Ministry for Primary Industries
Manatū Ahu Matua

Web camera and creel survey monitoring of recreational fisheries in FMAs 1, 8, and 9

New Zealand Fisheries Assessment Report 2015/52

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ISSN 1179-5352 (online)
ISBN 978-1-77665-046-0 (online)

September 2015

New Zealand Government

Growing and Protecting New Zealand

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A network of web cameras has been established overlooking key boat ramps in FMA 1 since 2004–05, and in FMAs 8 and 9 since 2006–07. Each camera system records a time-stamped image of the ramp every 60 seconds, which can be viewed in series to provide a count of the number of boats returning to that ramp during a 24 hour period. Images are viewed from a stratified random sample of 60 days per fishing year, and the resulting daily traffic counts are used to generate indices of boating effort.

Regional boating effort indices generated as part of this programme fluctuate from year to year, with little long-term trend. Similar annual patterns between ramps are apparent, with traffic peaking noticeably in 2010–11 at five out of the six ramps examined here. Traffic levels at all six ramps during the 2011–12 fishing year were more typical of those seen over the longer term, which suggests that the recent national panel survey, aerial-access survey, and western Bay of Plenty access surveys were conducted during a period when fishing effort was neither higher nor lower than the long term average.

However, additional data collected recently as part of this programme now strongly suggests that trends in recreational catch are only partially described by trends in boating effort at boat ramps. Creel survey data were collected during previous aerial access surveys, coupled with an ongoing creel survey initiated as part of this programme since 2012–13. Creel survey data are used for two purposes. First, to convert boat traffic indices into fishing boat traffic indices, given the proportion of intercepted parties who claimed to have fished during their trip. Second, and more importantly, combining indices of the number of fishing boats returning to each ramp annually with catch per boat indices provides an index of the annual harvest landed at each ramp.

For example, total harvest indices calculated from data collected at Takapuna in the Hauraki Gulf suggest that levels of recreational catch can fluctuate far more dramatically than previously thought, particularly in comparison to trends seen in commercial landings which are quota and not effort limited. The number of boats returning to the public boat ramp at Takapuna declined by 32% between 2011–12 and 2013–14. This decrease in boating effort coincided with a 58% decline in the average weight of snapper landed per boat returning to this ramp over the same period, and a 55% decline in the landed weight of kahawai. The combined effect of declines in effort and fishing success has been a 71% decline in the total estimated weight of snapper landed at this ramp since 2011–12 and a 69% decline in the total estimated weight of landed kahawai. The scale of the decline of harvest indices for snapper calculated solely from data collected at the Takapuna boat ramp has been at least partially corroborated by a comparison of these indices with harvest estimates for the wider Hauraki Gulf provided by two aerial-access surveys in 2004–05 and 2011–12.

Unfortunately, most previous creel surveys have only lasted for a few months, and comprehensive creel survey data are not available for most fishing years before 2012–13. This means that currently we can only generate total harvest indices for a small number of ramps/regions in a subset of years. The coupled web camera creel survey approach described here will be supported for at least another five years as part of Research Project MAF201404. Data from this project and future stock-wide recreational harvest estimation surveys are required to test the findings of this study, which could have significant implications for future recreational fisheries management.

1. INTRODUCTION

Although survey methods have now been developed to estimate and characterise harvests taken from large scale recreational fisheries, such as national panel survey and aerial-access surveys, the cost of these is considerable and their occurrence will be intermittent. Levels of recreational harvesting can vary substantially over time, and some means of interpolation is therefore required, to inform fisheries management.

Anglers fishing from boats account for the majority of the recreational harvest taken from most recreational finfish fisheries off the North Island and boat ramps act as choke points through which they must pass. A network of web camera overlooking high traffic boat traffic boat ramps has therefore been established which provides a cost effective means of continuously monitoring trends in boating effort, which is a key determinant of recreational catch. The first of these web camera systems was installed in the Hauraki Gulf in 2003–04, to provide daily effort profiles for an aerial-access survey (Hartill et al 2007a). The potential long term use of these systems was soon realised however, and two further systems were installed in East Northland (at Waitangi and Parua Bay) and in the Bay of Plenty (at Sulphur Point and Whakatane), in 2004–05. The network has since been further expanded to include two sites at Shelly Beach and Raglan in FMA 8 and at New Plymouth (FMA 9), and in the past year, at Twin Bridges – Paremata (FMA 9) and at Napier and Gisborne (FMA 2).

Creel survey data has also been collected concurrently since 2011–12, which are used to translate boat traffic indices into harvest indices, as these are of greater relevance to fisheries managers. The indices presented here provide a unique insight into the dynamic nature of recreational fisheries, which can account for a significant proportion of the catch landed from some of New Zealand's shared inshore fisheries.

Overall objective

To monitor changes in marine amateur fishing trailer boat effort in FMAs 1, 8 and 9.

Specific objectives

1. To maintain and operate the web camera network in FMA 1, FMA 8 and FMA 9 for the 2012/13 and 2013/14 fishing years.

2. To derive regional indices of amateur fishing effort in FMA 1, FMA 8 and FMA 9 using web camera data collected from boat ramps for the 2012/13 and 2013/14 fishing years.

3. To monitor boat ramp traffic to distinguish between trailer boat effort and fishing effort at selected web camera sites for the 2012/13 and 2013/14 fishing years.

2. METHODS

2.1 Overview of web camera network

A network of web cameras has been established overlooking key boat ramps in FMA 1 since 2004–05, and in FMAs 8 and 9 since 2006–07 (Figure 1). Each system is essentially comprised of: a video camera which transmits data to a nearby PC, a PC with a frame grabber that takes a static image at regular intervals which is time stamped and saved, and a modem that transmits batches of images to a secure NIWA server.

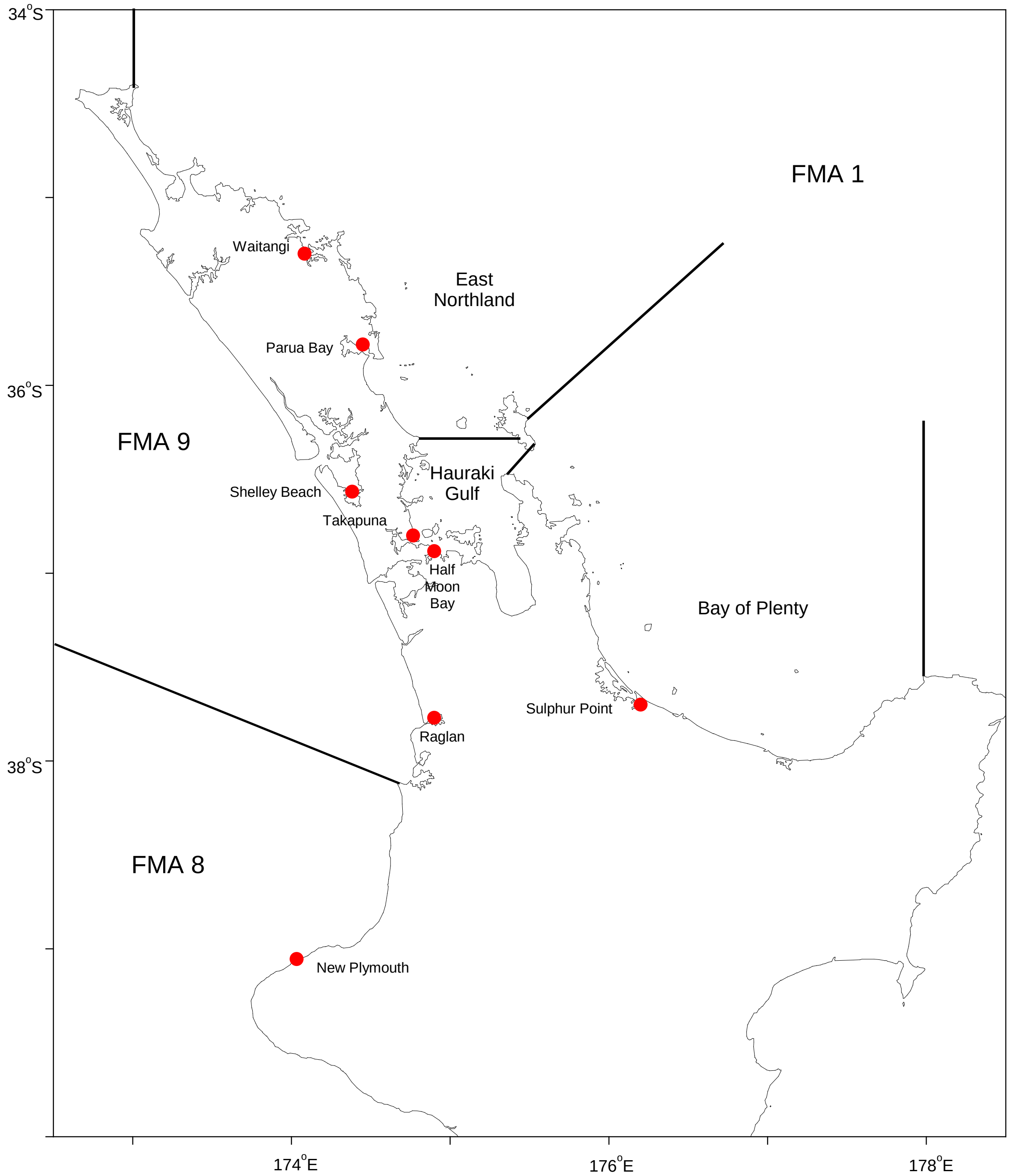


Figure 1: Locations of boat ramps where web cameras are currently installed in FMAs 1, 8 and 9. Two systems are installed at Shelly Beach and at Raglan.

Issues to be considered when establishing a web camera system include: the location and availability of structures which provide a good view of each ramp (e.g. power poles, street lights, private buildings); how power is provided to the web camera and associated PC/modem (national power grid, private power supply, intermittent street light power or solar power coupled with batteries and charger); how the image data is transmitted to the associated PC (wireless link or cable); and where to locate the PC and modem within reception range of the wireless camera. Broadband internet is required because at least 1440 images are collected every day (at least one per minute) which means that the PC must be within approximately 5 km of a Telecom exchange. However, data may be transmitted over cellular networks when a Telecom exchange is not within 5 km of the web camera system

Camera system outages sometimes occur for a variety of reasons including: teething issues associated with new installations; lightning strikes causing power surges; power and internet outages; and vandalism. Camera systems tend to become more reliable with time as they are re-engineered to overcome inherent site specific short comings. Problems are usually detected quickly via an automated email alarm protocol, and remedied as quickly as possible. Some substantial delays have been experienced because third parties, such as local councils, have taken time to reinstate light poles that have been knocked down. There has also been an increasing incidence of radio interference degrading the quality of images that are transmitted from the camera to a nearby PC connected to the internet. This is thought to be due to a proliferation of communication devices transmitting on the 2.4 GHz frequency and this problem is currently resolved by shifting to the less commonly used 5.8 GHz frequency (although public usage of that frequency is rapidly increasing too).

Web cameras were first installed in the inner Hauraki Gulf in early 2004, overlooking public boat ramps at Takapuna and Half Moon Bay (Figure 1). These cameras were initially installed to provide data on the diurnal profile of fishing effort on days surveyed as part of an aerial-access survey of the Hauraki Gulf snapper fishery (Hartill et al. 2007a), but they have since been used to monitor long term trends in boating effort. A further four camera systems were installed in FMA 1 in 2005; two in East Northland (Waitangi and Parua Bay) and two in the Bay of Plenty (Sulphur Point and Whakatane).

These systems provide a means of monitoring trends in boating effort in all three regions of FMA 1, but in most years, images have only been interpreted from a single camera in reach region; at Waitangi in East Northland, at Takapuna in the Hauraki Gulf, and at Sulphur Point in the Bay of Plenty. The merits of continuing to maintain a secondary system in each region (at Parua Bay, Half Moon Bay, and at Whakatane) has been assessed (Hartill 2015) and the decision was made to disestablish the system at Whakatane because traffic at this ramp was unduly influenced by the closure of the river bar, which means that trends in effort at this ramp are not always representative of the wider fishery.

Web camera systems were first installed overlooking boat ramps on the west coast of the North Island (FMAs 8 and 9) in 2006, as part of an assessment of the recreational snapper harvest in SNA 8 (Hartill et al. 2011). Fishing effort on the west coast is localised and spatially variable. Multiple cameras are required to monitor effort taking place in the large harbours to the north, on the open northern coast, and on the open coast to the south (Figure 1) which often experience very different weather regimes.

The first camera to be installed on the west coast was at Shelly Beach in the Kaipara Harbour, in July 2006. Many of the boats observed were potentially used for commercial rather than recreational fishing, and a second high resolution camera was subsequently installed to provide views of these boats from another angle. We can now more readily identify and discount commercial set net vessels given the presence of: large numbers of admiralty anchors, fish bins, nets, alkathene hoops over outboards, identification numbers painted on boats, and from the nature of the vehicles used to tow these boats.

A pair of systems was also installed at Raglan, in November 2009. One camera overlooks the boat ramp at Manu Bay, on the open coast, and another overlooks the entrance to Raglan Harbour (as some boats access the open coast from ramps in the harbour). The field of view at this second camera is approximately 250 m wide and we have calculated that a vessel travelling at 20 knots can only travel about 150 m in a 15 second period. The Raglan harbour camera therefore captures an image of this body of water once every 15 seconds. The combined counts from these two cameras can be used to provide an index of the level of effort on the open coast which originates from the Raglan area.

A third west coast camera was installed at New Plymouth in FMA 8, in December 2006. The initial performance of this camera system was not satisfactory, and several irresolvable issues including sun strike led to the repositioning of this camera in September 2010. The camera has now been repositioned across the water to the south of the ramp, and usable imagery has been collected almost continuously since this change was made.

