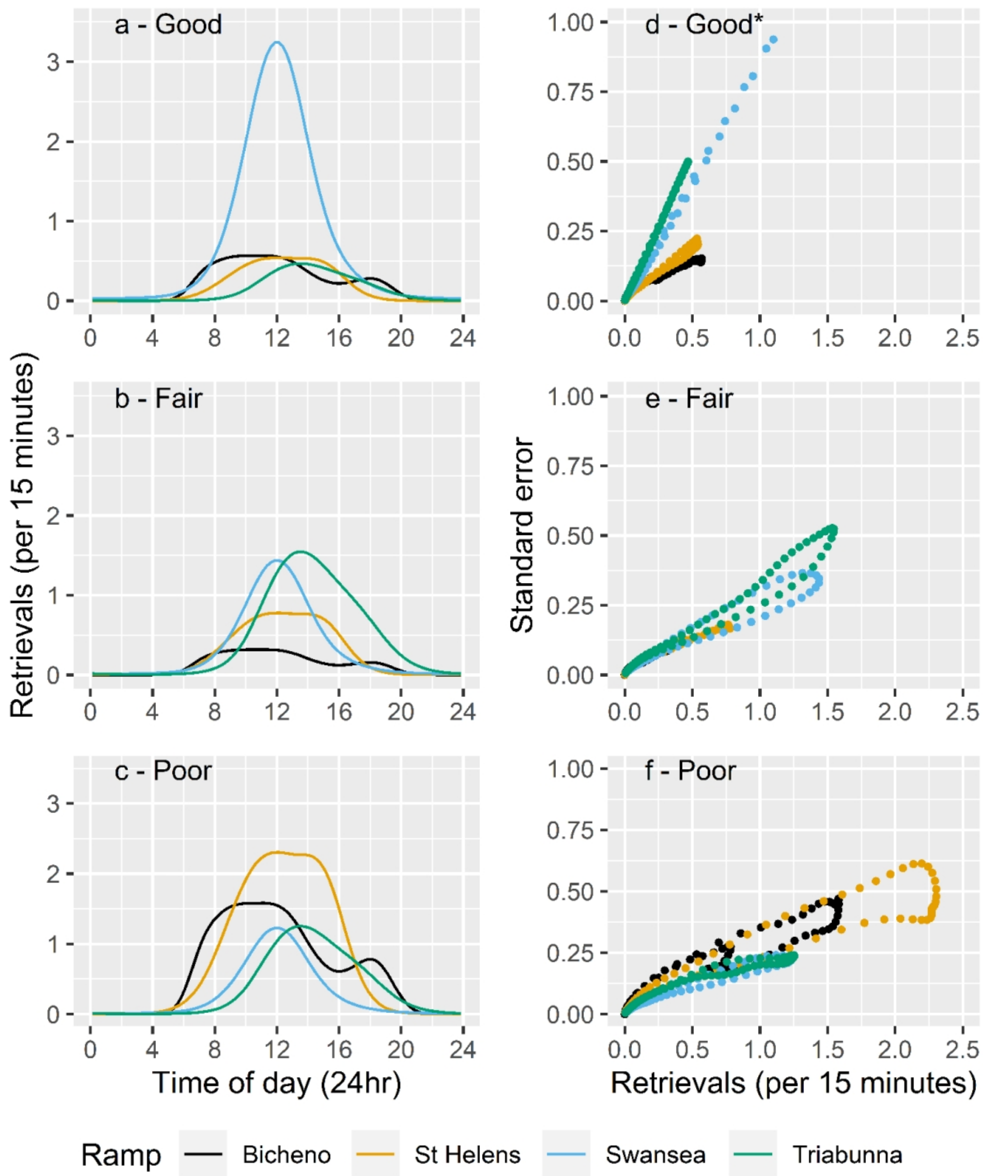


Figure 6. Predictive models of the a-c) timing and number of recreational fishing boat retrievals at four ramps on Tasmania's East Coast during Good, Fair and Poor weather conditions and d-f) the associated standard errors (SE). Modelled SE for Swansea in good weather (d – Good*) has been truncated for scaling visualisation purposes; this linear response extends to a maximum of 3.4 retrieval per 15 minutes with a SE of 2.7.

