Recreational catch and effort in the Ministry of Fisheries North region

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Introduction

Since the introduction of the Quota Management System in 1986, the necessity to assess the non-commercial catch of key recreational species has been recognised. The Marine Recreational Fisheries Working Group has accorded priority to the determination of the recreational catch and effort by species and area for all species of interest to the recreational fishing sector (Teirney & Olsen 1992). Recreational fisheries are difficult to assess, however, as fishing methods and fisher ability are highly variable. Previous comparisons of harvest rates from boat ramp surveys have ignored the highly variable "quality" of recreational fishing effort (Cryer & MacLean 1991). To date comparisons of catch rates have been unstandardised and hence have ignored the influence of environmental conditions and fisher ability on changes in catch rates (Sylvester 1993, Bradford 1999). Catch rates in Tauranga Harbour and catch rates and fishing effort in Ohiwa Harbour and the Bay of Islands were determined in 1998 from boat ramp surveys. These estimates are compared with those derived from previous surveys using standardised regression techniques.

Boat ramp surveys were carried out in the Auckland Fisheries Management Area (AFMA) in 1991, 1994, and 1996. Although similar questions were asked in all three surveys, the objectives and sample designs were different. The 1991 survey was designed to collect baseline information on harvest rates by recreational fishers interviewed at boat ramps throughout the AFMA. Most interviewing occurred at weekends and the survey went from Boxing Day 1990 to June 1991 (Sylvester 1993). The main objective of the 1994 survey was to verify aspects of a concurrent diary survey. Catches observed from boat ramp interviews were compared with those reported by diarists. Boat ramp data were also used in conjunction with an aerial survey to estimate harvest from the Hauraki Gulf. This estimate was compared with that from the diary programme (Sylvester 1994). In 1996 a nationwide boat ramp survey was carried out to estimate the mean weights of fish caught by recreational fishers (Hartill et al. 1998). These mean weights were used in conjunction with estimates of the numbers of fish caught (derived from a national diary survey (Bradford et al. 1998)) to provide estimates of the national recreational harvest of key species (Bradford 1998).

In 1998, a further boat ramp survey was conducted to gather information on catch rates and fishing effort in three key harbours in the AFMA. This was the first survey to be based on a predetermined random stratified design and is thought to be more representative than previous surveys as sampling took place regardless of the prevailing weather conditions. This study attempts to provide standardised indices of harvest rates and fishing effort which relate to management issues in Tauranga Harbour, Ohiwa Harbour, and the Bay of Islands.

Tauranga Harbour is the most popular recreational harbour fishery in the Bay of Plenty. In recent years there has been increasing conflict between recreational fishers and commercial drag net fishers. Recreational fishers believe that drag net fishers targeting trevally are depleting the local snapper population resulting in decreasing catch rates. Catch rates of snapper and trevally in 1998 were assessed and compared with those observed in 1991, 1994, and 1996.

Commercial drag netting activity in Ohiwa Harbour has also resulted in concerns of decreasing catch rates of snapper. In 1996, commercial drag net fishers agreed not to fish at night, not to fish areas other than the harbour entrance, and not to fish at all between 14 December and 1 March. Harvest rates of snapper and levels of fishing effort between March and May 1998 were compared with those observed in 1991 and 1996 when there were no controls on commercial drag netting.

The Bay of Islands is a complex area of inlets and islands. Management measures such as seasonal restrictions on fishing activity and taiapure apply to different areas within it. Information is available on relative levels of fishing effort in different areas from boat ramp surveys, as the area has been divided into five fishing areas. Not all fishing is done from boat ramps; some is done from boats that cruise the east Northland coast or are moored in the Bay of Islands. This study looked only at fishing associated with boat ramps as there was little historical information on other sources of fishing activity. Catch rates of the most commonly caught finfish, and fishing effort at the most commonly used boat ramp, were compared with those observed in previous boat ramp surveys in 1991, 1994, and 1996.

This project (REC9706) was carried out under contract to the Ministry of Fisheries.

Objectives

1. To estimate the recreational catch rates of snapper and trevally from 1 December 1997 to 30 November 1998 in the Tauranga Harbour from a boat ramp survey.

2. To determine the changes in catch rates for snapper and trevally in Tauranga Harbour by comparison with boat ramp surveys carried out in 1991, 1994, and 1996.

3. To determine recreational fishing effort and snapper catch rates in Ohiwa Harbour from 1 March to 30 May 1998 from a boat ramp survey.

4. To assess changes in recreational fishing effort and snapper catch rates in Ohiwa Harbour by comparison with boat ramp surveys carried out in 1991 and 1996.

5. To determine the distribution of recreational fishing effort and catch rates from 1 December 1997 to 30 November 1998 in the Bay of Islands from a boat ramp survey.

6. To assess changes in recreational fishing effort and catch rates in the Bay of Islands by comparison with boat ramp surveys carried out in 1991, 1994, and 1996.

Methods

Minor differences in the methods were dictated by harbour-specific objectives, and the nature of data collected from previous surveys. Historical data were extracted from the recreational database (rec_data) where fishing effort took place within the three harbours studied. The fishing areas of interest were: KAT and MAK for Tauranga Harbour (Figure 1a); OHI for Ohiwa Harbour (Figure 1b); RUS, KER, BLA, RAW, and BRT for the Bay of Islands (Figure 1c). These historical data were used to determine the sample design for the 1998 survey and in the calculation of indices of CPUE and/or effort specific to each harbour.

For each harbour, all data from previous surveys were pooled. The designs for 1998 boat ramp surveys of Tauranga Harbour and the Bay of Islands were based on data collected from boat ramp surveys in 1991, 1994, and 1996. The 1998 sample design for Ohiwa Harbour was based on historical data for March to May of 1991 and 1996 (Ohiwa Harbour was not surveyed in 1994). The pooled data were stratified into eight season/day-type strata. The seasons were defined as: September to November for spring, December to February for summer, March to May for autumn, and June to August for winter. Day-type was defined as weekday or weekend, the latter including public holidays. Means and standard deviations of catch rates and fishing effort were calculated for each stratum and these statistics were used to estimate an optimal allocation of sampling effort for the 1998 survey. Estimates of CPUE were assumed to be log-normally distributed and estimates of fishing effort were assumed to be normally distributed.

Sampling designs for 1998 were derived using an iterative procedure. Each successive hour of sampling effort was assigned to the stratum that gave the greatest reduction in the c.v. of the final overall estimate (of CPUE or fishing effort). Strata were weighted according to the number of fishers historically interviewed per hour and the number of days within each season/day-type stratum. The predicted c.v. was plotted against the number of interview hours. The optimal sampling effort was estimated as the level beyond which there was no appreciable improvement in predicted c.v. with the addition of further sampling effort. Once the overall level of sampling effort (in hours) was determined, the level of sampling effort for each seasonal/day-type stratum was extracted from the iterative mean weighted c.v. calculations.

In Tauranga Harbour, only 186 trevally were caught by 2089 fishers interviewed in the three previous surveys. It was therefore decided that survey effort would be optimised on snapper catch rates alone, as there were insufficient trevally data for any meaningful analysis. An examination of data from the 1991, 1994, and 1996 surveys indicated that interviewing had taken place at two ramps in Tauranga Harbour, Bowentown and Sulphur Point (see Figure 1a). Sampling was therefore apportioned between these two ramps on the basis of the average number of fishers interviewed per hour at each ramp in the three previous surveys. As a result, 6 more hours of interviewing were allocated overall to the Sulphur Point ramp than to the Bowentown ramp. Hours were allocated to seasonal and day-type strata in 2 h blocks to randomly chosen days within each season/day-type stratum. Interviewers were instructed to conduct interviews at a time of day that was likely to maximise the number of boats encountered given factors such as time of day, weather, and tide.

For Ohiwa Harbour, separate optimisations based on historical snapper catch rates and fishing effort were conducted and the results compared. Given that there were many hours allocated to only three months, sampling was randomly allocated in 4 h blocks to days within each day-type stratum. These 4 h blocks consisted of a pair of 2 h sessions, with each session conducted at a different access point on the harbour.

Separate optimisations based on historical finfish catch rates and fishing effort in the Bay of Islands were conducted and the results compared. Hours were subsequently allocated to each season/day-type stratum in 2 h blocks, with each block representing a single sampling event. Sampling events were randomly allocated to days within each season/day-type stratum. Interviewers were instructed to conduct interviews at a time of day that was likely to maximise the number of boats encountered given factors such as time of day, weather, and tide. An examination of data from the 1991, 1994, and 1996 surveys indicated that interviewing had taken place consistently only at the Waitangi ramp in the Bay of Islands (see Figure 1c). Surveying was therefore restricted to this ramp to avoid any possible confounding "ramp effects".

Three catch rate statistics were calculated for each species–seasonal–day-type stratum; the mean of the ratios estimator, H_1 (the mean of all individual estimates of catch for effort), the ratio of the means estimator, H_2 (the mean of catch divided by the mean of effort), and the proportion of unsuccessful trips P_0. The mean of ratios estimator, H_1, is recommended when a measure of fisher satisfaction is required (Jones et al. 1995). This estimator may be biased by errors in individual harvest rates particularly when short fishing trips with high catch rates are involved, and its variance may be poorly defined (Pollock et al. 1997). The ratio of means, H_2, is recommended when the harvest rate is multiplied by an independent measure of effort to give an estimate of the total harvest. The proportion of unsuccessful trips, P_0, may be the best measure to use when describing catch rates for less frequently caught bycatch species. A more comprehensive discussion of these statistics and their formulas was given by Bradford (1999). The term trip used in this report refers to the use of a given fishing method in a given fishing location by a single fisher.

Catch rate statistics were calculated for snapper and trevally in Tauranga Harbour, snapper in Ohiwa Harbour, and for the three most commonly caught species in the Bay of Islands; snapper, kahawai, and jack mackerel/koheru. Jack mackerel and koheru catches were combined as these species are easily confused.

Recreational fishing effort was estimated for Ohiwa Harbour and the Bay of Islands. In Ohiwa Harbour, all probable access points to the harbour were surveyed so that total fishing effort could be estimated (see Figure 1b). Initially surveying took place at five ramps, but two were subsequently abandoned when it became apparent that they were not in use. Sampling effort at the main ramp, used in previous surveys, was twice that initially allocated to the other four ramps. When two ramps were abandoned, the sampling effort allocated to these ramps was transferred to the main ramp in recognition of its clear importance as a access point. Use of ramps in Ohiwa Harbour is tidal and the interviewer restricted her interviewing to about 2 h either side of high tide, conducting one 2 h session at one ramp before high tide, and another 2 h session at another ramp after high tide.

Effort was estimated using the number of hours of fishing effort encountered during each hour of interviewing. Estimates of fishing effort encountered hourly were scaled to the number of hours within 2.5 h of high tide occurring within a day-type stratum for the 3 months of the survey. A sample mean and variance were estimated for each temporal stratum. Estimates were calculated for each fishing method encountered separately.

Because of the many potential access points, the number of boats on moorings, and the number of boats visiting the Bay of Islands, it is not possible to assess total fishing effort from a boat ramp survey. Interviewing in the Bay of Islands took place at the Waitangi boat ramp, where interviewing had occurred in all three previous surveys. As sampling took place only at the Waitangi boat ramp, estimates of fishing effort can be used only to investigate the relative distribution of effort of the Waitangi ramp fishing population.

Catch rates and fishing effort observed in the 1998 survey were compared with those observed in previous surveys by performing stepwise regressions, using the statistical package S-PLUS©, to generate relative year effects. Indices were created for snapper and trevally catch rates in Tauranga Harbour; snapper catch rates and fishing effort in Ohiwa Harbour; and snapper, kahawai, and jack mackerel/koheru catch rates and fishing effort in the Bay of Islands.

For each species-harbour combination a standardised index of catch rate was created using a combination of linear and binomial models (Vignaux 1994). For the linear model, trips with zero catch were dropped from the analysis and the remaining catch rates, fish caught per hour fished, were log-transformed to make the catch rates more normally distributed and the variance more homogeneous. The success of each trip was modelled using a binomial family model, where the response variable was assigned a value of 1 when there was no catch of the species being investigated and 0 when there was a catch. The combined index was calculated using the linear and binomial indices and the proportion of zeros in the first year $P0_1$

$$C = \frac{1}{1 - P0_1} * (1 - C_b) * C_l \qquad (3)$$

where C_b is the binomial index expressed as the exponential of the negative relative year effect coefficient from the binomial model, and C_l is the linear index expressed as the exponential of the relative year effect coefficient from the linear model of non-zero catches (Vignaux 1994). The combined model therefore decreases CPUE indices in years where there is a higher than average proportion of zero catches and vice versa. Where binomial indices are presented graphically in this report, the binomial outcomes are reversed so that the indices represent the relative chance of fishing success in a given year. We consider this to be more easily interpreted when viewed in conjunction with the linear model.

First order interaction terms were considered in addition to individual variables, although interaction terms including the variable year itself and those with no data for one or more combinations of the interacted variables were not considered. Stratification or exclusion of data causing an interaction with the variable year would have resulted in insufficient sample sizes for any meaningful analysis. The stepwise iterations of each regression included both forwards and backwards inclusion and rejection of variables and their interactions at each iteration. Each subsequent iteration was included into the model automatically if it resulted in an improvement in the minimisation of the Akaike Information Criterion statistic (AIC; Akaike 1974). Only those terms which resulted in a 0.5% improvement in the AIC value were finally included as many other terms were often included automatically with minimal improvement in the model fit. Diagnostic plots of each regression are given in Appendix 1.

For Tauranga Harbour, only those trips in which the method was bait fishing and which took place in Tauranga Harbour, or where the fishing area was not specified, were considered. Because the surveys were conducted over different ranges of months, only trips during December to May were considered. For the snapper CPUE regressions, only those trips on which snapper was the target species or the target species was unspecified (when snapper was highly likely to be the target species) were used. For the trevally CPUE regressions, all trips, regardless of target species, were included as restriction to trevally or unspecified target trips would have resulted in very low sample sizes in one or more years.

There was a change from 25 to 27 cm in the minimum legal size (MLS) of snapper for recreational fishers part way through the time series under investigation. This could have had serious implications for any measure of catch per unit effort based only on those fish over the MLS. Therefore, we used an estimator of catch per unit effort which included all fish caught, including legal sized fish thrown back, fish filleted before returning to the ramp, and undersized fish thrown back. Inspection of the data from Tauranga Harbour suggested that there may have been differences among years in the proportions of fish landed or returned to the sea (as might be expected for a species with variable recruitment), but we have assumed that catch 'observation' codes have been used consistently through time. Our catch rate statistic is therefore a catch per unit effort statistic and not to be confused with an estimate of harvest per unit effort.

We initially considered a variable for angler experience, which has been shown to have explanatory power in another recreational fishery (Cryer & MacLean 1991). The experience variable was based on responses to questions such as "How many times have you been fishing in the last year?". In 1994, however, the question asked was "How many times have you been fishing in the last four weeks?". These two questions are not likely to have been answered with the same accuracy nor are they analogous when scaled to a common number of potential days fished. When the 1994 four weekly experience data were scaled up to 365 potential days fishing, the frequencies of fishers with multiples of 13 days experience were approximately four times higher than those observed in other years. Experience data from 1994 (58% of fishers interviewed) were therefore scaled up to 365 days and then divided by four to transform the 1994 data to an assumed similar level to that observed in other years. Regressions were performed on those interviews which included the experience data, but this variable was not selected for inclusion in the model. The experience variable was therefore dropped and all available interviews were used in the final regressions.

A snapper catch rate index was calculated for Ohiwa Harbour for 1991, 1996, and 1998. Only those trips in which the fishing method was bait fishing and which took place during March, April, or May in Ohiwa Harbour, or where the fishing area was not specified, were considered. Only those trips where snapper was the target species or the target species was unspecified were used. Estimates of catch per unit effort included only those fish landed, as there was only one legal snapper thrown back in 1991 and the numbers of undersized fish thrown back did not appear to have been recorded in a consistent manner. All snapper of 25 and 26 cm were also excluded from the analysis to overcome the change in MLS in 1994. As only landed fish were used in the regressions, the catch rate statistics given are therefore estimates of harvest per unit effort for snapper over 26 cm in length. These could be used to estimate harvest in conjunction with a suitable measure of fishing effort.

Catch rate indices were calculated for 1991, 1994, 1996, and 1998 for the three most commonly caught finfish in the Bay of Islands: snapper, kahawai, and jack mackerel/koheru. Only those trips in which the fishing method was bait fishing and which took place in the Bay of Islands or where the fishing area was not specified were considered. Because each survey spanned a different range of months, only trips which occurred during summer, December to August, were considered. For the snapper CPUE regressions, only those trips where snapper was the target species or the target species was unspecified were used. For the kahawai and jack mackerel/koheru CPUE regressions, all trips regardless of target species were included, as restriction to target or unspecified target trips would have resulted in very low sample sizes in one or more years.

Estimates of catch per unit effort included all fish caught, including legal sized fish thrown back, fish filleted before returning to the ramp, and undersized fish thrown back. The data from the Bay of Islands suggested that there were differences among years in the proportions of fish landed or returned to the sea. It was assumed that catch 'observation' codes were used consistently as interviewing was conducted by the same interviewer in all four years surveyed. The catch statistic is a catch per unit effort statistic and not to be confused with an estimate of harvest per unit effort. The use of all fish caught overcame difficulties arising from the change in the snapper MLS from 25 to 27 cm in 1994.

An index of fishing effort in Ohiwa Harbour was calculated for 1991, 1996, and 1998 using stepwise linear regression. The measure of fishing effort used was the number of hours of fishing effort encountered during each hour of interviewing, where the fishing effort took place within Ohiwa Harbour. Only data relating to the ramp OH (see Figure 1b) were used as this was the only ramp used consistently in all three survey years. The comparison was also restricted to March, April, and May as this period was common to all three surveys. When no fishers were encountered during an interview session, the data were not used as the proportion of zero interview sessions differed markedly between years and this was thought to be an artefact of differences among years in the sampling design and survey objectives rather than a trend in fishing activity. The days surveyed in 1998 were randomly predetermined, to enable assessment of total fishing effort, and probably included days when weather conditions precluded fishing activity. Estimates of fishing effort were log transformed to make the data more normally distributed and the variance more homogeneous.

Linear regressions were performed in a similar manner to that performed on the CPUE data. First order interaction terms excluding the variable year were considered with both forward and backwards inclusion of variables taking place at each iteration, depending on the AIC statistic.

An index of fishing effort was also calculated for the Bay of Islands for 1991, 1994, 1996, and 1998 using the same method as that used for Ohiwa Harbour. The measure of fishing effort used was the number of hours of fishing effort encountered during each hour of interviewing. Only data collected at the Waitangi boat ramp relating to the areas BLA, BRT, KER, RAW, and RUS (see Figure 1c) were used. The comparison was also restricted to summer, autumn, and winter which were sampled in all four survey years.

Results

Tauranga Harbour

The allocation of sampling effort for Tauranga Harbour is given in Table 1 and Figure 2. The winter/weekday stratum had high historical variance and had an overwhelming effect on the overall allocation of sampling effort. Consequently very little sampling effort would have been allocated to the remaining season/day type stratum which would make it difficult to characterise these parts of the year. Initial sampling levels of 10 and 20 h were therefore allocated to each stratum before the iterative addition of extra hours. The final design used was based on an initial allocation of 20 h to each stratum. For designs of 200 h or more, there was very little change in the performance with increasing initial allocations (see Figure 2). It was predicted that a total of 210 h of sampling effort would result in an estimated c.v. of 12.1%. Beyond this there was little gain in predicted precision with further sampling effort. The overall c.v.s actually achieved in this survey for the mean of ratios and ratio of means estimates of snapper harvest were 2.8 % and 3.8 % respectively (Table 2).

For optimising sampling effort, the historical CPUE data were considered to be log normally distributed. Subsequent examination of the data suggested that recreational CPUE data could not be normalised using a logarithmic transformation as most trips resulted in zero catches. A preliminary analysis of the data did suggest, however, that variances of estimated means in the current survey were similar to those observed historically and predicted by the optimisation procedure.

Catch rates of snapper in Tauranga Harbour varied with season during 1998, with the highest rates occurring in summer and autumn (see Table 2). No snapper were caught by fishers interviewed during spring. Fishing trips lasted between 1 and 7 h and took place throughout the year. Snapper catch and CPUE were highly skewed, with a high proportion of unsuccessful trips (Figure 3). In all four years the proportion of trips on which snapper was not caught exceeded 60% (Table 3).

Only 15 trevally were caught by the 183 fishers interviewed during the year (see Table 2). These low catch rates are similar to those observed in pervious surveys.

Snapper catch rates from the four years were standardised using the following variables which were considered to influence fishing success: year, season, day type, fishing area, time of day, state of tide, moon state, and length of trip (Table 4). Because these data are highly skewed, a combined linear and binomial index was calculated (Table 5). In both regressions, year was included automatically. Unstandardised, linear, binomial, and combined linear/binomial indices are presented in Table 6 and Figure 4. Catch rates were lowest in 1991, similar in 1994 and 1996 and highest in 1998.

The proportion of trips on which trevally was not caught exceeded 90% in all four survey years and the unstandardised catch rates were low (Table 7). Trevally catch rates from the four years were standardised using the following variables which were considered to influence fishing success: year, season, day type, fishing area, time of day, state of tide, moon state, and length of trip (Table 8). Because these data were highly skewed, a combined linear and binomial index was calculated (Table 9). Unstandardised, linear, binomial, and combined linear/binomial indices do not show similar trends (Table 10), but catch rates of trevally appear to have been highest in 1994 (Figure 5).

Ohiwa Harbour

An overall allocation of 152 h was chosen, as beyond this there was little gain in predicted precision with further sampling effort (Table 11). A minimum of 20 sampling hours was allocated to each day type stratum. Predicted c.v.s were 13.7% for the estimate of snapper CPUE, and 3.3% for the estimate of fishing effort (Figure 6). The overall c.v.s achieved in this survey for the mean of ratios and ratio of means estimates of snapper harvest were 5.9% and 5.7% respectively (Table 12). The overall c.v. of fishing effort by bait fishers in 1998 was 18.9%. The final allocation of sampling effort is given in Table 11.

For optimising sampling effort, the historical CPUE data were considered to be log normally distributed and the effort normally distributed. Subsequent examination of the data suggested that recreational CPUE data could not be normalised using a log-normal transformation as most trips resulted in zero catches. A preliminary analysis of the data did suggest, however, that variances of estimated means in the current survey were similar to those observed historically and predicted by the optimisation procedure.

Catch rates of snapper in Ohiwa Harbour in autumn 1998 were low, but the highest rates occurred midweek (see Table 12). The proportion of unsuccessful trips was 92% for weekend trips and 79% for weekday trips. Fishing trips generally lasted between 1 and 6 h (Figure 7), but there was one 12 h trip by two fishers (this may be an error given the size and tidal nature of the harbour). Snapper catch and CPUE were highly skewed, with a high proportion of unsuccessful trips.

The two main fishing methods used in Ohiwa Harbour were bait fishing and fishing from Ohiwa Wharf (Table 13). Drag netting from a boat, set netting, and trolling were observed occasionally.