2.2 Temporal subsampling of image data

Time-stamped images of each ramp are stored in a separate subdirectory for each day, which can be viewed as a sequential time lapse video. Each camera system collects 525 600 images a year (when an image is collected every 60 seconds), however, and the effort required to manually interpret all of the images collected at all ramps is considerable. Some form of stratified random subsampling is therefore required if indices of effort are to be generated in a cost effective manner. Parametric bootstrapping of daily traffic counts from FMA 1 collected in 2004–05 suggested that a stratified random sample of 60 days per fishing year should yield a reasonably precise estimate of the number of boats using a ramp annually (Hartill et al. 2007b, Figure 2).

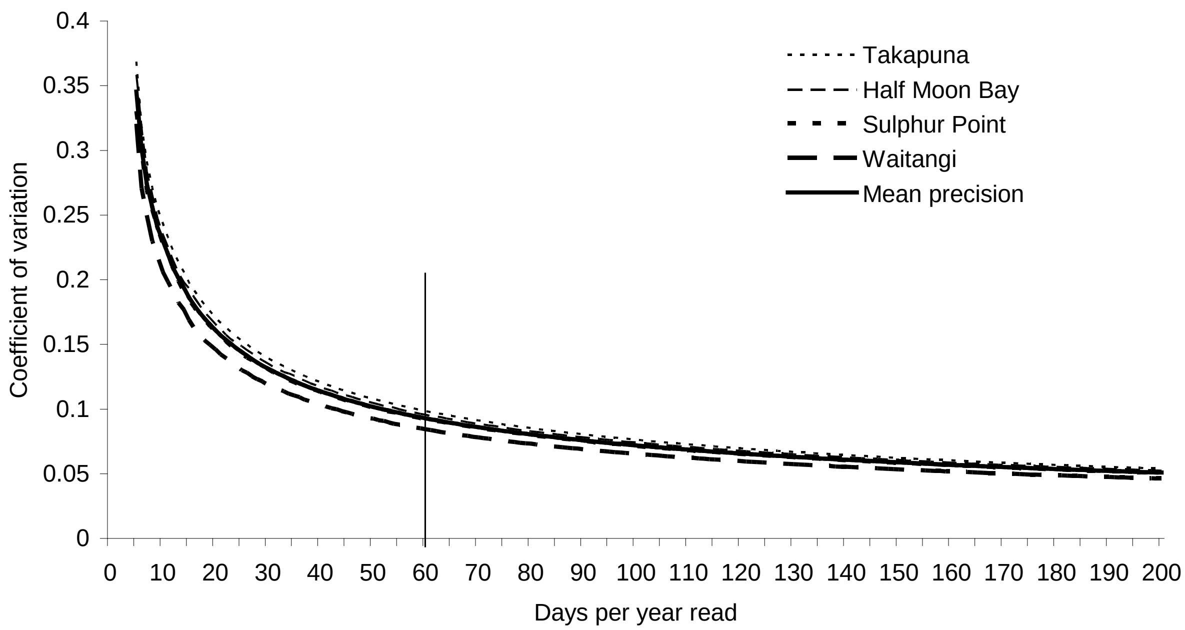


Figure 2: Relationship between precision and optimal allocation of sampling effort across temporal strata, by ramp. The average level of precision is also given, as this was used to determine the overall level of sampling effort beyond which there was little improvement in estimates of average daily boat ramp traffic (from Hartill et al. 2007b).

The temporal strata considered in this optimisation were based on combinations of seasons (Summer – 1 October to 30 April versus Winter – 1 May to 30 September) and day-types (Midweek days versus Weekend/public holiday days). Midweek days were defined as Monday to Friday, excluding any days that fall on a public holiday. The optimal allocation of 60 days across these temporal strata is given in Table 1.

Table 1: Temporal sampling design and the resulting intensity of sampling effort. The number of days within each temporal stratum differs from year to year depending on when public holidays fall and whether neighbouring days might be treated as an extended weekend break.

Season	Day type	Sampled days	All days	Sampling intensity
Summer	Mid-week	20	134 – 141	14.2% – 14.9 %
	Weekend/PH	24	71 – 78	30.8% – 33.8%
Winter	Mid-week	8	108 – 110	7.3% – 7.4%
	Weekend/PH	8	43 – 45	17.8% – 18.6%

The subsequent and ongoing generation of regional effort indices has therefore been based on counts of boats returning to a key ramp in each region/FMA on 60 days preselected from each fishing year according to the temporal sampling design given in Table 1. In the first index year, the 60 days were selected randomly, but in all subsequent years the selection of days has been closely based on that in the first year. This non-random selection of days in subsequent years is necessary because recreational activity can be influenced by the proximity of public holidays, fishing contests and other social phenomena. It is therefore desirable, where possible, to hold these influences constant across years as interannual consistency in methods is desirable with any long term index. The selection of survey days in the first year took the following considerations into account.

- Temporal strata conform to the fishing year.
- The random allocation of days resulted in a roughly even spread of samples over the months considered.
- Public holidays which could either fall on a midweek day or weekend day were not selected as they may or may not result in a long weekend, and can influence levels of fishing effort on neighbouring days in a given season (namely Waitangi Day and Anzac Day).
- The timing of public holidays that can vary from year to year; namely the Easter holidays.

The total number of boats returning to each ramp within each seasonal/day-type stratum is the product of the average level of traffic on sampled days and the inverse of the sampling intensity for that stratum (see Table 1). Sampling intensities for any given temporal stratum can vary from year to year as the total number of days falling within the two summer strata varies over time, as Waitangi Day and ANZAC Day were not Mondayised before 2015. Further, normal working days that are bracketed by a public holiday and a weekend day are often popular choices for annual leave, and levels of traffic on these days are often more similar to those seen on weekends and public holidays.

2.3 Predicting traffic counts on days when system outages occur

Web camera systems sometimes fail for a wide range of unforeseeable reasons (see Section 2.1). These outages are regarded as random events as they are unlikely to be related to levels of fishing effort occurring at the time the outage occurred. On two occasions, outages have occurred for a significant proportion of a given season: at Takapuna during the summer of 2008–09; and at Waitangi during the winter of the same year. In these instances the temporal coverage of the remaining data was not considered sufficiently representative to provide an unbiased estimate of the average daily level of traffic crossing these ramps, within the affected seasonal strata.

There appears to be a reasonable degree of correlation between relative levels of effort across the three regions of FMA 1. Daily traffic counts at Waitangi, Takapuna, and Sulphur Point are available for 349 days between 25 December 2004 and 24 December 2005 and Pearson correlation coefficient coefficients calculated from pairwise comparisons of ramp counts ranged from 0.776 (between Waitangi and Sulphur Point) to 0.881 (between Takapuna and Sulphur Point) (Hartill et al. 2007b). These levels of correlation are high enough to suggest that meaningful predictions of effort can be made for one ramp on a day when an outage occurs, based on counts made at the other two ramps where the web camera systems were both fully operational on the same day. Generalised Linear Models were therefore used to predict levels of traffic for the 121 instances where a system outage was experienced on a preselected survey day by one of the three ramps considered here (out of a combined sample size of 1668 survey days falling between 1 April 2005 and 30 September 2014 across these three ramps).

Separate models were generated for each region, to determine the relationship between daily traffic counts at each ramp relative to those observed at the other two ramps given the fishing year, season, and day type in which these observations were made. Counts from the other two ramps were square root transformed to produce a more even spread of observations along the predicted space, and in doing so to reduce the leverage of extreme observations on the fit to the model. These counts were fitted as third order polynomials to allow for any non-linearity in their relationship with concurrent counts at the response ramp. Ramp:Year interaction terms were also offered to each model, to allow for the fact that the relationship between levels of traffic at each ramp can change over time. Each model was fitted in a stepwise manner to determine whether each variable should be selected, and the order in which those variables should be fitted (see Appendix 1 for model selection statistics and diagnostic plots at each ramp). These generalised models were then used to predict missing observations (and associated estimates of error for these estimates) when counts were available from the other two ramps on those days when outages occurred at the response ramp.

Although this model-based approach can be used to provide predictions of effort when counts are available from highly correlated alternative ramps in the same FMA, it cannot be used to provide predictions for outage affected days at Takapuna and Waitangi during mid to late November in 2012. This is because the outages at these ramps coincided at that time, and the traffic levels at the remaining FMA 1 ramp (at Sulphur Point) were suppressed due to reduced fishing effort following the nearby grounding of the M.V. *Rena*, on 5 October 2012. The number of days sampled during the summer of 2011–12 at Takapuna and Waitangi were consequently lower than in previous years, and the loss of counts on these days were assumed to be random with respect to fishing effort.

Levels of correlation across the three ramps in FMAs 8 and 9 were too low to support the use of the GLM based approach used in FMA 1. This means that system outages that coincide with preselected sample days reduce the number of observations available to inform any index of effort, and potentially, the extent to which that index describes the true level of that taking place throughout an affected temporal stratum.

2.4 Generating web-camera vessel indices

Separate traffic-based effort indices were calculated for each region of FMA 1, and in FMAs 8 and 9, based on the counts available from the ramp selected from that region. Daily counts from sampled days were averaged for each seasonal/day-type stratum, and these averages were scaled by the number of days occurring within each stratum, to provide an estimate of the number of boats that returned to the ramp on those days. These stratum specific estimates of traffic volumes were then combined to produce an estimate of the number of boats that had returned to a given ramp during each fishing year (and also for each season within each year).

A two stage bootstrapping procedure was used to estimate variances. Daily counts were selected with replacement from each temporal stratum, and these counts were averaged and combined in the manner described above. When a sample day was selected for which the boat count was predicted rather than observed, the variance associated with this estimate (which was derived from the Generalised Additive Model) was used to generate a random normal deviate, which was added to the predicted count for that day. Standard error estimates were calculated from 1000 bootstrap estimates generated for each stratum.

Although these indices are actually estimates of the number of boats returning each fishing year to the ramp of interest, it is assumed that the relative trends observed at this ramp broadly would reflect those occurring at other ramps within the same region. The high degree of between region correlation seen in 2004–05 suggests that this within region assumption is reasonable. This assumption is further investigated and discussed in Hartill (2015).

2.5 Collection of concurrent interview data

Many of the boats observed returning to a ramp will have been used for purposes other than fishing, and any index of effort based solely on web camera imagery will therefore describe trends in boating effort rather than fishing effort. Additional data are therefore required to estimate the proportion of observed boats that have been used for fishing, which can only be determined reliably from face-to-face interviews with fishers (creel surveys) returning to the same ramp.

Creel survey interviews conducted by NIWA have followed a standard format since the early 1990s, with data collected on whether a boat was used for fishing, and if so, on the methods used, areas fished, hours spent fishing, and on the composition of the catch (which is measured when possible). Data from these interviews have been used to generate ramp-specific indices of the proportion of boats used for fishing, which have been combined with web camera based indices of boating effort from the same ramp, to provide indices of the number of fishing boats returning to the ramp over time.

Interview-based catch per trip data have also been used to generate species specific indices of the average weight of fish landed per boat trip at each ramp over time. These catch per trip indices have been combined with the fishing boat effort indices, described above, to provide an index of the harvest returning to each boat ramp over time. Indices of harvest are of far greater interest to fisheries managers than the web based traffic indices, as they provide a means of monitoring trends in recreational harvest over time.

Creel survey data have been intentionally collected for this purpose since 1 October 2011, and intermittently for other purposes since 1990. The temporal sampling design used in recent creel surveys is the same as that used when subsampling web camera data, so that both forms of data are collected concurrently.

The collection of creel survey data is, however, relatively expensive, and interviews have only been conducted over a four hour period on each survey day, which is timed to coincide with the expected period of peak fishing effort based on data collected throughout the day in 2011–12 (Table 2, Figures 3 and 4).

Table 2: Scheduled timing of fixed four hour interview sessions by month and day type.

	Weekends/public holidays	Midweek days
October to November	1230 to 1630	1430 to 1830
December to March	1300 to 1700	1500 to 1900
April	1200 to 1600	1400 to 1800
May to July	1200 to 1600	1300 to 1700
August to September	1200 to 1600	1330 to 1730

The diurnal pattern seen in in 2011–12 (Figure 3) broadly matches that seen in other years in which aerial-access surveys have been conducted. The number of boats returning to five ramps overlooked by web cameras surveyed throughout the day in 2011–12 peaked in the early afternoon on weekend days and in the late afternoon on midweek days. Midweek interview sessions were therefore scheduled two hours later than sessions on weekends and public holidays. These data suggest that the scheduling of interview sessions during the mid to late afternoon broadly maximises the number of boats encountered, whereas a randomised start time would result in an approximate sample loss of 15–35% of boats during the weekend and 25–40% on midweek days.

Although fixed session timing maximises the number of interviews achieved, non-randomised start times could potentially result in the collection of data which is not representative and potentially biased if the relative intensity of other types of boating activity or catch rates change with time of day. Diurnal plots of the proportion of boats used for fishing and for other purposes at five key ramps surveyed throughout the day are shown in Figure 4. These plots suggest that boats used for purposes other than fishing account for a relatively similar level of effort throughout the day (relative to traffic rates of all boats including boats used for fishing). Previous examinations of diurnal catch rate profiles suggest that catch rates are also relatively steady throughout the day, apart from brief but sharp peaks in fishing success at dawn and at dusk, when relatively few boats are on the water.