127x152mm (300 x 300 DPI)

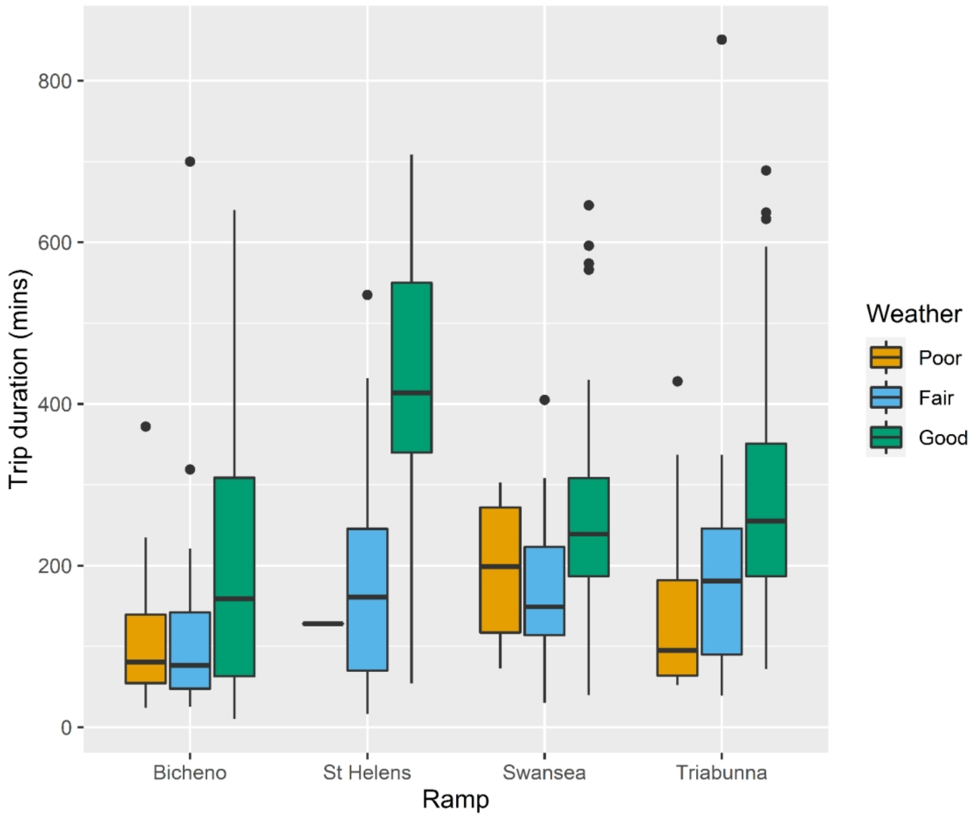


Figure 7. Distribution of recreational trailer boat fishers trip durations by ramp and weather.

152x127mm (300 x 300 DPI)