In all three years the proportion of trips on which snapper was not caught exceeded 85% and unstandardised catch rates were low (Table 14). Variables considered to influence snapper catch rates which were used in the standardised regression were year, season, day type, fishing area, time of day, state of tide, moon state, fishing experience, and length of trip (Table 15). Because these data were highly skewed, a combined linear and binomial index was calculated (Table 16). The experience variable was considered for this analysis as it was recorded in 95% of the interviews using the same question. In both the linear and binomial regressions, the variable year had to be "forced" in order to provide a year index as it was not automatically included by the stepwise regressions. This means that year effects will be poorly estimated. Catch rates appear highest in 1991 (Table 17 and Figure 8), but these indices are probably of little utility as the number of unsuccessful trips is high, the number of snapper caught was low, and the variable year had to be "forced" in both the linear and binomial models. Diagnostic plots of each regression are given in Appendix 1.

Much more sampling was conducted in 1998 compared with 1991 and 1996 (Table 18) and the effort indices were therefore standardised to 1998. Variables considered to influence fishing effort which were used in the standardised regression were year, month, day type, moon state, sea state, cloud cover, wind direction, wind speed, and rain (Table 19). Wind direction was stratified as onshore (northwesterlies to easterlies), offshore (southeasterlies to westerlies), and null or variable winds. The standardised linear model of fishing effort had significant effects for month, day type, and wind direction (Table 20). It was necessary to "force" the variable year in order to provide a year index. The unstandardised and linear indices show different trends (Table 21 and Figure 9). The lower index for 1998 for the standardised model probably reflects its randomised design. Surveying in 1998 would have taken place regardless of weather conditions, whereas surveying in 1991 and 1996 was targeted at times when fishing effort was expected to be high. When environmental conditions were incorporated in the standardised regression, fishing effort appears to have decreased in 1998, relative to previous surveys. The low sample size (57 interview sessions) probably makes these inferences suspect. Diagnostic plots of the regression are given in Appendix 1.

Bay of Islands

An overall allocation of 228 h was chosen, as beyond this there was little gain in predicted precision with further sampling effort (Table 22). A minimum of 20 sampling hours was allocated to each season/day type stratum. The predicted mean weighted c.v.s for fishing effort were less precise than those predicted for CPUE (Figure 10). Predicted c.v.s given this level of sampling effort were 9.6% for the estimate of fishing effort, and 3.1% for the estimate of CPUE. The overall c.v.s achieved in this survey for the mean of ratios and ratio of means estimates of snapper harvest were both 0.3% (Table 23). The final allocation of sampling effort to season/day type stratum is given in Table 22.

For optimising sampling effort, the historical CPUE data were considered to be log normally distributed and the effort normally distributed. Subsequent examination of the data suggested that recreational CPUE data could not be normalised using a log-normal transformation as most trips resulted in zero catches. A preliminary analysis of the data did suggest, however, that variances of estimated means in the current survey were similar to those observed historically and predicted by the optimisation procedure.

The three most commonly caught species in the four survey years by bait fishers were snapper (caught by 55.7% of fishers interviewed), kahawai (24.7% of fishers), and jack mackerel/koheru (11.5% of fishers; see Table 23).

Catch rates of snapper in the Bay of Islands varied with season during 1998, with the highest rates occurring in autumn and winter (see Table 23, Figure 11). Average catch rates were consistently higher midweek, which may be due to a higher proportion of experienced people fishing during the week than at the weekend. Fishing trips lasted between 1 and 11 h and took place throughout the year (see Figure 11).

Snapper catch and CPUE were highly skewed, with a high proportion of unsuccessful trips. The proportion of trips on which no snapper were caught ranged from 40% in 1991 to 59% in 1996 (Table 24). This is a much lower proportion of trips with zero catch than at the other two sites examined. Variables considered to influence snapper catch rates which were used in the standardised regression were year, season, day type, fishing area, time of day, state of tide, moon state, and length of trip (Table 25). Because these data were highly skewed, a combined linear and binomial index was calculated. Effects for length of trip, area, season, year, day type, time of day, and moon phase were included in the linear model of catch rates (Table 26). The latter two effects did not appear in the binomial model, but a day type-length of trip interaction was selected. Information on angler experience was available for only 64% of the fishers interviewed. This information on angler experience was not used in any of the catch rate regressions for reasons similar to those discussed for Tauranga Harbour. In both regressions, year was automatically included into the model. Both the unstandardised and combined model indices show a similar trend, with catch rates highest in 1994 and 1996 (Table 27, see Figure 14).

There appears to be little seasonal change in catch rates of kahawai, although catch rates are consistently higher midweek (see Table 23). Fewer fishers were interviewed in the winter and spring months, and trips tended to be shorter (Figure 12). Kahawai catch and CPUE were highly skewed, with the proportion of unsuccessful trips exceeding 60% in all seasonal day-type strata.

The proportion of trips on which kahawai was not caught exceeded 65% in all years (Table 28). Variables considered to influence kahawai catch rates which were used in the standardised regression were year, season, day type, fishing area, time of day, state of tide, moon state, and length of trip (Table 29). Because these data were highly skewed, a combined linear and binomial index was calculated. Effects for length of trip, area, tide, season, day type, year, and some interactions, mainly with length of trip, were included in the linear model of catch rates (Table 30). The same effects appeared in the binomial model, but no interaction terms were selected. In both regressions, year was included into the model automatically, although year was not included in the linear regression until the tenth iteration where it improved the fit of the model by only 0.11%. Both the unstandardised and combined model indices show a similar trend with catch rates highest in 1996 (Table 31 and Figure 15).

Catch rates of jack mackerel/koheru were highest in summer (Table 23). The proportion of trips on which no jack mackerel/koheru were caught exceeded 70% in all seasonal day-type strata. Catch rates were highly skewed (Figure 13).

The proportion of trips on which no jack mackerel/koheru were caught exceeded 85% in all years (Table 32). Variables considered to influence jack mackerel/koheru catch rates which were used in the standardised regression were year, season, day type, fishing area, time of day, state of tide, moon state, and length of trip (Table 33). Because these data were highly skewed, a combined linear and binomial index was calculated. Effects for length of trip, tide, time of day, and season were automatically included in the linear model of catch rates, but the year effect had to be "forced "(Table 34). Year effects were automatically selected by the binomial model as were area and tide. Both the unstandardised and combined model indices show a similar trend, with higher catch rates in 1994 and 1998 (Table 35 and Figure 16).

The fishing effort of fishers returning to the Waitangi boat ramp in 1998 was distributed throughout the Bay of Islands, although little fishing occurred in Kerikeri Inlet (KER, Figure 17). These estimates of fishing effort are based on data from the Waitangi boat ramp only and are not necessarily indicative of levels of usage by the entire Bay of Islands fishing population. With the exception of the Kerikeri Inlet area, fishing effort was generally higher at weekends and public holidays (Figures 18 to 22).

There were more sampling sessions in 1998 than in 1991, 1994, and 1996 (Table 36) and the effort indices were therefore standardised to 1998. Variables considered to influence fishing effort were year, season, day type, moon state, sea state, cloud cover, wind direction, wind speed, and rain (Table 37). The proportion of boat ramp sessions where no interviews took place was far higher in 1998 (0.20) than in any previous survey (see Table 36). This is probably due to the more representative nature of the random sample design used in 1998 with boat ramp sessions occurring regardless of weather conditions. Year effects were automatically selected by the linear model as were fishing area, wind direction, day type, and an interaction between day type and wind direction (Table 38). The unstandardised and linear indices show similar trends with fishing effort increasing in each successive survey (Table 39 and Figure 23). Diagnostic plots of the regression are given in Appendix 1.

Discussion

Interaction and conflict for fisheries resources between commercial and non-commercial users is widespread in the Ministry of Fisheries North region (which includes all three sites examined here). Frequently, such conflict is not based on sound information. A boat ramp survey in 1998 was designed to collect representative information on catch rates and fishing effort in Tauranga Harbour, Ohiwa Harbour, and the Bay of Islands. Each area has its own fishery management issues related to perceived poor or declining catch rates. Except for trips on which snapper was targeted in the Bay of Islands, most trips in all three locations resulted in no catch.

Standardised and unstandardised indices of catch rate were usually very similar, suggesting that little has been gained by standardising. However, the standardisation of catch rates does give some insight into those variables which may drive fishing success. Variables such as moon phase and state of tide appear to have less influence on catch rates than is generally believed. The length of a fishing trip and the time of year appear to have the most influence on catch rates. Fishing experience is thought to be a key variable in predicting fishing success (Cryer & MacLean 1991). Unfortunately, experience was assessed differently in 1994, days fished in the last four weeks as opposed to in the last year, and the results are not comparable with data collected in other surveys. In addition, no information on fishing experience is available for most of the fishers interviewed. Fishing experience was therefore ignored in the analyses presented here. Standardised questions should be designed for future surveys to ensure that fisher experience and catch, as opposed to harvest, is consistently quantified, thus ensuring that information is directly comparable between surveys. When designing future boat ramp surveys, randomised stratified designs should be used to ensure that the data being collected are representative. The boat ramp surveys in 1991 and 1994 appear to have given too much emphasis to sampling during the weekend and on days when the weather conditions are favourable for fishing. This may be desirable when trying to maximise the number of fishers interviewed per hour, but information on catch rates collected from such surveys may not be representative of that experienced by the local fishing population.

Levels of fishing effort in Ohiwa Harbour and the Bay of Islands in 1998 were compared with levels observed in previous surveys. The measure of fishing effort used was the number of hours of fishing encountered at a given ramp per hour of interviewing. This is a relative estimate of fishing effort. There appears to be little change in the level of fishing effort since 1991, but as the sample size is small, the changes observed may be misleading. Fishing effort in the Bay of Islands associated with fishers using boat ramps appears to have increased steadily since 1991. It is not possible to use boat ramp surveys alone to assess total fishing effort in large harbours, such as the Bay of Islands, as a significant proportion of fishing effort is associated with cruising yachts and boats which are stored on moorings or in marinas.

Snapper catch rates in Tauranga Harbour varied seasonally, declining in winter with no catch reported during spring 1998. The highest stratum-specific catch rates in 1998 were in the range 0.25–1.25 fish per hour, and the raw average catch rate for the year was 0.61 fish per hour. A combined linear and binomial standardised year index shows a similar trend to that found with an unstandardised index, with catch rates highest in 1998. However, conflict between recreational fishers and commercial drag netters persists as there is still a perception of declining catch rates (R. Fanslow, MFish policy analyst, pers. comm.). As in previous surveys in 1991, 1994, and 1996, catch rates of trevally were very low (less than 0.05 fish per hour). Both the standardised and unstandardised year indices indicate that trevally catch rates were highest in 1994 and have since declined.

Catch rates of snapper in Ohiwa Harbour were low (less than 0.1 fish per hour). Both the standardised and unstandardised indices were highest in 1991. The standardised index should be regarded with some caution, however, as in both the linear and binomial regressions the variable year had to be "forced" because the model failed to detect a significant difference in catch rates over time. Most fishing in Ohiwa Harbour in 1998 was from Ohiwa Wharf (2911 h), and bait fishing from boats (2000 h). There was also some set netting (1092 h) and very small amounts of trolling and drag netting. The interviewer at Ohiwa Harbour considered the ramps to be tidal (Heather Ludlow, pers. comm.), so interviewing and scaling of fishing effort corresponded to a period of potential ramp use 2 h either side of high tide. These estimates of fishing may be conservative if fishing occurred outside this period. A standardised index of fishing effort is highest in 1998, although the number of interview sessions in the 1991 and 1996 surveys is limited. We consider neither standardised nor unstandardised comparison of fishing effort among years to be valid, however, because no two surveys had the same design due to different survey objectives. Only the 1998 survey was based on a randomised design in which surveying took place regardless of weather conditions. The sample sizes for Ohiwa Harbour were also low.

Catch rates of snapper, kahawai, and jack mackerel/koheru in the Bay of Islands in 1998 were similar throughout the year (snapper 0.23–0.92 with a mean of 0.50; kahawai 0.05–0.40 with a mean of 0.16; jack mackerels 0.06–0.29 with a mean of 0.11). Fishing effort varied seasonally and was highest during summer and autumn. Standardised and unstandardised indices showed similar trends, but the trends were different for each species. Catch rates were highest for snapper in 1994 and 1996, for kahawai in 1996, and for jack mackerel/koheru in 1994 and 1998. Estimates of relative fishing effort for the five fishing areas in the Bay of Islands are based on the Waitangi boat ramp only and are not necessarily indicative of the entire fishing population in this area. Both standardised and unstandardised indices indicate that fishing effort has steadily increased since the first survey in 1991, but these comparisons are suspect. No two surveys had the same design, and only the 1998 survey was based on a randomised design in which surveying took place regardless of environmental conditions.

Conclusions

1. Catch rates for snapper in 1998 were 0.25–1.25, 0.07, and 0.23–0.92 fish per hour in Tauranga Harbour, Ohiwa Harbour, and the Bay of Islands respectively. Catch rates were consistently lower in winter and spring.

2. Average catch rates for snapper were higher in Tauranga harbour and Ohiwa Harbour, and lower in the Bay of Islands than they were in 1996.

3. Fishing effort appears to have increased since 1991 in both the Bay of Islands and Ohiwa Harbour, although support for the latter conclusion is not strong.

4. Catch rates appear to vary by year, but these changes cannot be explained.

5. Factors most likely to influence recreational catch rates are length of fishing trip, area fished, and season, but many other factors are included in multivariate models sometimes with several interaction effects.

6. The available data do not support useful standardisation of catch rates by multivariate methods which are commonly used in the assessment of commercial fisheries.

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Table 1: **Sample design for Tauranga Harbour based on an allocation of 210 interview hours.**

Day-type	Summer	Autumn	Winter	Spring
Weekend	20	20	20	20
Weekday	20	30	50	30

Table 2: **Catch rates of snapper where snapper or mix was the targeted species and trevally, regardless of species targeted, caught by baited line in Tauranga Harbour during the 1998 survey. Three catch rate statistics are given: H_1 the mean of the ratios, H_2 the ratio of the means, and p_0 the proportion of unsuccessful trips.**

Species	Season	Day type	Survey hours	No. trips	Fishing hours	Fish	H_1	c.v.	H_2	c.v.	p_0
Snapper	Summer	Weekend	24	32	72	18	0.155	0.14	0.251	0.18	0.78
		Weekday	26	11	35	13	0.522	0.23	0.376	0.19	0.55
	Autumn	Weekend	22	36	86	22	0.288	0.12	0.256	0.13	0.72
		Weekday	34	34	101	126	1.638	0.05	1.251	0.07	0.35
	Winter	Weekend	20	32	94	9	0.179	0.31	0.096	0.19	0.81
		Weekday	42	16	33	1	0.031	1.00	0.030	1.06	0.94
	Spring	Weekend	16	34	122	0	0.000	–	0.000	–	1.00
		Weekday	28	12	29	0	0.000	–	0.000	–	1.00
	Overall		212	207	572	189	0.401	0.03	0.331	0.04	0.75
Trevally	Summer	Weekend	24	37	85	0	0.000	–	0.000	–	1.00
		Weekday	26	13	36	2	0.035	1.00	0.057	1.02	0.92
	Autumn	Weekend	22	37	91	0	0.000	–	0.000	–	1.00
		Weekday	34	34	101	5	0.040	0.39	0.049	0.36	0.91
	Winter	Weekend	20	35	103	6	0.038	0.37	0.058	0.38	0.91
		Weekday	42	19	44	1	0.009	1.00	0.023	1.04	0.95
	Spring	Weekend	16	36	126	1	0.005	1.00	0.008	1.01	0.97
		Weekday	28	12	29	0	0.000	–	0.000	–	1.00
	Overall		212	223	615	15	0.016	0.13	0.024	0.13	0.96

***Table 3*: Summary of Tauranga Harbour snapper catch and effort data used in the standardised CPUE analyses.**

Survey year	No. snapper	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE (fish/hour)
1991	363	579	450	0.78	0.18
1994	353	323	220	0.68	0.31
1996	434	507	362	0.71	0.31
1998	179	112	68	0.61	0.61

***Table 4*: Summary of variables used in the standardised model of snapper CPUE in Tauranga Harbour. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 2	Summer and Autumn
Day	cat 2	Weekday and weekend/holiday
Area	cat 3	Area in harbour or unspecified
Time	cat 8	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Length	cont	Time fished in hours

***Table 5*: Comparison of variables selected for the Tauranga Harbour snapper CPUE regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

	Linear model				Binomial model		
Variable	% variance explained	d.f.	% improve of AIC	Variable	% variance explained	d.f.	% improve of AIC
Length	15.2	420	–	Length	5.1	1519	–
Time	20.8	413	6.97	Time	8.3	1512	2.61
Year	25.2	410	7.84	Tide	11.7	1504	2.69
Time*Length	29.6	403	4.87	Year	13.3	1501	1.32
Day	30.9	402	2.37	Area	14.3	1499	0.81
Day*Length	33.2	401	4.73				
Area	34.5	399	1.55				
Day*Area	37.3	397	2.21				
Season	38.0	396	0.71				
Tide	40.7	388	1.02				
Day*Time	44.6	379	0.78				

***Table 6*: Relative year effects from the linear model of log (catch per hour), binomial model of successful trips (non-zero catch) and unsuccessful trips (zero catch), and combined indices for snapper caught in Tauranga Harbour.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1994	1.72	1.22	1.59	1.72
1996	1.72	0.93	1.82	1.43
1998	3.39	1.34	3.22	2.90

***Table 7*: Summary of Tauranga Harbour trevally catch and effort data used in the standardised CPUE analyses.**

Survey year	No. trevally	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE (fish/hour)
1991	52	599	566	0.94	0.08
1994	86	331	306	0.92	0.18
1996	57	555	514	0.93	0.09
1998	15	121	117	0.97	0.07

***Table 8*: Summary of variables used in the standardised model of trevally CPUE in Tauranga Harbour. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 2	Summer and Autumn
Day	cat 2	Weekday and weekend/holiday
Area	cat 3	Area in harbour or unspecified
Time	cat 8	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Length	cont	Time fished in hours

***Table 9*: Comparison of variables selected for the Tauranga Harbour trevally CPUE regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

Linear model				Binomial model			
Variable	% variance explained	d.f.	% improve of AIC	Variable	% variance explained	d.f.	% improve of AIC
Length	37.1	101	–	Length	2.4	1604	–
Year	45.2	98	6.95	Season	3.8	1603	1.07
Area	48.8	96	2.35	Day	5.0	1602	10.60
				Time	8.2	1595	1.42
				Day*Length	8.7	1594	0.22
				Year	9.7	1591	0.17

***Table 10*: Relative year effects from the linear model of log (catch per hour), binomial model of successful trips (non-zero catch) and unsuccessful trips (zero catch), and combined indices for trevally caught in Tauranga Harbour.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1994	2.15	1.71	1.19	2.01
1996	1.08	0.89	1.75	1.51
1998	0.80	1.06	0.57	0.62

***Table 11*: Sample design for Ohiwa Harbour based on an allocation of 152 interview hours.**

Day-type	Autumn
Weekend	64
Weekday	88

***Table 12*: Catch rates of snapper where snapper or mix was the targeted species and trevally, regardless of species targeted, caught by baited line in Ohiwa Harbour during the 1998 survey. Three catch rate statistics are given: H_1 the mean of the ratios, H_2 the ratio of the means, and p_0 the proportion of unsuccessful trips.**

Species	Season	Day type	Survey hours	No. trips	Fishing hours	Fish	H_1	c.v.	H_2	c.v.	p_0
Snapper	Autumn	Weekend	64	87	242	12	0.045	0.15	0.050	0.15	0.92
	Autumn	Weekday	88	53	124	12	0.077	0.08	0.097	0.08	0.79
	Overall		152	140	366	24	0.057	0.06	0.066	0.06	0.87

Table 13: **Weighted estimates of fishing effort (hours), c.v.s and number of interviews (n) for methods used in Ohiwa Harbour during the 1998 boatramp survey at three ramps OH, OHA and OHW.**

Method	Strata	Effort	c.v.	n
Bait	OH weekend	797	0.26	87
	OH weekday	694	0.22	54
	OHA weekend	325	0.74	8
	OHA weekday	112	1.00	2
	OHW weekend	72	1.00	2
	OHW weekday	0	–	0
	OH All	1 492	0.17	141
	OHA All	437	0.61	10
	OHW All	72	1.00	2
	Weekend all	1 194	0.27	97
	Weekday all	806	0.24	56
	Total	2 000	0.19	153
Drag net	OH weekend	34	1.00	3
	OH weekday	0	–	0
	OHA weekend	0	–	0
	OHA weekday	53	1.00	2
	OHW weekend	0	–	0
	OHW weekday	0	–	0
	OH All	34	1.00	3
	OHA All	53	1.00	2
	OHW All	0	–	0
	Weekend all	34	1.00	3
	Weekday all	53	1.00	2
	Total	87	0.72	5
Set net	OH weekend	75	0.59	5
	OH weekday	180	0.40	11
	OHA weekend	0	–	0
	OHA weekday	0	–	0
	OHW weekend	177	0.68	3
	OHW weekday	660	1.00	2
	OH All	254	0.33	16
	OHA All	0	–	0
	OHW All	837	0.80	5
	Weekend all	252	0.51	8
	Weekday all	840	0.79	13
	Total	1 092	0.62	21

Method	Strata	Effort	c.v.	n
Trolling	OH weekend	21	0.73	6
	OH weekday	0	–	0
	OHA weekend	0	–	0
	OHA weekday	0	–	0
	OHW weekend	0	–	0
	OHW weekday	47	1.00	2
	OH All	21	0.73	6
	OHA All	0	–	0
	OHW All	47	1.00	2
	Weekend all	21	0.73	6
	Weekday all	47	1.00	2
	Total	68	0.73	8
Wharf fishing	OH weekend	0	–	0
	OH weekday	0	–	0
	OHA weekend	0	–	0
	OHA weekday	0	–	0
	OHW weekend	1 821	0.24	107
	OHW weekday	1 090	0.43	28
	OH All	0	–	0
	OHA All	0	–	0
	OHW All	2 911	0.22	135
	Weekend all	1 821	0.24	107
	Weekday all	1 090	0.43	28
	Total	2 911	0.22	135

Table 14: **Summary of Ohiwa Harbour snapper catch and effort data used in the standardised CPUE analyses.**

Survey year	No. snapper	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE (fish/hour)
1991	35	138	128	0.93	0.14
1996	4	80	76	0.95	0.02
1998	24	134	116	0.87	0.07

Table 15: **Summary of variables used in the standardised model of snapper CPUE in Ohiwa Harbour. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 3	Year of survey
Month	cat 3	March, April, May
Day	cat 2	Weekday and weekend/holiday
Time	cat 8	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Experience	cont	Days fished in last 12 months
Length	cont	Time fished in hours

Table 16: **Comparison of variables selected for the Ohiwa Harbour snapper CPUE regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

Linear model

Variable	% variance explained	d.f.	% improve of AIC
Year (forced)	18.7	30	–
Month	36.8	27	12.97

Binomial model

Variable	% variance explained	d.f.	% improve of AIC
Year (forced)	2.2	349	–
Time	8.5	346	3.72
Month	16.0	344	5.42
Length	18.0	343	1.13
Month*Length	26.3	341	7.19
Experience	28.5	340	1.42
Length*Experience	31.3	339	2.32
Moon	35.9	336	2.22
Experience*Moon	40.5	333	2.21
Length*Moon	45.1	330	2.32

Table 17: **Relative year effects from the linear model of log (catch per hour), binomial model of successful trips (non-zero catch) and unsuccessful trips (zero catch), and combined indices for snapper caught in Ohiwa Harbour.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1996	0.14	0.37	0.62	0.24
1998	0.50	0.47	0.68	0.33

