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Settlement indices for 2014/15 fishing year for the red rock lobster (*Jasus edwardsii*)

New Zealand Fisheries Assessment Report 2016/12

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EXECUTIVE SUMMARY

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This report addresses objective one of the Ministry for Primary Industries project CRA201502A (Estimating settlement).

We update the information on annual patterns of settlement for the red rock lobster (*Jasus edwardsii*) on crevice collectors at key sites in CRA 3 (Gisborne), CRA 4 (Napier and Castlepoint), CRA 5 (Kaikoura), CRA 7 (Moeraki), and CRA 8 (Halfmoon Bay and Jackson Bay).

In the 2014/15 fishing year, two groups of collectors in Gisborne, Napier, and Castlepoint, four groups in Kaikoura, and one group in Moeraki, Halfmoon Bay, and Jackson Bay were monitored. Each group has at least three collectors that are checked monthly when possible and a monthly mean catch per group of collectors is calculated. A raw and standardised index based on the rock lobster fishing year, April to March, is produced from the groups of collectors at each site.

Puerulus settlement in 2014/15 was notable again for extremely high levels recorded in Jackson Bay, where 23 times the normal number of pueruli were collected. This follows on from very high settlements recorded in 2012 and 2013. At other sites settlement was average (Napier), below average (Castlepoint, Kaikoura, Halfmoon Bay), or well below average (Gisborne, Moeraki). The low settlement in Gisborne continues with 8 of the last 9 years below the long term mean.

Data and standardisations for Kaikoura (CRA 5), Moeraki, (CRA 7), and Halfmoon Bay, Chalky Inlet and Jackson Bay (CRA 8) were explored in some detail, and the final standardised indices were used as data for the respective stock assessments.

1. INTRODUCTION

Rock lobsters support one of New Zealand's most valuable fisheries. Understanding larval recruitment processes should greatly assist the management of this fishery by explaining changes in levels of recruitment to the fishery and enabling the prediction of trends in catch levels at least four years in advance, allowing management and commercial strategies to be implemented. This report updates the patterns of spatial and temporal settlement of *Jasus edwardsii* on crevice collectors in New Zealand.

Rock lobsters spend several months as phyllosoma larvae in waters tens to hundreds of kilometres offshore. They return to the shore as postlarvae (pueruli) after metamorphosing near the shelf break. The puerulus is the settling stage: it resembles the juvenile in shape and is 9–13 mm in carapace length, but it is transparent. Pueruli settle when they cease extensive forward swimming and take up residence on the substrate. Some older pueruli and young juveniles, however, move after first settling elsewhere. Post-settlement migration (secondary dispersal) such as this is not uncommon among invertebrates (e.g., Reyns & Eggleston 2004), the young redistributing from high-density settlement habitats is thought to be a strategy to reduce density-dependent mortality. The puerulus moults into the first juvenile instar (sometimes referred to as the first-moult postpuerulus) a few days to three weeks after settlement. Higher water temperatures reduce the time taken to moult. Depending on sex and locality, the rock lobster then takes about 4–11 years to reach minimum legal size.

The development of sampling programmes to estimate levels of postlarval settlement that can be used to predict fishery performance is a goal for both palinurids (e.g., Phillips et al. 2000, Gardner et al. 2001) and homarids (e.g., Wahle et al. 2004), with encouraging or well-demonstrated success for some projects. In New Zealand there are significant correlations between the level of settlement and the time-lagged fishery catch per unit effort (CPUE) for most fishery areas. The best correlations occur in fisheries with shorter intervals between settlement and recruitment, and those with large contrasts in the settlement record (Booth & McKenzie 2008).

Monthly occurrence of pueruli and young juveniles on crevice collectors (Booth & Tarring 1986) has been followed at up to nine key sites within the main New Zealand rock lobster fishery since the early 1980s. The indices of settlement are now reported annually. It has become clear from this and other monitoring, that settlement is not uniform in time or space. Settlement occurs mainly at night and at any lunar phase, is seasonal, and levels of settlement can vary by an order of magnitude or more from year to year (Booth & Stewart 1993, Forman et al. 2014). Since monitoring began, the highest mean annual settlement has been along the east coast of the North Island south of East Cape (referred to as the southeast North Island or SENI), in the general region of highest abundance of phyllosoma larvae in adjacent offshore waters (Booth 1994).

For detailed further information on the puerulus sampling program in New Zealand see Booth et al. (2006).

OBJECTIVES

1. To determine trends in puerulus settlement at selected key sites around New Zealand.

Specific Objectives

To estimate monthly and annual indices of puerulus settlement at key sites in CRA 3, CRA 4, CRA 5, CRA 7 and CRA 8 (Gisborne, Napier, Castlepoint, Kaikoura, Moeraki, Halfmoon Bay, and Jackson Bay).

2. METHODS

2.1 Recording settlement on collectors

Levels of puerulus settlement are monitored using 'crevice' collectors (Booth & Tarring 1986, Booth et al. 1991) at seven key sites that sample much of the main rock lobster fishing coastline of New Zealand. The collector was developed in New Zealand to catch *J. edwardsii* pueruli and is now used throughout much of the range of *J. edwardsii*. They are inexpensive, easily set and checked, and provide (unlike many other types of collector) a standard settlement surface for between-month and between-site comparisons.

Each key site is separated from its neighbour by 150–400 km, and most sites were chosen after trying many locations (Figure 1). Criteria for the establishment of key sites included the distance from the neighbouring site, proximity to the open ocean, accessibility, tractability, and the level of puerulus catch.

At each key site, collectors are set in groups of between 3 and 20, with at least 2–3 m between individual collectors. It is unclear whether or not there is interference in the catch between collectors at these spacings, but because the distances remain unaltered, any interference is likely to have a minimal impact on the overall monthly and annual index. At each site there is a core group of at least three (although usually five) collectors. At most sites there have been up to three additional groups of three or more collectors, set in both directions along the coast as conditions allow. Since 2002, however, fewer of these additional groups of collectors have been monitored; the focus is now on the core group (usually the one first established, and therefore with the longest record of settlement). Where feasible, one other group of collectors is also monitored. See Table 1 for a summary of the collector sites and the number of collectors by site and the method of collector deployment. Methods of deployment include shore based collectors which are attached to concrete weights in sheltered subtidal locations, suspended collectors which are hung from wharf piles with the collectors suspended just off the bottom, and closing collectors which have a closing mechanism that surrounds the collector as it is hauled up by boat.

Collectors are generally checked monthly as weather and tides allow and are cleaned of heavy growth so that the condition of collectors is consistent. Repairs required are noted at each collector check and these are made in the field where possible. Spare (and conditioned) collectors are maintained at each site or nearby as replacements. If possible, collector replacement is made outside the main settlement season.

At most sites, local people are employed to check the collectors, under NIWA's direction. Quality control of checks and equipment is maintained with direct contact once or twice a year. A standard result form is filled out and sent to NIWA after each check. At Castlepoint and Moeraki, NIWA staff check the collectors. Monthly checks, especially during the main winter settlement season, are not always possible for all groups of collectors because of logistical issues. The Chalky Inlet site (CHI001) is under the management of CRAMAC 8 and is checked by lobster fishers whenever they are in the vicinity of the collectors. Because of the remoteness of this site, these collectors can only be checked opportunistically by the fishers and cannot be checked on a regular basis. Two groups of collectors in Kaikoura (KAI005 and KAI006) are fully managed by CRAMAC 5 and one other group of collectors in Kaikoura (KAI003) is funded by CRAMAC 5 but is maintained by NIWA.

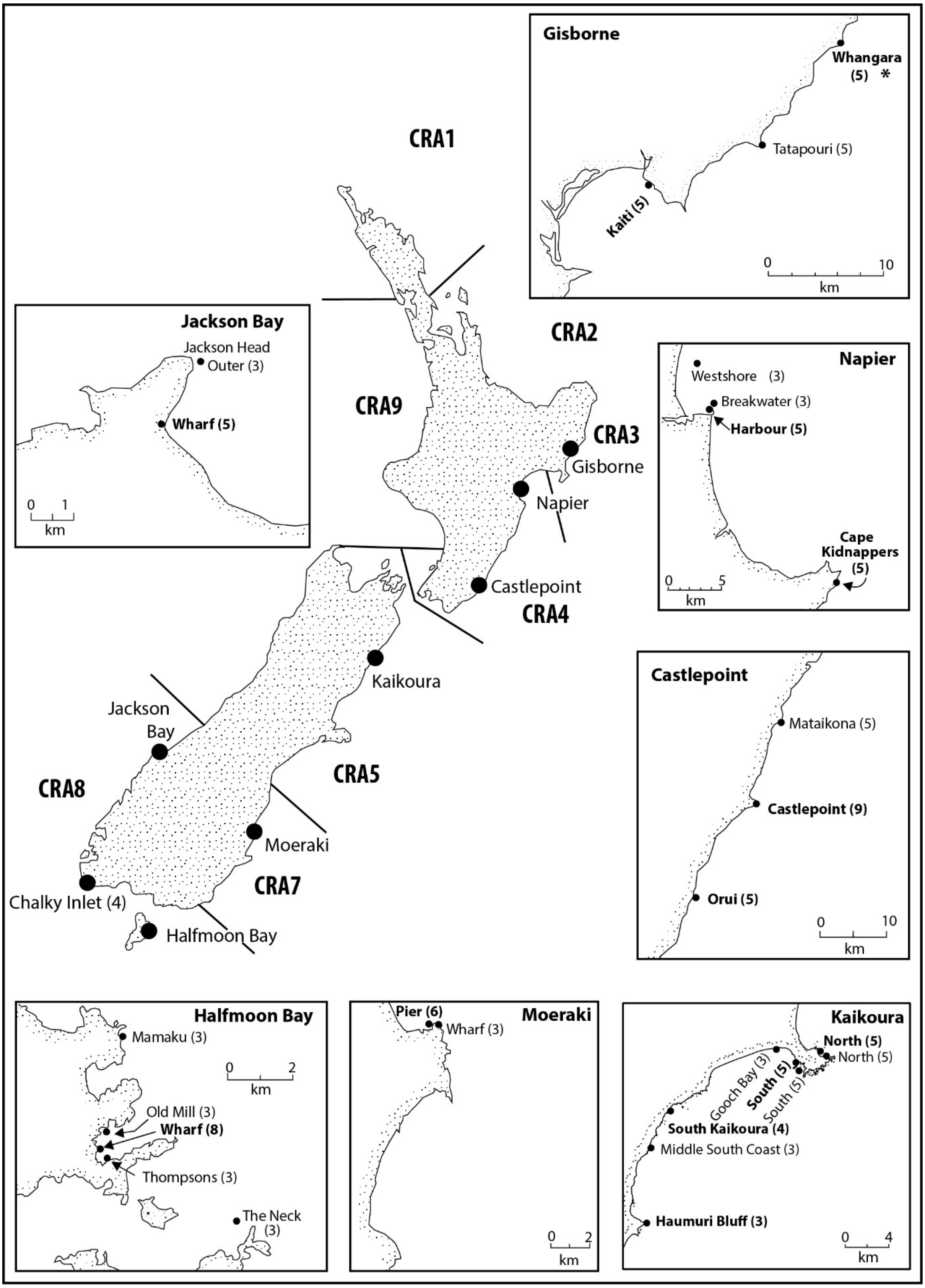

Figure 1: Map of New Zealand showing the location of collectors at the key monitoring sites (although not all groups are now checked). The sites that are checked are in bold and the number of collectors in that set is in brackets. Also shown are the CRA Quota Management Areas; CRA 6 is the Chatham Islands and CRA 10 is the Kermadec Islands (to the northeast of the North Island).