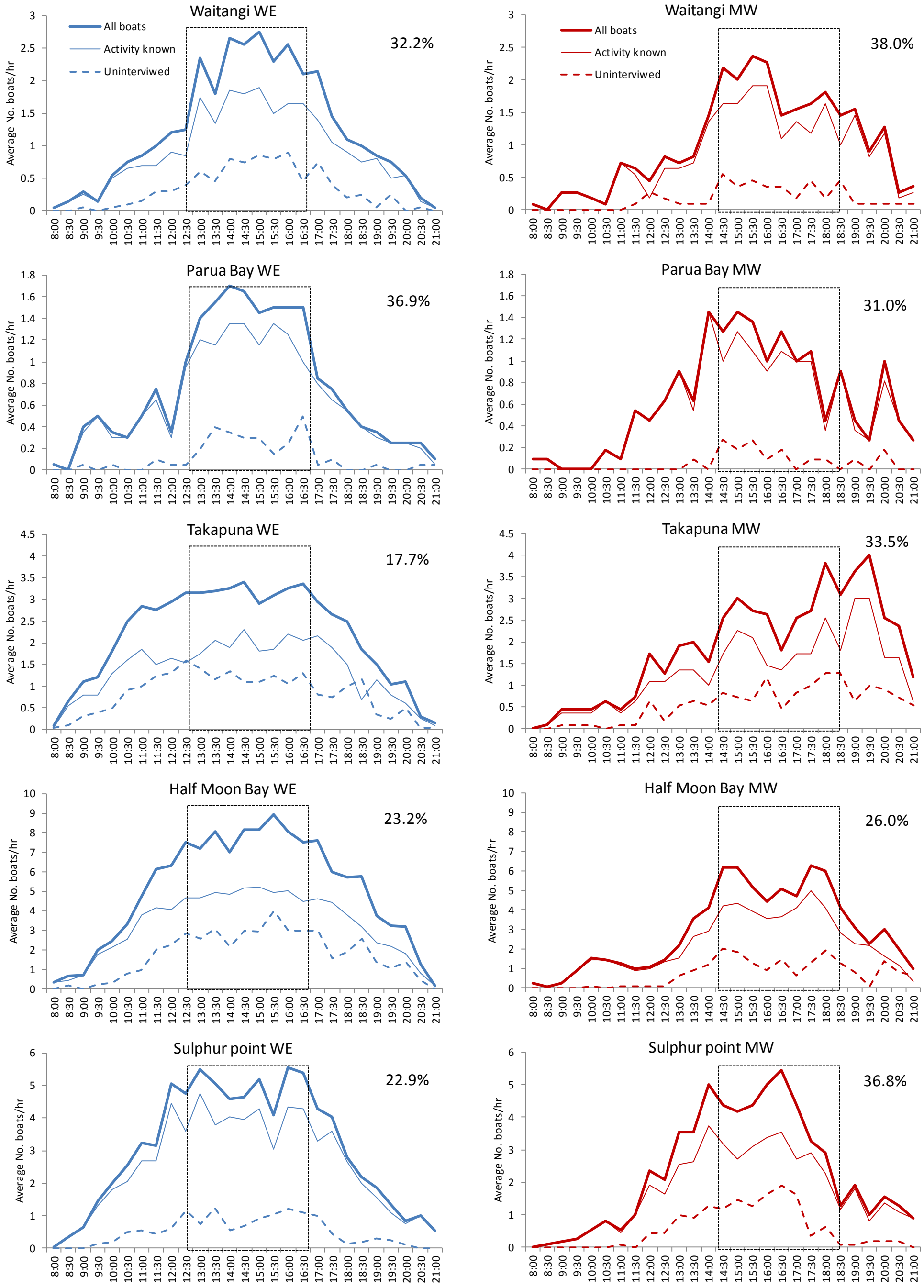


Figure 3: Diurnal profiles of the average number of boats returning per hour to five boat ramps in FMA 1 which will be regularly surveyed by boat ramp interview staff. The left panels show average diurnal traffic profiles observed over 20 weekend/public holiday days (WE) falling between 1 October 2011 and 30 April 2012, and the right panels show average diurnal profiles observed over 11 midweek days (MW) during the same period. Black dashed rectangles denote the approximate timing of a fixed four hour interview session and the percentages given in the top right corner of each panel show the estimated percentage of boats that would have been missed if the timing of this four hour session had been randomised from day to day.

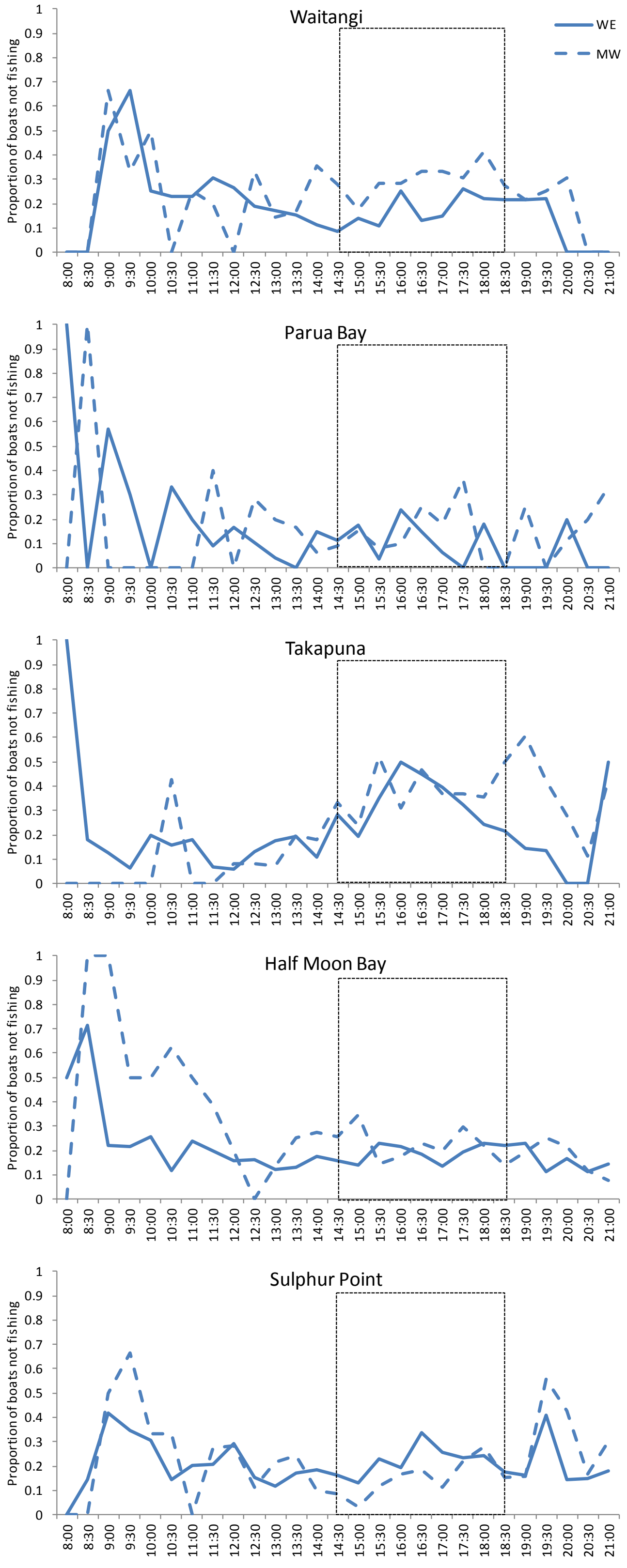


Figure 4: Diurnal profiles of the proportion of interviewed boats that were not used for fishing, at five boat ramps in FMA 1 that have been regularly surveyed by boat ramp interview staff. Solid lines denote average profiles based on interviews conducted over 20 weekend/public holiday days (WE) falling between 1 October 2011 and 30 April 2012, and the dashed lines denote profiles observed over 11 midweek days (MW) during the same period.

Fixed session times are also desirable from a logistical point of view, as previous experience suggests that interviewers tend to be more reliable when their working routine is clearly defined. It is also easier to make spot checks if both NIWA and its employees know when work should be taking place, although absenteeism is less of a concern when interviewing is readily detected via the web cameras at these ramps.

2.6 Generating indices of fishing effort and harvest from web camera and creel survey data

Web camera counts are combined with creel data on the proportion of boats interviewed on the same day, to determine the number of fishing boats returning to a given ramp on a given day. This count of fishing boats is then multiplied by the average weight of fish landed per fishing boat on the same day, to produce an estimate of the weight of fish of a given species landed at that ramp on that day. Indices of fishing effort and harvest are generated where possible from web camera and creel survey data collected on the same day, but it is sometimes necessary to impute values from data collected at the same ramp on other days within the same temporal stratum, when web camera image or creel survey data are not available.

Indices of fishing effort and harvest were generated from these survey day statistics in a similar manner to that used to generate the web camera traffic indices discussed earlier in this report. Effort and harvest statistics calculated for each day within a temporal stratum were averaged and then scaled up by the number of days occurring within that stratum. Estimates for each stratum were then combined to provide estimates for each fishing year. Variance estimates were calculated by a two stage bootstrapping procedure, whereby interviewed boats were bootstrapped within days, and days were bootstrapped within temporal strata.

3. RESULTS

3.1 FMA 1

Web camera image based counts of the number of boats using the Waitangi, Takapuna and Sulphur Point boat ramps are available for most of the 60 survey days selected from each fishing year since 1 April 2005 (Table 3). Short term camera system outages have occurred on many occasions but the only appreciable periods of data loss were during the winter of 2008–09 and early summer of 2009–10 at Waitangi, and during the summer of 2008–09 at Takapuna. Nonetheless, counts for all outage affected days were available from predictions derived from GLM modelling of traffic counts at neighbouring ramps (see Section 2.3).

Regression based predictions were also used to extend the time series at Takapuna (in the Hauraki Gulf) back to the period between 1 October and 30 November 2004, based on data collected nearby at Half Moon Bay during this fishing year which was the site of the only established web camera system at that time (see Hartill et al. 2010).

Table 3: Availability of web camera and creel survey data collected at for three key boat ramps in FMA 1. Web camera systems sometimes malfunction and boat ramp traffic counts are therefore not available for some preselected survey days. The first year in which creel survey data were intentionally collected in conjunction with web camera data was in 2011–12, although interview data collected for other purposes are also available for some previous years.

			Waitangi				Takapuna				Sulphur Point			
			Web camera data		Creel survey		Web camera data		Creel survey		Web camera data		Creel survey	
Fishing year	Season	Day type	Usable	Target	Days worked	Boats interviewed	Usable	Target	Days worked	Boats interviewed	Usable	Target	Days worked	Boats interviewed
2004–05	Summer	Weekend	17	24	17	418	13	24	39	738	12	24	70	1663
		Midweek	14	20	14	182	17	20	29	179	17	20	51	486
	Winter	Weekend	8	8	5	38	8	8	5	76	8	8	11	276
		Midweek	8	8	5	22	8	8	9	18	8	8	15	51
			47	60	41	660	16	60	82	1 011	45	60	147	2 476
2005–06	Summer	Weekend	24	24	28	277	24	24	23	402	24	24	22	690
		Midweek	20	20	3	18	20	20	3	28	20	20	6	64
	Winter	Weekend	8	8	–	–	8	8	–	–	8	8	–	–
		Midweek	8	8	–	–	8	8	–	–	8	8	–	–
			60	60	31	295	60	60	26	430	60	60	28	754
2006–07	Summer	Weekend	24	24	17	119	23	24	31	579	24	24	14	502
		Midweek	20	20	2	14	20	20	22	111	20	20	4	145
	Winter	Weekend	8	8	–	–	8	8	11	86	8	8	–	–
		Midweek	8	8	–	–	8	8	12	11	8	8	–	–
			60	60	19	133	59	60	76	787	60	60	18	647
2007–08	Summer	Weekend	20	24	24	606	24	24	42	649	24	24	16	516
		Midweek	17	20	1	43	19	20	20	199	20	20	3	56
	Winter	Weekend	7	8	–	–	7	8	–	–	7	8	–	–
		Midweek	6	8	–	–	7	8	–	–	7	8	–	–
			50	60	25	649	57	60	62	848	58	60	19	572
2008–09	Summer	Weekend	24	24	–	–	6	24	–	–	24	24	–	–
		Midweek	20	20	–	–	2	20	–	–	20	20	–	–
	Winter	Weekend	2	8	–	–	8	8	–	–	8	8	–	–
		Midweek	1	8	–	–	8	8	–	–	8	8	–	–
			47	60	–	–	24	60	–	–	60	60	–	–
2009–10	Summer	Weekend	21	24	–	–	23	24	–	–	24	24	–	–
		Midweek	13	20	–	–	20	20	–	–	20	20	–	–
	Winter	Weekend	8	8	–	–	5	8	–	–	8	8	–	–
		Midweek	6	8	–	–	7	8	–	–	8	8	–	–
			48	60	–	–	55	60	–	–	60	60	–	–
2010–11	Summer	Weekend	24	24	19	364	24	24	17	356	23	24	40	828
		Midweek	20	20	9	132	20	20	1	17	19	20	1	6
	Winter	Weekend	8	8	–	–	8	8	–	–	8	8	–	–
		Midweek	7	8	–	–	8	8	–	–	8	8	–	–
			59	60	28	496	60	60	18	373	58	60	41	834
2011–12	Summer	Weekend	22	24	41	393	21	24	43	511	24	24	72	976
		Midweek	16	20	25	203	18	20	25	267	20	20	39	417
	Winter	Weekend	7	8	15	72	7	8	15	54	8	8	29	186
		Midweek	8	8	18	75	7	8	16	67	8	8	26	122
			53	60	99	743	53	60	99	899	60	60	166	1 701
2012–13	Summer	Weekend	21	24	19	303	23	24	22	420	23	24	20	433
		Midweek	19	20	20	178	20	20	22	174	20	20	21	252
	Winter	Weekend	7	8	8	50	7	8	8	76	8	8	8	123
		Midweek	7	8	8	23	7	8	8	30	8	8	8	39
			54	60	55	554	57	60	60	700	59	60	57	847
2013–14	Summer	Weekend	23	24	22	372	24	24	23	429	24	24	22	589
		Midweek	20	20	22	201	20	20	21	137	19	20	20	149
	Winter	Weekend	5	8	8	63	8	8	8	84	8	8	8	141
		Midweek	6	8	8	34	8	8	8	39	8	8	8	58
			54	60	60	670	60	60	60	689	59	60	58	937

Seasonal and annual boat traffic indices are shown for each of the three FMA 1 sites in Figure 5. Levels of effort at all three regional ramps have fluctuated over time, but annual trends in boat traffic differ regionally. There appears to be no long term trend in effort at Waitangi (in East Northland), with relatively fewer boats returning to this ramp during the 2011–12 fishing year, when recreational harvests taken from FMA 1 were estimated by two alternative survey designs (Hartill et al. 2013; Wynne-Jones et al. 2014). Annual traffic rates at Takapuna (in the Hauraki Gulf) have fluctuated to a far greater degree, peaking noticeably in 2010–11 and declining since. The trend at Sulphur Point (in the Bay of Plenty) is most similar to that seen at Takapuna, although the peak in effort in 2010–11 is less marked and traffic rates since the 2011–12 survey year have stabilised at a lower level.