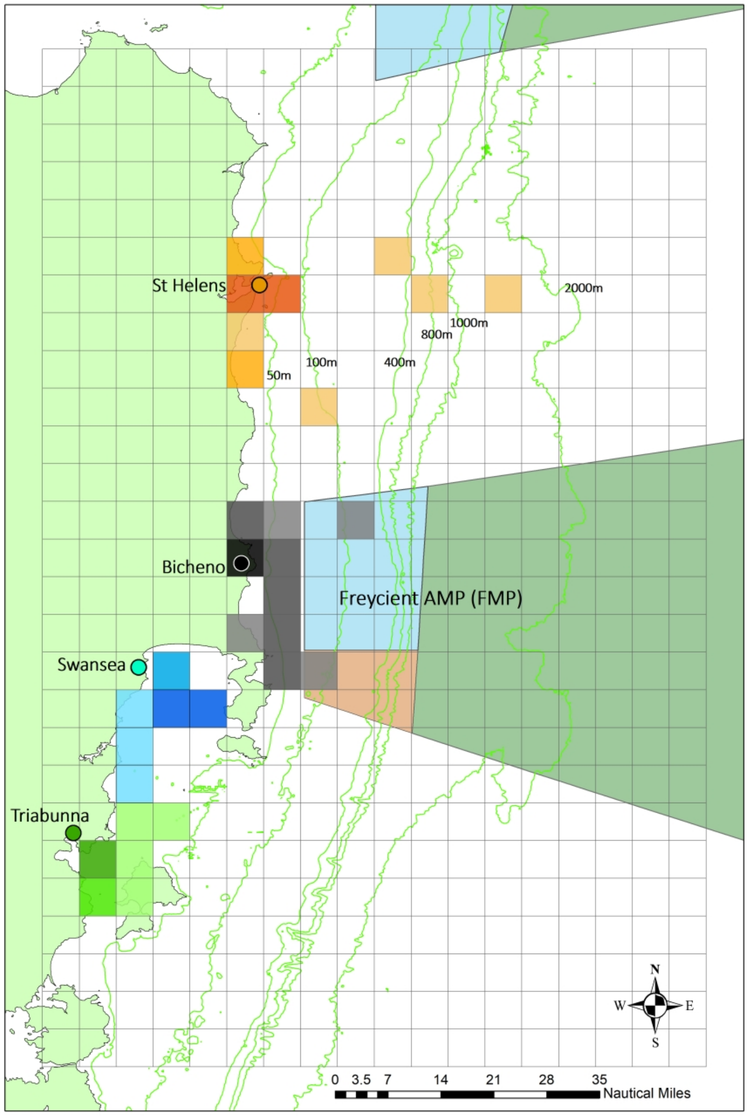


Figure 8. Summed counts of grids fished on trips across the Easter holiday survey period. Grids are colour coded by the ramp fishers' launched from and tint graduated by intensity, light to dark, 1-4 (Triabunna and St Helens) and 1-3 (Bicheno and Triabunna) counts. The Freycinet AMP (FMP) zoning for 'No-take' or International Union for Conservation of Nature (IUCN) protected area category II is coloured dark green, 'Recreational Use' (IUCN IV) is orange and 'Multiple Use' (IUCN VI) is blue. The bathymetry is in light green and marked by depth in meters off St Helens.

296x419mm (300 x 300 DPI)