Table 1: Number of collectors (presently used), method of collector deployment, and years of operation of all collectors used in the settlement index. For definitions of collector type see Section 2.1, Booth & Tarring (1986), and Phillips & Booth (1994).

Site	Number of collectors	Location	Method of deployment	Years of operation
Gisborne	5	Harbour (GIS001)	Shore	1987–2003
	5	Whangara (GIS002)	Shore	1991–Present
	5	Tatapouri (GIS003)	Shore	1994–2006
	5	Kaiti (GIS004)	Shore	1994–Present
Napier	5	Harbour (NAP001)	Suspended	1979–Present
	3	Westshore (NAP002)	Closing	1991–1999
	5	Cape Kidnappers (NAP003)	Shore	1994–Present
	3	Breakwater (NAP004)	Shore	1991–2002
Castlepoint	9	Castlepoint (CPT001)	Shore	1983–Present
	5	Orui (CPT002)	Shore	1991–Present
	5	Mataikona (CPT003)	Shore	1991–2006
Kaikoura	5	South peninsula (KAI001)	Shore	1981–Present
	3	South peninsula (KAI002)	Shore	1988–2003
	5	North peninsula (KAI003)	Shore	1980–Present
	3	North peninsula (KAI004)	Shore	1992–2003
	4	South Kaikoura KAI005)	Shore	2008–Present
	3	Haumuri Bluff (KAI006)	Shore	2008–Present
	3	Gooch Bay (KAI008)	Shore	1980–1983
	3	Middle South Coast (KAI009)	Shore	1981–1988
Moeraki	3	Wharf (MOE002)	Closing	1990–2006
	6	Pier (MOE007)	Suspended	1998–Present
Halfmoon Bay	8	Wharf (HMB001)	Suspended	1980–Present
	3	Thompsons (HMB002)	Closing	1988–2002
	3	Old Mill (HMB003)	Closing	1990–2002
	3	The Neck (HMB004)	Closing	1992–2002
	3	Mamaku Point (HMB005)	Closing	1992–2002
Jackson Bay	5	Jackson wharf (JAC001)	Suspended	1999–Present
	3	Jackson Head (JAC002)	Closing	1999–2006
Chalky Inlet	4	Chalky Inlet (CHI001)	Closing	1986–2012

2.2 Calculating indices of settlement

In previous standardisations the year used for settlement data was from January to December. In contrast all standardisations presented here use the fishing year from 1 April to 31 March, with the year label being the one which April is in. For example, 20 April 2004 is in the 2004 fishing year, while 11 Feb 2004 is in the 2003 fishing year. An alternative labelling also used is to call the 2004 fishing year the 2004/05 fishing year. The change from a calendar to a fishing year was requested by the Rock Lobster Working Group (RLWG), and aligns with the year used in stock assessments, for which the standardised puerulus indices are offered as data inputs.

The standardised index of annual settlement used here incorporates all settlement for the year for each site, irrespective of month. This approach to the standardisation was based on Bentley et al. (2004), but with the adjustments noted below: assignment of the month for settlement, and the groups of collectors used. The term ‘settlement’ to refers to the presence of pueruli and juveniles up to 14.5 mm carapace length (CL, the maximum size for a first-instar juvenile observed in laboratory studies).

Following Bentley et al. (2004) the standardisation used collectors that were sampled at least 36 times (equivalent to three years of monthly sampling). No outliers were removed from any of the data sets after fitting. In Bentley et al. (2004) outliers were removed, but the effect on the standardised indices was minor.

Because a collector check on any one day is thought to be a snapshot of what has been going on for about the last 14 days, then the appropriate month to label settlement with may not be the nominal month. In previous standardisations, if the check took place up to the seventh of the month its catch was attributed to the previous month. This also avoids the situation where if a collector is checked on the first and last day of a month, there are two records for that month, but none for the previous or subsequent months. However, it was decided by the RLWG that the nominal month should be used for standardisations.

At three sites (Gisborne, Jackson Bay, and Moeraki) some pilot groups of collectors were dropped. For Jackson Bay and Moeraki even the best groups of collectors, after dropping of pilot groups, recorded very low counts (Forman et al. 2014, Appendix 1). Because of the low counts recorded at some sites during certain periods of the year, for some standardisations the months used are restricted to those where the counts are not low. In some fishing years the number of samples is low, and the year is dropped from the standardisation if the number of samples is less than 10.

The annual index takes into account changes in collector location and sampling to date. A generalised linear model framework was used, in which the response (dependent) variable is the log of numbers of settlers per collector sample and a negative binomial distribution is used. For Kaikoura and Moeraki alternative distributions were investigated (quasi-Poisson, zero-inflated Poisson, zero-inflated negative binomial) and the negative binomial was chosen as the best. In a previous standardisation for Gisborne alternative distributions were investigated and the negative binomial was chosen as the best (Forman et al. 2015). For the other sites the RLWG decided that the negative binomial distribution should be used.

The predictor variables available to the standardisations were year, group, and month. The year variable was included in all models; the other independent variables group and month were added to the model in a stepwise process. At each step the variable that most improved the fit of the model measured by the Akaike Information Criterion (AIC) was included (Akaike 1974).

In summary, the standardisation method common to all sites followed the following rules:

1. use the fishing year from 1st April to 31st March;
2. use the actual month in which a sample was taken (instead of samples taken up to the 7th of the month being assigned to the previous month);
3. drop collectors with fewer than 36 samples;
4. restrict where necessary the months used (to reduce the proportion of zero counts in the data);
5. drop fishing years with fewer than 10 samples;
6. use a negative binomial model;
7. use as predictor variables in the standardisation year, month, and group (collector is not offered as an alternative to group).

Each set of annual indices is presented as the annual value divided by the geometric mean of the annual values, or where the annual values are close to zero (Moeraki and Halfmoon Bay) by dividing by the arithmetic mean of the annual values. In either case, a value for the index above 1 represents above average settlement for that year, and a value below 1 indicates below average settlement. For comparison, a raw form of these indices is also given (arithmetic mean for each year), which is also scaled to have an average value of 1 over all years.

The data set used for all sites is an extract from the *rocklob* database and is complete for the 2014 fishing year (i.e. data is complete up to 31 March 2015).

3. RESULTS

3.1 Introduction

In the first part of this section detailed data characterisations and standardisations are presented for the sites at Kaikoura (CRA 5), Moeraki (CRA 7), and Jackson Bay, Chalky Inlet, and Halfmoon Bay (CRA 8). A more detailed analysis was undertaken for these sites because their standardised indices were used as data inputs for stock assessments for CRA 5, CRA 7, and CRA 8 (Appendix 1). These are followed by standardisation results for the other sites (Gisborne, Napier, and Castlepoint).

For Kaikoura and Moeraki the initial standardisation model was the same as the previous standardisation (quasi-Poisson) but alternative standardisation models were investigated including negative binomial, zero-inflated Poisson (ZIP), and zero-inflated negative binomial (ZINB). The Rock Lobster Working Group decided upon the negative binomial standardisation as the final standardisation model, and also decided to use this model for Jackson Bay, Chalky Inlet, and Halfmoon Bay. The Gisborne site standardisation was previously investigated in detail and the negative binomial model was selected as the best model (Forman et al. 2015).

Throughout the document reference is made to a group of collectors from a particular site using a shorthand label. For example, KAI006 represents the group of collectors labelled 006 from the Kaikoura site. Collectors also have numeric labels and for the purpose of this document are identified by joining the site, group, and collector labels. For example, the label KAI0063 represents the Kaikoura site for group 006 and collector 3.

3.2 Kaikoura data characterisation

Kaikoura is the only site in the CRA 5 area with collectors (Figure 1), and henceforth reference is made to Kaikoura instead of CRA 5.

In recent Kaikoura standardisations six groups of collectors have been used (001, 002, 003, 004, 005, 006) and only collectors for which at least 36 samples have been taken are included. In the following we look at the characteristics of sampling from the Kaikoura collectors before any subsetting of the data is done.

At the Kaikoura site 11 groups have been in place at various times with a total of 38 collectors used. These groups are labelled 001, 002, . . . , 011 (Table 2). Note that two new group labels 010 and 011 are introduced in this document. These represent pre-1987 groups of collectors that have previously being incorporated in the database with the 005 and 006 groups, but are in fact at different locations. The collector groups 005 and 006 groups of collectors were set up as new groups in 2007.

The number of samples by group and year is shown in Table 3. The sampling periods for the collectors are shown graphically in Figure 2, and the total number of samples from each is shown in Figure 3.

In recent standardisations the groups 001, . . . , 006 have been used. In the first standardisation for Kaikoura the groups 001, 002, 003, 004, 008, 009, 011 were used (Bentley et al. 2004). The groups 007 and 010 appear to have been absent from the data extract for this standardisation (Bentley et al. 2004, see table 1) while the groups 005 and 006 were not yet set up. The subsequent standardisation, taking the indices to the 2003 calendar year, used only the four groups 001, 002, 003, 004 (Booth et al. 2006). The same four groups were used for standardisations to the 2011 calendar year, after which the 005 and 006 groups were introduced (Forman et al. 2014).