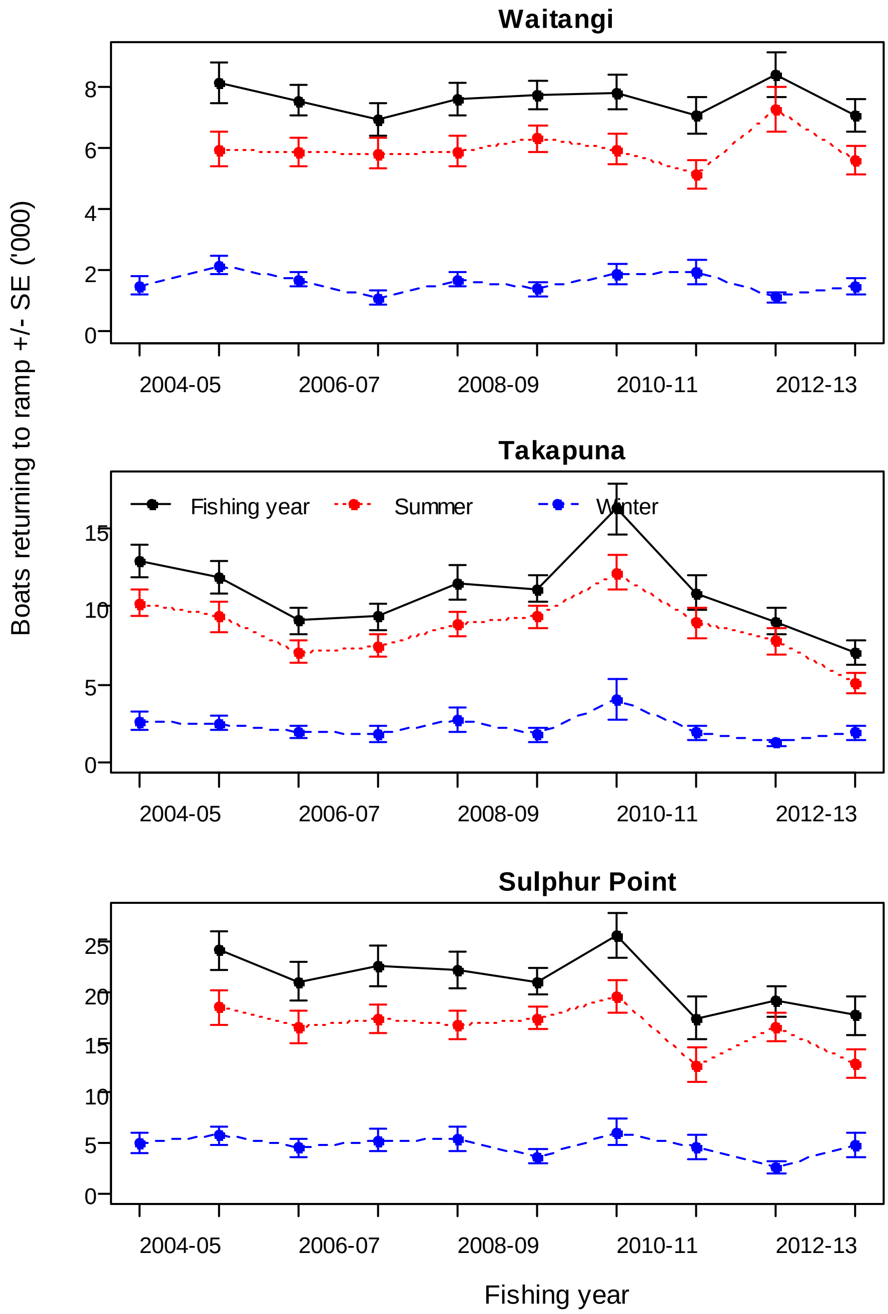


Figure 5: Indices of recreational effort for three regions of FMA 1 based on imagery taken at a single ramp within each of those regions on a subsample of 60 days per fishing year, for the period 2004–05 to 2013–14.

Annual indices at all three ramps are directly compared in Figure 6. This comparison suggests that there may have been a slight decline in the level of boating effort across FMA 1 over the last 10 years, as most effort occurs in the Hauraki Gulf, and to a far lesser extent, in the Bay of Plenty.

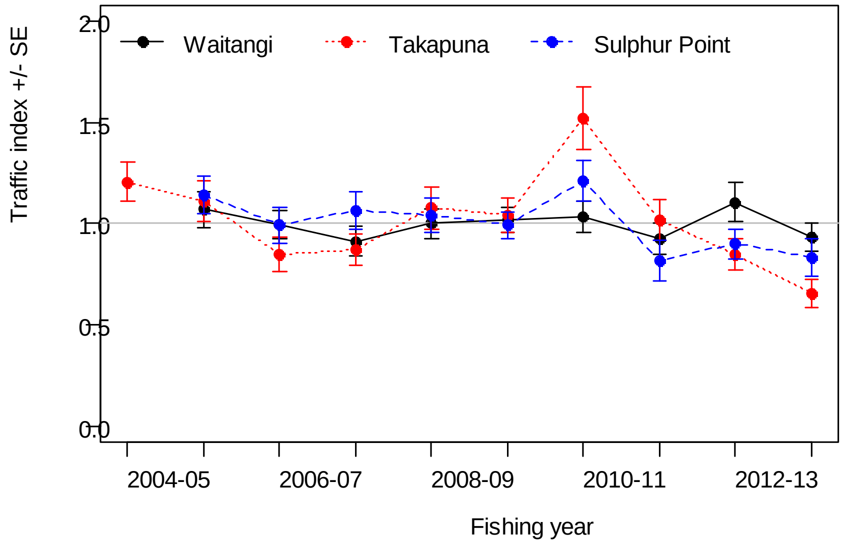


Figure 6: Comparison of relative indices of annual effort for the three regions of FMA 1. Indices for all three regions are averaged to 1.0 for the period 2005–06 to 2013–14, as images of the ramps at Waitangi and Sulphur Point are not available for the summer of 2004–05.

As discussed earlier, creel survey data are also required to estimate the proportion of observed boats which were used for fishing, and to provide estimates of the average weight of each species landed per boat trip. Concurrent creel survey data have been collected on almost all scheduled days since 2011–12, during which large numbers of boats have been interviewed (see Table 3). Creel survey data collected for other purposes on other randomly selected days were also collected: at all three ramps throughout 2004–05; at Takapuna throughout 2005–06, and at all three sites during all other summers since 2004–05 (although almost all of these interview sessions fell on weekend days).

The availability of creel survey data is therefore patchy, but there are sufficient web camera count and creel survey data available to generate annual harvest indices for snapper and kahawai, for six fishing years in the Hauraki Gulf and for three fishing years in East Northland and the Bay of Plenty (fourth panel of Figures 7 and 8 for each species respectively). These harvest indices are the product of annual ramp traffic indices (first panel and as seen for these years in Figure 6), creel survey based indices of the proportion of interviewed boats which were used for fishing (second panel), and average catch rate per boat indices for each species (third panel). The resulting web camera/creel survey based harvest indices for snapper and kahawai (fourth panel) have been scaled so that their geometric mean matches the geometric mean of the aerial-access harvest estimates from the Hauraki Gulf in 2004–05 and 2011–12, and the other two regions in 2011–12.

The degree of difference between the 2004–05 and 2011–12 aerial-access snapper harvest estimates is very similar to that seen in the harvest index calculated from web camera and interview data collected at the Takapuna boat ramp (fourth panel in Figure 7). This degree of similarity suggests that the trend in weight of snapper landed at Takapuna since 2004–05 is reasonably indicative of that occurring throughout the Hauraki Gulf over the same period. And by extension, that the trend in boat traffic at the Takapuna boat ramp broadly reflects that occurring at other boat ramps in the Hauraki Gulf.

The comparison between the aerial-access and web camera/creel survey indices for kahawai is less compelling, as the degree of difference between the two aerial-access harvest estimates is greater than that inferred from data collected at Takapuna. This difference may in part be due to the greater uncertainty associated with kahawai catch rates, as this species is landed more infrequently.

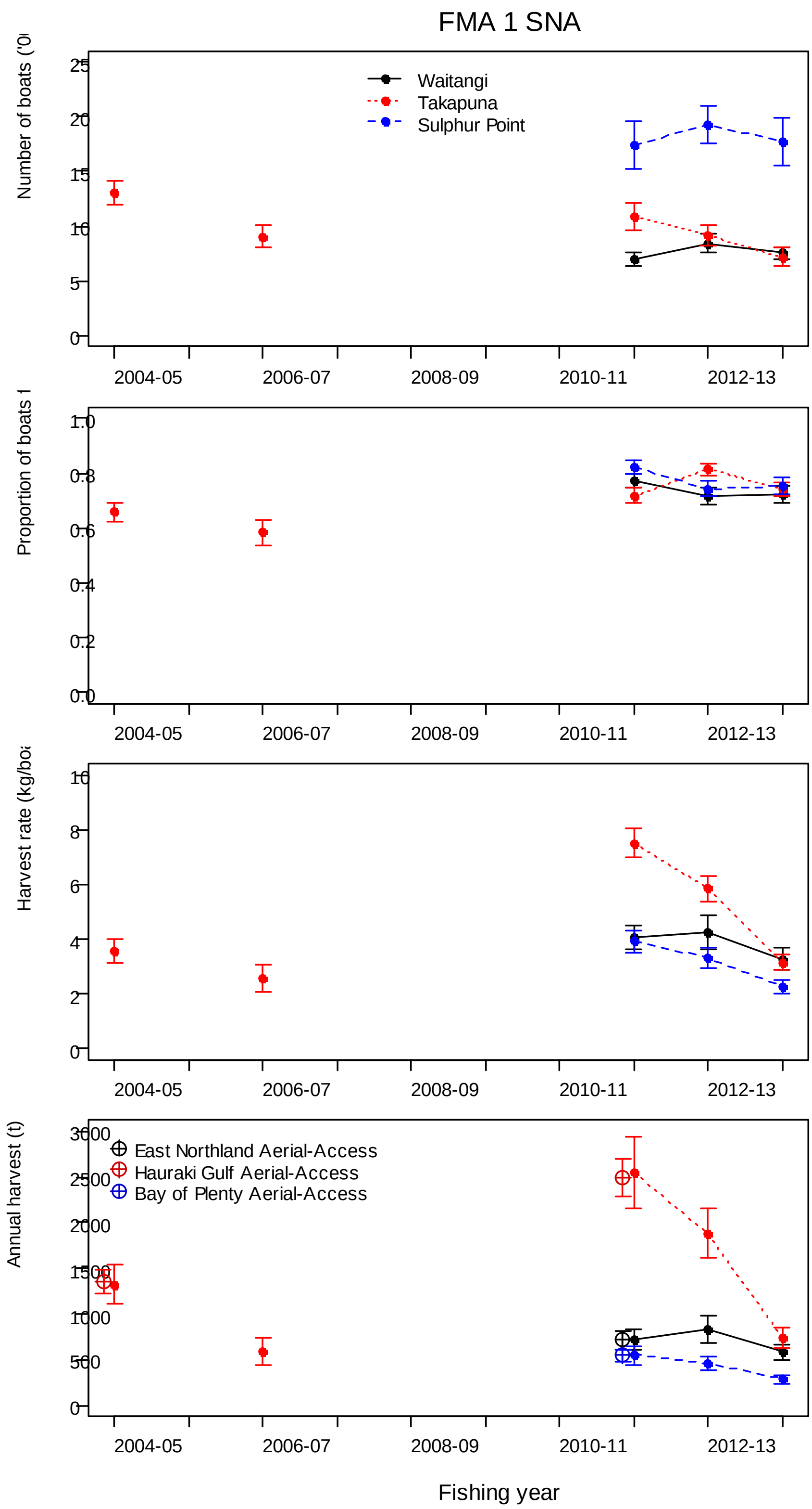


Figure 7: Annual estimates of numbers of boats using surveyed regional ramps in FMA 1 (upper panel – based on web camera counts only), the proportion of observed boats that were used for fishing (second panel), the average weight of snapper harvested per boat (third panel), and the annual snapper harvest landed at surveyed ramps throughout each year (bottom panel). Aerial-access harvest estimates of the snapper harvest in 2004–05 and 2011–12 for the entire Hauraki Gulf are also plotted in the lower panel (note scale tonnage on left axis) so that a comparison can be made between the relative change in level of harvesting estimated from this programme with the ramp at Takapuna. This comparison was only possible in the Hauraki Gulf, as web cameras were not operational in East Northland and the Bay of Plenty during the summer of 2004–05.