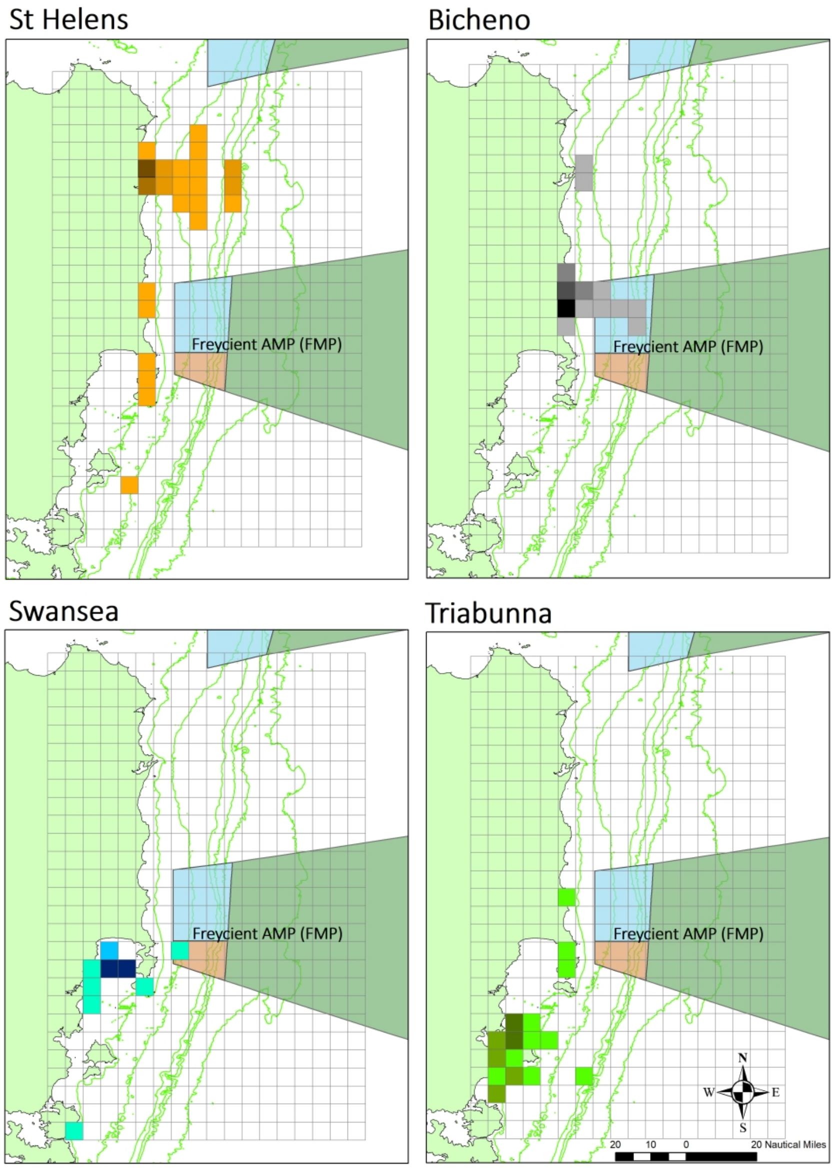


Figure 9. Summed counts of grids fished across the three months prior to this study. Grids are colour coded by fishers' interview ramp and tint graduated, light to dark, from 1-3 (Swansea), 1-4 (Bicheno and Triabunna) and 1-7 (St Helens) counts. The Freycinet AMP (FMP) zoning for 'No-take' or International Union for Conservation of Nature (IUCN) protected area category II is coloured dark green, 'Recreational Use' (IUCN IV) is orange and 'Multiple Use' (IUCN VI) is blue. The bathymetry is in light green.

297x420mm (300 x 300 DPI)