There does not, however, appear to be any a priori reason for any group of collectors to be dropped, apart from the filtering rule requiring at least 36 samples for a collector to be used in the standardisation, which has the effect of dropping one collector from 005, and all the collectors from 007, 010 and 011 (Figure 3).The collectors remaining after filtering therefore belong to 001 to 006, 008 and 009. The additional groups compared to the previous standardisation are 008 and 009. These additional groups are unlikely to significantly alter the index, as they show the same pattern as the other groups (Figures 4–5).

3.3 Kaikoura puerulus settlement standardisation

3.3.1 Summary of Kaikoura standardisation data

After the data was filtered to ensure that there were 36 samples for each collector, collector groups 001–006, 008 and 009 remained in the dataset. The number of samples for the first year 1980 is rather low at 12 (Table 4), with some months missed for sampling (Figure 6). Other than the early years, sampling is mostly spread across the year, with highest settlement occurring from January to September (Figure 7).

The proportion of zeros for Kaikoura is higher than at the Gisborne site, for which only the May–September months were used in the standardisation to reduce the number of zeros (Figure 8). Based on when the mean count value is highest, and the months with the highest proportion of non-zeros, the months January–September were selected for the Kaikoura standardisation (Figure 9). The numbers of samples by year is shown in Table 5. As with other puerulus standardisations, years with fewer than 10 samples are dropped, so the 1980 year was dropped from the data.

3.3.1 Initial standardisation

An initial standardisation was done using the quasi-Poisson model of the previous standardisation. Both group and month were offered to the standardisation as predictor variables, and accepted into the model. The resultant index is shown in Figure 10, and residual and quantile-quantile plots are shown in Figures 11–13.

The fitted model has an estimated dispersion of 1.89 and fewer zeros than the data (Figure 14). The standardised and raw indices are very similar. The small differences are mostly due to the group effect in the standardisation (Figure 15). It makes little difference to the standardised index if collector is used instead of groups in the standardisation (Figures 16–17).

3.3.2 Other standardisation models

An alternative model for overdispersed data is the negative binomial. In this model, group and month were selected as predictor variables. The standardised index is very similar to that from the quasi-Poisson (Figures 18–19) however residual diagnostics are better for the negative binomial model than the quasi-Poisson in that they are smaller, and the quantiles are a better fit at the high end (Figures 20–21). The fitted negative binomial distribution has a size parameter of 1.46 and is a better fit to the data than the quasi-Poisson model (Figure 22, Figure 14).

Another way of dealing with the excess zeros in the data is to use zero-inflated models, either (i) a zero-inflated Poisson (ZIP), or (ii) a zero-inflated negative binomial (ZINB).

For the ZIP model the index differs somewhat from the negative binomial (Figures 23–24). However except for the zeros, the ZIP model doesn’t fit the data as well as the negative binomial (Figure 25, Figure 22).

For the ZINB model the index also differs somewhat from the negative binomial (Figures 26–27). Compared to the negative binomial model the fit appears slightly worse for low counts, but possibly better for high counts (Figure 28, Figure 22).

Of the three alternative models, the one with lowest AIC is the ZINB, by about 250 (Table 6). Of the possible models, the Rock Lobster Working Group choose the negative binomial model, mainly based on the fit to the data.

Table 2: Location of Kaikoura groups of collectors, all of which are shore collectors. The locations Lab 1 and Lab 2 most likely refer to a group of collectors located off the University of Canterbury Edward Percival Marine Laboratory (Jeff Forman pers. comm.).

Group	Location
KAI001	South peninsula
KAI002	South peninsula
KAI003	North peninsula
KAI004	North peninsula
KAI005	South Kaikoura
KAI006	Haumuri Bluff
KAI007	New Wharf
KAI008	Gooch Bay
KAI009	Middle South Coast
KAI010	Lab 1
KAI011	Lab 2

Table 3: Number of puerulus samples from Kaikoura by group and fishing year.

	KAI001	KAI002	KAI003	KAI004	KAI005	KAI006	KAI008	KAI009	KAI010	KAI011
1980	0	0	12	0	0	0	15	0	0	0
1981	24	0	24	0	0	0	24	21	0	19
1982	24	0	24	0	0	0	24	24	0	22
1983	24	0	21	0	0	0	6	27	0	9
1984	33	0	33	0	0	0	0	33	0	0
1985	27	0	23	0	0	0	0	33	0	0
1986	27	0	26	0	0	0	0	27	0	0
1987	36	0	36	0	0	0	0	36	0	0
1988	36	12	36	0	0	0	0	24	12	0
1989	36	36	39	0	0	0	0	0	36	0
1990	36	36	33	0	0	0	0	0	36	0
1991	36	33	36	0	0	0	0	0	33	0
1992	30	30	30	30	0	0	0	0	30	0
1993	30	30	30	30	0	0	0	0	21	0
1994	32	33	33	33	0	0	0	0	0	0
1995	36	36	36	36	0	0	0	0	0	0
1996	21	21	21	21	0	0	0	0	0	0
1997	18	18	18	15	0	0	0	0	0	0
1998	18	18	15	15	0	0	0	0	0	0
1999	21	21	24	24	0	0	0	0	0	0
2000	35	35	36	36	0	0	0	0	0	0
2001	36	33	36	36	0	0	0	0	0	0
2002	36	33	36	35	0	0	0	0	0	0
2003	60	0	60	0	0	0	0	0	0	0
2004	59	0	60	0	0	0	0	0	0	0
2005	60	0	60	0	0	0	0	0	0	0
2006	60	0	60	0	0	0	0	0	0	0
2007	60	0	65	0	21	9	0	0	0	0
2008	60	0	59	0	29	27	0	0	0	0
2009	59	0	60	0	30	27	0	0	0	0
2010	60	0	60	0	30	24	0	0	0	0
2011	60	0	60	0	24	18	0	0	0	0
2012	60	0	55	0	18	12	0	0	0	0
2013	54	0	55	0	4	3	0	0	0	0
2014	55	0	55	0	28	21	0	0	0	0

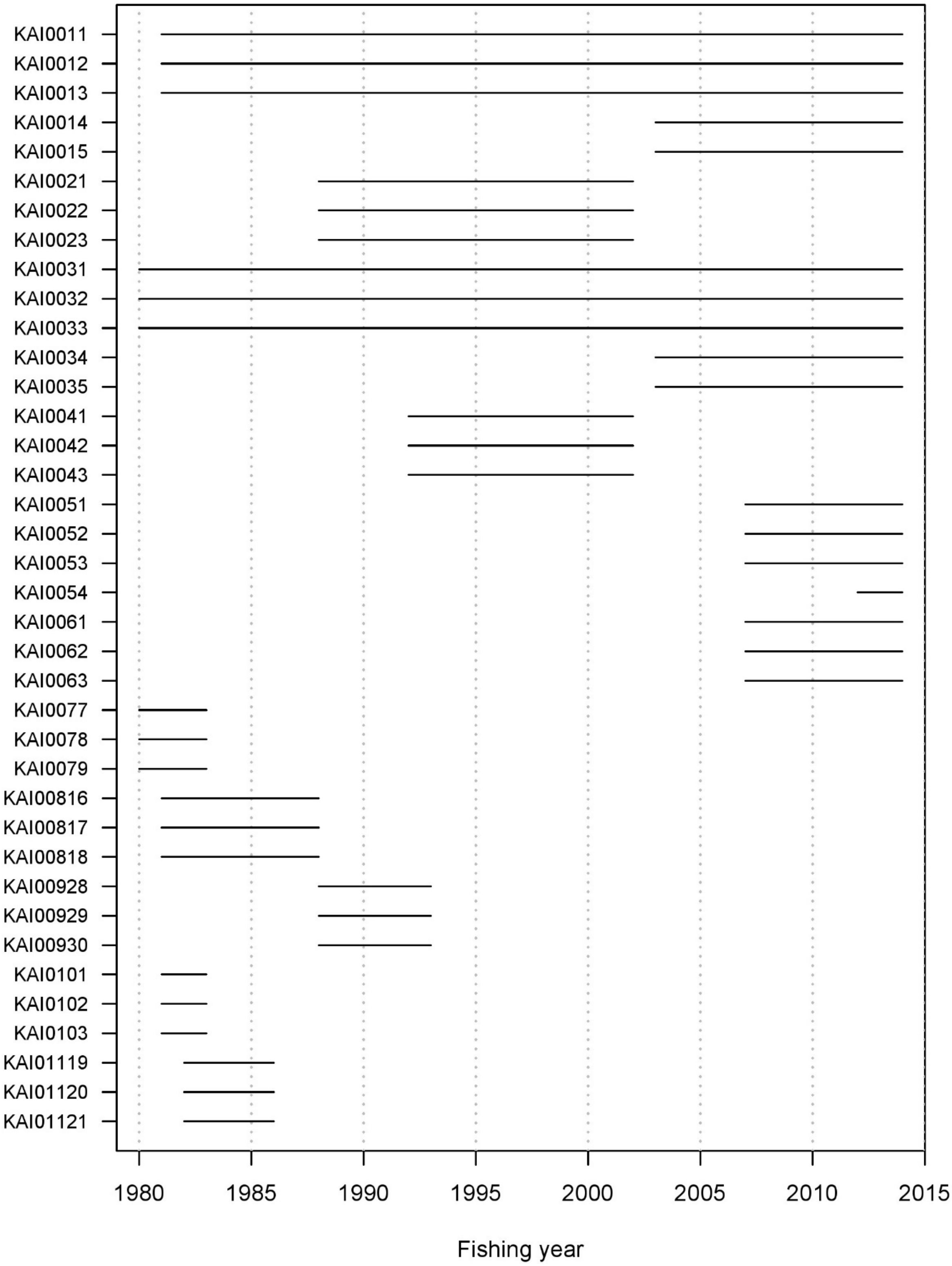

Figure 2: The fishing years over which the collectors have been in operation in Kaikoura.