***Table 18*:** **Summary of OhiwaHarbour fishing effort data used in the standardised fishing effort analyses.**

Survey year	No. sessions	No. session hours	Sessions with zero interviews	Proportion zero interviews	Raw effort (interview/hour)
1991	14	51	1	0.07	5.27
1996	14	32	0	0.00	7.76
1998	45	90	15	0.33	4.70

***Table 19*:** **Summary of variables used in the standardised model of fishing effort in OhiwaHarbour. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 3	Year of survey
Month	cat 3	March, April, May
Day	cat 2	Weekday and weekend/holiday
Moon	cat 4	Quarter of moon phase on day fished
Sea state	cat 4	Smooth, slight, moderate, rough
Cloud cover	cat 4	Nil, mainly sunny, nainly cloudy, continuous
Wind direction	cat 3	Onshore, offshore, variable or null
Wind speed	cat 4	Nil, light, medium, strong
Rain	cat 4	Nil, light continuous, light scattered, medium scattered

***Table 20*:** **Comparison of variables selected for the OhiwaHarbour fishing effort linear regression model in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

Variable	% variance explained	d.f.	% improve of AIC
Year (forced)	–	55	–
Month	18.8	53	56.55
Day	28.8	52	20.11
Wind direction	35.4	50	5.52

***Table 21*:** **Relative year effects from the linear model of log (hours of fishing effort encountered per interview hour) in Ohiwa Harbour.**

Year	Unstandardised	Linear
1991	1.12	0.67
1996	1.65	0.95
1998	1.00	1.00

Table 22: **Sample design for the Bay of Islands based on an allocation of 228 interview hours.**

Day-type	Summer	Autumn	Winter	Spring
Weekend	20	20	20	20
Weekday	34	50	34	30

Table 23: **Catch rates of snapper where snapper or mix was the targeted species, and kahawai and jack mackerel/koheru, regardless of species targeted, caught by baited line in the Bay of Islands during the 1998 survey. Three catch rate statistics are given: H_1 the mean of the ratios, H_2 the ratio of the means, and p_0 the proportion of unsuccessful trips.**

Species	Season	Day type	Survey hours	No. trips	Fishing hours	Fish	H_1	c.v.	H_2	c.v.	p_0
Snapper	Summer	Weekend	20	247	796	181	0.207	0.02	0.227	0.02	0.64
		Weekday	34	66	236	103	0.465	0.05	0.464	0.05	0.52
	Autumn	Weekend	20	174	685	270	0.396	0.02	0.394	0.02	0.51
		Weekday	50	232	931	626	0.822	0.01	0.673	0.01	0.34
	Winter	Weekend	20	153	526	294	0.490	0.02	0.559	0.02	0.44
		Weekday	34	67	238	218	0.987	0.02	0.915	0.02	0.21
	Spring	Weekend	20	96	338	119	0.371	0.05	0.352	0.04	0.54
		Weekday	30	94	269	129	0.445	0.04	0.479	0.04	0.55
	Overall		228	1129	4017	1940	0.496	0.00	0.482	0.003	0.48
Kahawai	Summer	Weekend	20	278	930	249	0.063	0.08	0.049	0.05	0.90
		Weekday	34	84	285	59	0.205	0.05	0.211	0.04	0.70
	Autumn	Weekend	20	193	769	148	0.134	0.04	0.129	0.03	0.77
		Weekday	50	250	1 018	158	0.257	0.01	0.264	0.02	0.63
	Winter	Weekend	20	168	580	138	0.080	0.04	0.078	0.03	0.82
		Weekday	34	67	238	42	0.340	0.05	0.403	0.05	0.63
	Spring	Weekend	20	119	426	109	0.091	0.13	0.068	0.13	0.92
		Weekday	30	96	274	75	0.332	0.09	0.333	0.07	0.78
	Overall		228	1255	4520	978	0.158	0.01	0.163	0.01	0.78
Jack mackerel / koheru	Summer	Weekend	20	278	930	88	0.246	0.13	0.096	0.05	0.89
		Weekday	34	84	285	66	1.029	0.14	0.232	0.09	0.83
	Autumn	Weekend	20	193	769	96	0.124	0.07	0.125	0.04	0.79
		Weekday	50	250	1 018	64	0.081	0.04	0.063	0.04	0.86
	Winter	Weekend	20	168	580	42	0.047	0.10	0.072	0.10	0.92
		Weekday	34	67	238	69	0.359	0.08	0.290	0.08	0.73
	Spring	Weekend	20	119	426	39	0.096	0.10	0.094	0.07	0.86
		Weekday	30	96	274	53	0.258	0.19	0.194	0.17	0.85
	Overall		228	1255	4520	517	0.213	0.03	0.115	0.01	0.86

Table 24: **Summary of Bay of Islands snapper catch and effort data used in the standardised CPUE analyses.**

Survey year	No. snapper	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE (fish/hour)
1991	309	247	145	0.59	0.37
1994	1415	764	367	0.48	0.62
1996	2061	840	337	0.40	0.72
1998	1663	890	406	0.46	0.50

Table 25: **Summary of variables used in the standardised model of snapper CPUE in the Bay of Islands. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 3	Summer, Autumn and Winter
Day	cat 2	Weekday and weekend/holiday
Area	cat 6	Area in harbour or unspecified
Time	cat 6	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Length	cont	Time fished in hours

Table 26: **Comparison of variables selected for the Bay of Islands snapper CPUE regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

	Linear model				Binomial model		
Variable	% variance explained	d.f.	% improve of AIC	Variable	% variance explained	d.f.	% improve of AIC
Length	17.9	1485	–	Length	8.5	2740	–
Area	20.9	1480	6.23	Season	9.4	2738	0.87
Season	22.8	1478	4.20	Year	10.5	2735	1.07
Year	24.5	1475	3.61	Area	11.6	2730	0.92
Day	26.6	1474	4.75	Day	12.4	2729	0.89
Time	27.6	1469	1.37	Length*Day	12.9	2728	0.72
Moon	28.3	1466	0.93				

Table 27: **Relative year effects from the linear model of log (catch per hour), binomial model of successful trips (non-zero catch) and unsuccessful trips (zero catch), and combined indices for snapper caught in the Bay of Islands.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1994	1.68	1.30	2.86	2.11
1996	1.94	1.22	2.40	1.85
1998	1.35	0.87	1.53	1.09

Table 28: **Summary of Bay of Islands kahawai catch and effort data used in the standardised CPUE analyses.**

Survey year	No. kahawai	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE (fish/hour)
1991	56	267	242	0.91	0.06
1994	326	853	729	0.85	0.13
1996	855	902	600	0.67	0.28
1998	612	991	748	0.75	0.16

Table 29: **Summary of variables used in the standardised model of kahawai CPUE in the Bay of Islands. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 3	Summer, Autumn and Winter
Day	cat 2	Weekday and weekend/holiday
Area	cat 6	Area in harbour or unspecified
Time	cat 8	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Length	cont	Time fished in hours

Table 30: **Comparison of variables selected for the Bay of Islands kahawai CPUE regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

Linear model

Variable	% variance explained	d.f.	% improve of AIC
Length	21.4	692	–
Area	23.3	687	1.64
Length*Area	25.1	682	1.45
Tide	27.6	674	1.61
Length*Tide	30.1	666	1.82
Season	30.9	664	0.86
Day	31.4	663	0.77
Length*Day	32.4	662	1.58
Area*Day	33.7	657	0.89
Year	34.3	654	0.11

Binomial model

Variable	% variance explained	d.f.	% improve of AIC
Season	3.9	3010	–
Year	7.9	3007	3.96
Length	10.5	3006	2.69
Area	11.5	3001	0.76
Day	12.1	3000	0.62
Tide	12.9	2992	0.37

Table 31: **Relative year effects from the linear model of log (catch per hour), binomial model of successful trips (non-zero catch) and unsuccessful trips (zero catch), and combined indices for kahawai caught in the Bay of Islands.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1994	2.01	0.92	2.85	2.23
1996	4.31	1.08	6.38	4.58
1998	2.57	0.94	3.78	2.83

***Table 32*: Summary of Bay of Islands jack mackerel/koheru catch and effort data used in the standardised CPUE analyses.**

Survey year	No. fish	No. trips	Trips with zero catch	Proportion zero catch	Raw CPUE fish/hour
1991	20	267	260	0.97	0.02
1994	295	853	751	0.88	0.12
1996	130	902	836	0.93	0.04
1998	408	991	849	0.86	0.11

***Table 33*: Summary of variables used in the standardised model of jack mackerel/koheru CPUE in the Bay of Islands. Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 3	Summer, Autumn and Winter
Day	cat 2	Weekday and weekend/holiday
Area	cat 6	Area in harbour or unspecified
Time	cat 6	Time code at midpoint of trip
Tide	cat 9	Quarter of tidal phase, pair of tidal phases or multiple tidal phases fished
Moon	cat 4	Quarter of moon phase on day fished
Length	cont	Time fished in hours

***Table 34*: Comparison of variables selected for the Bay of Islands jack mackerel/koheru regression models in the order in which they entered the model down to a 0.5% improvement in the model or until year was included.**

			Linear model
Variable	% variance explained	d.f.	% improve of AIC
Year (forced)	4.9	313	–
Length	45.8	312	44.61
Tide	58.5	304	36.06
Time	61.8	299	7.94
Season	62.5	297	0.72

			Binomial model
Variable	% variance explained	d.f.	% improve of AIC
Area	2.8	3007	–
Year	5.3	3004	2.24
Tide	8.1	2996	2.09

***Table 35*: Relative year effects from the linear model of log (catch per hour), binomial model of successful (non-zero catch) and unsuccessful trips (zero catch), and combined indices for jack mackerel/koheru caught in the Bay of Islands.**

Year	Unstandardised	Linear	Binomial	Combined
1991	1.00	1.00	1.00	1.00
1994	5.09	1.54	5.07	7.06
1996	1.83	1.32	2.88	3.63
1998	4.80	1.51	6.65	8.74

Table 36: **Summary of Bay of Islands fishing effort data used in the standardised fishing effort analyses.**

Survey year	No. sessions	No. session hours	Sessions with zero interviews	Proportion zero interviews	Raw effort (interview/hour)
1991	22	88	2	0.09	12.95
1994	48	146	0	0.00	23.96
1996	68	138	2	0.03	29.30
1998	89	142	18	0.20	31.80

Table 37: **Summary of variables used in the standardised model of fishing effort in the Bay of Islands Variable types are: cont, continuous; cat n, categorical with n categories.**

Variable	Type	Description
Year	cat 4	Year of survey
Season	cat 3	Summer, Autumn, Winter
Day	cat 2	Weekday and weekend/holiday
Area	cat 6	Fishing location
Moon	cat 4	Quarter of moon phase on day fished
Sea state	cat 4	Smooth, slight, moderate, rough
Cloud cover	cat 4	Nil, mainly sunny, mainly cloudy, continuous
Wind direction	cat 3	Onshore, offshore, variable or null
Wind speed	cat 4	Nil, light, medium, strong
Rain	cat 4	Nil, light continuous, light scattered, medium scattered

Table 38: **Comparison of variables selected for the Bay of Islands fishing effort linear regression model in the order in which they entered the model.**

Variable	% variance explained	d.f.	% improve of AIC
Area	7.5	200	–
Year	10.1	197	83.36
Wind direction	10.8	195	3.94
Day	11.2	194	2.71
Day:Wind direction	11.7	189	3.83

Table 39: **Relative year effects from the linear model of log (hours of fishing effort encountered per interview hour) in the Bay of Islands.**

Year	Unstandardised	Linear
1991	0.41	0.58
1994	0.75	0.64
1996	0.92	0.90
1998	1.00	1.00