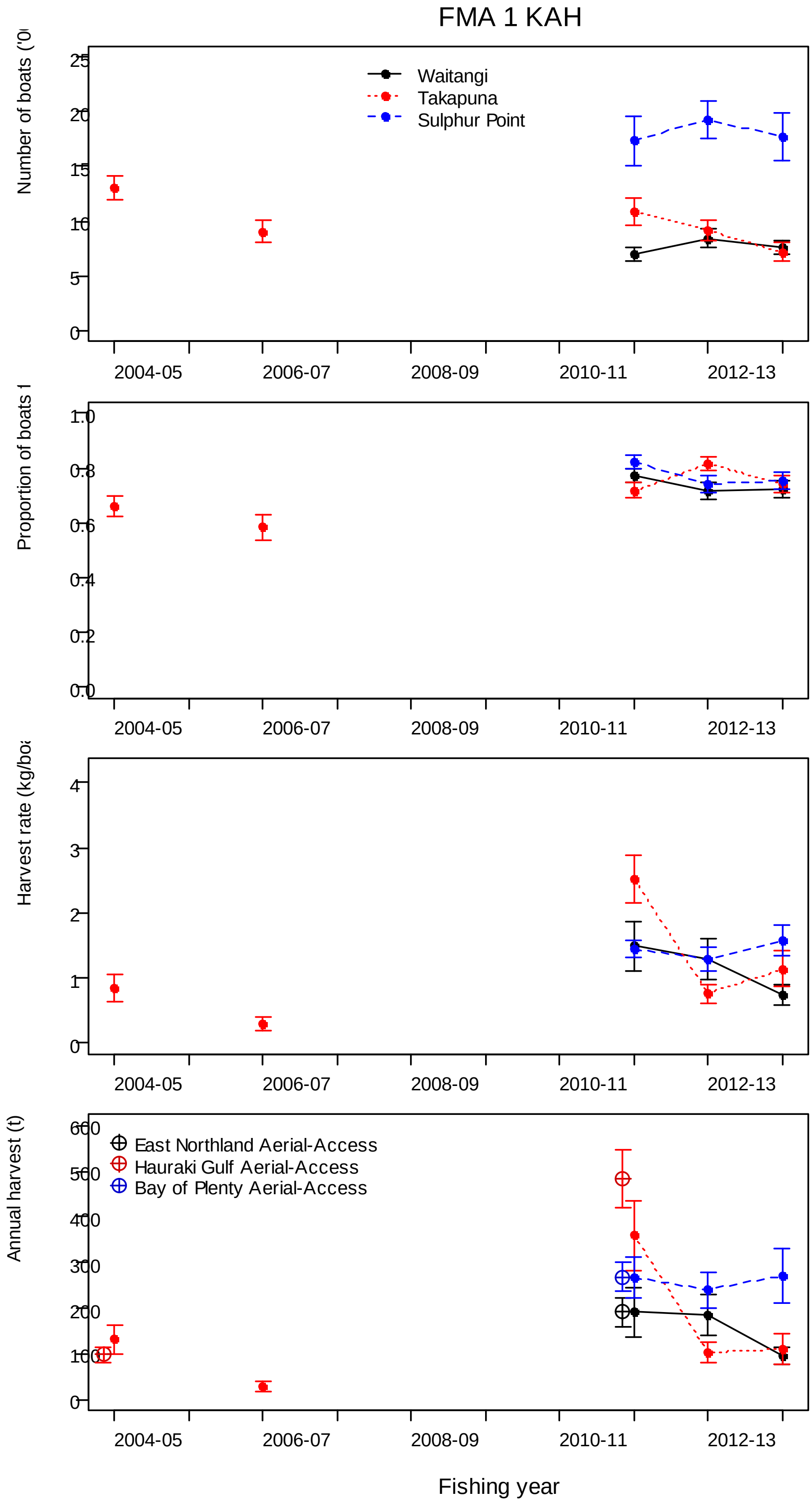


Figure 8: Annual estimates of numbers of boats using surveyed regional ramps in FMA 1 (upper panel – based on web camera counts only), the proportion of observed boats that were used for fishing (second panel), the average weight of kahawai harvested per boat (third panel), and the annual kahawai harvest landed at surveyed ramps throughout each year (bottom panel). Aerial-access harvest estimates of the kahawai harvest in 2004–05 and 2011–12 for the entire Hauraki Gulf are also plotted in the lower panel (note scale tonnage on left axis) so that a comparison can be made between the relative change in level of harvesting estimated from this programme with the ramp at Takapuna. This comparison was only possible in the Hauraki Gulf, as web cameras were not operational in East Northland and the Bay of Plenty during the summer of 2004–05.

More complete indices of effort and catch can be calculated for the summer weekend/public holiday stratum, as web camera and creel survey data are available for eight of the ten years since 2004–05. This is because fishers were routinely interviewed on weekends during the months of January to April in most years to provide data on the age composition of kahawai landed by recreational fishers in each region. Creel survey data are not available from other times of the year in some years.

The trends seen in the more continuous weekend/summer stratum indices for snapper are broadly similar to those seen in the more intermittent full year indices (compare Appendix 2 to Figure 7). The weekend/summer stratum indices suggest that fishing effort in the Hauraki Gulf and Bay of Plenty was higher in 2010–11 than in the 2011–12 harvest survey year, and although catch rates were lower, it is likely that landings of snapper peaked in 2010–11.

3.2 FMAs 8 and 9

The collection of reliable web based boat traffic data on the west coast of the North Island has only been achieved in recent years (Table 4). The web camera systems in FMA 9 have provided almost continuous coverage of traffic at Shelly Beach since the summer of 2006–07 and at Raglan since the summer of 2010–11. Images provided by the New Plymouth system in FMA 8 were initially unreadable at times (due to sun strike in the winter and also an unstable camera mounting) but the system has provided almost continual and reliable coverage since the summer of 2009–10.

The regression based methods used to predict traffic at FMA 1 ramps on days when images are not available, given concurrent counts observed at ramps in neighbouring regions, cannot be used to provide similar predictions for FMA 8 and 9 ramps, because there is a low degree of correlation between any pair of ramps on the west coast. This is because environmental conditions in the Kaipara Harbour (Shelly Beach) are often far more conducive to fishing than on the open coast off Raglan and on at the more distant New Plymouth coast, where wind strengths and directions are often markedly different from elsewhere.

There are, therefore, two alternatives available when generating indices of effort in FMAs 8 and 9, based on the available data. The first option is to just use boat counts on the survey days for which a full 1440 minute-by-minute set of images are available, and assume that levels of traffic on those days provide a sufficient and representative measure of the average daily level of effort occurring on all days within each temporal stratum. The second option is to read images from additional alternative days that fall as close as possible within a given temporal stratum. Although the second approach should be valid when short term outages occur, long term outages are still problematic due to seasonal patterns in effort. At this stage we have generated indices of effort for the FMA 8 and 9 ramps based on the preselected days for which readable images are fully available.

Table 4: Availability of web camera and creel survey data collected at for three key boat ramps in FMAs 8 and 9. Web camera systems sometimes malfunction and boat ramp traffic counts are therefore not available for some preselected survey days.

			Shelly Beach				Raglan				New Plymouth			
			Web camera data		Creel survey		Web camera data		Creel survey		Web camera data		Creel survey	
Fishing year	Season	Day type	Usable	Target	Days worked	Boats interviewed	Usable	Target	Days worked	Boats interviewed	Usable	Target	Days worked	Boats interviewed
2006–07	Summer	Weekend	24	24	–	–	–	–	–	–	13	24	–	–
		Midweek	20	20	–	–	–	–	–	–	7	20	–	–
	Winter	Weekend	8	8	–	–	–	–	–	–	7	8	–	–
		Midweek	8	8	–	–	–	–	–	–	7	8	–	–
			60	60	–	–	–	–	–	–	34	60	–	–
2007–08	Summer	Weekend	24	24	–	–	–	–	–	–	22	24	–	–
		Midweek	19	20	–	–	–	–	–	–	17	20	–	–
	Winter	Weekend	8	8	–	–	–	–	–	–	4	8	–	–
		Midweek	8	8	–	–	–	–	–	–	5	8	–	–
			59	60	–	–	–	–	–	–	48	60	–	–
2008–09	Summer	Weekend	24	24	–	–	–	–	–	–	21	24	–	–
		Midweek	19	20	–	–	–	–	–	–	18	20	–	–
	Winter	Weekend	8	8	–	–	–	–	–	–	0	8	–	–
		Midweek	8	8	–	–	–	–	–	–	2	8	–	–
			59	60	–	–	–	–	–	–	41	60	–	–
2009–10	Summer	Weekend	23	24	–	–	–	–	–	–	21	24	–	–
		Midweek	20	20	–	–	–	–	–	–	19	20	–	–
	Winter	Weekend	8	8	–	–	7	8	–	–	8	8	–	–
		Midweek	8	8	–	–	6	8	–	–	8	8	–	–
			59	60	–	–	13	60	–	–	56	60	–	–
2010–11	Summer	Weekend	20	24	–	–	23	24	–	–	24	24	–	–
		Midweek	17	20	–	–	18	20	–	–	19	20	–	–
	Winter	Weekend	6	8	–	–	8	8	–	–	8	8	–	–
		Midweek	8	8	–	–	8	8	–	–	8	8	–	–
			51	60	–	–	57	60	–	–	59	60	–	–
2011–12	Summer	Weekend	22	24	20	183	23	24	7	98	22	24	17	467
		Midweek	20	20	13	66	20	20	5	25	20	20	13	192
	Winter	Weekend	8	8	8	32	6	8	8	22	8	8	8	71
		Midweek	8	8	8	12	8	8	8	11	8	8	9	42
			58	60	49	293	57	60	28	156	58	60	47	772
2012–13	Summer	Weekend	23	24	20	170	23	24	22	221	23	24	21	151
		Midweek	21	20	21	49	21	20	22	98	21	20	22	166
	Winter	Weekend	8	8	8	49	8	8	8	21	8	8	8	21
		Midweek	8	8	8	8	8	8	9	11	8	8	8	12
			60	60	57	276	60	60	61	351	60	60	59	350
2013–14	Summer	Weekend	23	24	23	202	22	24	24	239	23	24	25	279
		Midweek	20	20	20	34	17	20	20	46	20	20	20	116
	Winter	Weekend	7	8	8	59	8	8	8	26	8	8	8	50
		Midweek	6	8	8	13	7	8	7	8	8	8	8	21
			56	60	59	308	54	60	59	319	59	60	61	466

Trends in effort at Shelly Beach and Raglan in FMA 9 and at New Plymouth in FMA 8 appear to be broadly similar given the length of the time series available, which are shorter than those available from FMA 1 (Figure 9). As in FMA 1, levels of effort peaked in 2010–11 although the number of boats returning to the boat ramp at New Plymouth was also high in 2006–07. The degree of similarity seen in the comparison of ramp specific indices is surprising given the differing geography at each site (Figure 10). The Shelly Beach ramp is on the southern arm of the Kaipara Harbour, and this body of water is far more sheltered than the open coast off Raglan and New Plymouth to the south. Further, previous experience from an aerial-access survey conducted on the west coast in 2006–07 (Hartill et al. 2011) suggests that weather conditions can vary considerably with latitude.

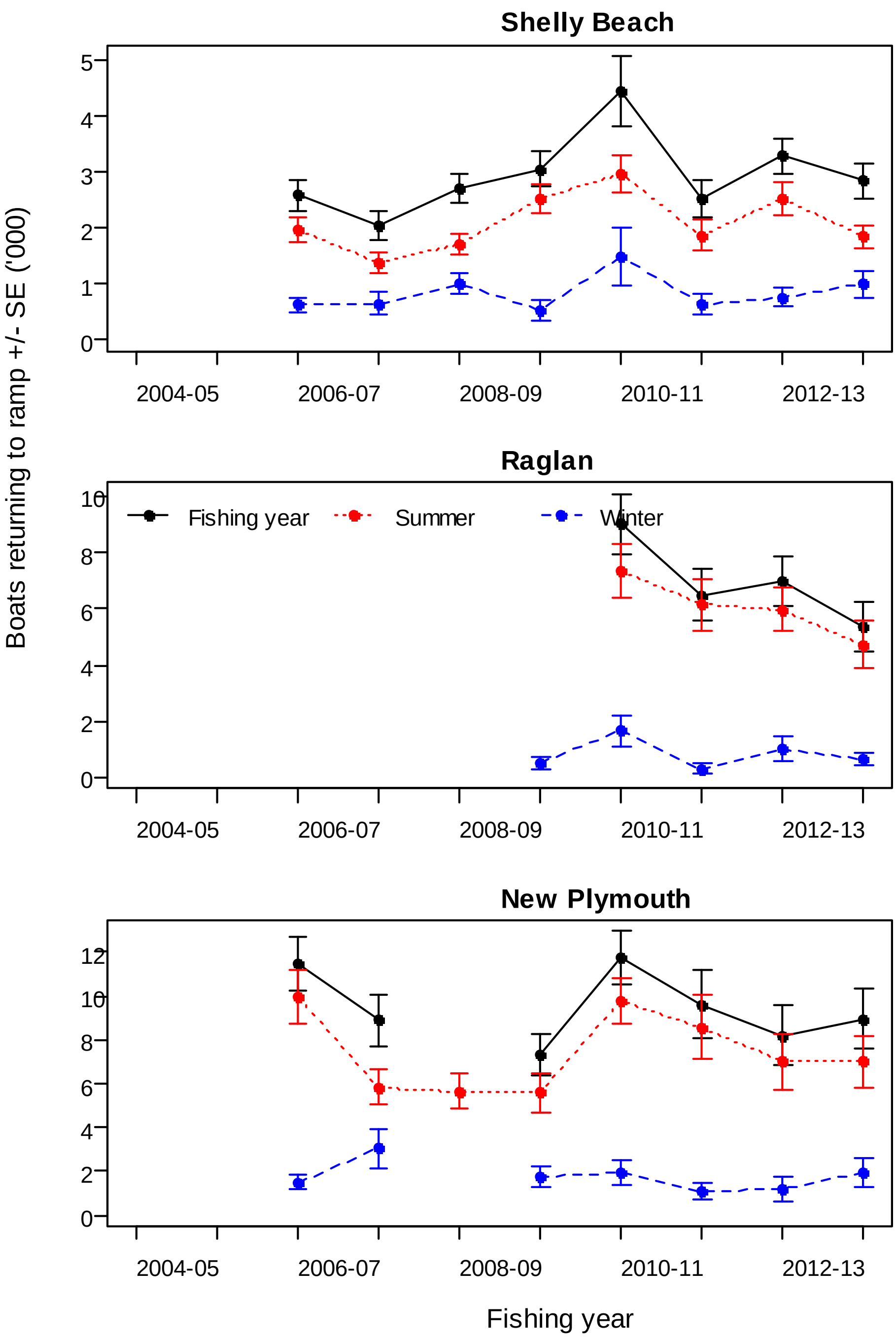


Figure 9: Indices of recreational effort at Shelly Beach in FMA 9 and at New Plymouth in FMA 8 based on imagery taken on a subsample of 60 days per fishing year.