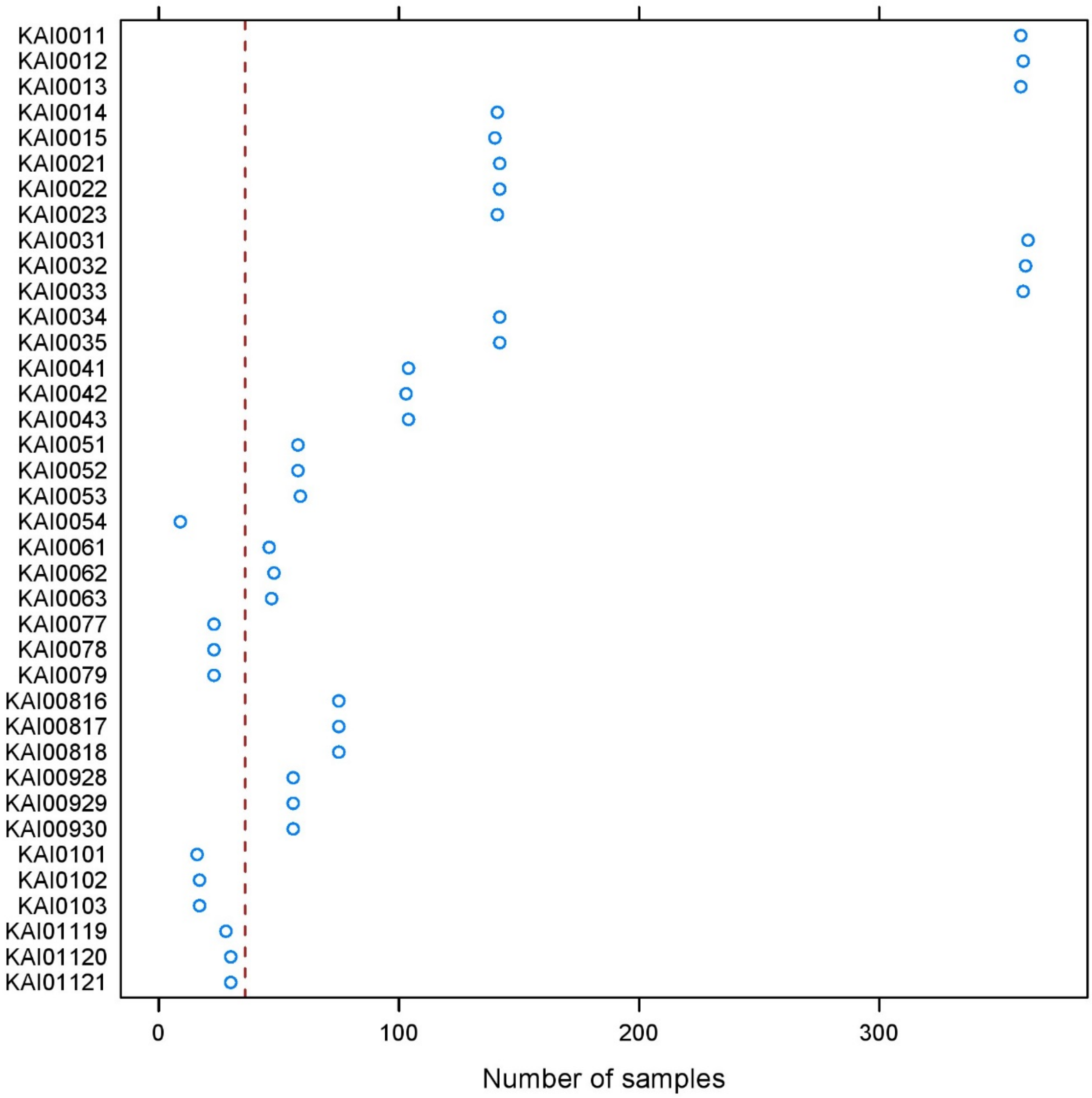

Figure 3: The total number of samples taken from each collector in Kaikoura.

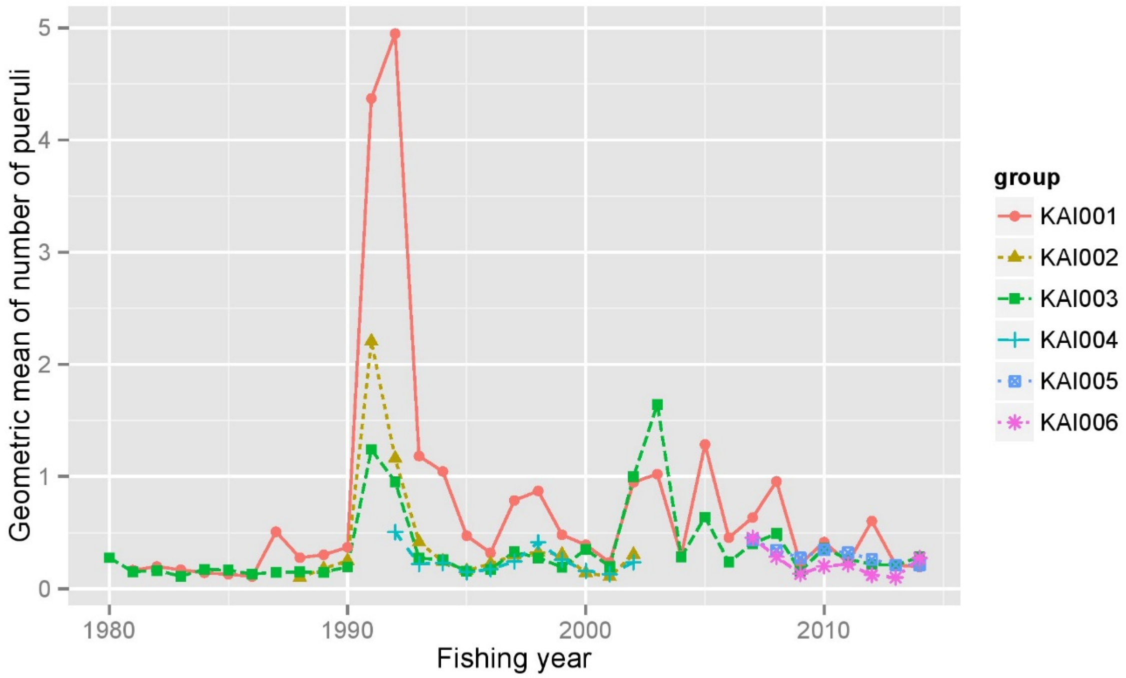

Figure 4: Geometric mean of the number of sampled pueruli for collector groups used in the previous standardisation for Kaikoura.

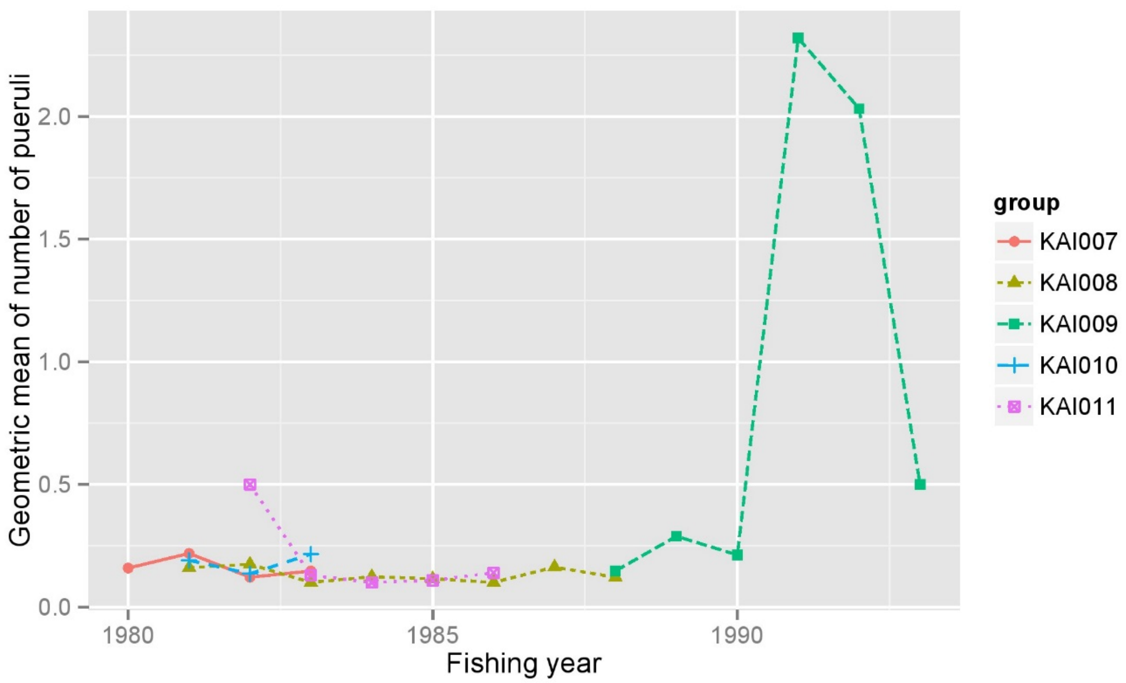

Figure 5: Geometric mean of the number of sampled pueruli for groups not used in the previous standardisation for Kaikoura.

Table 4: Kaikoura standardisation data set. Number of puerulus samples by group and fishing year.

	KAI001	KAI002	KAI003	KAI004	KAI005	KAI006	KAI008	KAI009	Total
1980	0	0	12	0	0	0	0	0	12
1981	24	0	24	0	0	0	21	0	69
1982	24	0	24	0	0	0	24	0	72
1983	24	0	21	0	0	0	27	0	72
1984	33	0	33	0	0	0	33	0	99
1985	27	0	23	0	0	0	33	0	83
1986	27	0	26	0	0	0	27	0	80
1987	36	0	36	0	0	0	36	0	108
1988	36	12	36	0	0	0	24	12	120
1989	36	36	39	0	0	0	0	36	147
1990	36	36	33	0	0	0	0	36	141
1991	36	33	36	0	0	0	0	33	138
1992	30	30	30	30	0	0	0	30	150
1993	30	30	30	30	0	0	0	21	141
1994	32	33	33	33	0	0	0	0	131
1995	36	36	36	36	0	0	0	0	144
1996	21	21	21	21	0	0	0	0	84
1997	18	18	18	15	0	0	0	0	69
1998	18	18	15	15	0	0	0	0	66
1999	21	21	24	24	0	0	0	0	90
2000	35	35	36	36	0	0	0	0	142
2001	36	33	36	36	0	0	0	0	141
2002	36	33	36	35	0	0	0	0	140
2003	60	0	60	0	0	0	0	0	120
2004	59	0	60	0	0	0	0	0	119
2005	60	0	60	0	0	0	0	0	120
2006	60	0	60	0	0	0	0	0	120
2007	60	0	65	0	21	9	0	0	155
2008	60	0	59	0	29	27	0	0	175
2009	59	0	60	0	30	27	0	0	176
2010	60	0	60	0	30	24	0	0	174
2011	60	0	60	0	24	18	0	0	162
2012	60	0	55	0	17	12	0	0	144
2013	54	0	55	0	3	3	0	0	115
2014	55	0	55	0	21	21	0	0	152