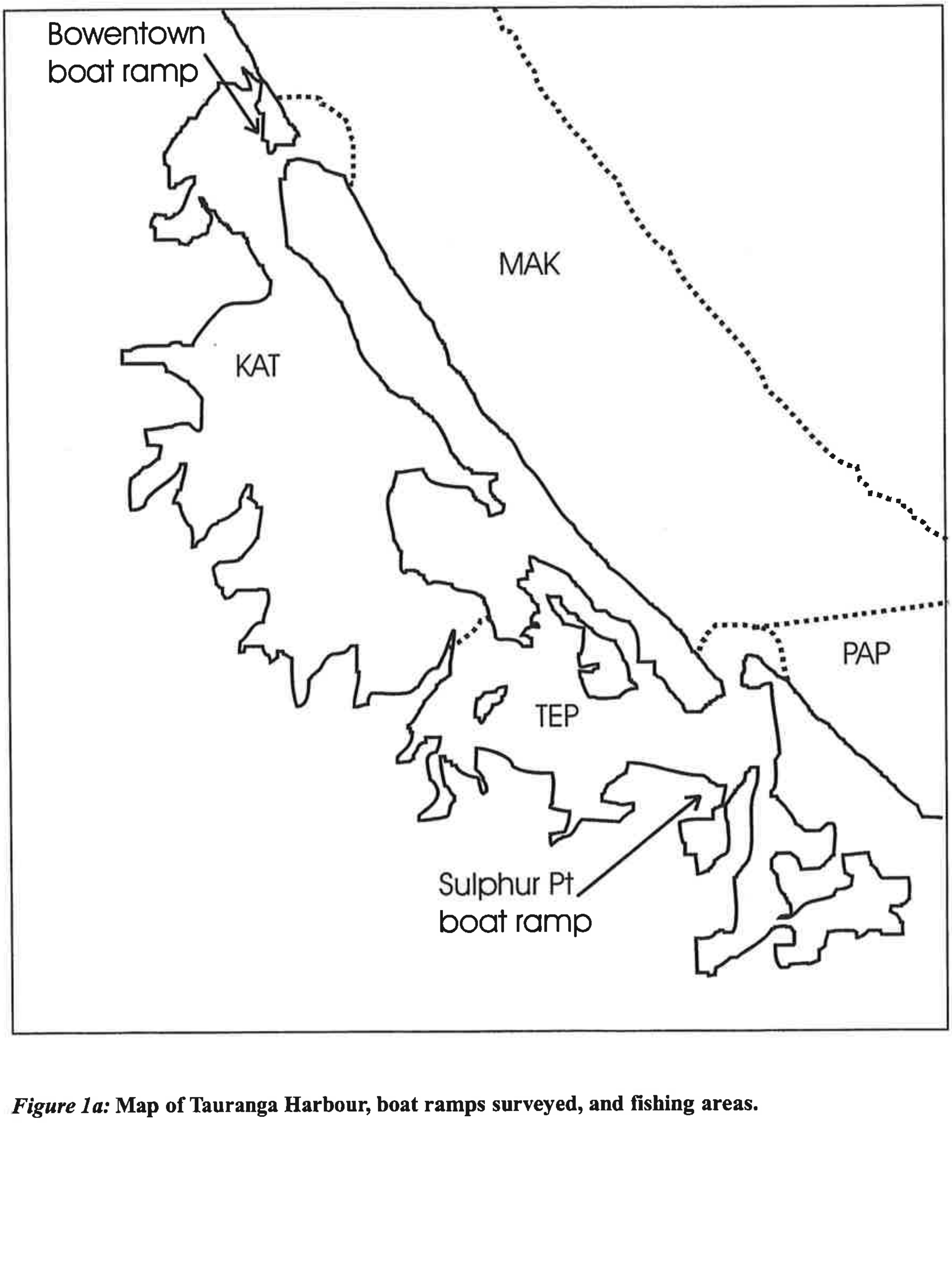


Figure 1a: **Map of Tauranga Harbour, boat ramps surveyed, and fishing areas.**

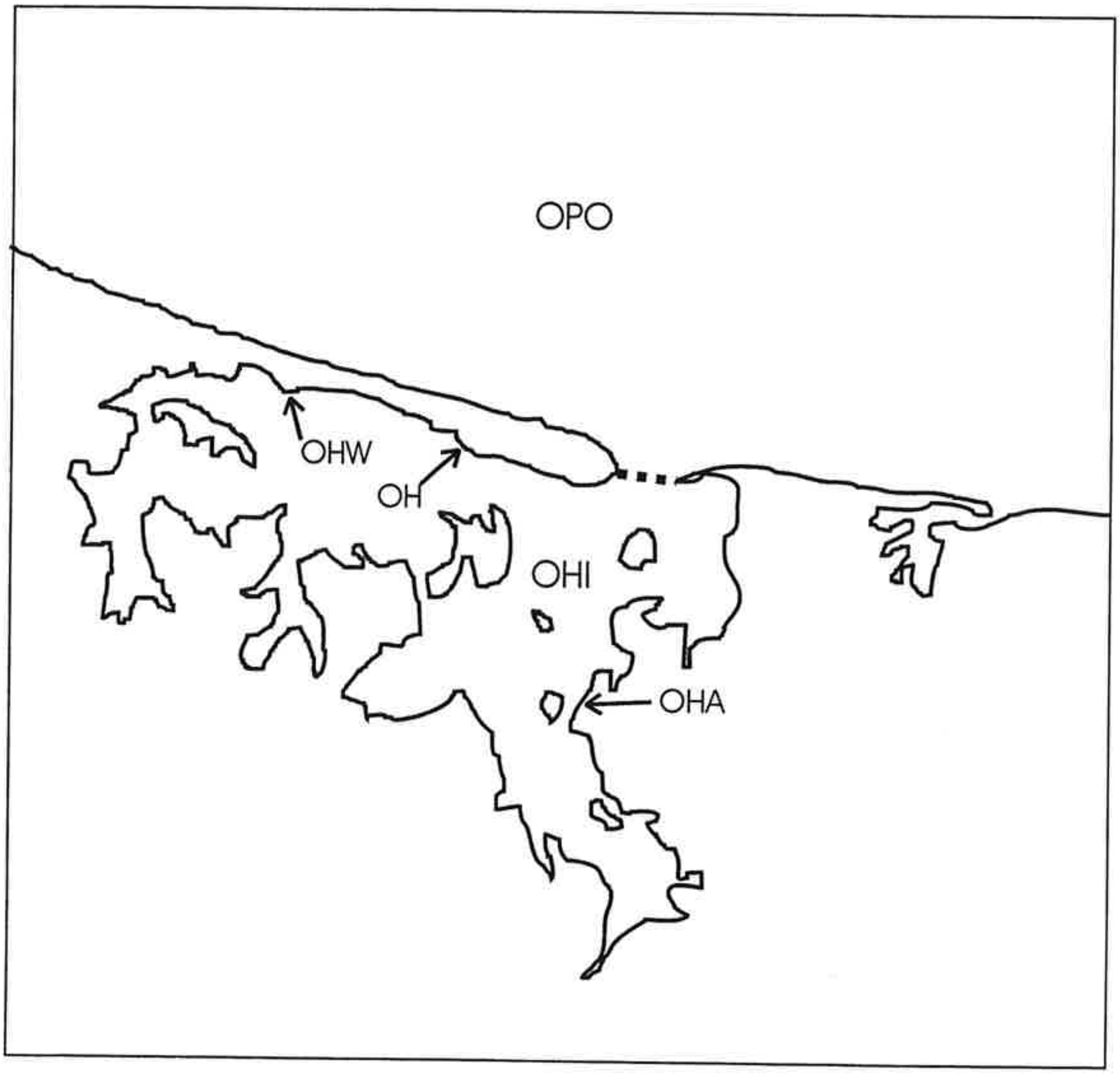


Figure 1b: **Map of Ohiwa Harbour, boat ramps surveyed, and fishing areas.**

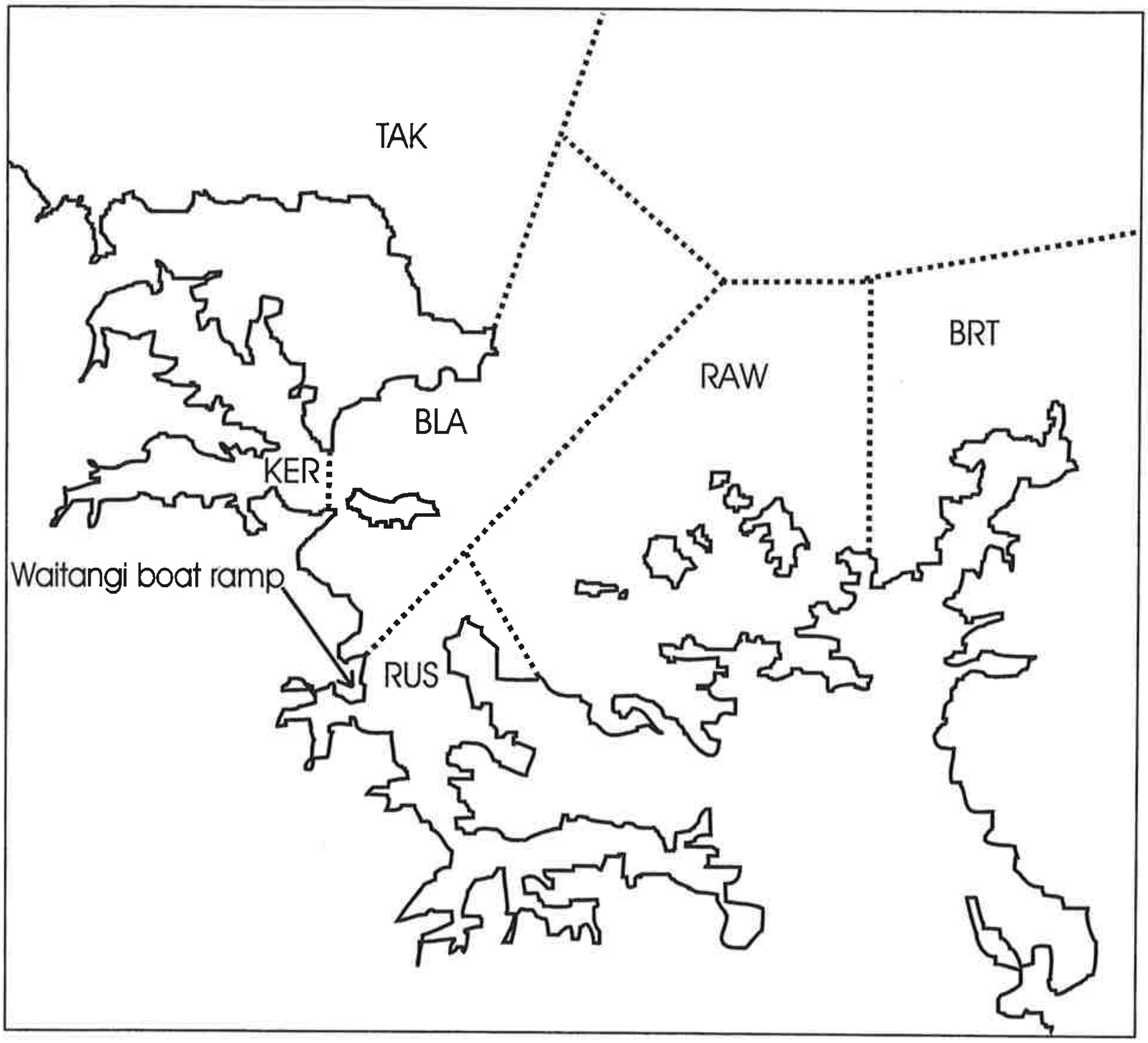


Figure 1c: **Map of the Bay of Islands, Waitangi boat ramp, and fishing areas.**

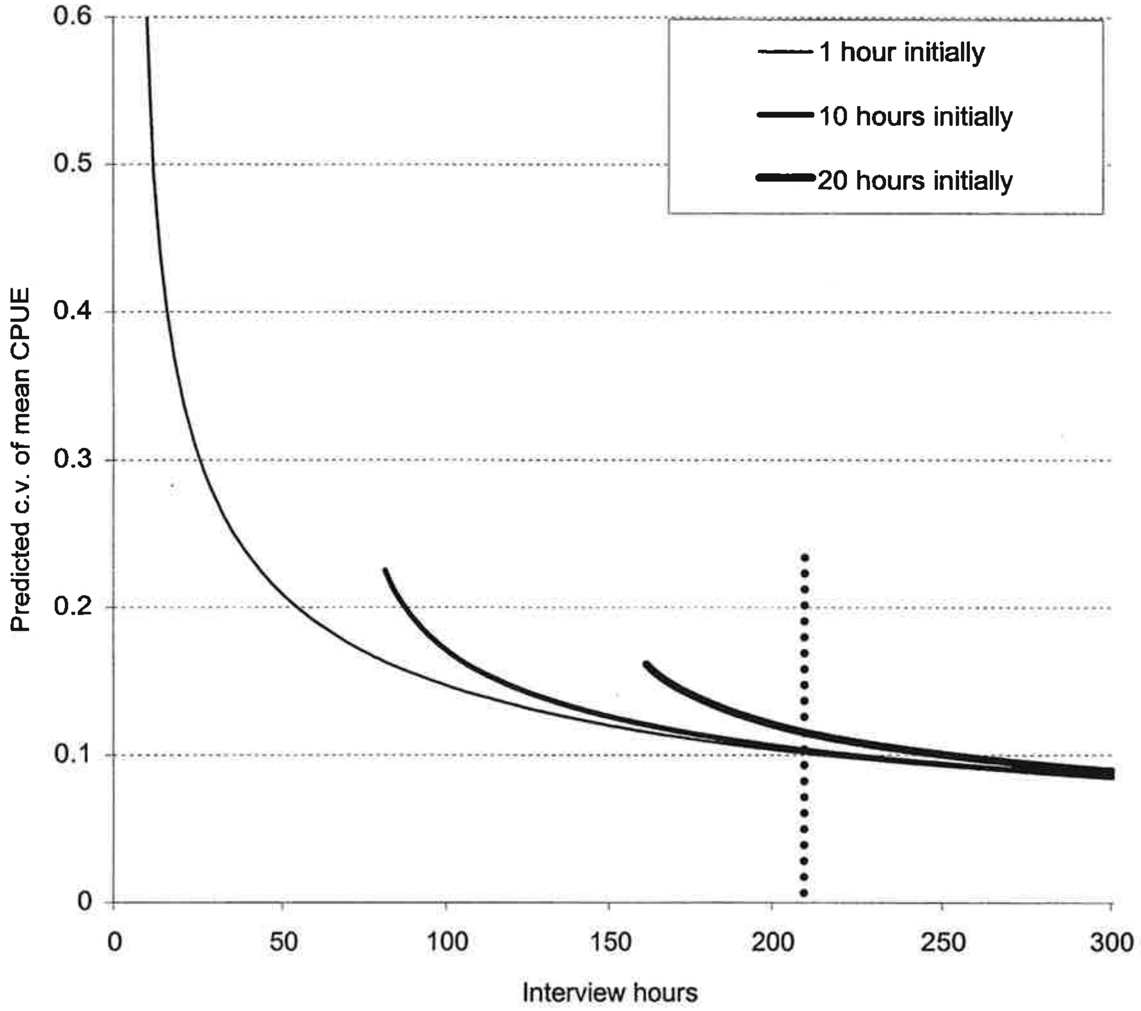


Figure 2 **: Relationship between hours spent interviewing recreational fishers and the predicted precision of snapper CPUE estimates in Tauranga Harbour based on 1991, 1994, and 1996 boat ramp data with differing initial allocation of hours to each temporal strata.**

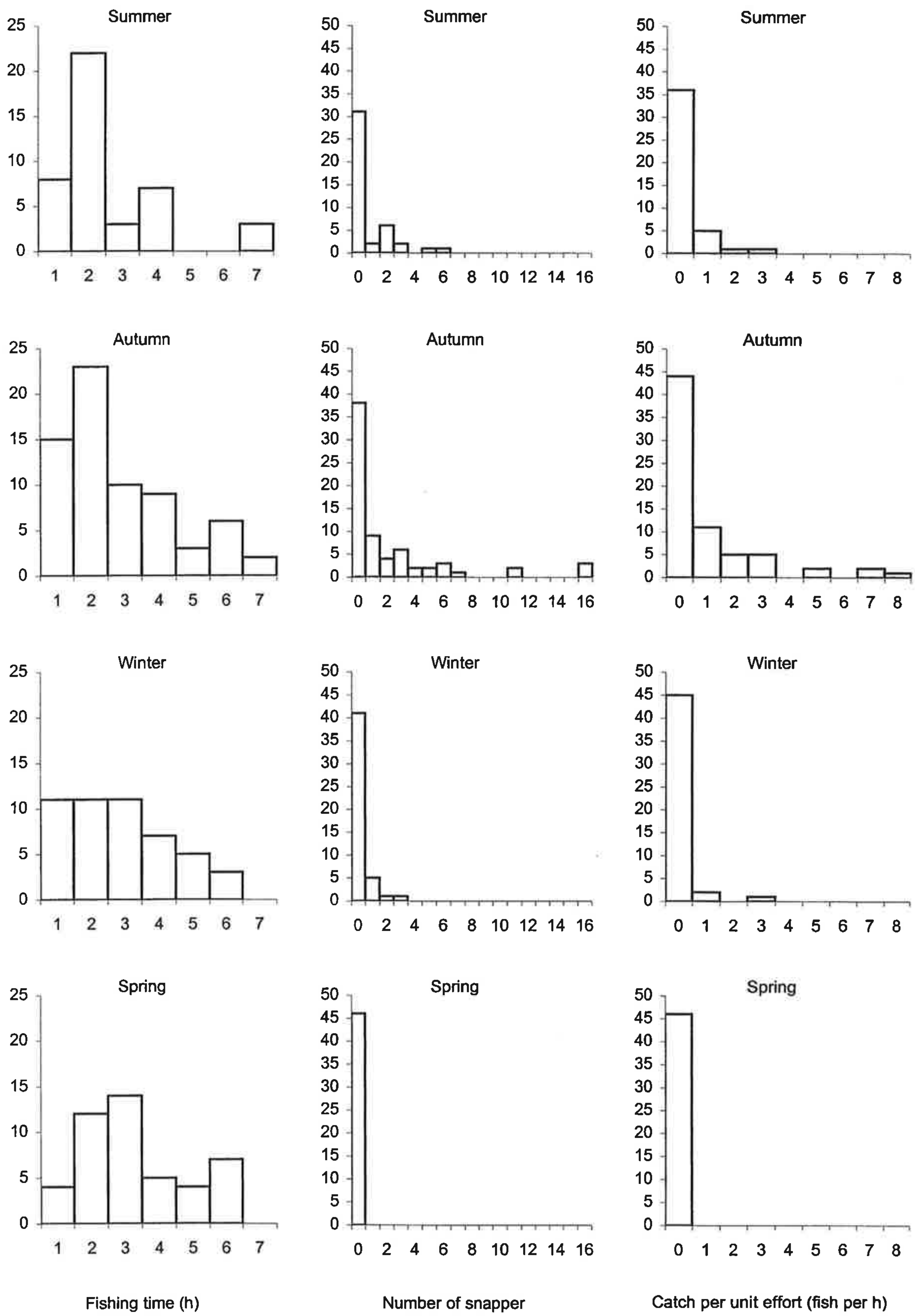


Figure 3 **: Seasonal frequencies of fishing effort, catch of snapper and snapper catch per unit effort, for those trips where fishing took place in Tauranga Harbour in 1998, and the targeted species was snapper or unspecified, and the method used was bait fishing.**

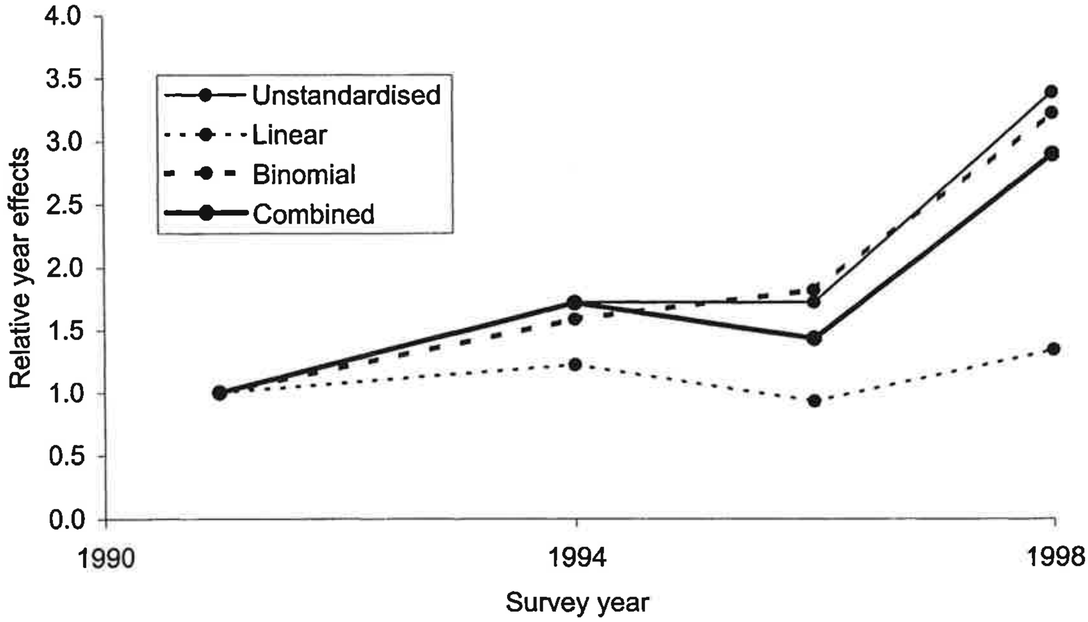


Figure 4 : **Comparison of relative year effects for Tauranga Harbour snapper CPUE.**

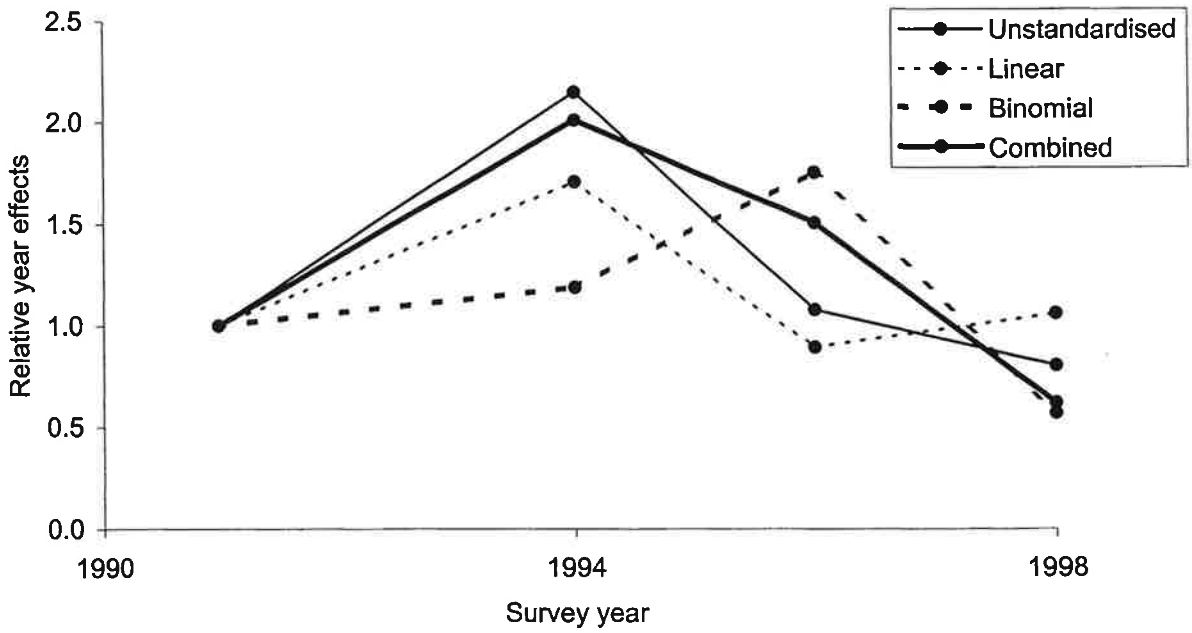


Figure 5 : **Comparison of relative year effects for Tauranga Harbour trevally CPUE.**

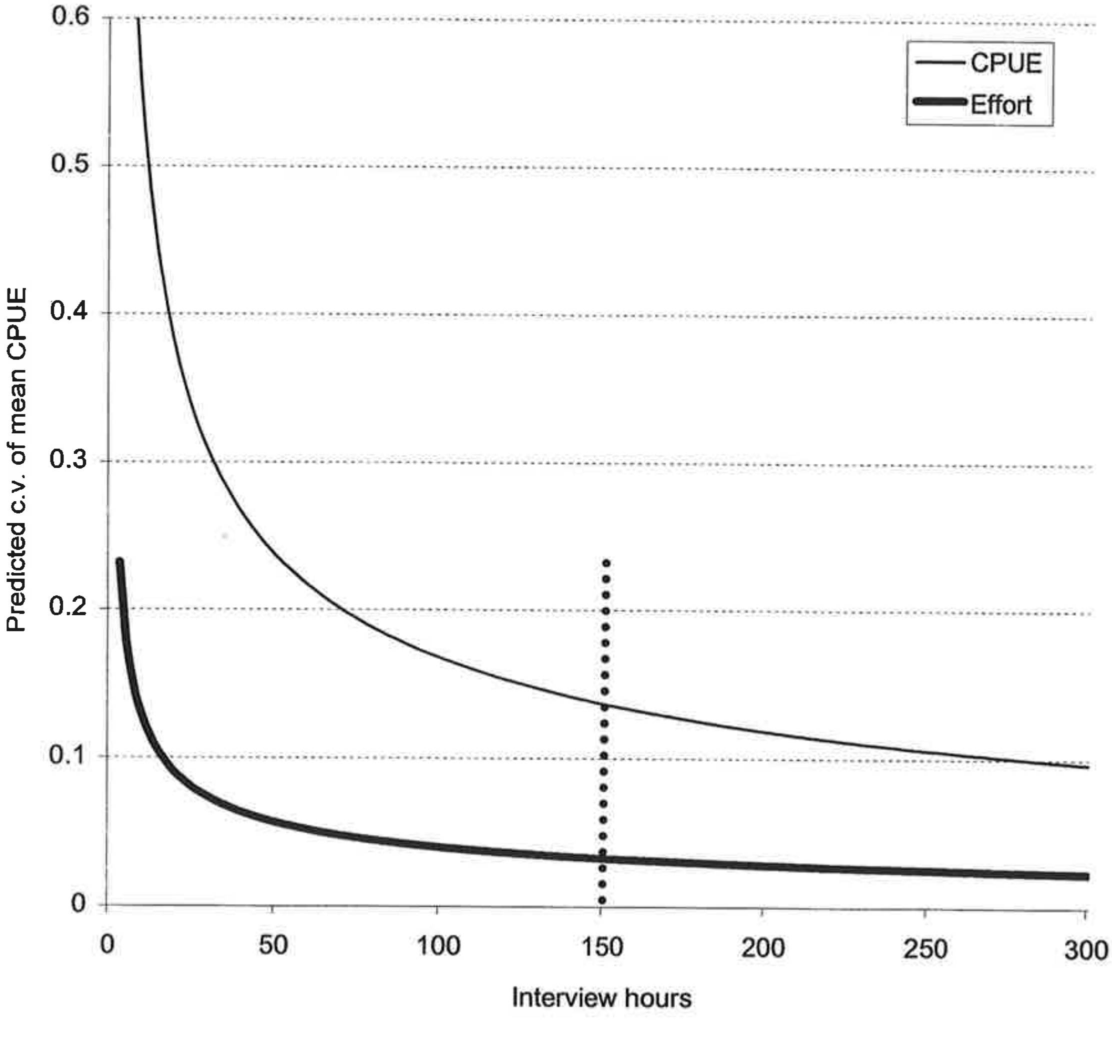


Figure 6 **: Relationship between hours spent interviewing recreational fishers and the predicted precision of snapper CPUE and fishing effort estimates in Ohiwa Harbour based on 1991 and 1996 boat ramp data.**

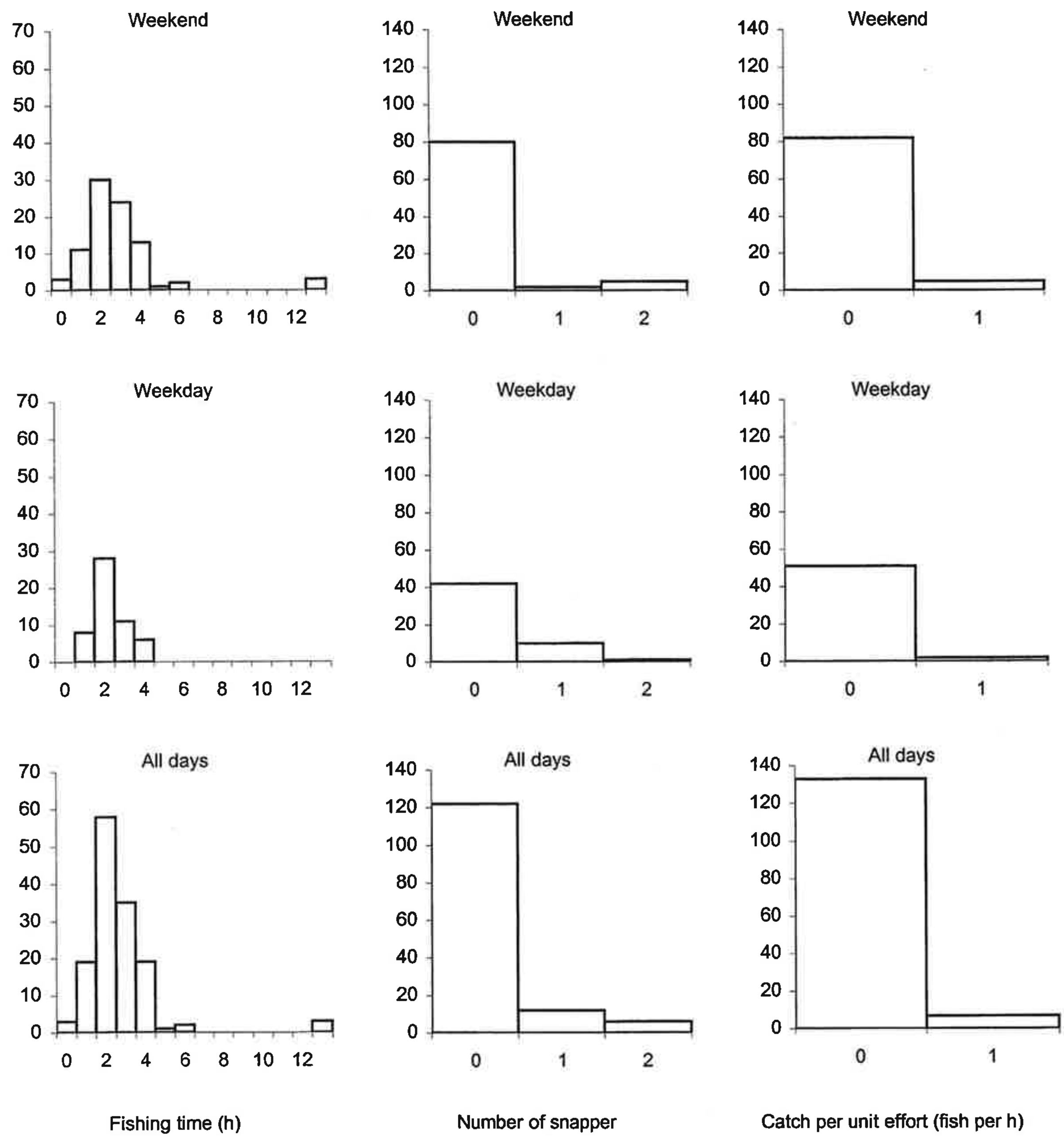


***Figure 7*: Seasonal frequencies of fishing effort, catch of snapper and snapper catch per unit effort, for those trips where fishing took place in Ohiwa Harbour between March and May 1998, and the targeted species was snapper or unspecified, and the method used was bait fishing.**

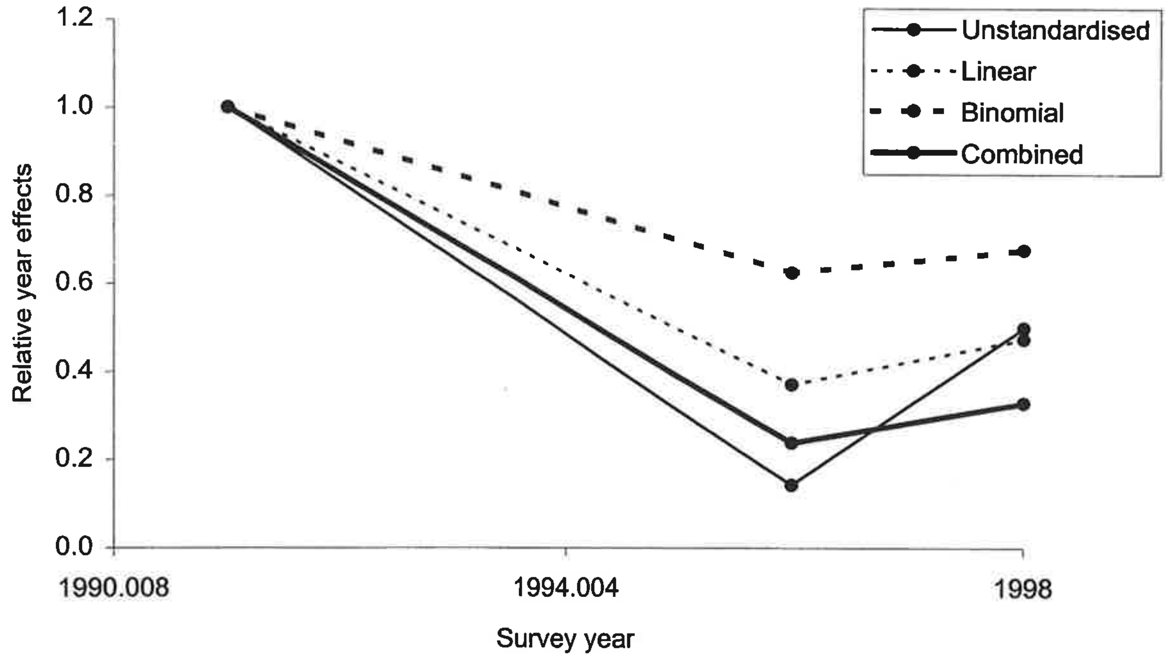


Figure 8 **: Comparison of relative year effects for Ohiwa Harbour snapper CPUE.**