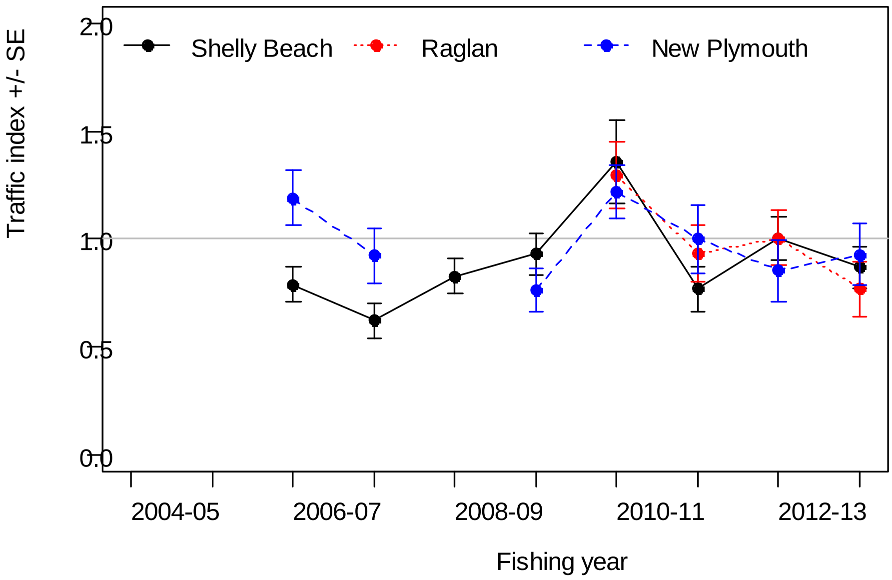


Figure 10: Comparison of relative indices of annual effort for the three ramps in FMAs 8 and 9. Indices for all three regions are averaged to 1.0 for the period 2010–11 to 2013–14, as images for Raglan have only been available since the winter of 2009–10.

Creel survey data have also been collected at these west coast boat ramps since the beginning of the 2011–12 fishing year (Table 4). Fishers were interviewed throughout 2011–12 to provide mean fish weight data for the national panel survey (Hartill & Davey 2015), but four hour interview sessions have since been scheduled to occur on the 60 web camera count days. Very few of the interview sessions scheduled over the past three years have been missed.

The lack of creel survey data before 2011–12 limits the period over which harvest indices can be calculated. The snapper harvest indices calculated for the two ramps on the open coast (at Raglan and New Plymouth), follow a similar trend of decreasing then increasing levels of harvest, but for different reasons (Figure 11). At Raglan this trend is primarily driven by changes in catch rates, but at New Plymouth it is driven by the trend in effort over the two years. Meaningful harvest indices can only be calculated for snapper on this coast because catches of other species are relatively infrequent.

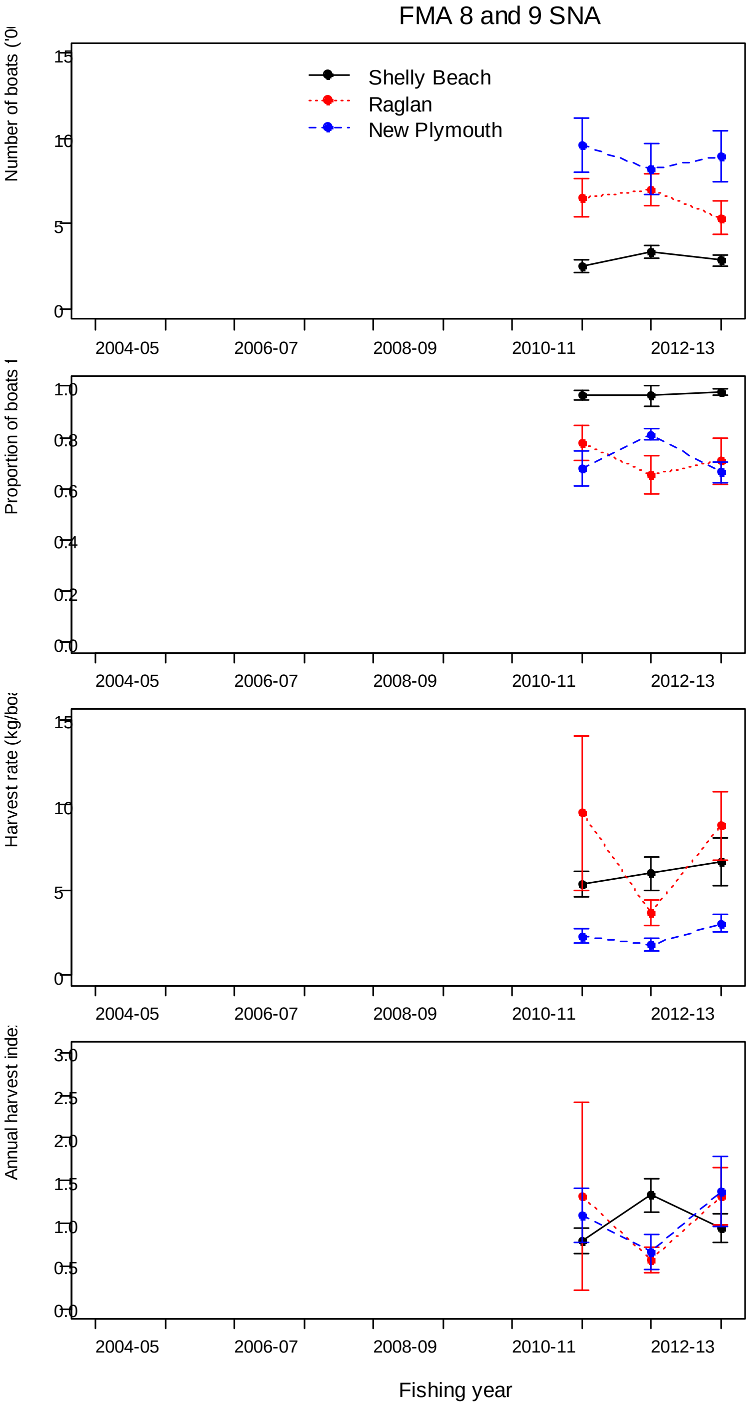


Figure 11: Annual estimates of numbers of boats using surveyed regional ramps in FMAs 8 (New Plymouth) and 9 (Shelly Beach and Raglan) (upper panel – based on web camera counts only), the proportion of observed boats that were used for fishing (second panel), the average weight snapper harvested per boat (third panel), and the annual kahawai harvest landed at surveyed ramps throughout each year (bottom panel).

3.3 Other methods of continuously monitoring trends in recreational effort

Another method of continuously monitoring trends in recreational effort has recently come to light, which appears to be both accurate and cost effective, but it is currently only viable at one location. The Outboard Boating Club of Northland maintains a multi-lane boat ramp at Parua Bay in Whangarei

Harbour (where one of this programme's web cameras is installed). This ramp is surrounded by a chain link fence and it can only be accessed by club members with electronic swipe cards. Each swipe card has a unique identification number and each swipe of the card is electronically logged. The club has made this data available to NIWA, going back as far as the 18th of October 2010. Club members have to swipe their card to both enter and leave the compound, and they sometimes swipe their cards several times in rapid succession to raise the barrier arm.

The most reliable way of deriving accurate counts of the number of boats using the club ramp on a day is to just count the first logged swipe of a club member's card and to ignore all subsequent swipes of that card on the same day. The accuracy of this approach has been assessed by regressing unique card counts against web camera based counts of the number of boats observed returning to the ramp on the same day (Figure 12). Paired web camera and swipe card based counts are available for 111 days between 02/11/11 and 30/01/13. These results are very promising, as it suggests that the web camera system is no longer needed to quantify the numbers of boats returning daily to this ramp. The total swipe card based count across all 111 days is higher than the web camera based count (1979 and 1860 respectively) and this difference can largely be explained by the fact that some maintenance and cleaning contractors also have cards, which are not used when launching boats. These card numbers will be identified so that they can be removed from the swipe card data set in the future. Unfortunately this is the only existing site where a swipe card is required to access the boat ramp.

The comparison in Figure 12 also provides independent corroboration of existing web camera based counts of boats returning to this ramp, although the web camera counts at this secondary East Northland ramp have only been read as far back as 02/11/13. The web camera system was first installed at this ramp in November 2005, and images have been stored on a secure server since this date, from which retrospective counts could be made.

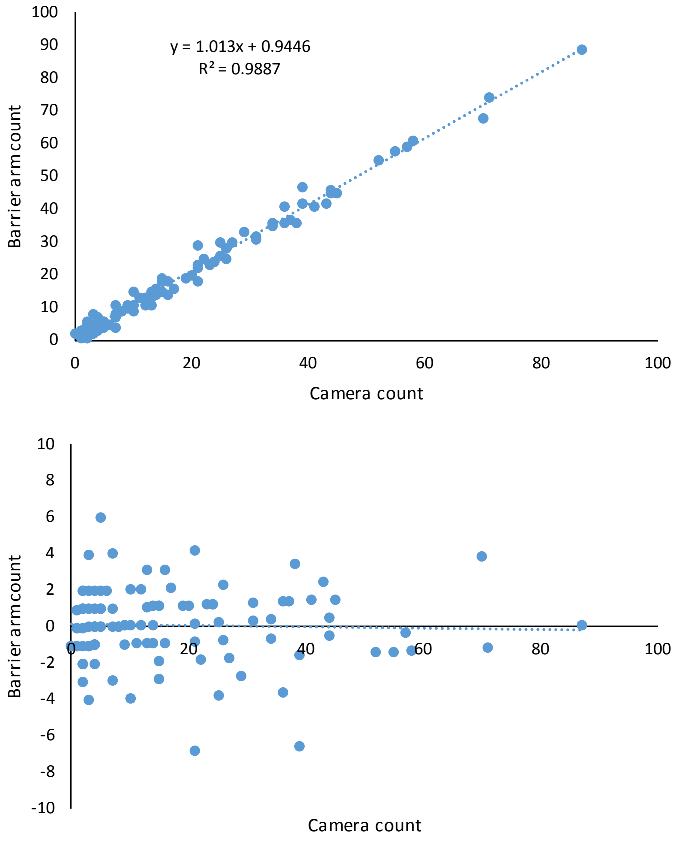


Figure 12: Barrier arm swipe card counts regressed against web camera based counts of the number of boats returning to the Outboard Boating Club of Northland ramp at Parua Bay on the Whangarei Harbour. Regression residuals are shown in the lower panel.

4. DISCUSSION

Although survey methods have now been developed to estimate and characterise harvests taken from large scale recreational fisheries, such as national panel survey and aerial-access surveys, the cost of these is considerable and their occurrence will be intermittent. Some means of interpolation is therefore required to inform the management of recreational fisheries, as levels of recreational harvesting can be more dynamic than quota constrained commercial fisheries. The web-camera based monitoring programme provides a cost effective means of monitoring trends in New Zealand's largest recreational fisheries and it is now a key element of the multi-survey approach that MPI is developing to inform inshore fisheries management. The main limitations of the programme are the effort required to interpret images and the reliability of the web camera systems.

The effort required to interpret images has steadily increased, despite the fact that only a subsample of 60 days of imagery from each camera are viewed each year. A PhD student is therefore developing computer vision software which could be used to automate the boat counting process so that counts can be provided in real time (and retrospectively) without the need for any subsampling. Preliminary regressions of manual and automated counts are promising, although it is likely that this approach will not be universally applicable.

Although web camera systems are mostly reliable, outages sometimes occur, which occasionally take some time to resolve. The configuration of each system differs depending on the facilities available at each site, and some sites are more vulnerable than others. Outages usually occur for three reasons: loss of power to either the camera or the nearby PC; failed radio transmission between the video camera and nearby PC which is usually housed in a separate building; or intentional or unintentional damage to the physical structure. Methods have been steadily developed to minimise the likelihood of these issues occurring, but the main limitation appears to be the separated installation of the video camera and the PC. The current intention is to build a single integrated modular unit that combines the camera, frame grabber, modem and cell phone into a single circuit board which is mounted on a single physical structure. This approach would remove many of the weak links that exist in most of the current systems, and rapid field repairs could be effected by simply swapping out the whole system.

This programme has demonstrated how web camera systems can be used to continuously monitor trends in recreational boat traffic returning to selected boat ramps, but other technologies should also be considered. The New Zealand Transport Authority routinely use web cameras and two other sensor technologies to monitor traffic; pneumatic road tube counters, and electro-magnetic induction sensors. Neither of these options are suited to monitoring trends in recreational boating effort at boat ramps. Pneumatic road tube counters wear out rapidly on sloped wet surfaces such as boat ramps, and ancillary data are still required to convert axel counts into boat counts, especially when trailers are involved and they cross wide unlaned ramps in an oblique fashion. Electro-magnetic induction sensors require very little maintenance, but these can only be installed by digging up the ramp. Another problem with this approach is that the ferrous metal content of boats and trailers is often too low to set off a sensor, and boats will therefore be missed. The positioning of any sensor is also a critical consideration, as tow vehicles could pass back and forth over a sensor at low tide, yet park over it at high tide.

The development of reliable and cost effective methods to monitor trends in boating effort only partially meets the objective of this programme, however, as some of the observed boats would have been used for purposes other than fishing. The recent decision to conduct creel survey interviews at the peak period of expected effort on each day is therefore a significant advancement, as these data can be combined with camera based counts of boats to monitor long term trends in fishing effort, and more significantly, harvest.