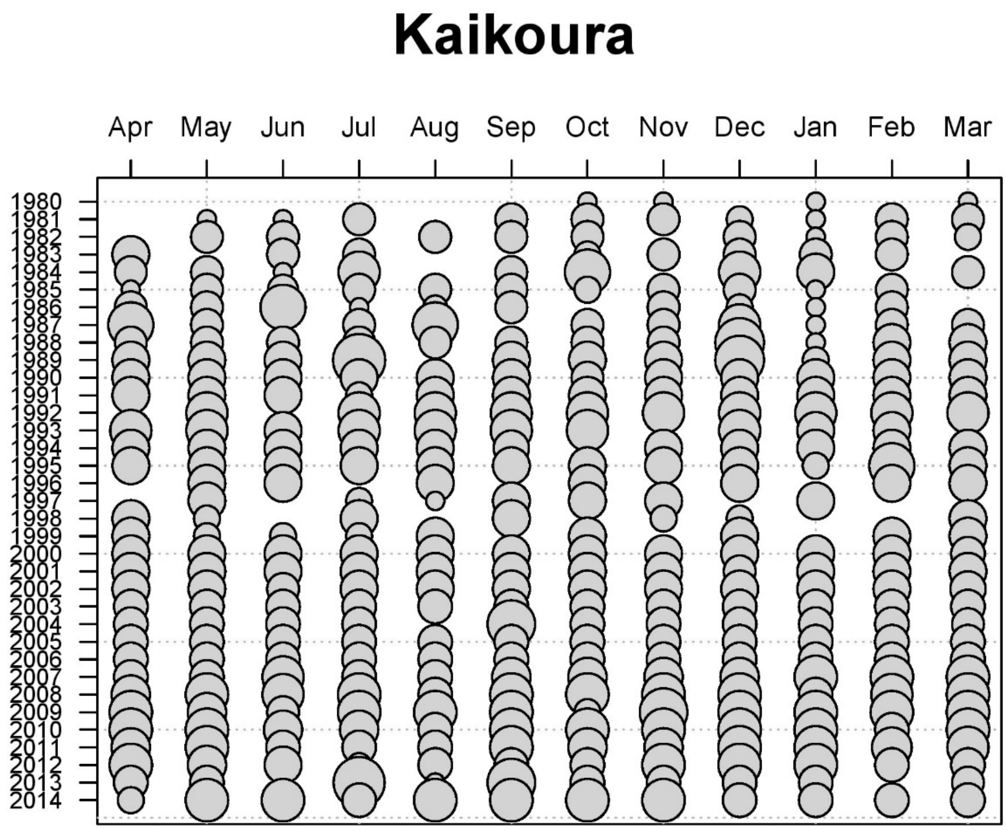

Figure 6: Number of samples by month and fishing year from Kaikoura. The area of a circle is proportional to the number of samples.

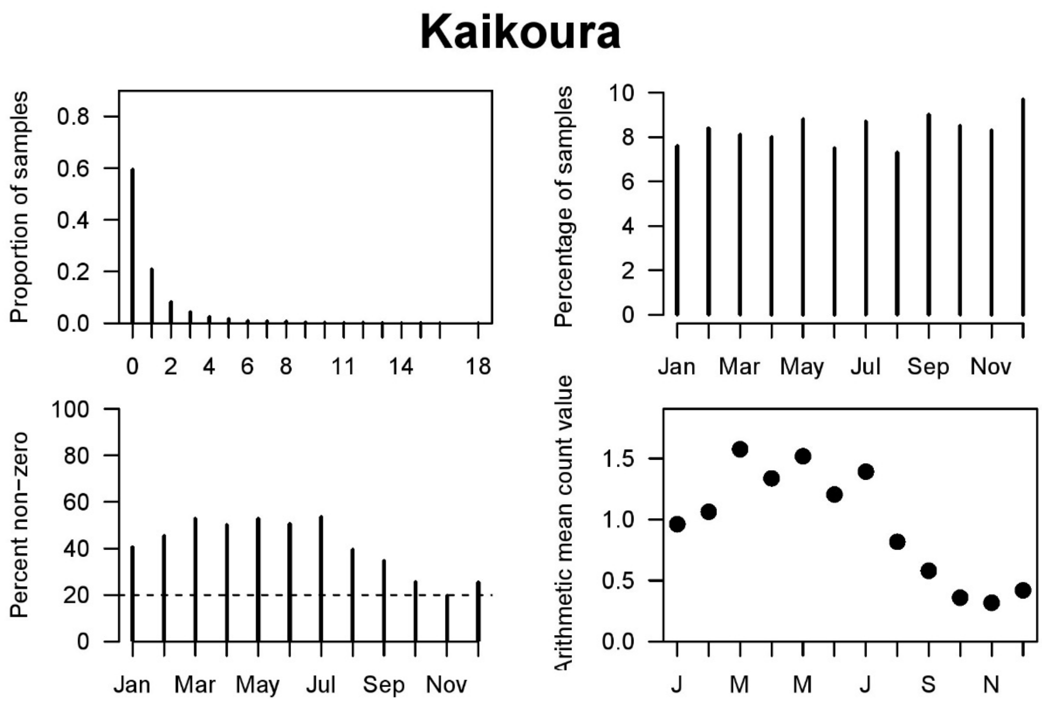

Figure 7: Characteristics of the Kaikoura puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample.

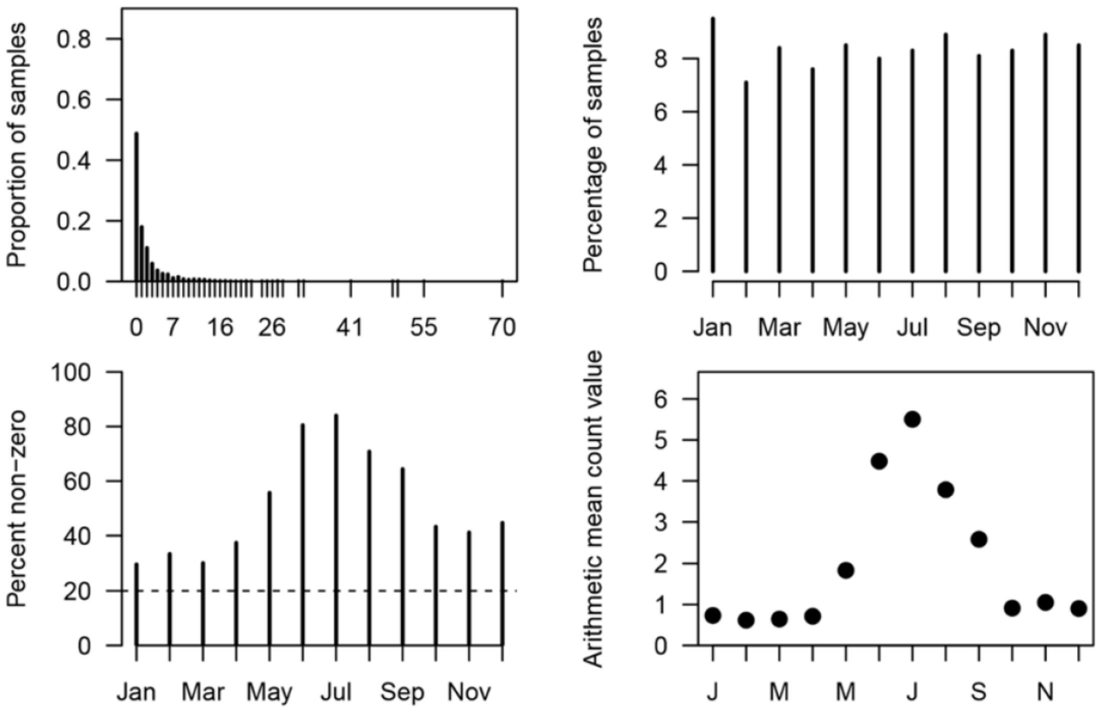

Figure 8: Characteristics of the Gisborne puerulus standardisation data from the previous standardisations (Forman et al. 2015). To reduce the proportion of zeros, the months May–September were used in the standardisation.

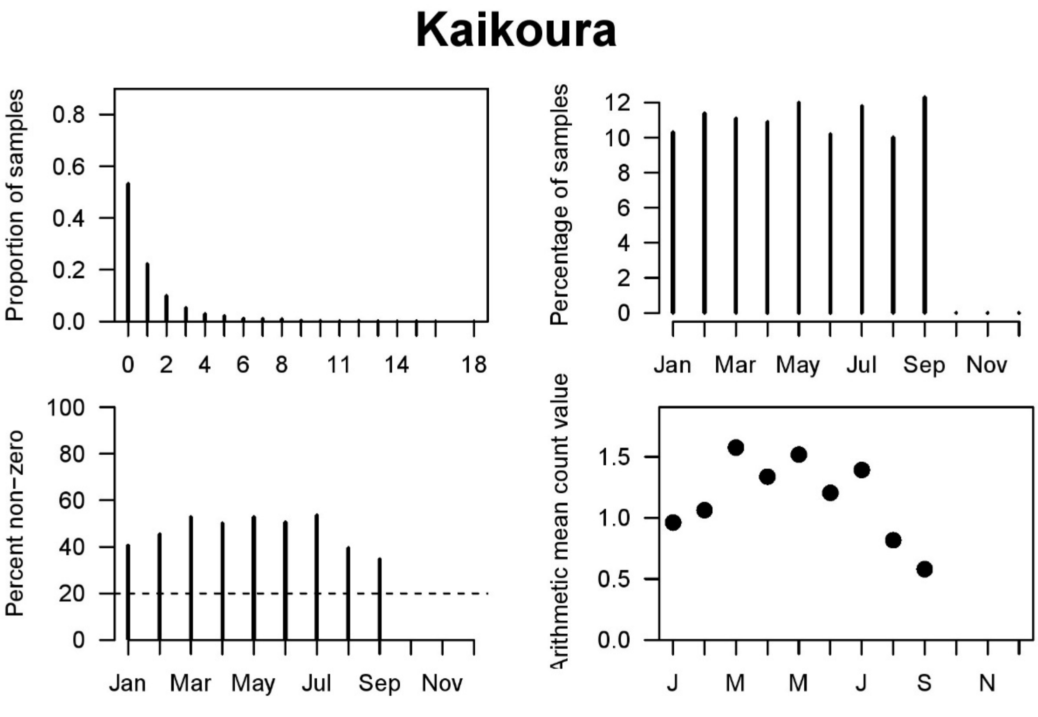

Figure 9: As in Figure 8, but retaining only data from the months January–September (inclusive).