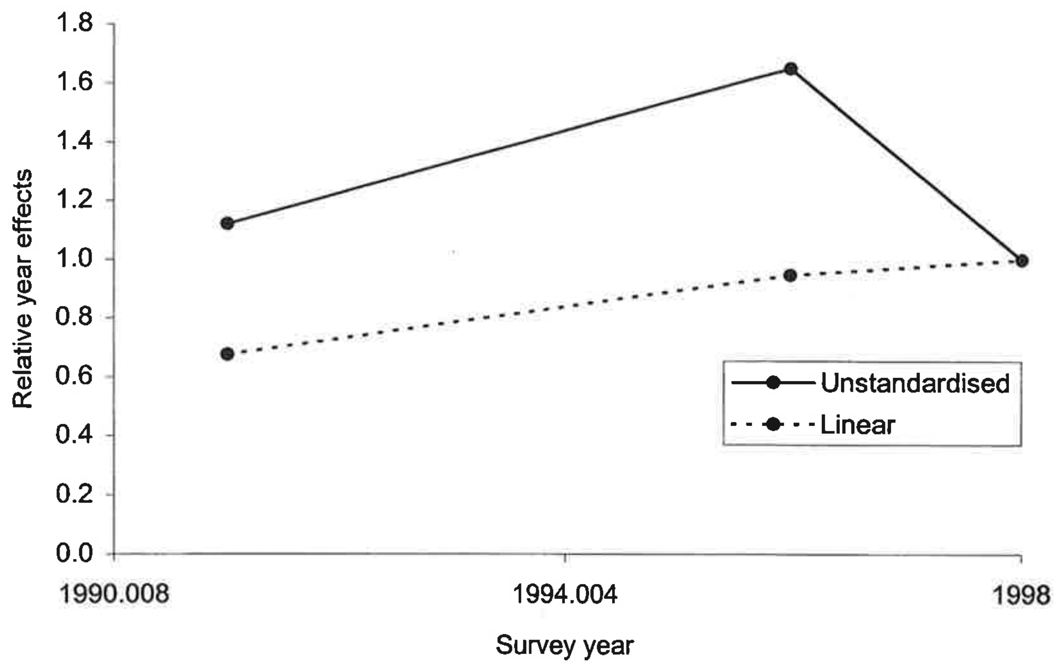


Figure 9 **: Comparison of relative year effects for Ohiwa Harbour fishing effort (hours of fishing effort encountered per hour of interviewing).**

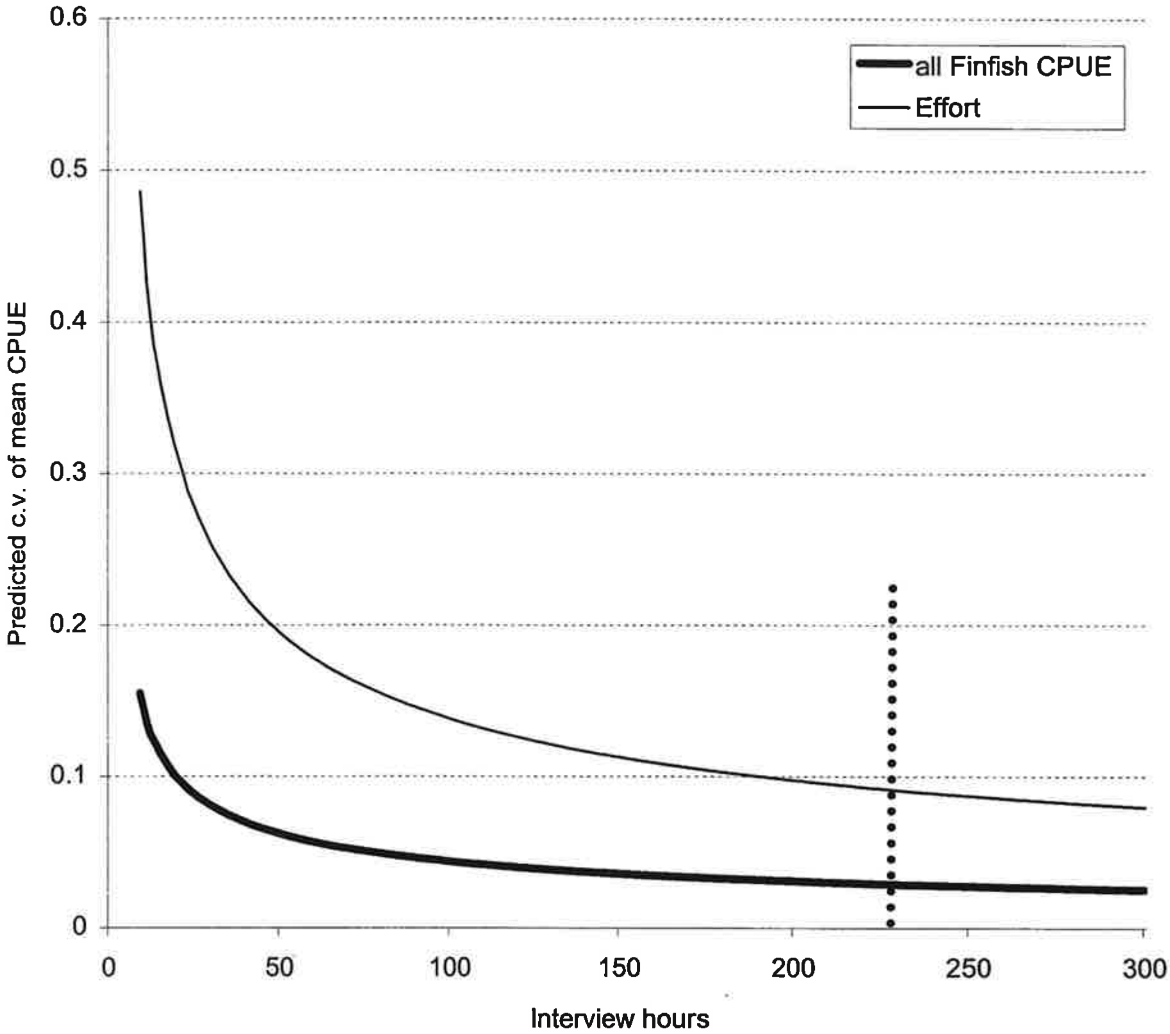


***Figure 10*: Relationship between hours spent interviewing recreational fishers and the predicted precision of CPUE and fishing effort estimates in the Bay of Islands based on 1991, 1994, and 1996 boat ramp data.**

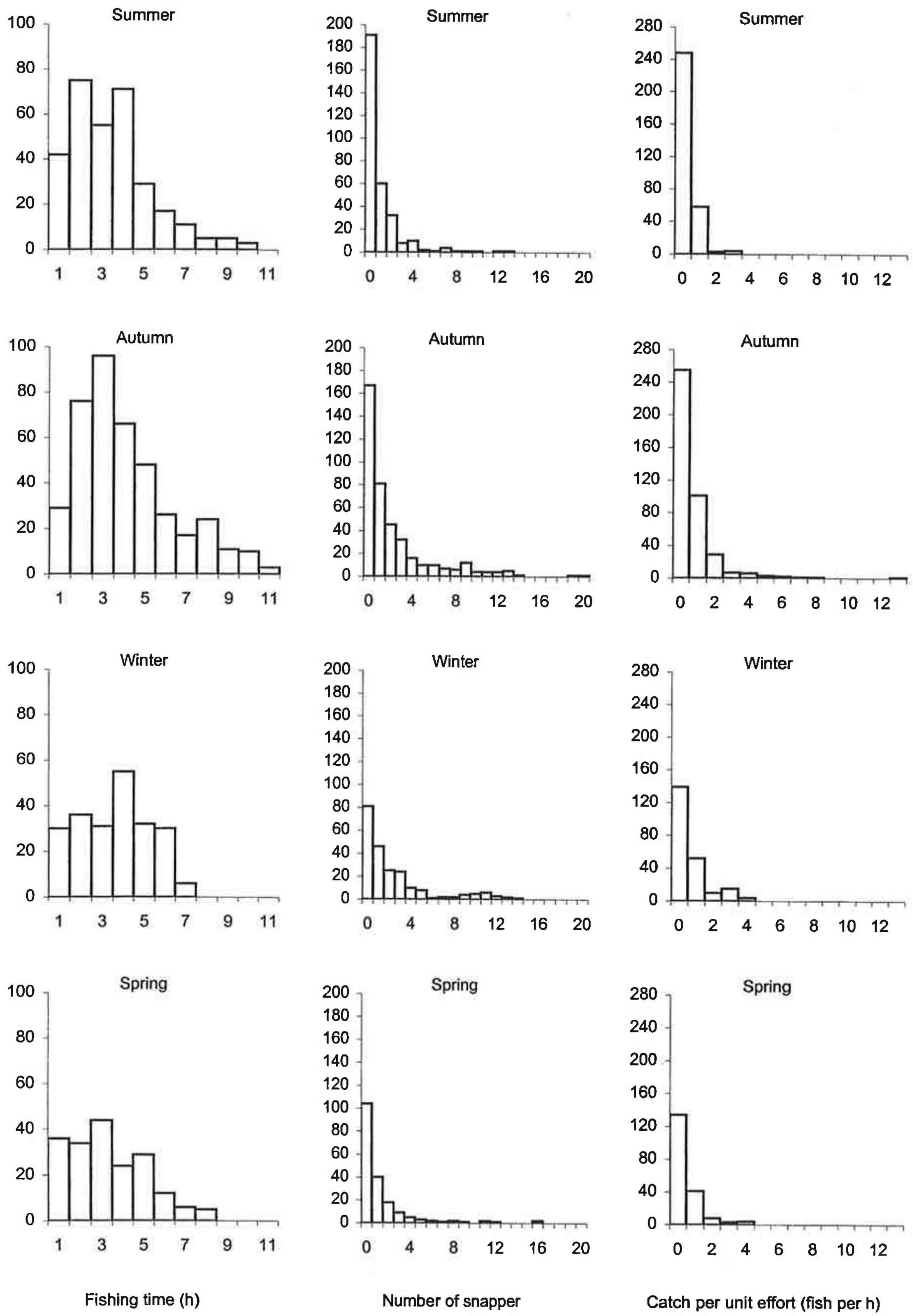


***Figure 11* : Seasonal frequencies of fishing effort, catch of snapper and snapper catch per unit effort, for those trips where fishing took place in the Bay of Islands in 1998, and the targeted species was snapper or unspecified, and the method used was bait fishing.**

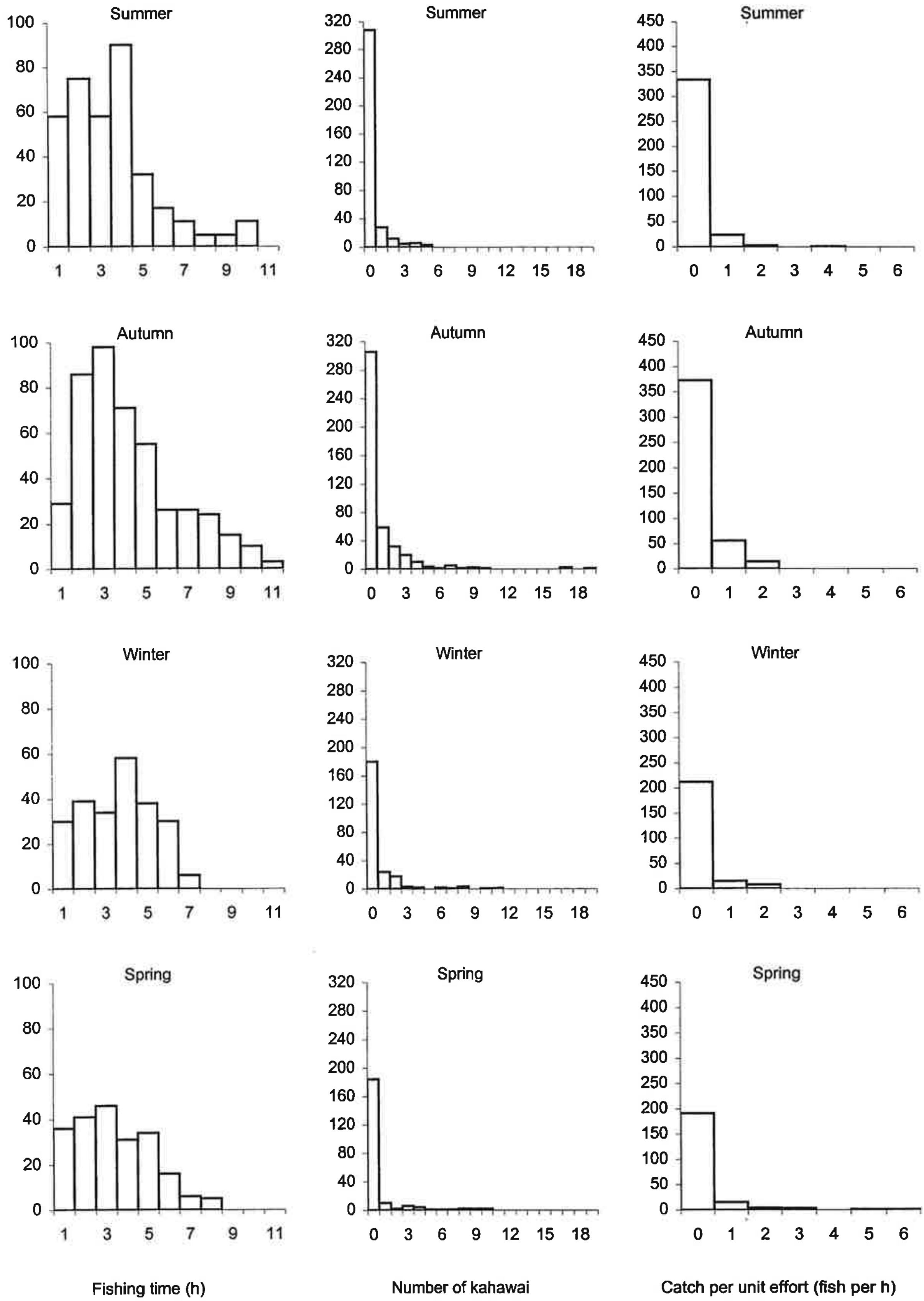


***Figure 12*: Seasonal frequencies of fishing effort, catch of kahawai and kahawai catch per unit effort, for those trips where fishing took place in the Bay of Islands in 1998, where any species was targeted, and the method used was bait fishing.**

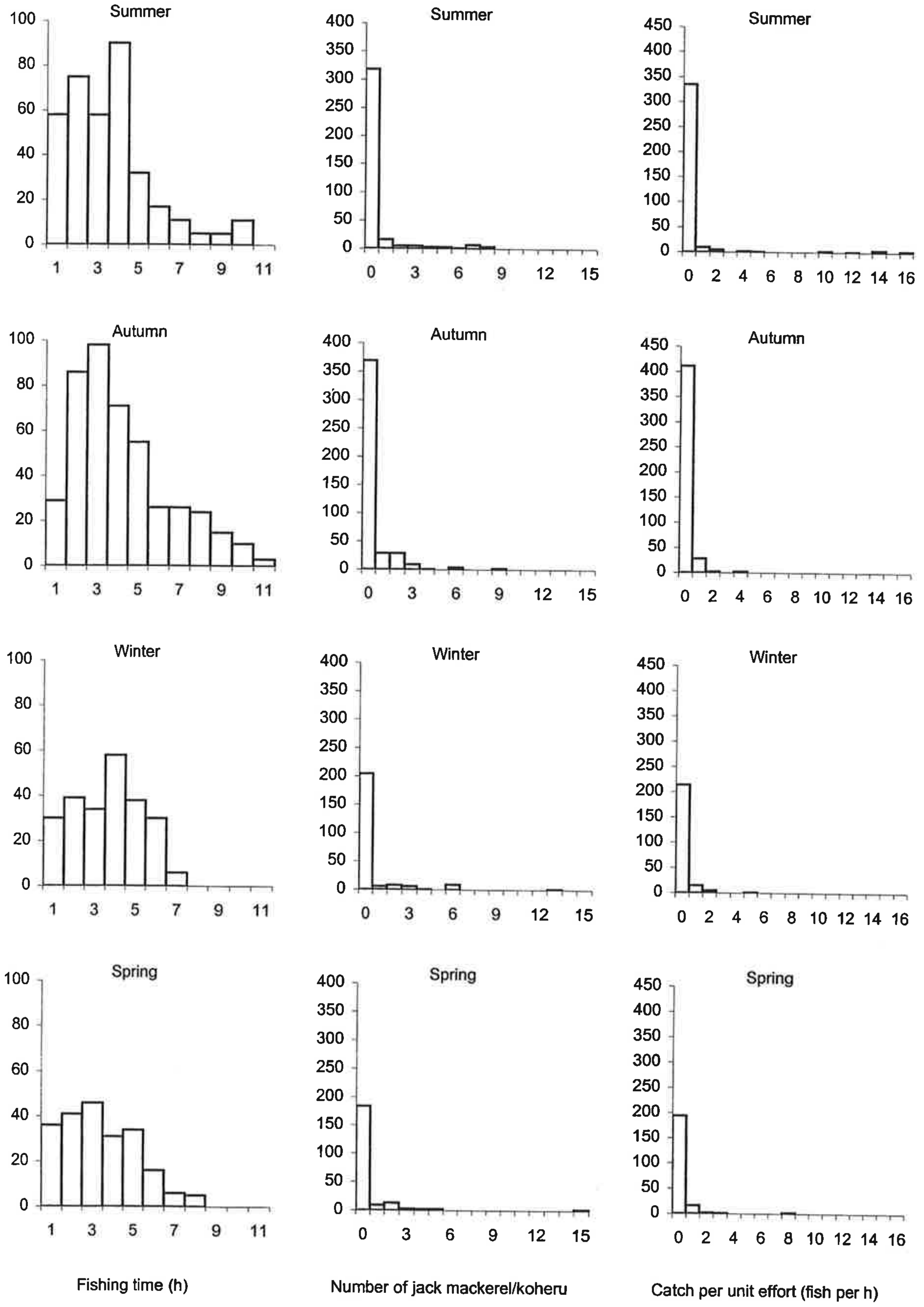


Figure 13 **: Seasonal frequencies of fishing effort, catch of jack mackerel/korehu and jack mackerel/koheru catch per unit effort, for those trips where fishing took place in the Bay of Islands in 1998, where any species was targeted, and the method used was bait fishing.**

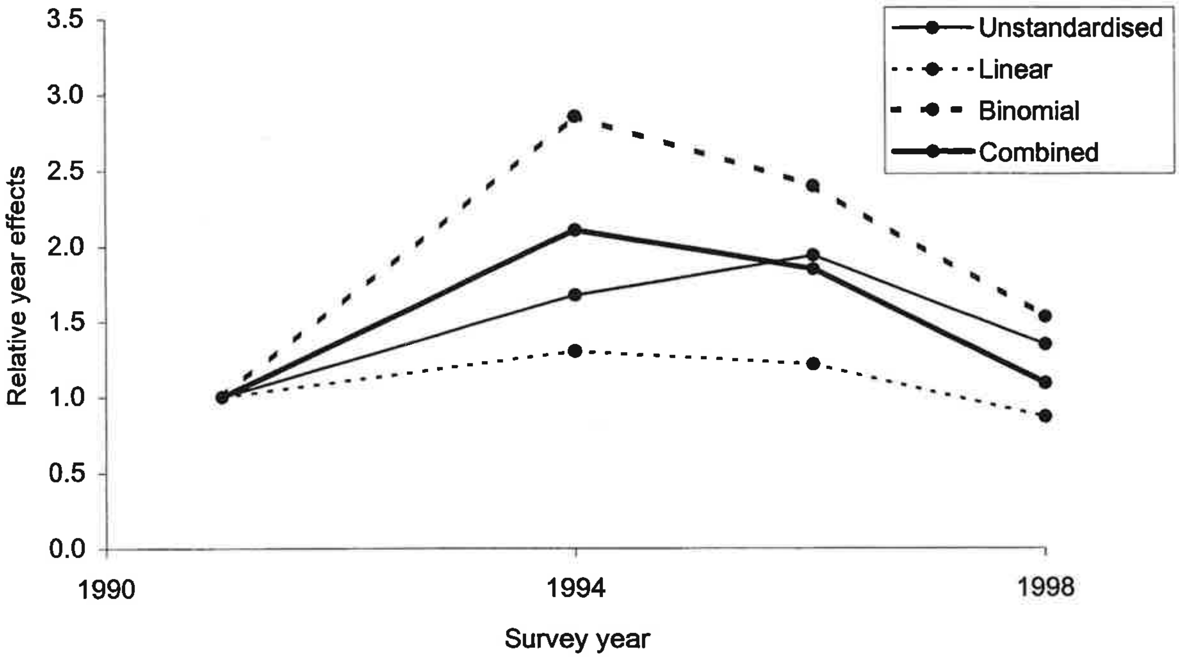


Figure 14: **Comparison of relative year effects for Bay of Islands snapper CPUE.**

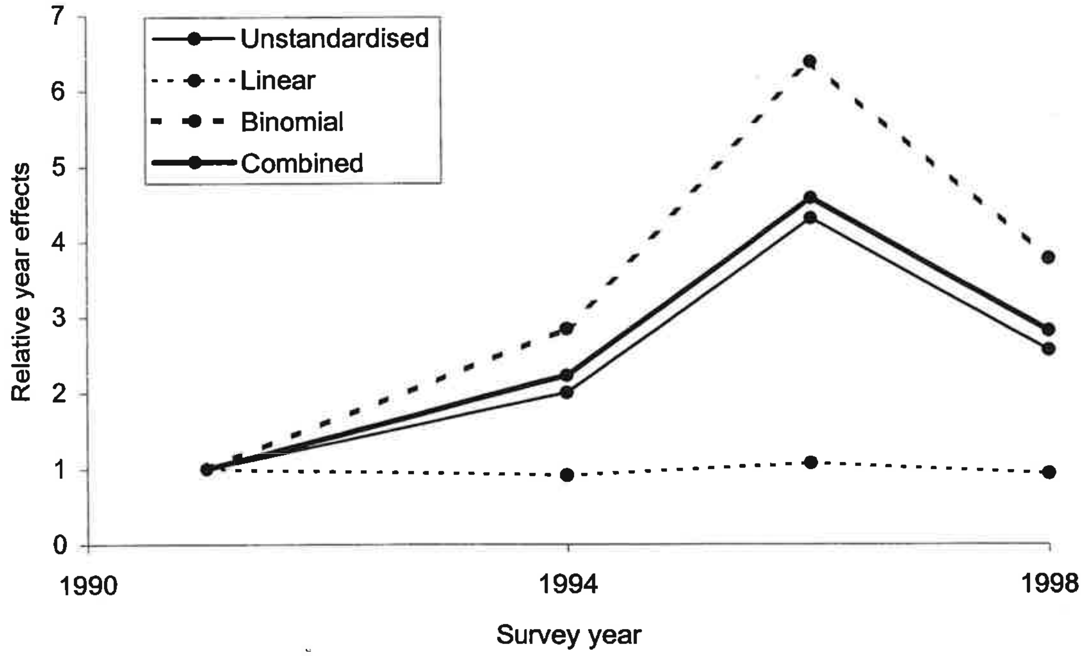


Figure 15: **Comparison of relative year effects for Bay of Islands kahawai CPUE.**