Creel surveys have only been conducted for this purpose since 2011–12 and the availability of creel survey data before then is patchy. Fortunately, creel survey data are also available from throughout 2004–05, when an aerial-access survey was also conducted. This meant that we were able to compare the degree of change seen in the aerial-access estimates snapper and kahawai harvests from the Hauraki Gulf, with that seen in the harvest indices provided by the combined web camera creel survey data for the same two years. This comparison suggests that the combination of web camera imagery and creel survey data can be used to monitor trends in recreational harvest to a reasonable and informative degree, for snapper at least. A comparison over time is only currently possible for the Hauraki Gulf fishery over these two years, however, as web cameras in East Northland and the Bay of Plenty were not fully operational during the summer of 2004–05. MPI currently plan to conduct another aerial-access survey in 2016–17, and estimates provided by that survey could be used to further test the likely accuracy of harvest indices provided by this programme. Harvest estimate indices provided by this programme could also be used to better inform recreational catch histories used in stock assessment models in the future.

The utility of the indices provided by this programme should become more evident as the dynamic nature of recreational effort and harvests becomes more apparent. Results from the few years that are available suggest that levels of recreational harvesting can change far more frequently and dramatically than quota constrained commercial fisheries, as the landed catch is determined by both localised availability and levels of fishing effort. Declining snapper catch rates between 2011–12 and 2013–14 have coincided with a concurrent decline in the number of boats observed returning to the Takapuna boat ramp over the same period. This suggests that lower catch rates can lead to lower levels of effort, as fishers are in part motivated by the prospects of fishing success. Snapper counted for 80% of the recreational catch from the Gulf in 2011–12 and this species therefore provides the best measure of fishing success in this area. Recreational fishing usually occurs in relatively shallow waters, and catch rates are more likely to reflect localised abundance rather than stock abundance. Localised abundance may reflect stock wide abundance on open coasts such as in FMA 8, the Bay of Plenty, and perhaps to a lesser extent in East Northland, but this is unlikely to be the case in the Hauraki Gulf, where the greatest intensity of recreational fishing occurs.

Combining web camera based monitoring with concurrent creel survey data therefore provides a cost effective means of monitoring trends in recreational catch and effort and a means of understanding the truly dynamic nature of recreational fisheries, which is not quantitatively available from any other source. The work undertaken by this programme has been extended for another 5 years as part of another programme funded by the Ministry for Primary industries (MAF201404).

5. MANAGEMENT IMPLICATIONS

Recreational harvests can vary to a far greater degree than quota-constrained commercial fisheries and regular monitoring and assessments of this sector is required. Fisheries managers also need to understand the drivers behind this variability if they are to successfully manage recreational fisheries in a sustainable fashion. For example, fishers may go fishing more often when catch rates are higher so the overall level of recreational catch in these circumstances could reach unsustainable levels. Conversely, lower catch rates at other times would lessen the need for management intervention. Short-term events such as a wet Christmas break can also have an impact on the annual recreational harvest taken from a fishery. The overall implication of this programme is that it is likely that recreational fishing regulations may need to be adaptive and change more frequently than in the past, when settings remained unchanged for 20 years.

6. ACKNOWLEDGMENTS

The authors wish to thank members of the Marine Amateur Fisheries Working Group for useful suggestions made during presentations of this and other web camera related programmes in the past. We are also grateful to the large number of recreational fishers who have participated in creel surveys that provided much of the data used in our analyses, and to the part time staff who interviewed these fishers. This work was funded by the Ministry of Primary Industries project MAF201202, which is a continuation of other work previously funded by this Ministry and its predecessors under the following projects: REC200506, REC200702, and REC200904.

7. REFERENCES

Hartill, B. (2015). Evaluation of web camera based monitoring of levels of recreational fishing effort in FMA 1. *New Zealand Fisheries Assessment Report 2015/22*. 13 p.

Hartill, B.; Bian, R.; Rush, N.; Armiger, H. (2013). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70.* 44 p.

Hartill, B.; Davey, N. (2015). Mean weight estimates for recreational fisheries in 2011–12. *New Zealand Fisheries Assessment Report 2015/25.* 37 p.

Hartill, B.; Payne, G.; Reddish, L.; Vaughan, M.; Spong, K.; Buckthought, D. (2007b). Monitoring recreational fishing effort in QMA 1. Final Research Report for Ministry of Fisheries Project REC2005/06. 17 p. (Unpublished report held by MPI Wellington.)

Hartill, B.; Rush, N.; Payne, G. (2010). Web camera based indices of recreational fishing effort in QMA 1 and QMA 8. Final Research Report for Ministry of Fisheries Project REC2007/02. 24 p. (Unpublished report held by MPI Wellington.)

Hartill, B.; Vaughan, M.; Rush, N. (2011). Recreational harvest estimate for SNA 8 in 2006–07. *New Zealand Fisheries Assessment Report 2011/51*. 48 p.

Hartill, B.; Watson, T.; Cryer, M.; Armiger, H. (2007a). Recreational marine harvest estimates of snapper and kahawai in the Hauraki Gulf 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Wynne-Jones, J.; Gray, A.; Hill, L.; Heinemann, A. (2014). National Panel Survey of Marine Recreational Fishers 2011–12: Harvest Estimates. *New Zealand Fisheries Assessment Report 2014/67*. 139 p.

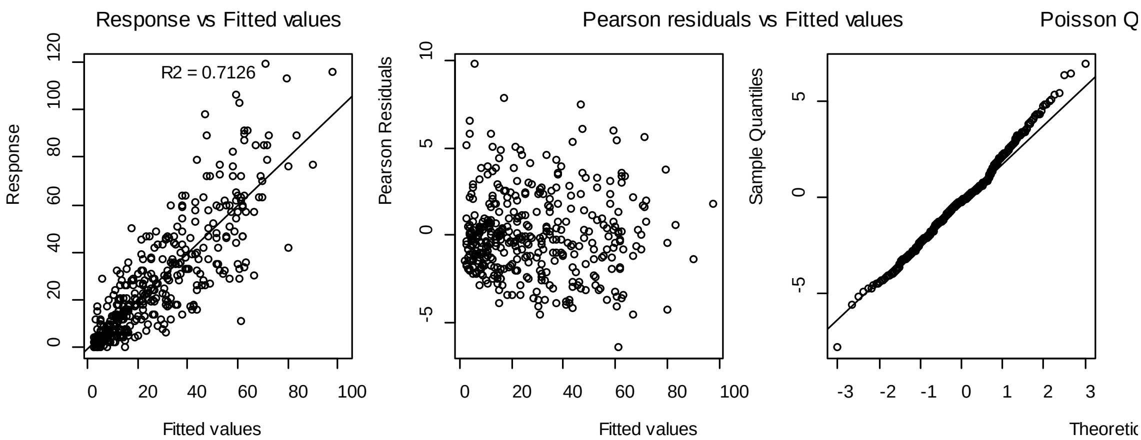
APPENDIX 1: Diagnostics for GLMs of FMA 1 daily traffic count data

Appendix 1a: Order in which explanatory variables are fitted to a model of daily boat traffic volumes at the Waitangi boat ramp in East Northland. The additional deviance explained by the sequential addition of each variable and the probability that the addition of that variable improves the explanatory power of the model is also given. TA denotes concurrent daily traffic counts at Takapuna in the Hauraki Gulf and SU denotes concurrent daily traffic counts at Sulphur Point in the Bay of Plenty.

WAITANGI

Variable	% Deviance explained	P(>|Chi|)	
sqrt(TA)	64.06%	< 2.2e-16	***
Fishing year	3.26%	1.0886E-50	***
Day type	2.35%	5.2924E-42	***
Season	1.66%	3.1607E-30	***
Fyear:sqrt(SU)	1.22%	1.2863E-16	***
Fyear:sqrt(TA)	0.94%	8.4703E-13	***

Diagnostic plots of the relationship between daily counts of boats returning to the Waitangi boat ramp relative to daily counts predicted from a model based on the variables given above [left panel]; residuals plotted against the daily counts predicted by the model [middle panel]; a Q–Q plot of these residuals.



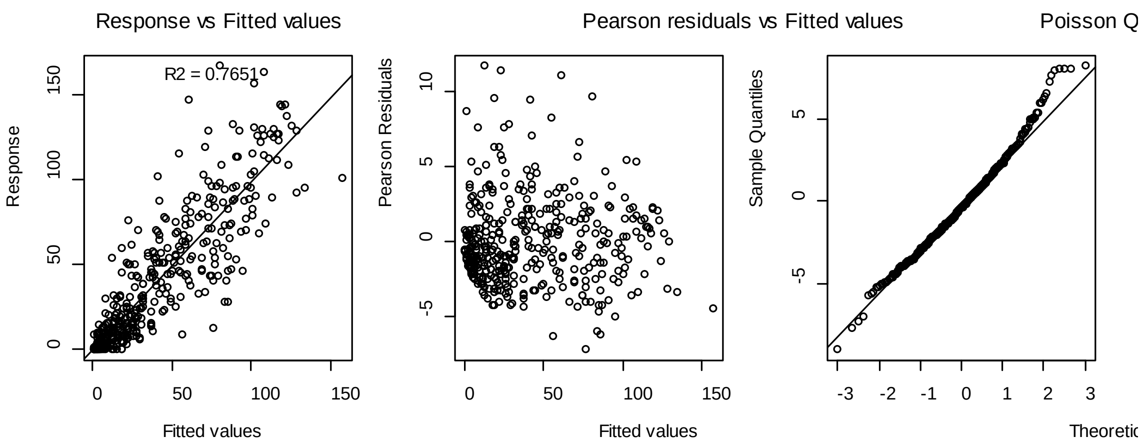
APPENDIX 1: Continued

Appendix 1b: Order in which explanatory variables are fitted to a model of daily boat traffic volumes at the Takapuna boat ramp in the Hauraki Gulf. The additional deviance explained by the sequential addition of each variable and the probability that the addition of that variable improves the explanatory power of the model is also given. SU denotes concurrent daily traffic counts at Sulphur Point in the Bay of Plenty and WG denotes concurrent daily traffic counts at Waitangi in East Northland.

TAKAPUNA

Variable	% Deviance explained	P(>|Chi|)	
poly(sqrt(SU),	63.45%	< 2.2e-16	***
poly(sqrt(WG),	10.89%	< 2.2e-16	***
Fyear	2.57%	2.1719E-79	***
Daytype	0.02%	0.1270232	***
Season	0.18%	0.1270232	***
Fyear:sqrt(SU)	0.44%	4.6548E-07	***
Fyear:sqrt(WG)	1.10%	2.9238E-11	***

Diagnostic plots of the relationship between daily counts of boats returning to the Takapuna boat ramp relative to daily counts predicted from a model based on the variables given above [left panel]; residuals plotted against the daily counts predicted by the model [middle panel]; a Q–Q plot of these residuals.



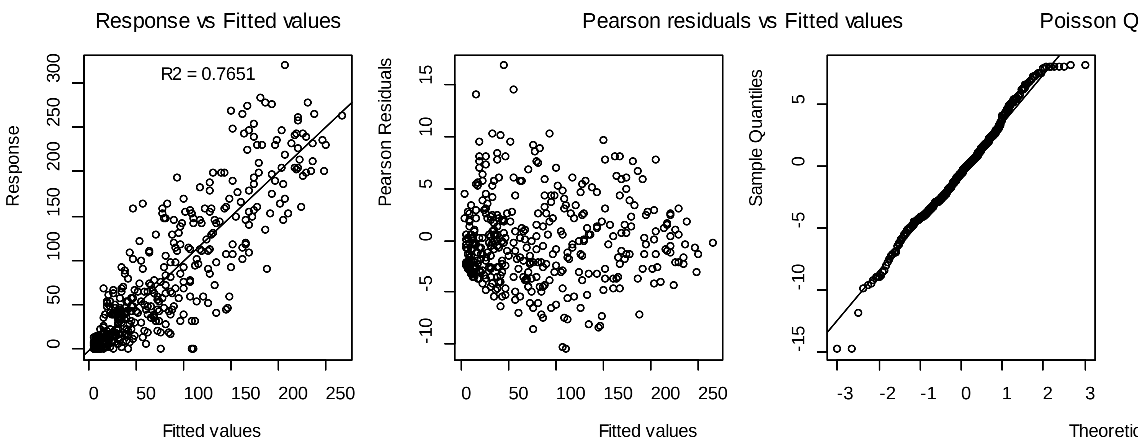
APPENDIX 1: Continued

Appendix 1c: Order in which explanatory variables are fitted to a model of daily boat traffic volumes at the Sulphur Point boat ramp in the Bay of Plenty. The additional deviance explained by the sequential addition of each variable and the probability that the addition of that variable improves the explanatory power of the model is also given. WG denotes concurrent daily traffic counts at Waitangi in East Northland and TA denotes concurrent daily traffic counts at Takapuna in the Hauraki Gulf.