Table 5: Number of puerulus samples from Kaikoura by group and fishing year after restricting to the months January–September (inclusive).

	KAI001	KAI002	KAI003	KAI004	KAI005	KAI006	KAI008	KAI009	Total
1980	0	0	6	0	0	0	0	0	6
1981	15	0	15	0	0	0	15	0	45
1982	18	0	18	0	0	0	18	0	54
1983	15	0	15	0	0	0	18	0	48
1984	21	0	21	0	0	0	24	0	66
1985	18	0	17	0	0	0	24	0	59
1986	21	0	20	0	0	0	24	0	65
1987	24	0	24	0	0	0	27	0	75
1988	24	6	24	0	0	0	18	9	81
1989	24	24	27	0	0	0	0	27	102
1990	27	27	27	0	0	0	0	27	108
1991	27	24	27	0	0	0	0	24	102
1992	21	21	21	21	0	0	0	21	105
1993	24	24	24	24	0	0	0	15	111
1994	26	27	27	27	0	0	0	0	107
1995	27	27	27	27	0	0	0	0	108
1996	15	15	15	15	0	0	0	0	60
1997	12	12	12	9	0	0	0	0	45
1998	12	12	15	15	0	0	0	0	54
1999	15	15	18	18	0	0	0	0	66
2000	26	26	27	27	0	0	0	0	106
2001	27	27	27	27	0	0	0	0	108
2002	27	24	27	26	0	0	0	0	104
2003	45	0	45	0	0	0	0	0	90
2004	44	0	45	0	0	0	0	0	89
2005	45	0	45	0	0	0	0	0	90
2006	45	0	45	0	0	0	0	0	90
2007	45	0	50	0	12	9	0	0	116
2008	45	0	44	0	20	18	0	0	127
2009	44	0	45	0	24	21	0	0	134
2010	45	0	45	0	21	15	0	0	126
2011	45	0	45	0	15	15	0	0	120
2012	45	0	40	0	11	6	0	0	102
2013	39	0	40	0	3	3	0	0	85
2014	40	0	40	0	15	15	0	0	110

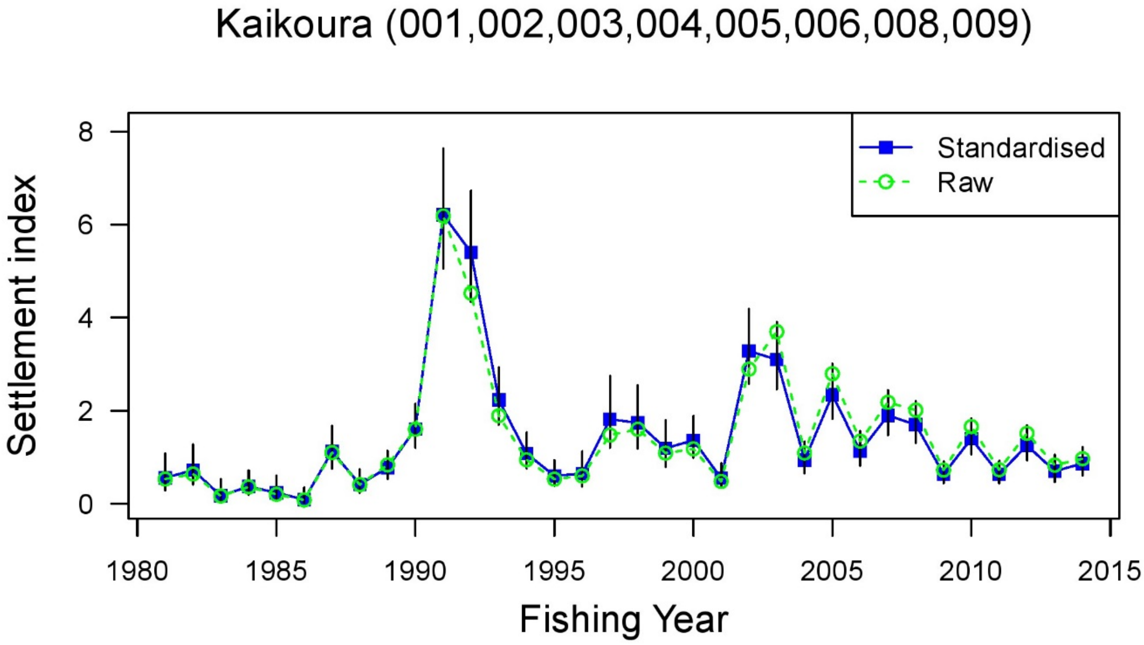

Figure 10: Standardised and raw indices of settlement from Kaikoura with 95% confidence intervals. Indices are scaled to have a geometric mean of one. The standardisation uses a quasi-Poisson model.

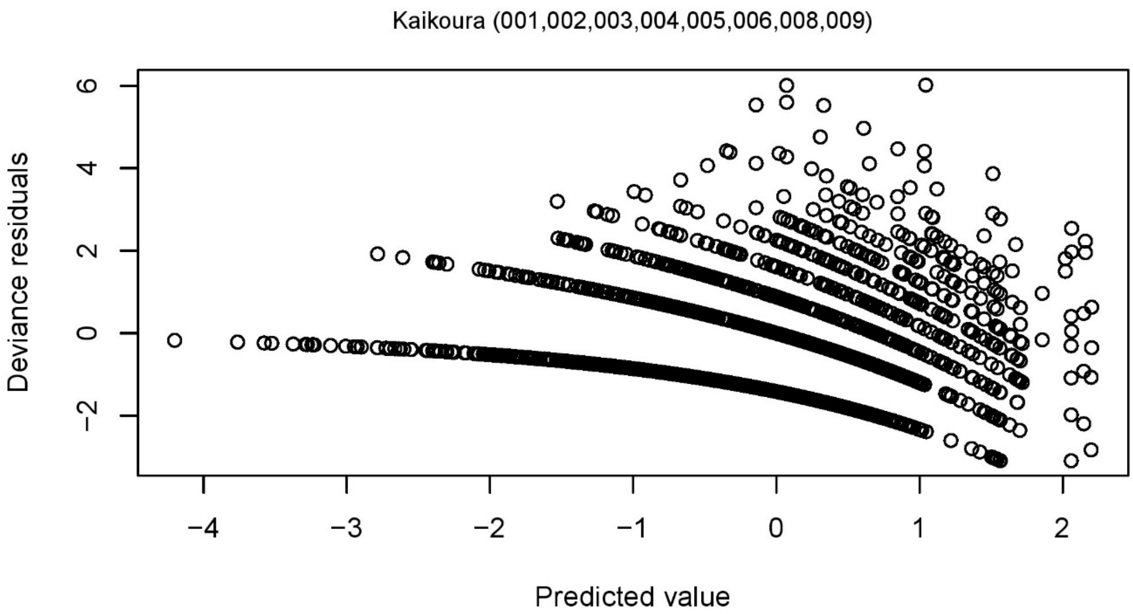

Figure 11: Residuals for the quasi-Poisson standardisation model (Kaikoura). The predicted values are in log space.

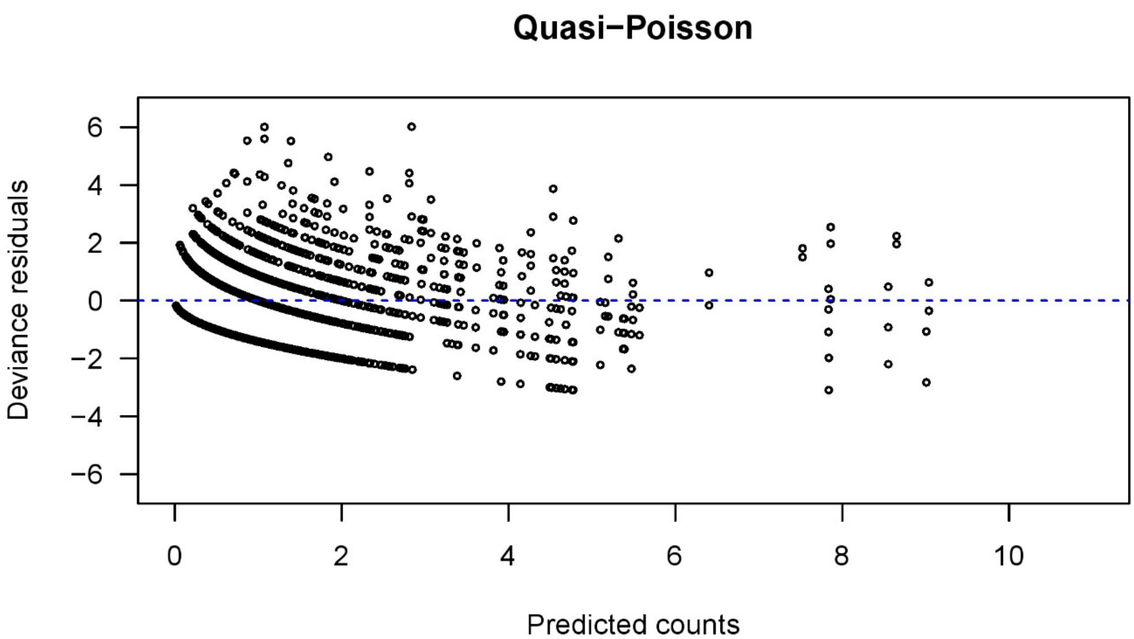

Figure 12: Deviance residuals for the quasi-Poisson model (Kaikoura). Predicted counts are in natural space.