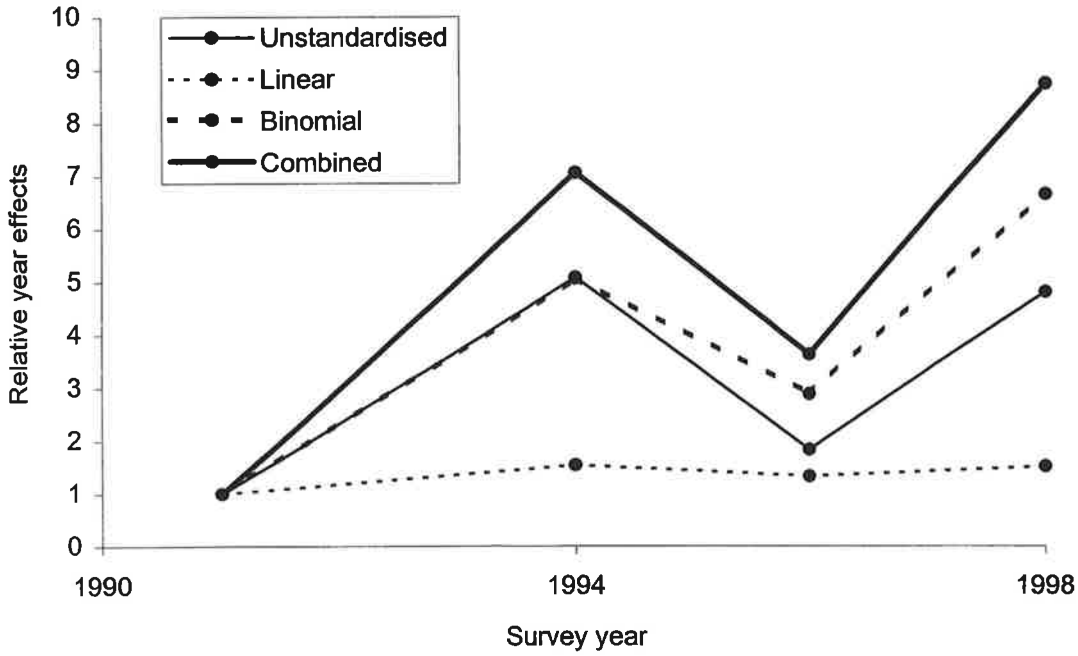


Figure 16 **: Comparison of relative year effects for Bay of Islands jack mackerel/koheru CPUE.**

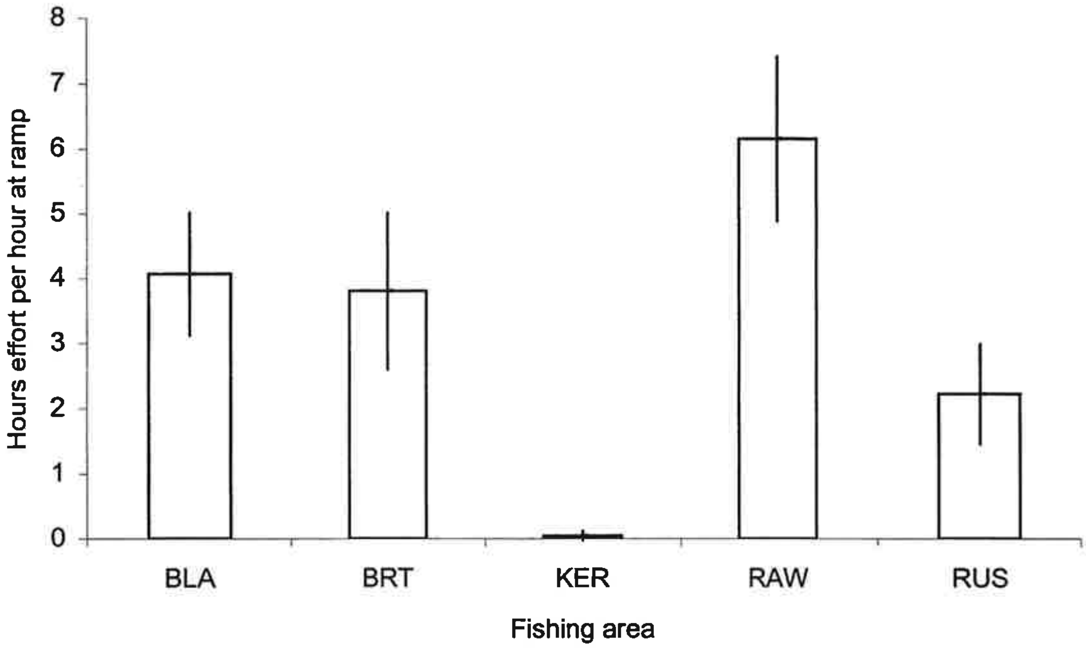


***Figure 17*: Hours of effort recorded per hour of interviewing at the Waitangi boatramp for the five fishing areas in the Bay of Islands in 1998. For a description of the fishing areas, see Figure 1c.**

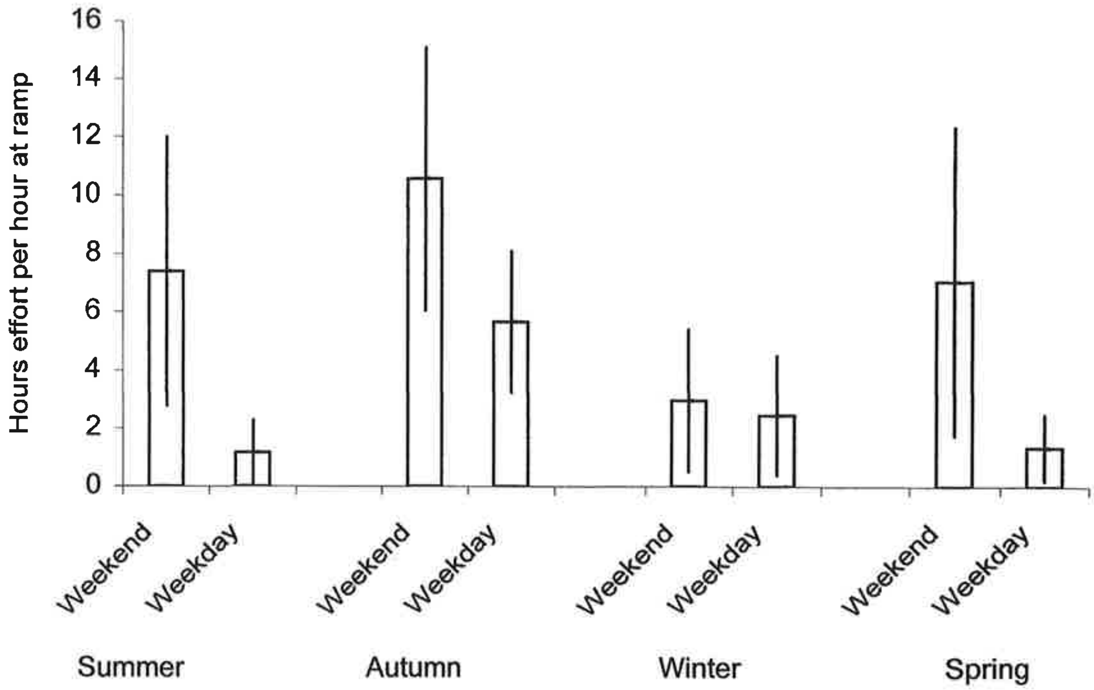


Figure 18 **: Hours of effort associated with the fishing area BLA recorded per hour of interviewing at the Waitangi boat ramp in the Bay of Islands during the 1998 survey by season and day-type.**

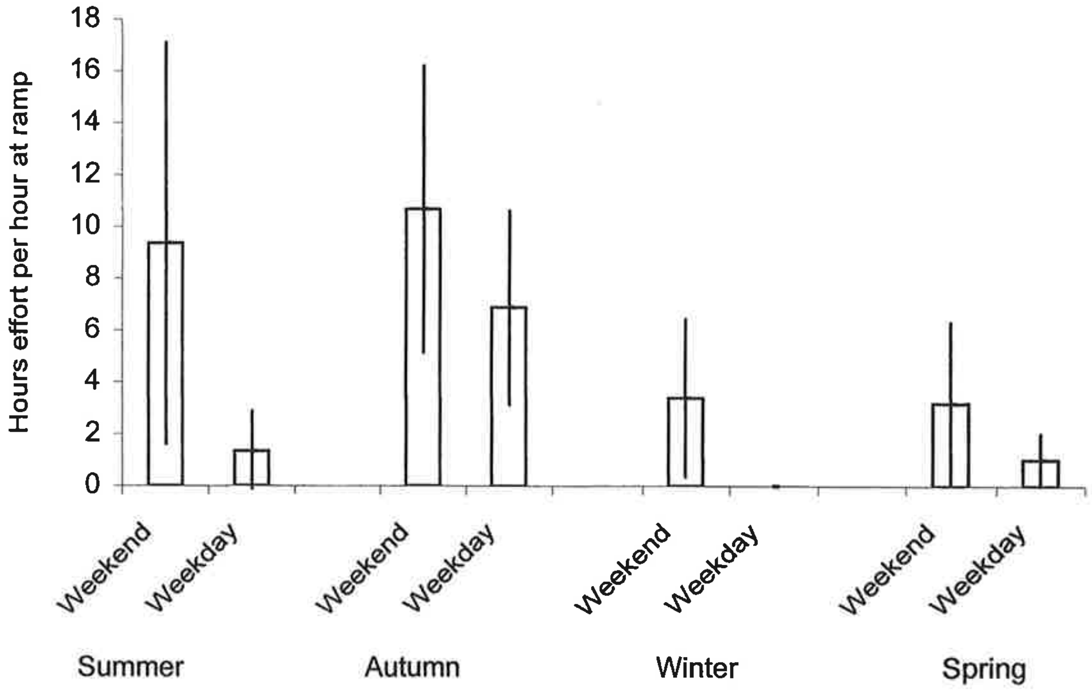


Figure 19 **: Hours of effort associated with the fishing area BRT recorded per hour of interviewing at the Waitangi boat ramp in the Bay of Islands during the 1998 survey by season and day-type.**

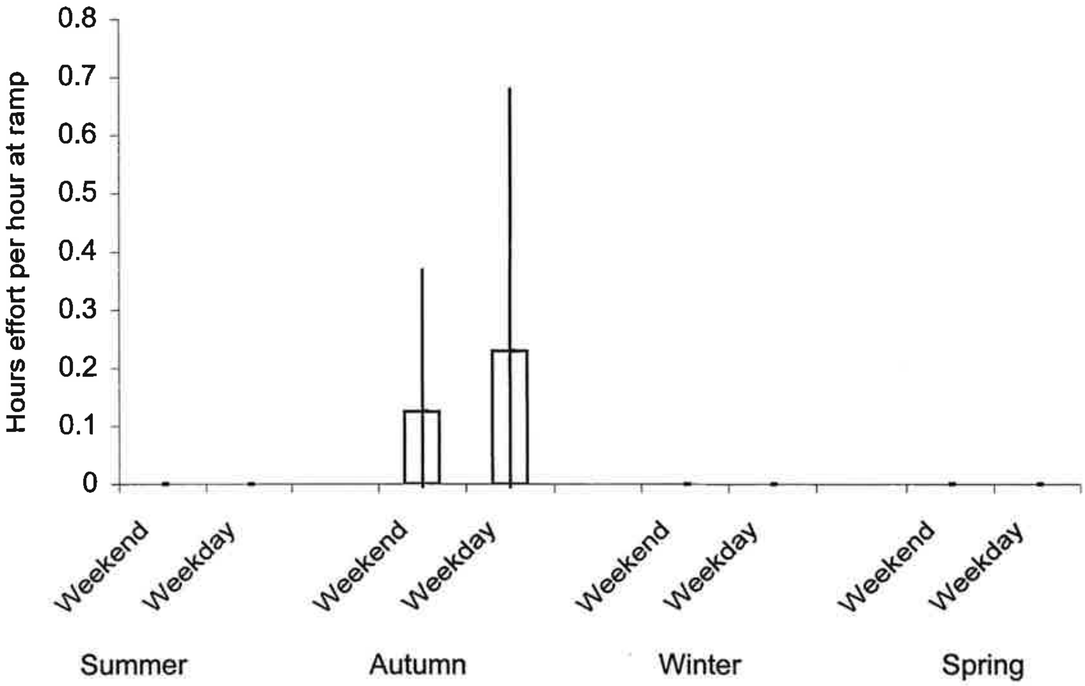


Figure 20 **: Hours of effort associated with the fishing area KER recorded per hour of interviewing at the Waitangi boat ramp in the Bay of Islands during the 1998 survey by season and day-type.**

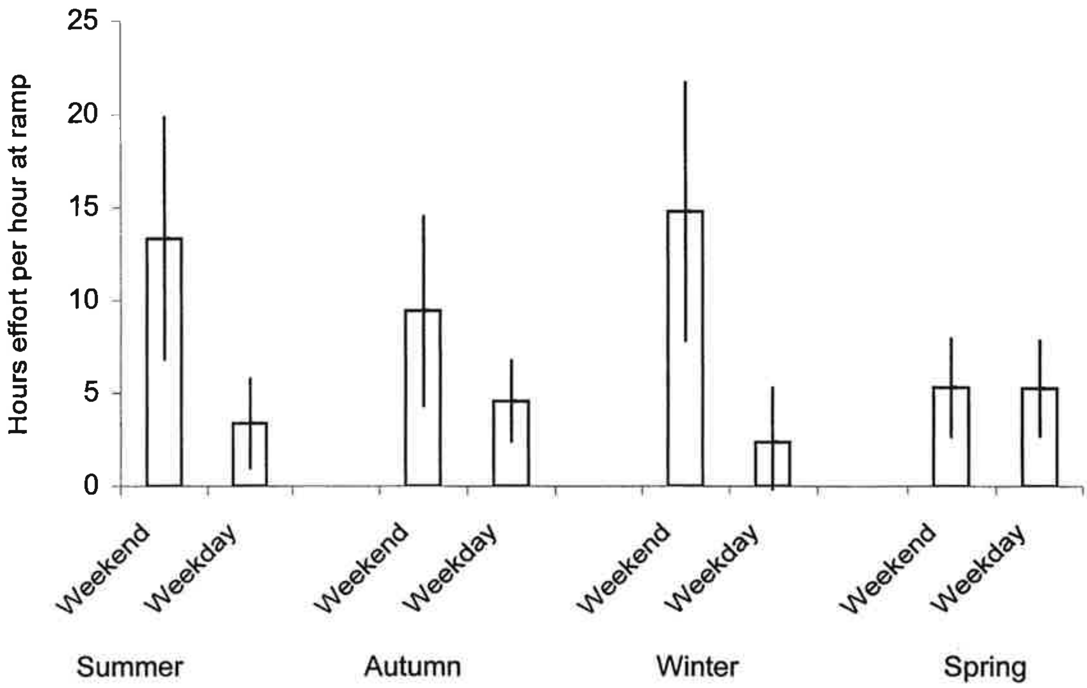


Figure 21 **: Hours of effort associated with the fishing area RAW recorded per hour of interviewing at the Waitangi boat ramp in the Bay of Islands during the 1998 survey by season and day-type.**

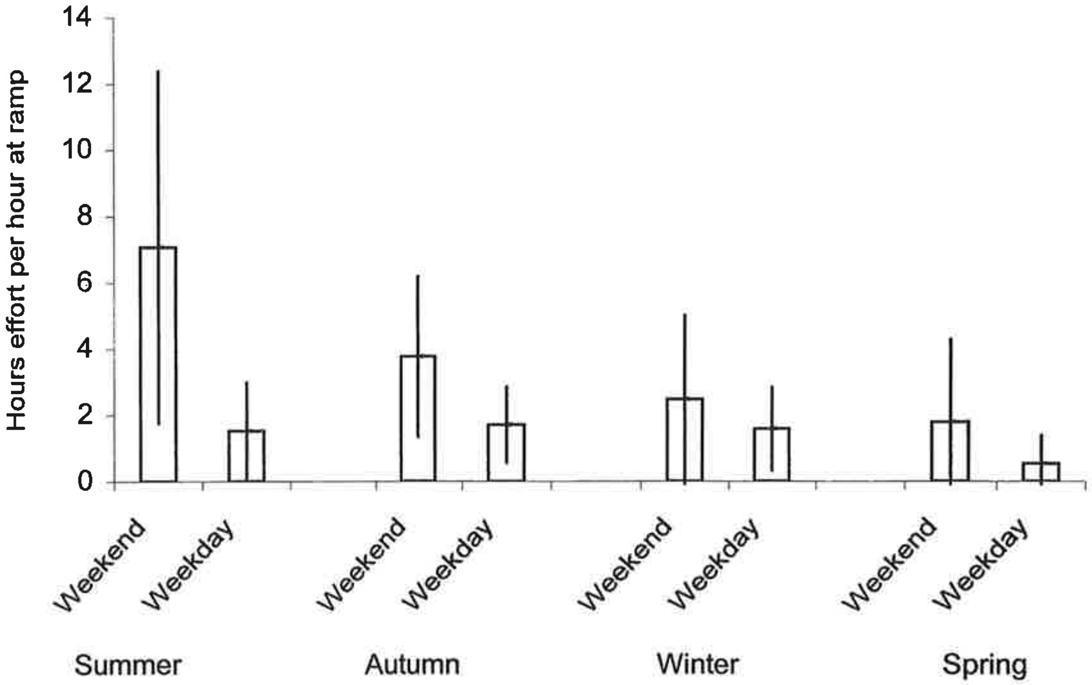


Figure 22 **: Hours of effort associated with the fishing area RUS recorded per hour of interviewing at the Waitangi boat ramp in the Bay of Islands during the 1998 survey by season and day-type.**

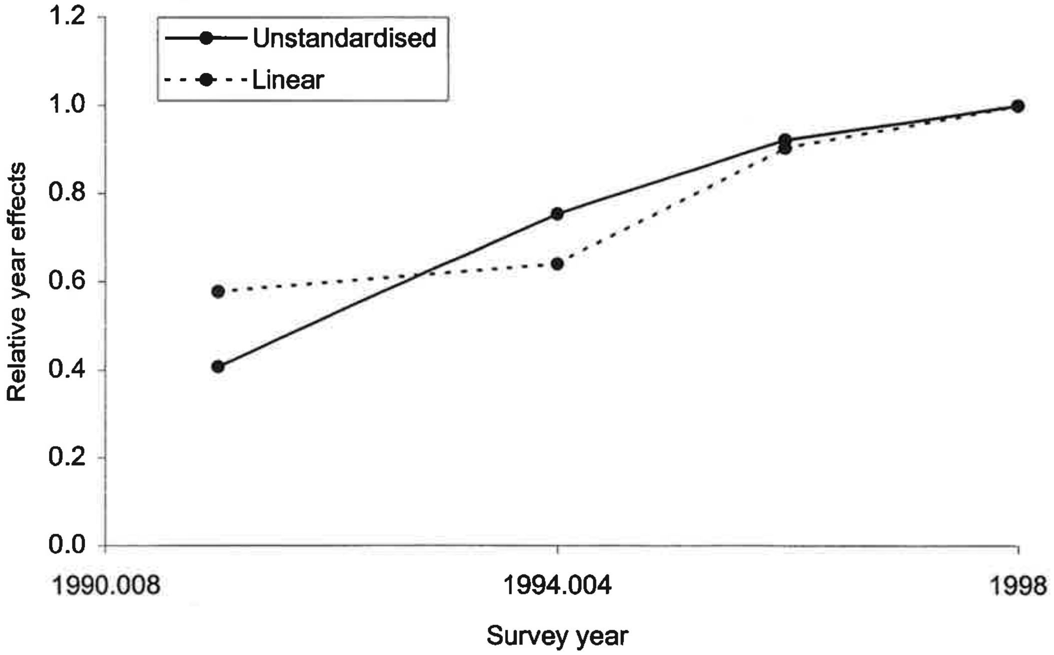
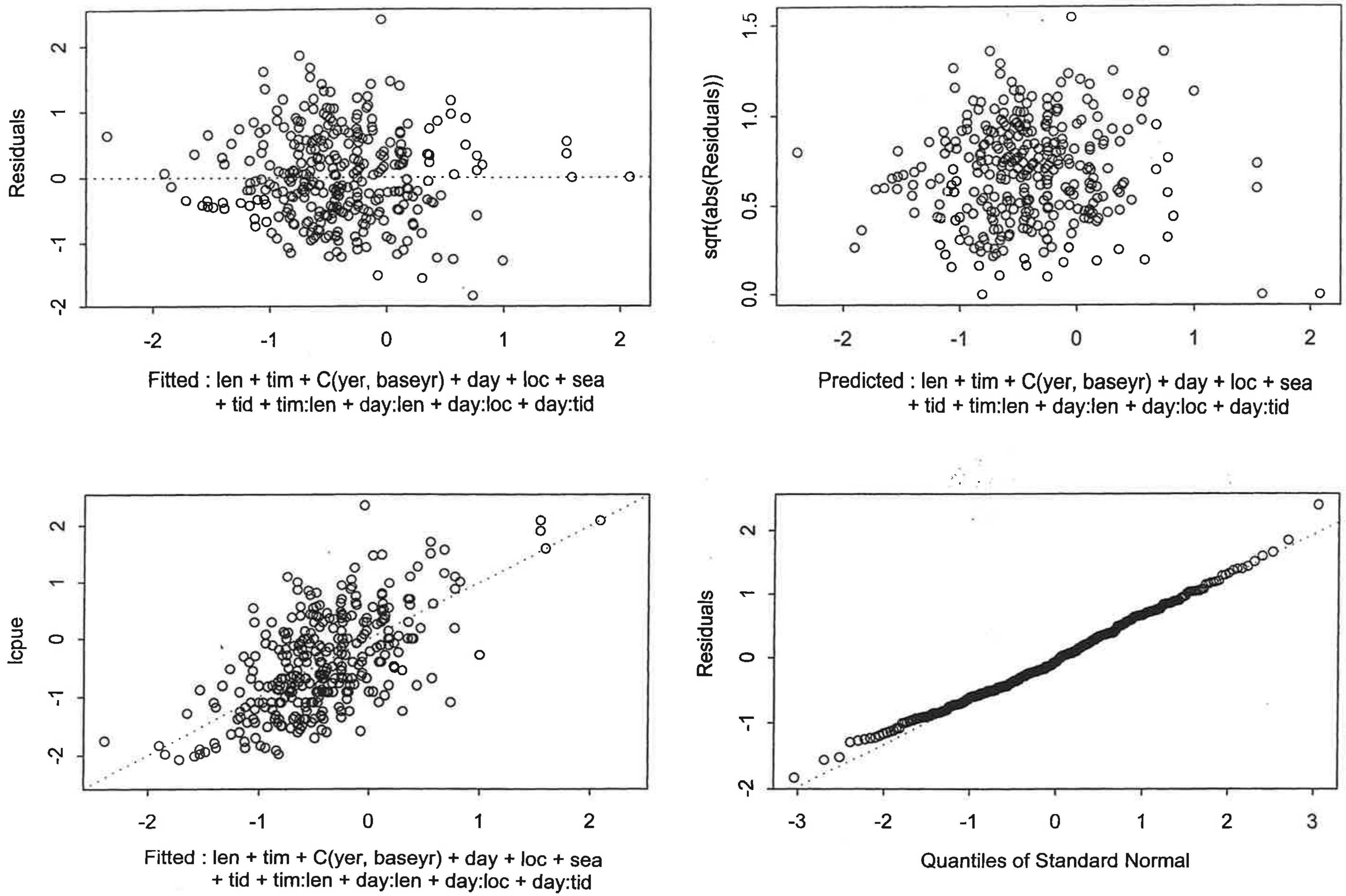