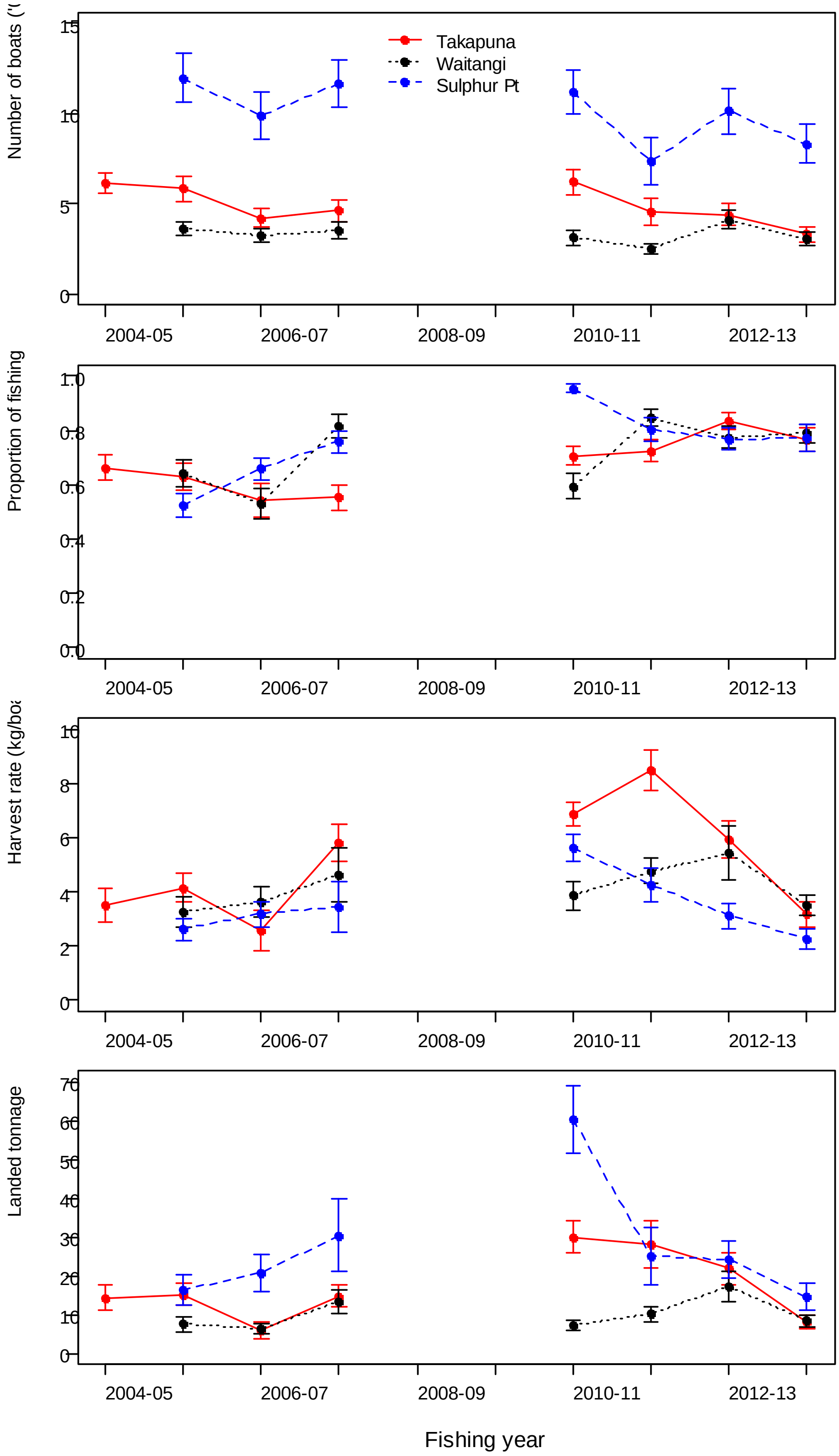
SULPHUR POINT

Variable	% Deviance explained	P(>|Chi|)	
poly(sqrt(WG),	53.90%	< 2.2e-16	***
poly(sqrt(TA),	15.47%	< 2.2e-16	***
Fyear	1.18%	4.3238E-68	***
Daytype	2.91%	1.292E-182	***
Season	0.62%	4.4444E-40	***
Fyear:sqrt(WG)	0.86%	1.2149E-48	***
Fyear:sqrt(TA)	0.81%	3.2942E-45	***

Diagnostic plots of the relationship between daily counts of boats returning to the Sulphur Point boat ramp relative to daily counts predicted from a model based on the variables given above [left panel]; residuals plotted against the daily counts predicted by the model [middle panel]; a Q–Q plot of these residuals.

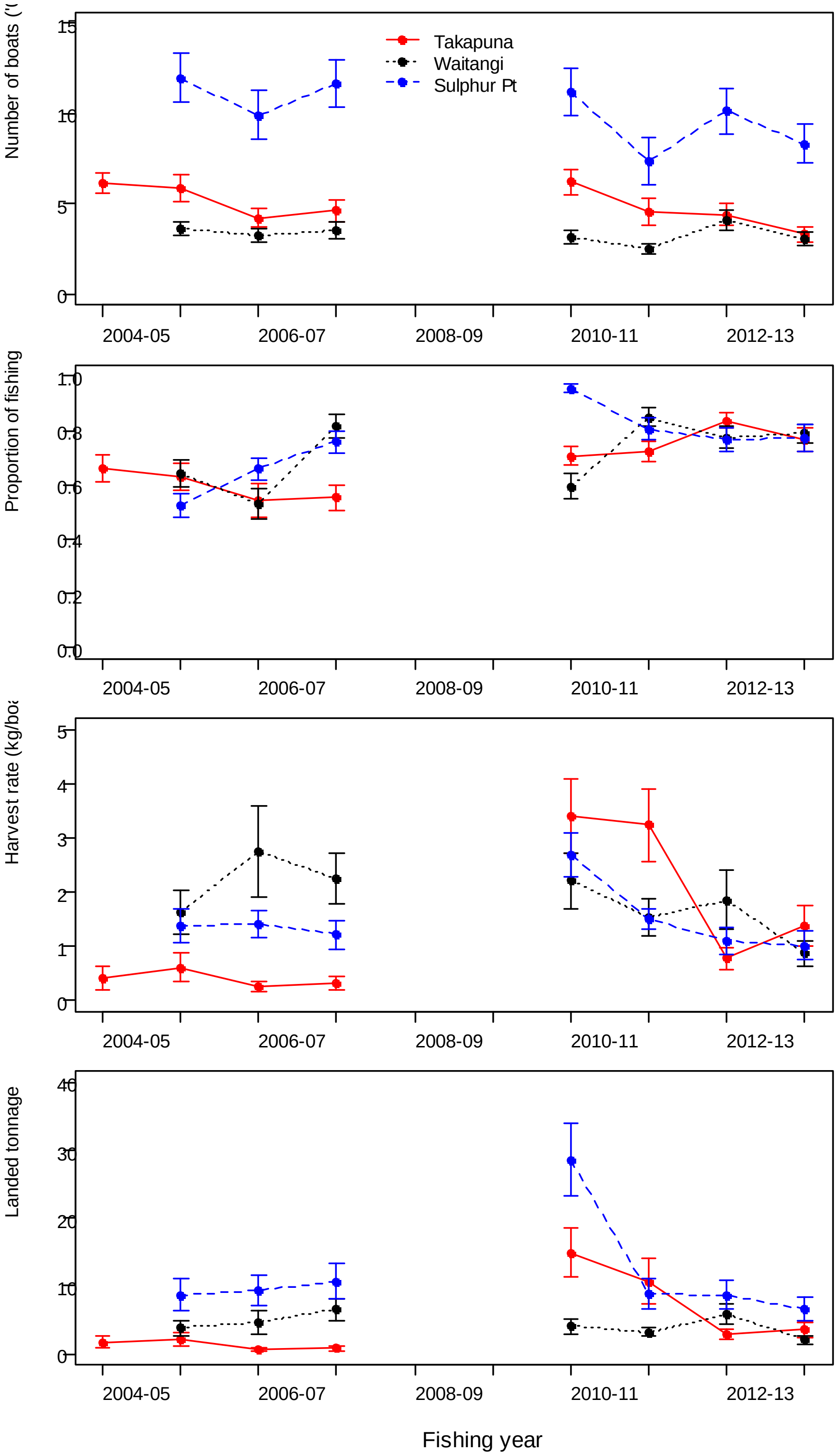


APPENDIX 2: Summer weekend/holiday indices for snapper



Estimates of numbers of boats using surveyed regional ramps in FMA 1 (upper panel – based on web camera counts only), the proportion of observed boats that were used for fishing (second panel), the average weight of snapper harvested per boat (third panel), and the annual snapper harvest landed at surveyed ramps during summer weekend and public holidays during each year (bottom panel).

APPENDIX 3: Summer weekend/holiday indices for kahawai



Estimates of numbers of boats using surveyed regional ramps in FMA 1 (upper panel – based on web camera counts only), the proportion of observed boats that were used for fishing (second panel), the average weight of kahawai harvested per boat (third panel), and the annual snapper harvest landed at surveyed ramps during summer weekend and public holidays during each year (bottom panel).

APPENDIX 4: Summary statistics for annual indices for FMA 1

Web camera based counts of the number of boats using the club ramp at Parua Bay in East Northland and at Half Moon Bay in the Hauraki Gulf are not currently available, but creel survey summary statistics are given for these ramps for comparative purposes.

					Snapper			Kahawai		
Ramp	Fishing year	Boats using ramp annually	Proportion of boats fishing	Fishing boats returning to ramp annually	Harvest per boat (kg)	Ramp harvest (t)	Regional harvest (t)	Harvest per boat (kg)	Ramp harvest (t)	Regional harvest (t)
Waitangi	2004-05	–	–	–	–	–	–	–	–	–
Waitangi	2005-06	–	–	–	–	–	–	–	–	–
Waitangi	2006-07	–	–	–	–	–	–	–	–	–
Waitangi	2007-08	–	–	–	–	–	–	–	–	–
Waitangi	2008-09	–	–	–	–	–	–	–	–	–
Waitangi	2009-10	–	–	–	–	–	–	–	–	–
Waitangi	2010-11	–	–	–	–	–	–	–	–	–
Waitangi	2011-12	6 995	0.77	5 385	4.09	22.0	718	1.49	8.0	191
Waitangi	2012-13	8 455	0.71	6 044	4.25	25.7	837	1.29	7.8	186
Waitangi	2013-14	7 549	0.72	5 457	3.29	18.0	585	0.75	4.1	97
Parua Bay club	2004-05	–	–	–	–	–	–	–	–	–
Parua Bay club	2005-06	–	–	–	–	–	–	–	–	–
Parua Bay club	2006-07	–	–	–	–	–	–	–	–	–
Parua Bay club	2007-08	–	–	–	–	–	–	–	–	–
Parua Bay club	2008-09	–	–	–	–	–	–	–	–	–
Parua Bay club	2009-10	–	–	–	–	–	–	–	–	–
Parua Bay club	2010-11	–	–	–	–	–	–	–	–	–
Parua Bay club	2011-12	–	0.84	–	4.37	–	–	0.77	–	–
Parua Bay club	2012-13	–	0.81	–	5.62	–	–	0.40	–	–
Parua Bay club	2013-14	–	0.83	–	5.09	–	–	1.01	–	–
Takapuna	2004-05	13 075	0.66	8 595	3.55	30.5	1 318	0.84	7.2	132
Takapuna	2005-06	–	–	–	–	–	–	–	–	–
Takapuna	2006-07	9 085	0.58	5 307	2.57	13.6	589	0.29	1.6	28
Takapuna	2007-08	–	–	–	–	–	–	–	–	–
Takapuna	2008-09	–	–	–	–	–	–	–	–	–
Takapuna	2009-10	–	–	–	–	–	–	–	–	–
Takapuna	2010-11	–	–	–	–	–	–	–	–	–
Takapuna	2011-12	10 905	0.72	7 828	7.52	58.8	2 540	2.52	19.7	359
Takapuna	2012-13	9 146	0.81	7 442	5.85	43.5	1 879	0.76	5.6	103
Takapuna	2013-14	7 214	0.74	5 347	3.17	16.9	731	1.14	6.1	111
Half Moon Bay	2004-05	–	–	–	–	–	–	–	–	–
Half Moon Bay	2005-06	–	–	–	–	–	–	–	–	–
Half Moon Bay	2006-07	–	0.50	–	7.67	–	–	0.41	–	–
Half Moon Bay	2007-08	–	–	–	–	–	–	–	–	–
Half Moon Bay	2008-09	–	–	–	–	–	–	–	–	–
Half Moon Bay	2009-10	–	–	–	–	–	–	–	–	–
Half Moon Bay	2010-11	–	–	–	–	–	–	–	–	–
Half Moon Bay	2011-12	–	0.76	–	9.70	–	–	2.26	–	–
Half Moon Bay	2012-13	–	0.73	–	6.68	–	–	1.29	–	–
Half Moon Bay	2013-14	–	0.67	–	6.16	–	–	1.61	–	–
Sulphur Point	2004-05	–	–	–	–	–	–	–	–	–
Sulphur Point	2005-06	–	–	–	–	–	–	–	–	–
Sulphur Point	2006-07	–	–	–	–	–	–	–	–	–
Sulphur Point	2007-08	–	–	–	–	–	–	–	–	–
Sulphur Point	2008-09	–	–	–	–	–	–	–	–	–
Sulphur Point	2009-10	–	–	–	–	–	–	–	–	–
Sulphur Point	2010-11	–	–	–	–	–	–	–	–	–
Sulphur Point	2011-12	17 379	0.82	14 277	3.94	56.3	546	1.45	20.7	201
Sulphur Point	2012-13	19 302	0.74	14 319	3.33	47.7	463	1.29	18.5	180
Sulphur Point	2013-14	17 689	0.75	13 289	2.25	29.9	290	1.57	20.9	203

APPENDIX 5: Summary statistics for annual indices for FMAs 8 and 9

Ramp	Fishing year	Boats using ramp annually	Proportion of boats fishing	Fishing boats returning to ramp annually	Snapper Harvest per boat (kg)	Snapper Ramp harvest (t)
Shelly Beach	2011-12	2 523	0.96	2 429	5.37	13.0
Shelly Beach	2012-13	3 341	0.96	3 218	5.97	19.2
Shelly Beach	2013-14	2 846	0.98	2 778	6.69	18.6
Raglan	2011-12	6 488	0.78	5 058	9.53	48.2
Raglan	2012-13	6 973	0.65	4 546	3.69	16.8
Raglan	2013-14	5 349	0.71	3 792	8.78	33.3
New Plymouth	2011-12	9 638	0.68	6 557	2.30	15.1
New Plymouth	2012-13	8 218	0.81	6 658	1.86	12.4
New Plymouth	2013-14	8 943	0.66	5 939	3.04	18.0