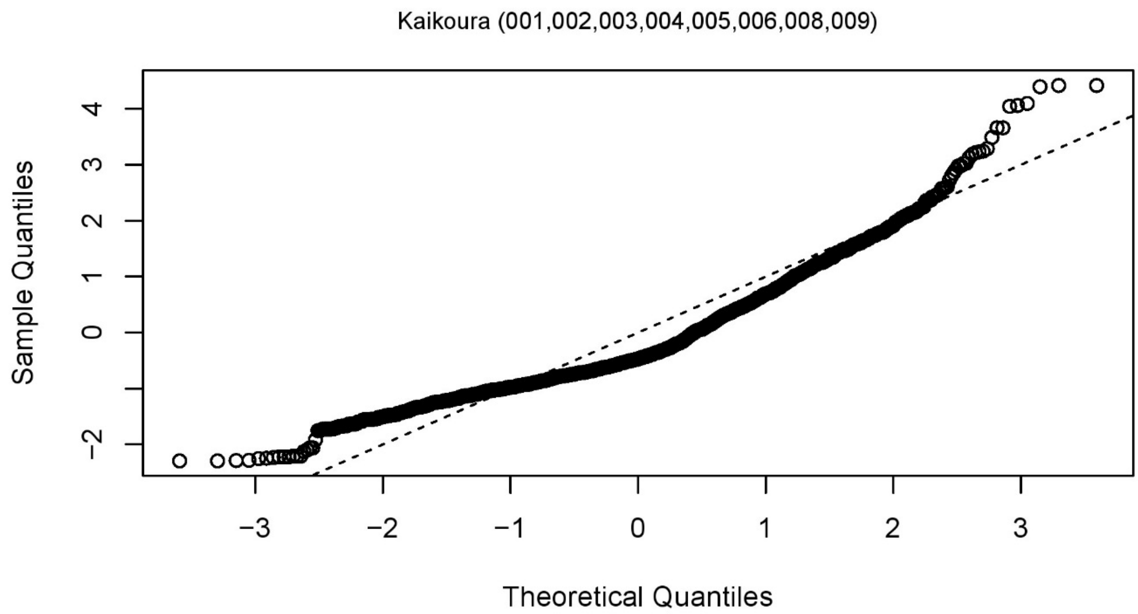

Figure 13: Quantile-quantile plot from the quasi-Poisson standardisation model for Kaikoura.

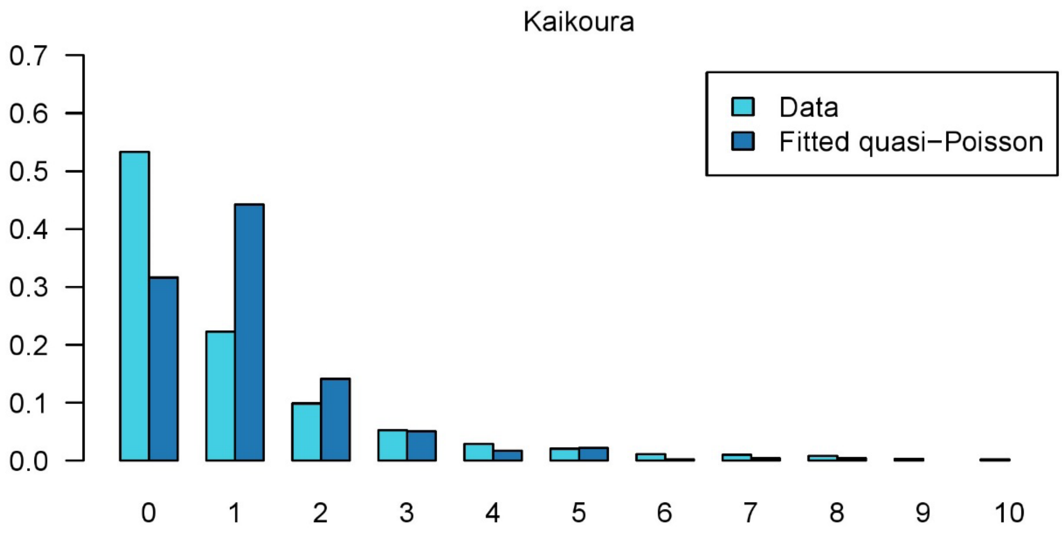

Figure 14: Data distribution and that from the fitted quasi-Poisson model for Kaikoura.

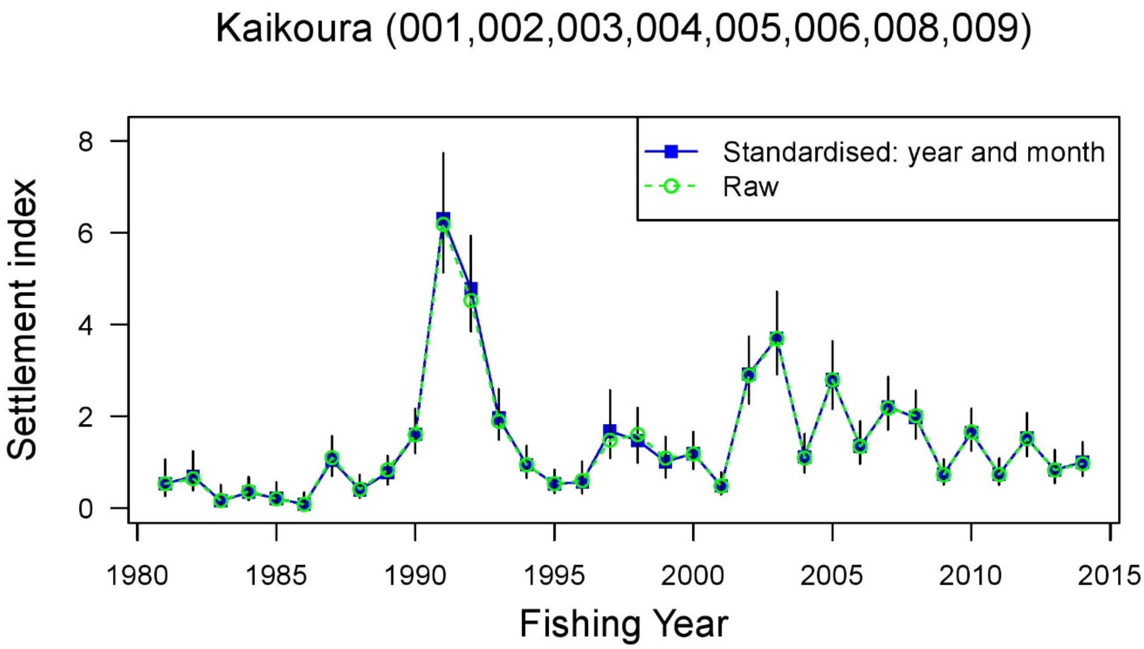

Figure 15: Effect on the standardised indices for Kaikoura of dropping group from the standardisation (thus using only year and month).

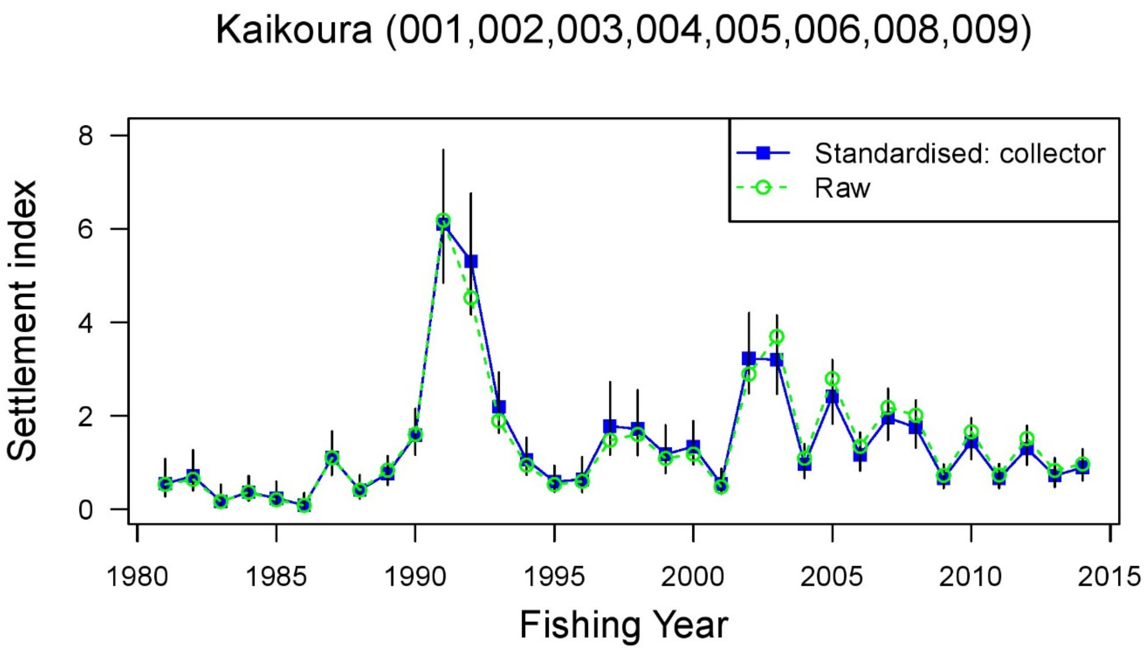

Figure 16: Effect on the standardised indices for Kaikoura of using collector instead of group in the standardisation. Standardised and raw indices of settlement with 95% confidence intervals.

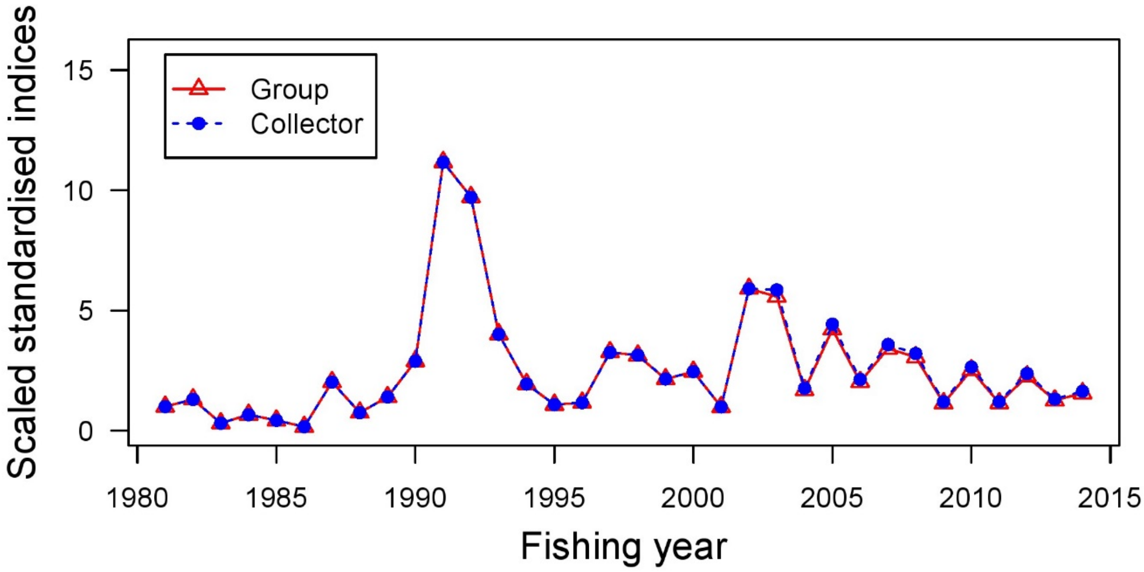

Figure 17: Using collector instead of group in the Kaikoura quasi-Poisson model standardisation. The indices are scaled to have the value 1.0 in the first year.