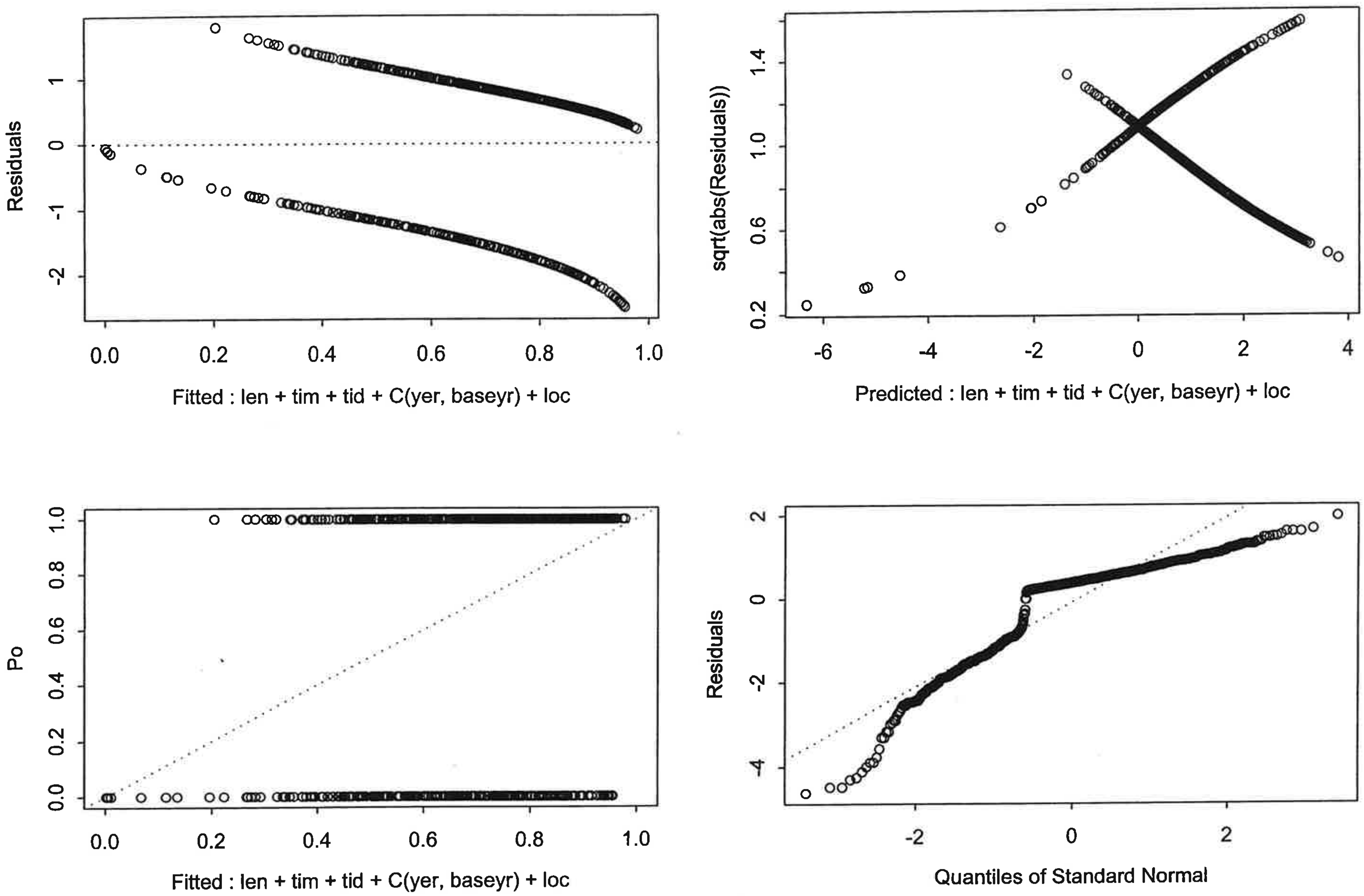
***Figure 23*:** **Comparison of relative year effects for Bay of Islands fishing effort (hours of fishing effort encountered per hour of interviewing).**

Appendix 1: Diagnostic plots of regressions

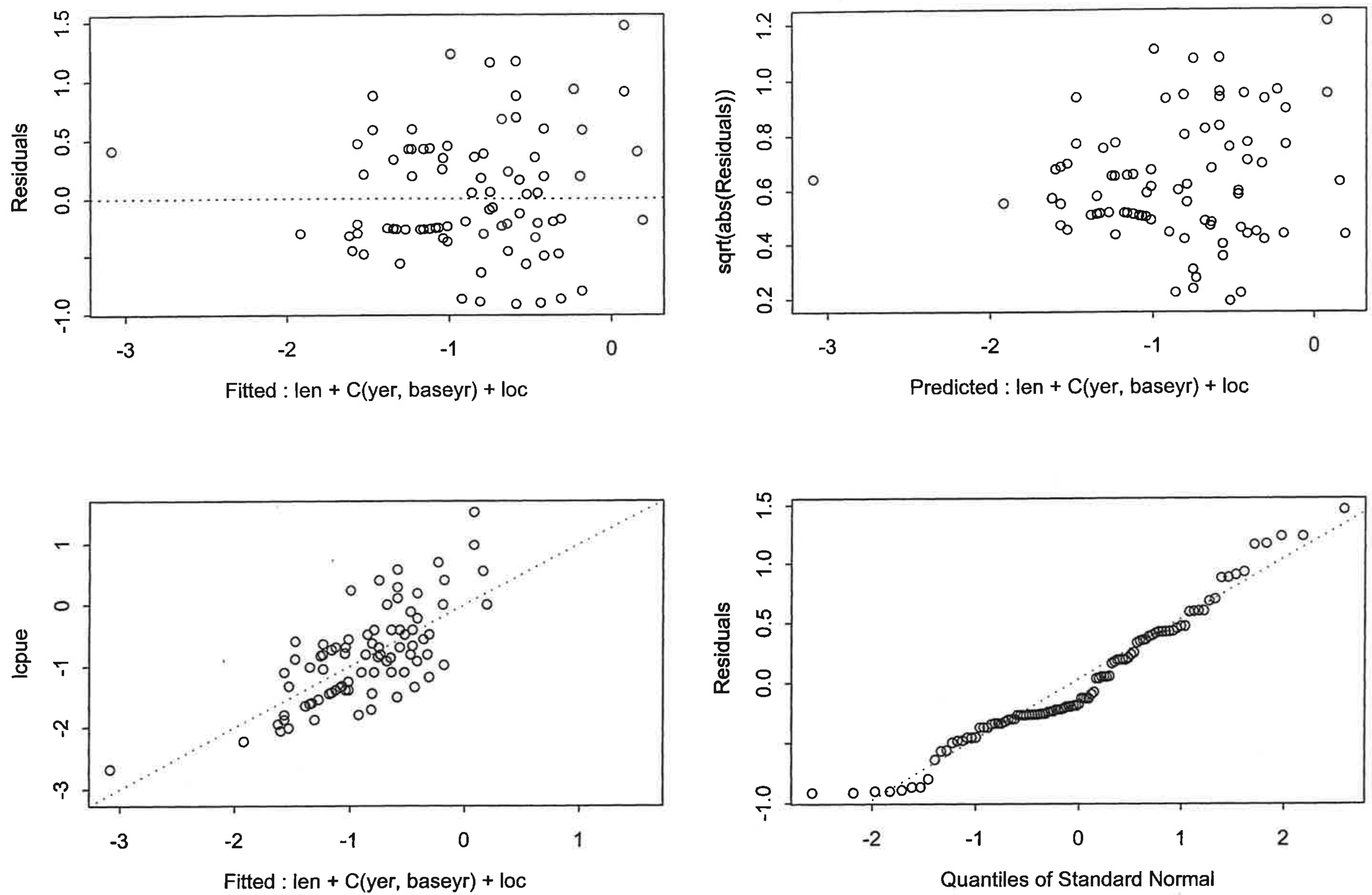
Diagnostic plots of the linear regression of snapper catch rates in Tauranga Harbour.



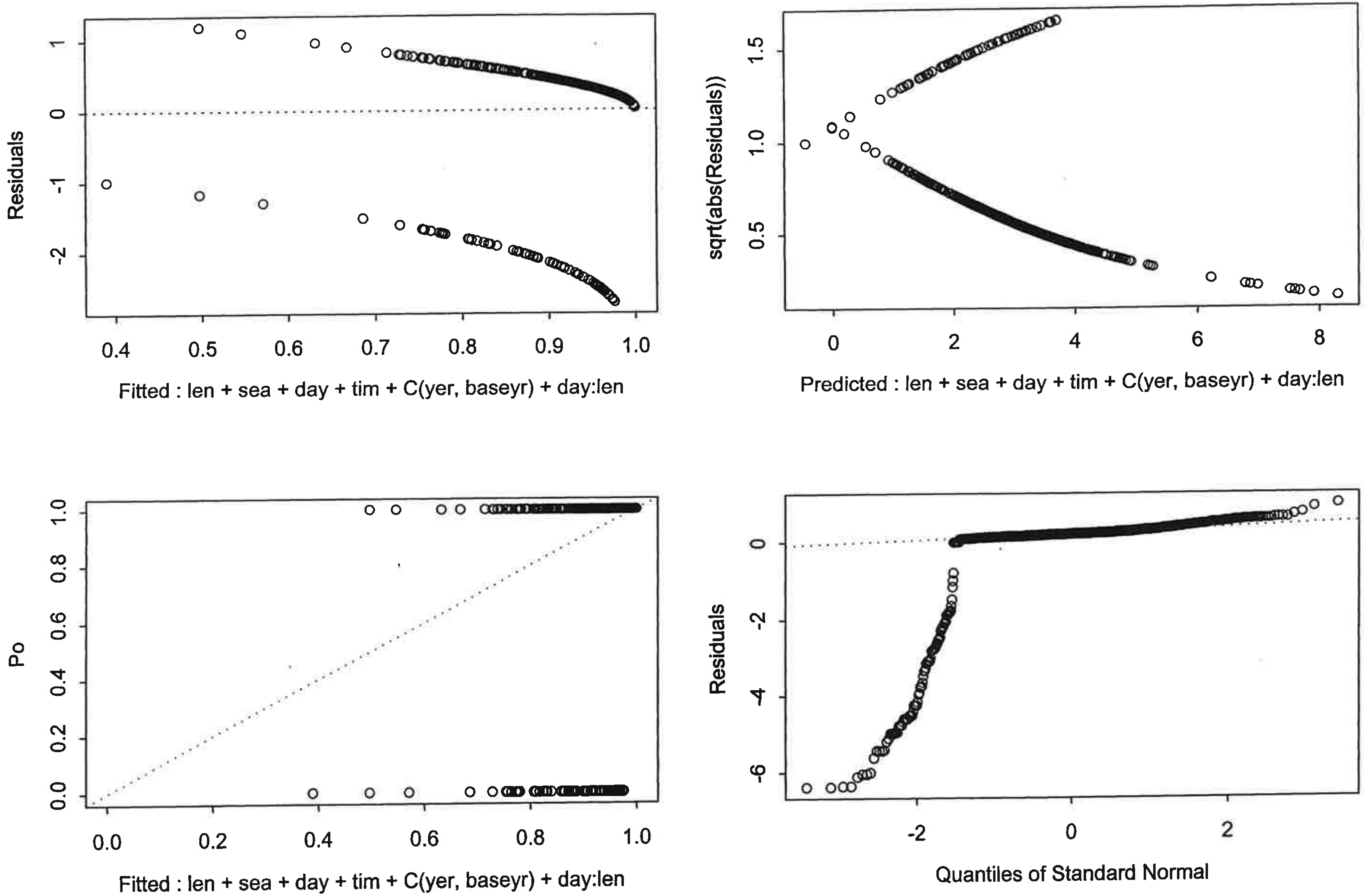
Diagnostic plots of the binomial regression of snapper catch rates in Tauranga Harbour.



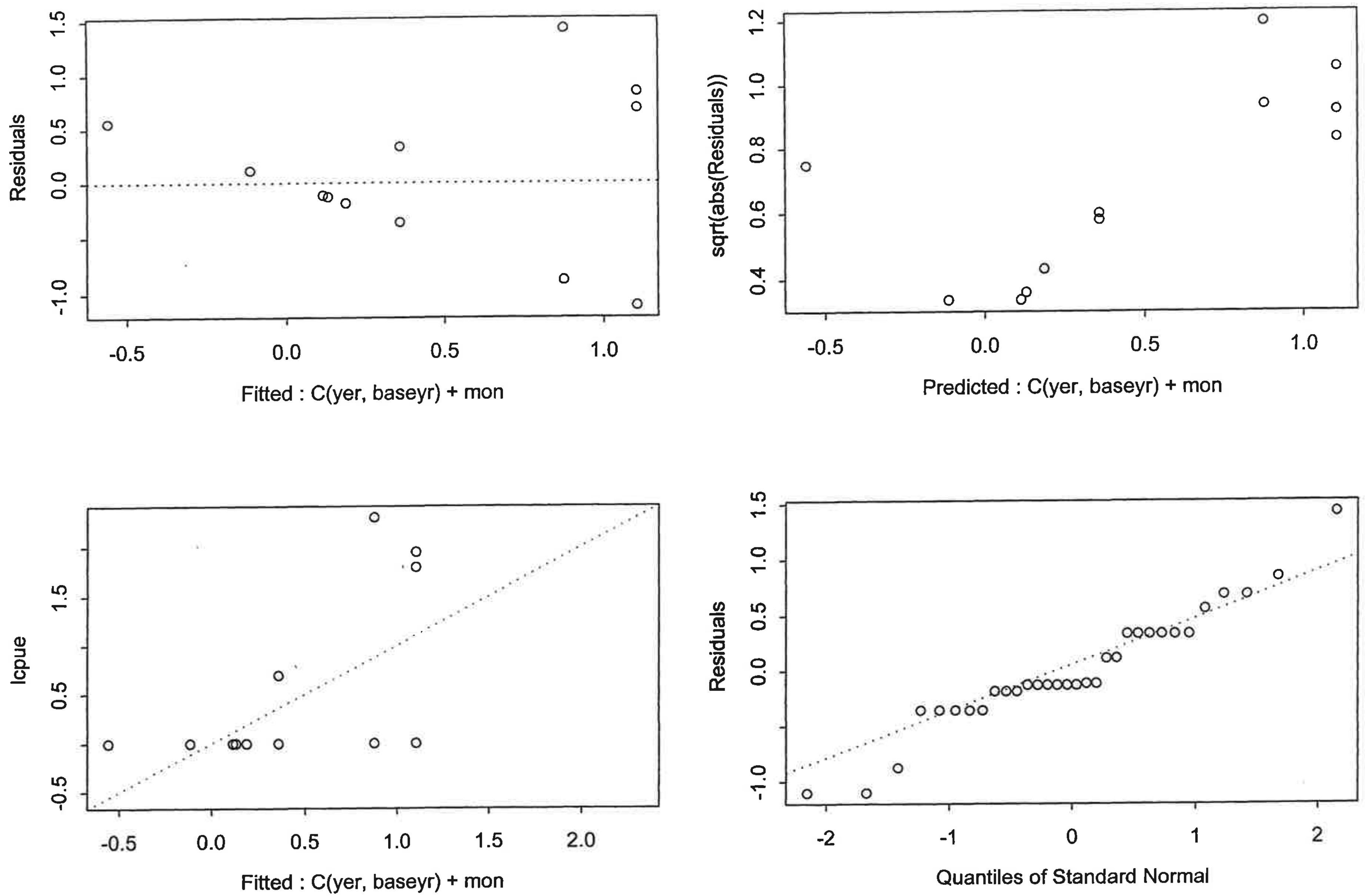
Diagnostic plots of the linear regression of trevally catch rates in Tauranga Harbour.



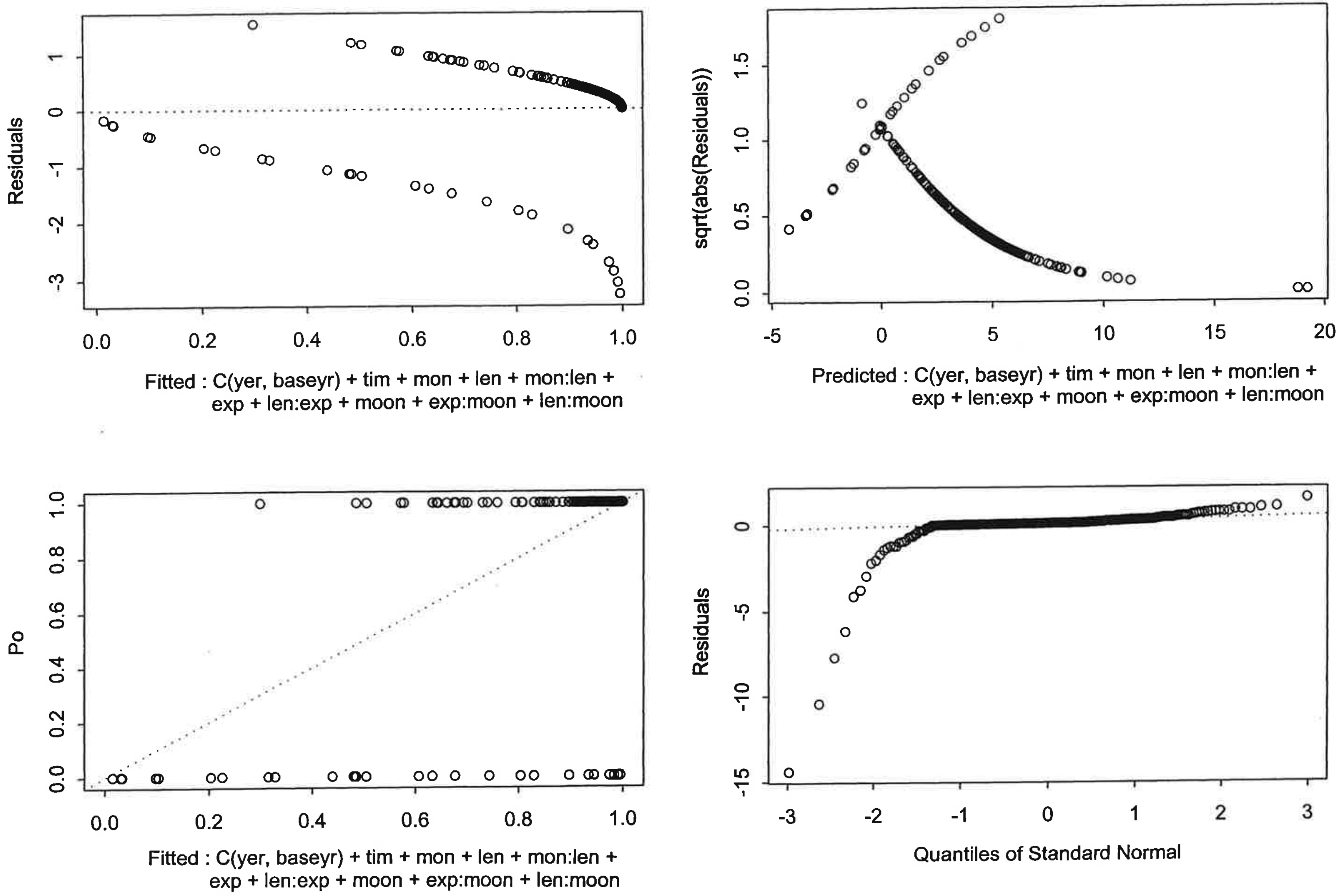
Diagnostic plots of the binomial regression of trevally catch rates in Tauranga Harbour.



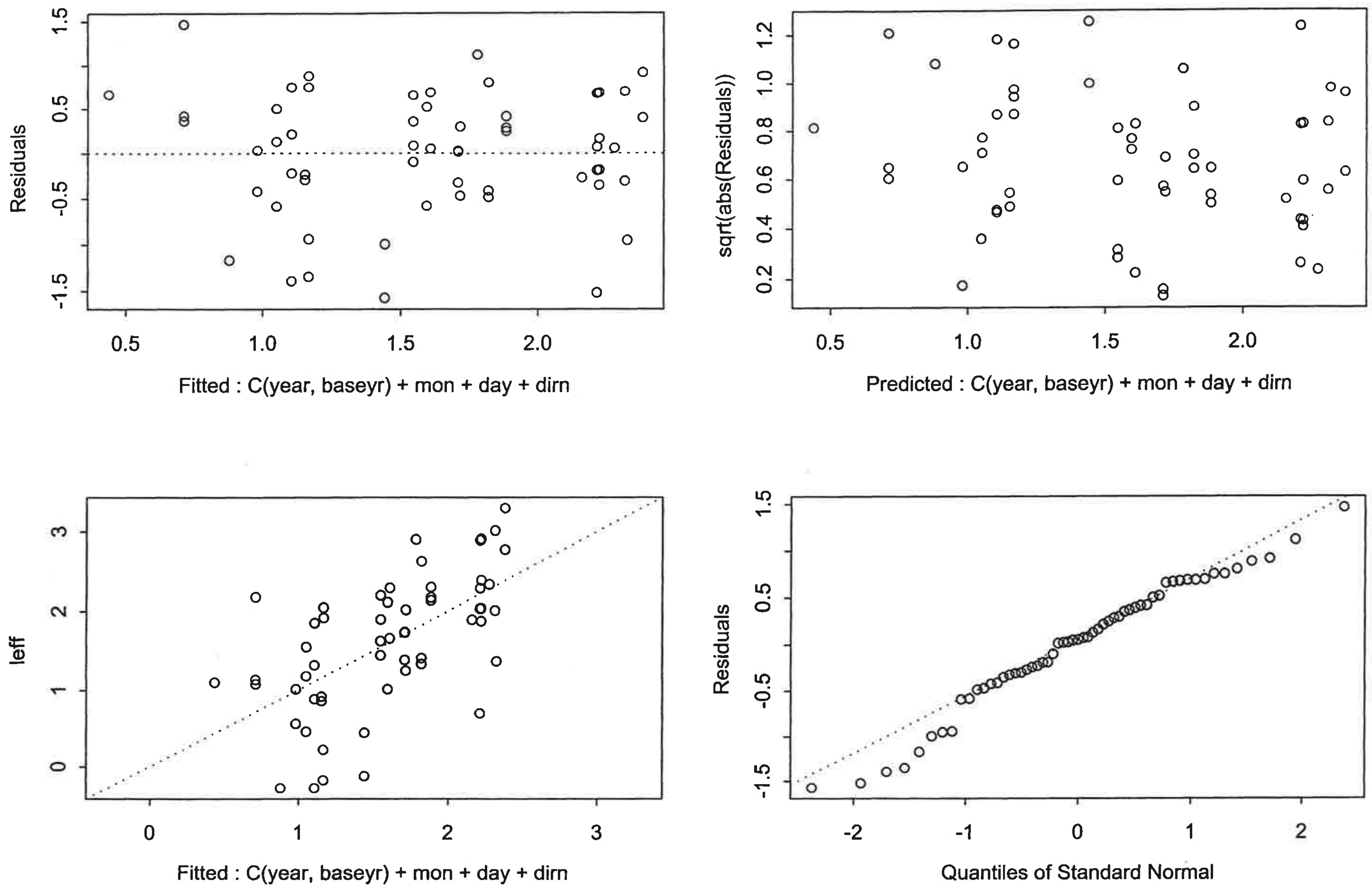
Diagnostic plots of the linear regression of snapper catch rates on Ohiwa Harbour.