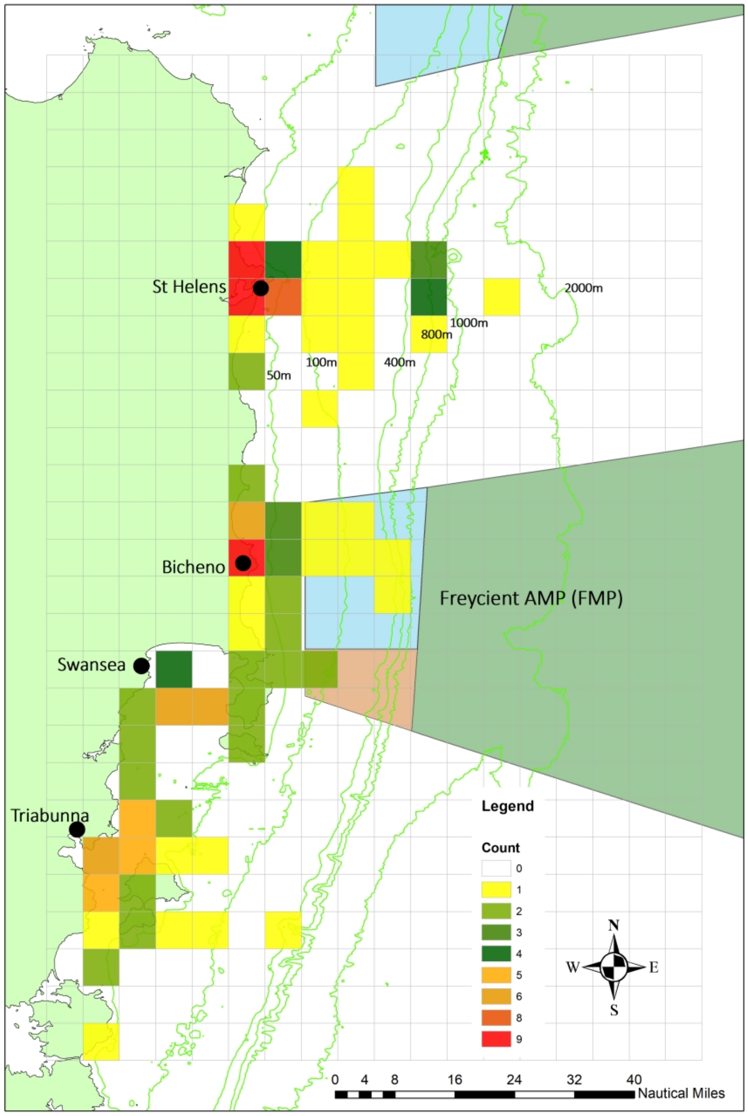


Figure 10. Summed counts of grids fished for all data collected (Study period + previous 3 months). Grids are colour graduated. The Freycinet AMP (FMP) zoning for ‘No-take’ or International Union for Conservation of Nature (IUCN) protected area category II is coloured dark green, 'Recreational Use' (IUCN IV) is orange and 'Multiple Use' (IUCN VI) is blue. The bathymetry is in light green and marked by depth in meters off St Helens.

296x419mm (300 x 300 DPI)

	Trail camera	**CCTV**
All launches and those not matched to returns (L)	140 (32)	145 (14)
All retrievals and those not matched launches (R)	122 (14)	139 (8)
Matched observations	108	131
Total number of boats observed = (L) + (R) + Matched	154	153

a) Launches		Trail Cam		
		Observed	Missed	Total Launches
CCTV	Observed	128	17	145
	Missed	12		
	Total Launches	140		

b) Retrievals		Trail Cam		
		Observed	Missed	Total Retrievals
CCTV	Observed	106	33	139
	Missed	16		
	Total Retrieves	122		

	Bicheno	St Helens	Swansea	Triabunna	Totals
Launch	212	203	192	140	747
Retrieved	199	190	181	122	692
Matched (%)	117 (59%)	132 (69%)	109 (60%)	108 (89%)	466 (67%)

Targeted species	**Habitat/depth**	**Bicheno**	**St Helens**	**Swansea**	**Triabunna**
Blue eye trevalla *Hyperoglyphe antarctica*	Demersal 350-1500m	1	3	0	0
Striped trumpeter *Latris lineata*	Reefs 50-400m	1	2	0	0
Jackass morwong *Nemadactylus macropterus*	Demersal 0-400m	0	2	0	0
Gummy shark *Mustelus antarcticus*	Demersal 0-350m	0	1	0	0
Flathead sand and tiger	Benthic	8	7	10	6
Platycephalus bassensis	0-25m (sand)				
Neoplatycephalus richardsoni	10-160m (tiger)				
Gurnard perch *Neosebastes scorpaenoides*	Demersal 2-100m	0	1	0	0
Blue throat wrasse *Notolabrus tetricus*	Reefs 1-160m	0	1	0	0
Abalone blacklip *Haliotis rubra*	Reefs 5-40m	0	1	0	0
Southern Rock lobster *Jasus edwardsii*	Reefs 5-200m	5	3	0	3
Southern calamari *Sepioteuthis australis*	Demersal/reefs 0-10m	3	1	4	1
Albacore Tuna *Thunnus alalunga*	Pelagic	0	1	0	0