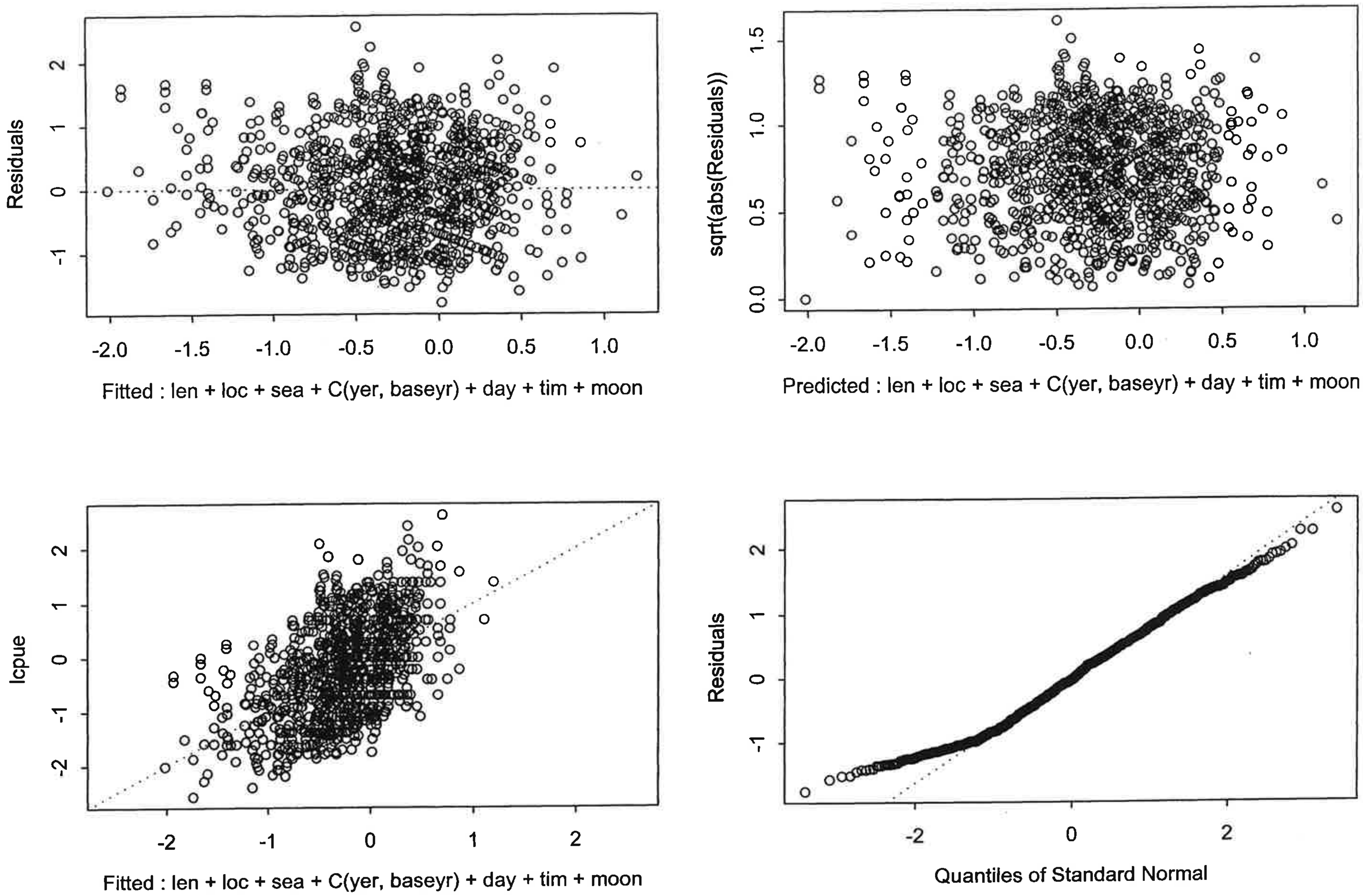
Diagnostic plots of the binomial regression of snapper catch rates on Ohiwa Harbour.



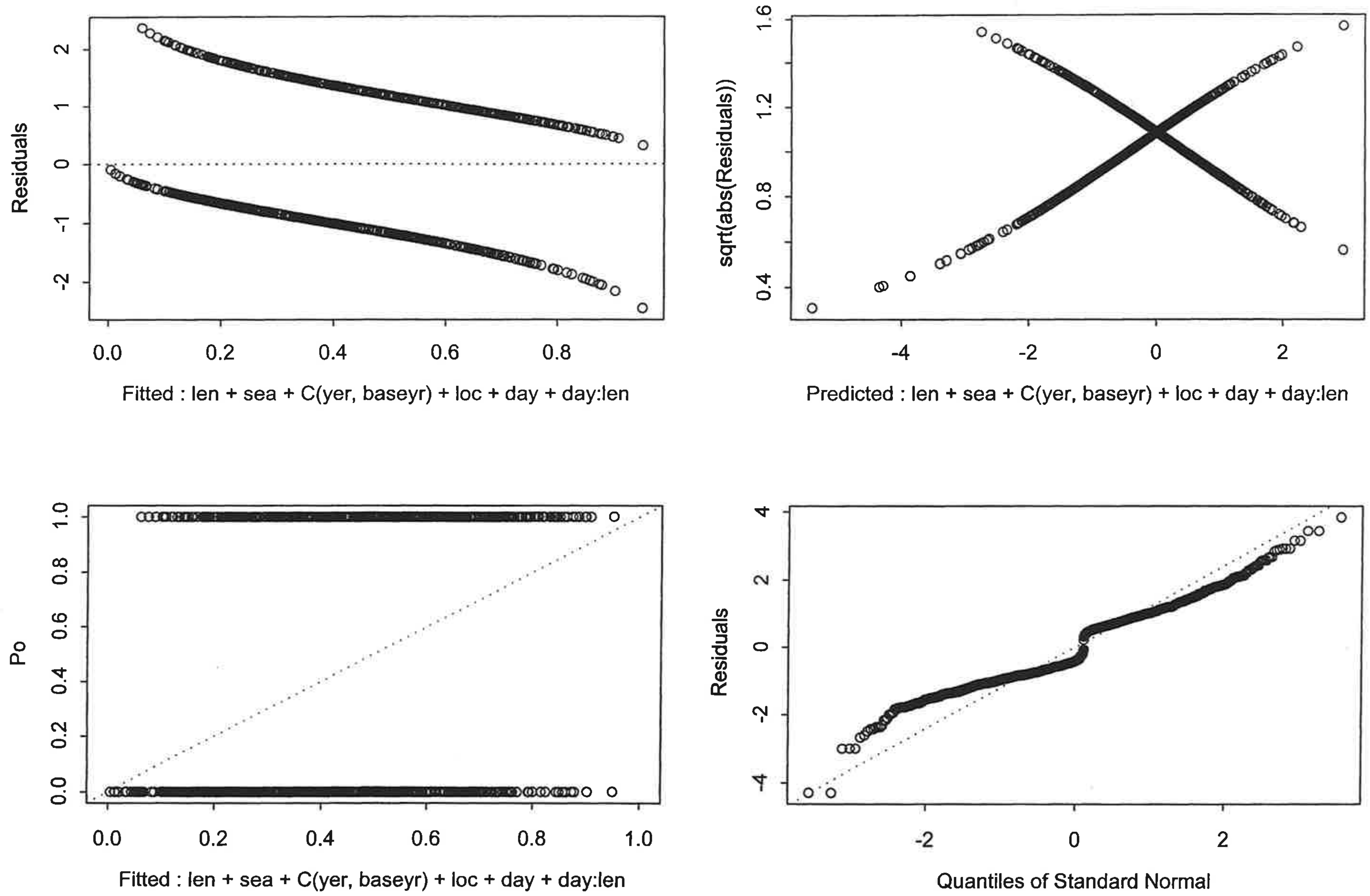
Diagnostic plots of the linear regression of fishing effort in Ohiwa Harbour.



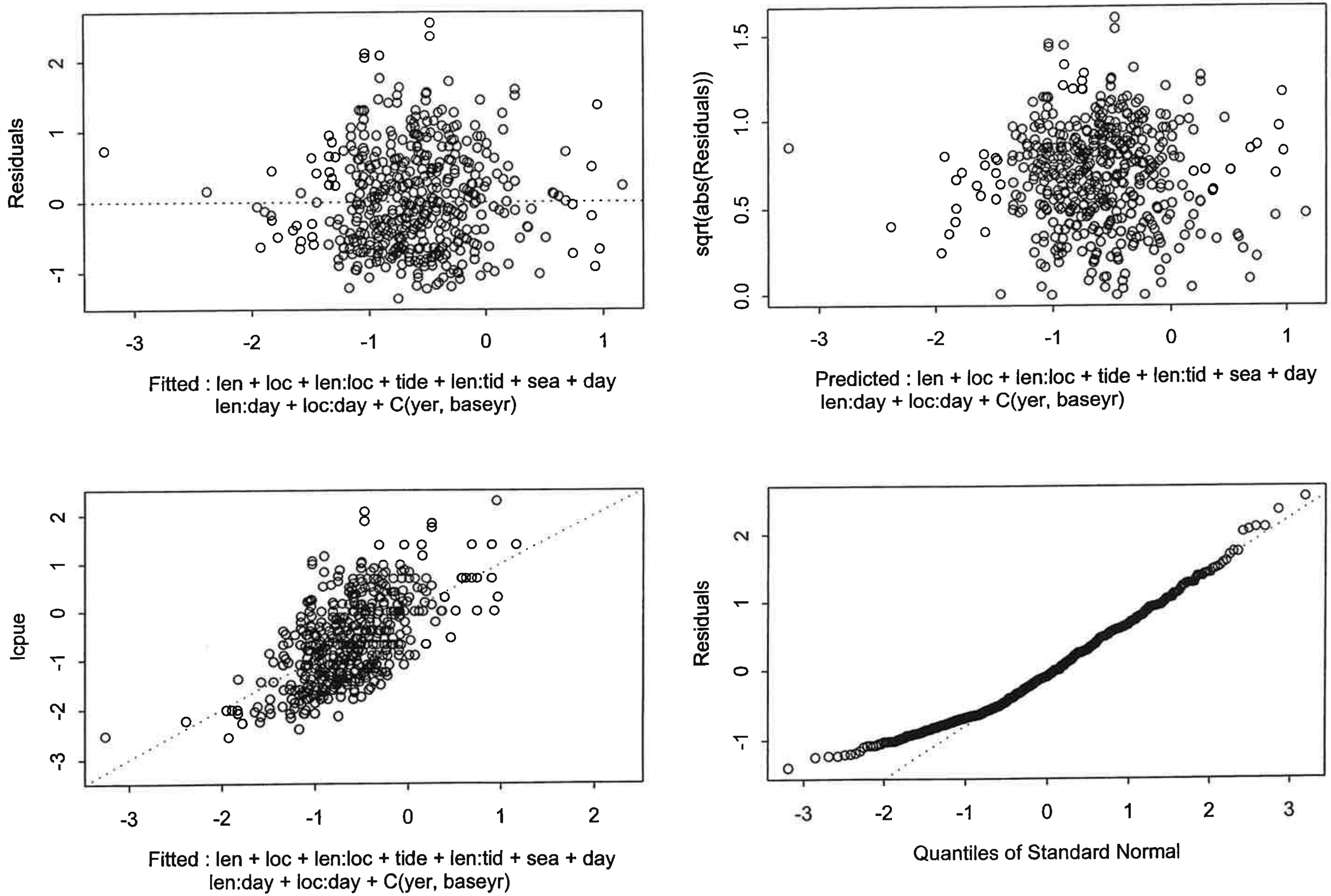
Diagnostic plots of the linear regression of snapper catch rates in the Bay of Islands.



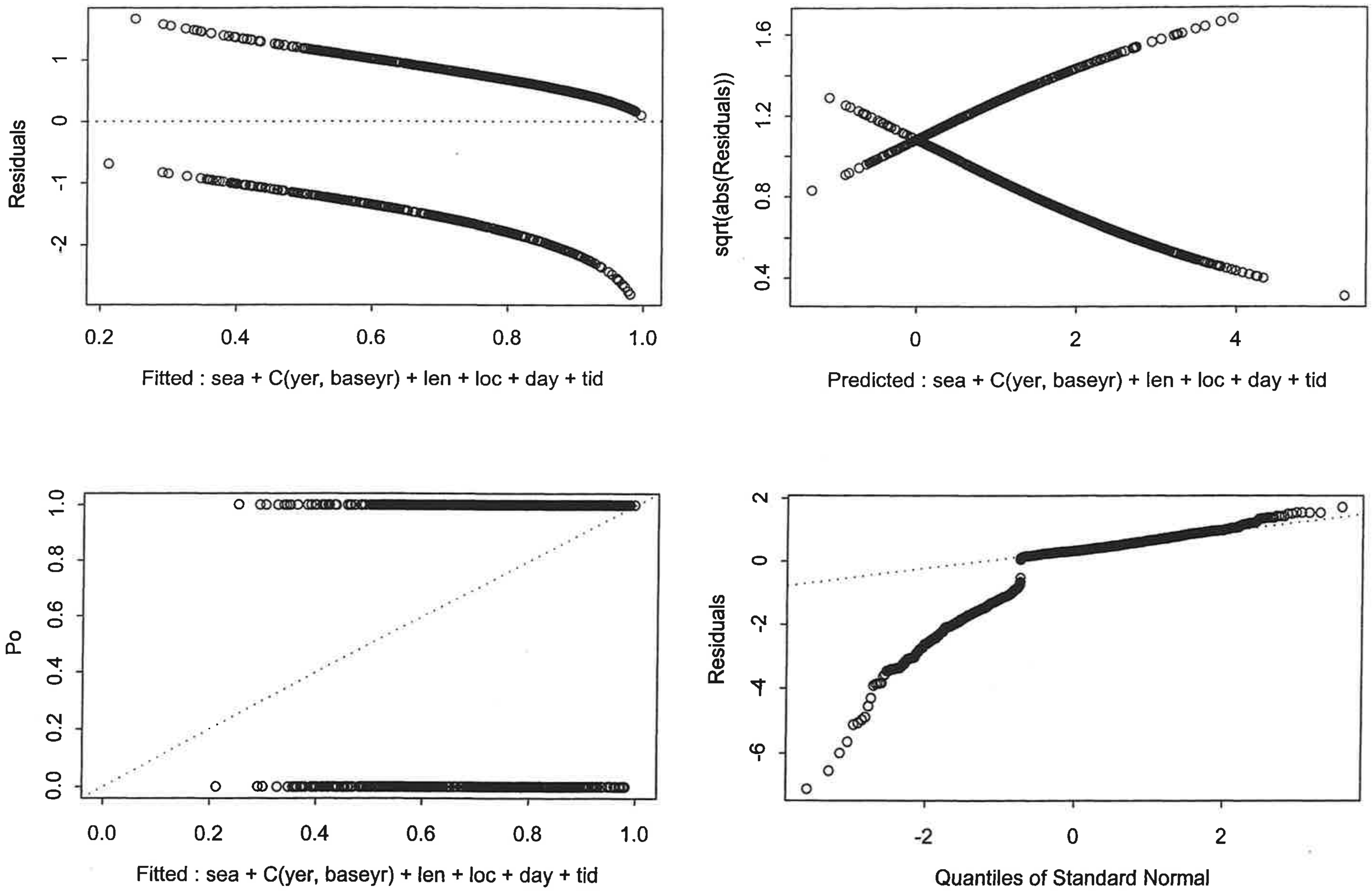
Diagnostic plots of the binomial regression of snapper catch rates in the Bay of Islands.



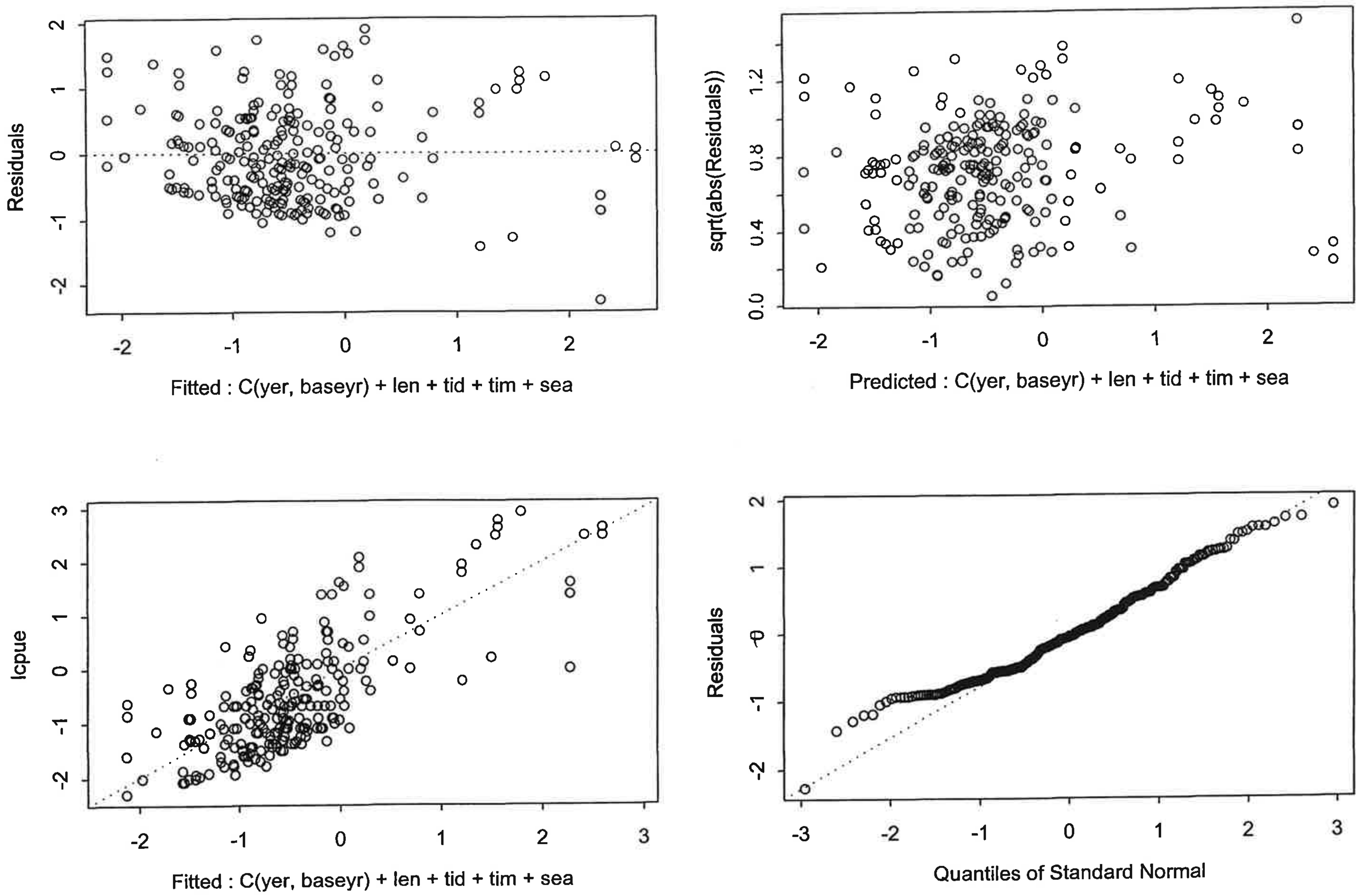
Diagnostic plots of the linear regression of kahawai catch rates in the Bay of Islands.



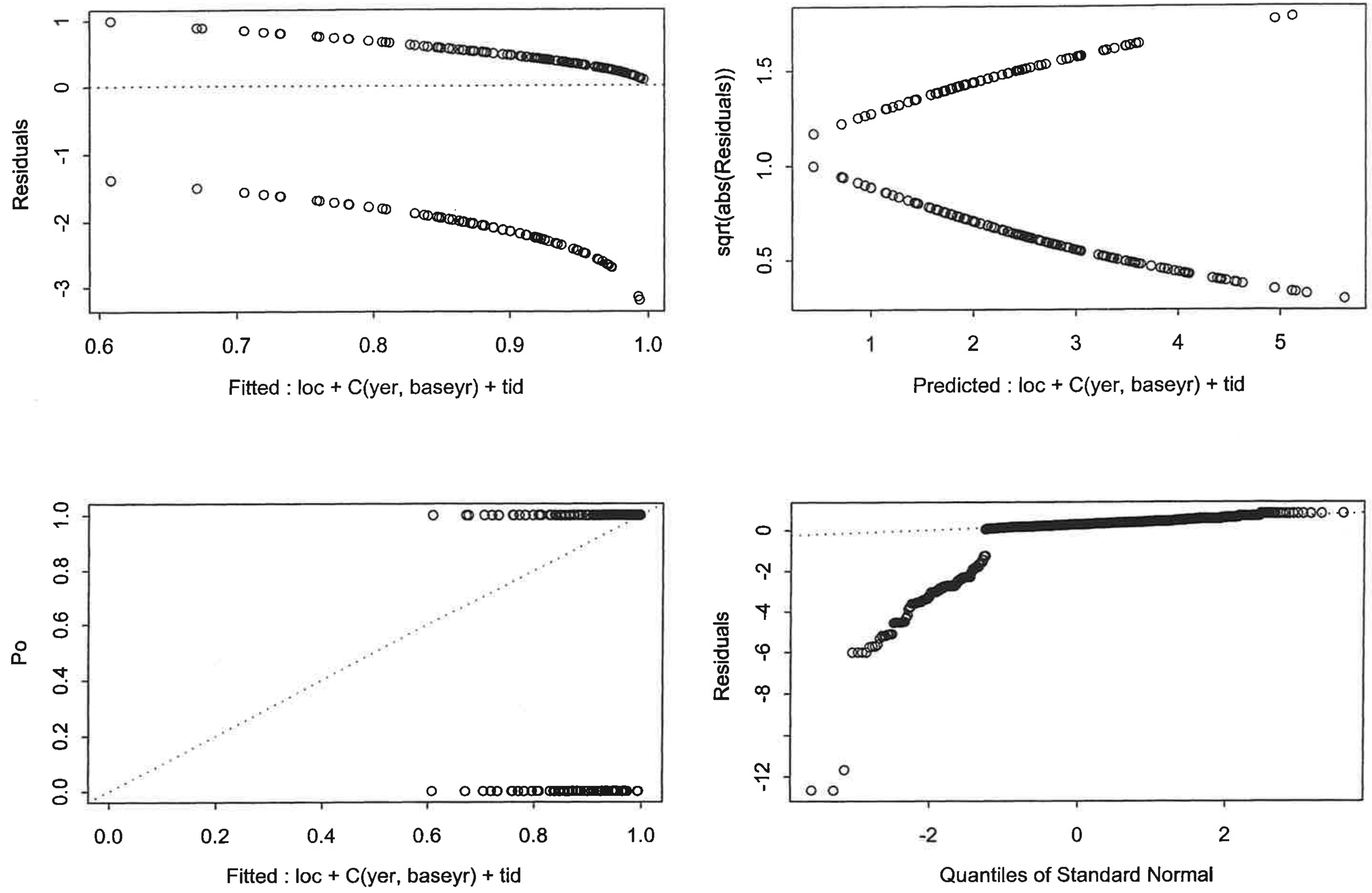
Diagnostic plots of the binomial regression of kahawai catch rates in the Bay of Islands.



Diagnostic plots of the linear regression of jack mackerel/koheru catch rates in the Bay of Islands.



Diagnostic plots of the binomial regression of jack mackerel/koheru catch rates in the Bay of Islands.



Diagnostic plots of the linear regression of fishing effort in the Bay of Islands.