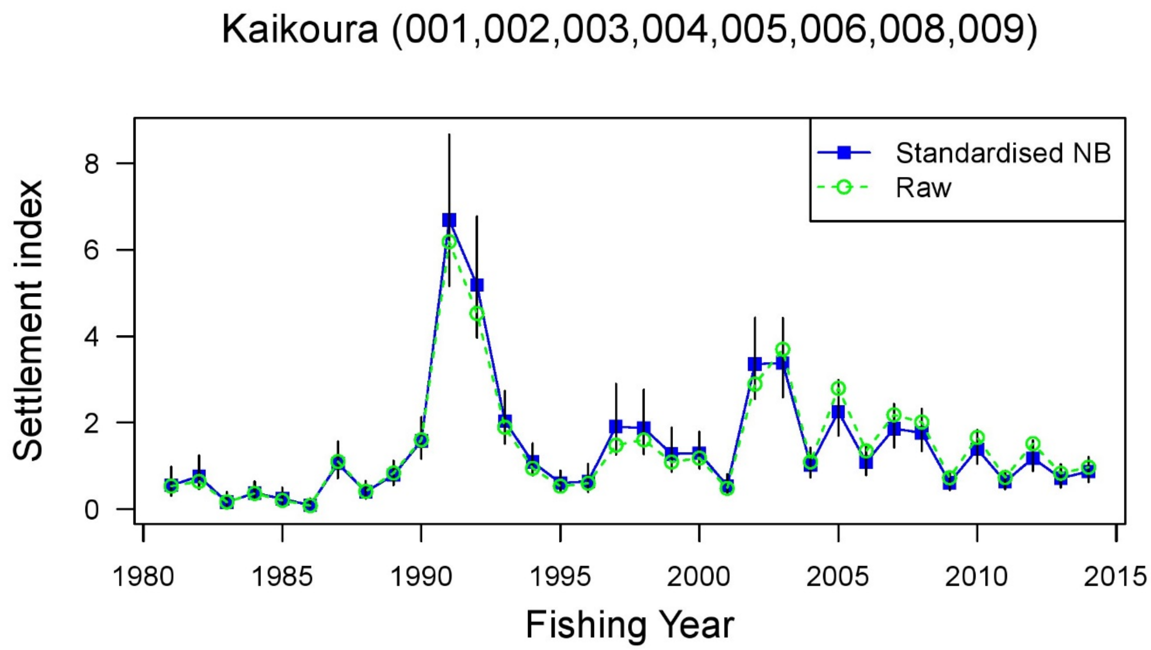

Figure 18: Negative binomial model for Kaikoura. Standardised and raw indices with 95% confidence intervals.

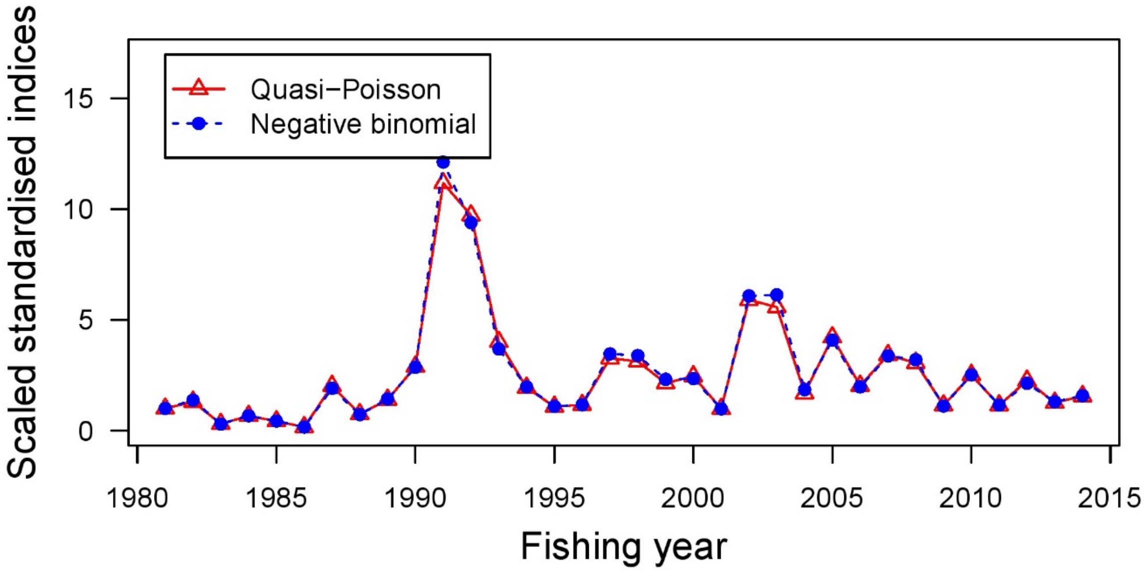

Figure 19: Using a negative binomial model instead of quasi-Poisson in the standardisation for Kaikoura. The standardised indices are scaled to value 1.0 in the first year.

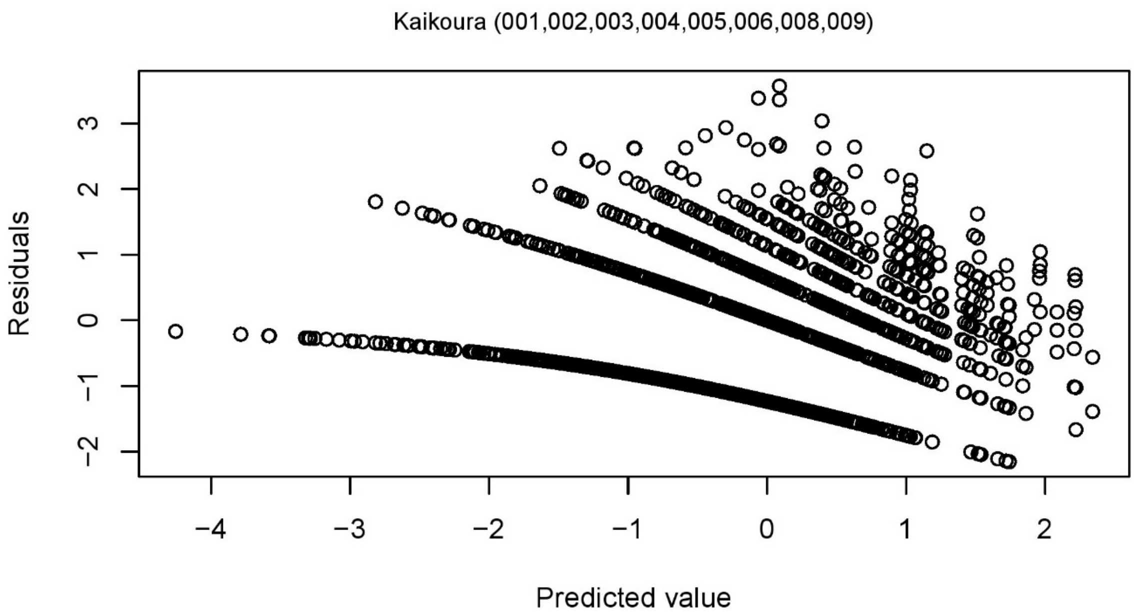

Figure 20: Residuals for negative binomial standardisation model for Kaikoura data. The predicted values are in log space.

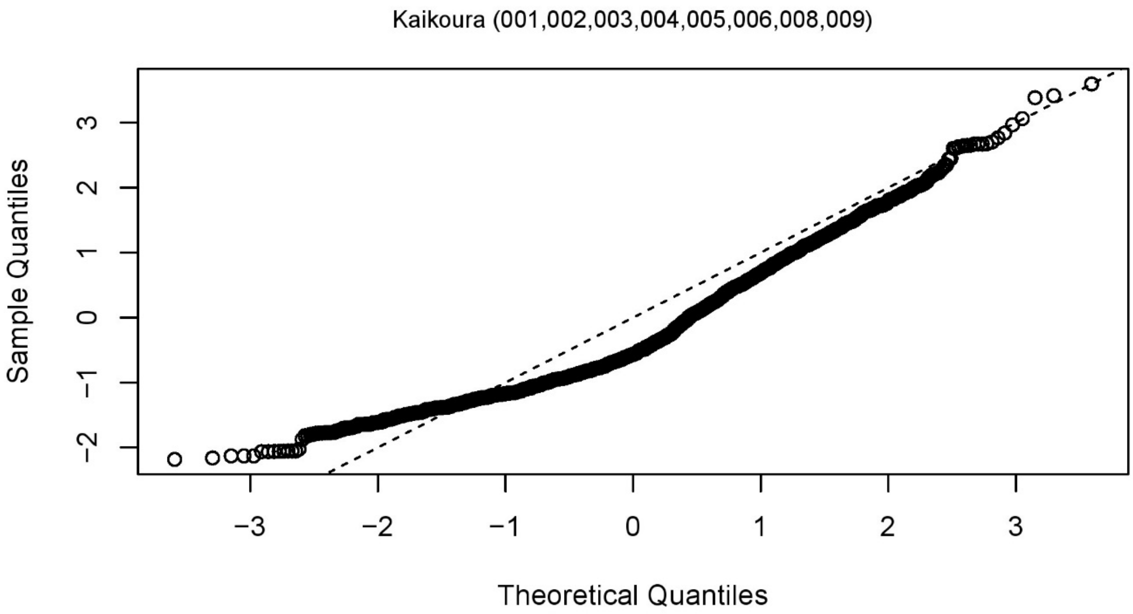

Figure 21: Quantile-quantile plot for the negative binomial standardisation model for Kaikoura.

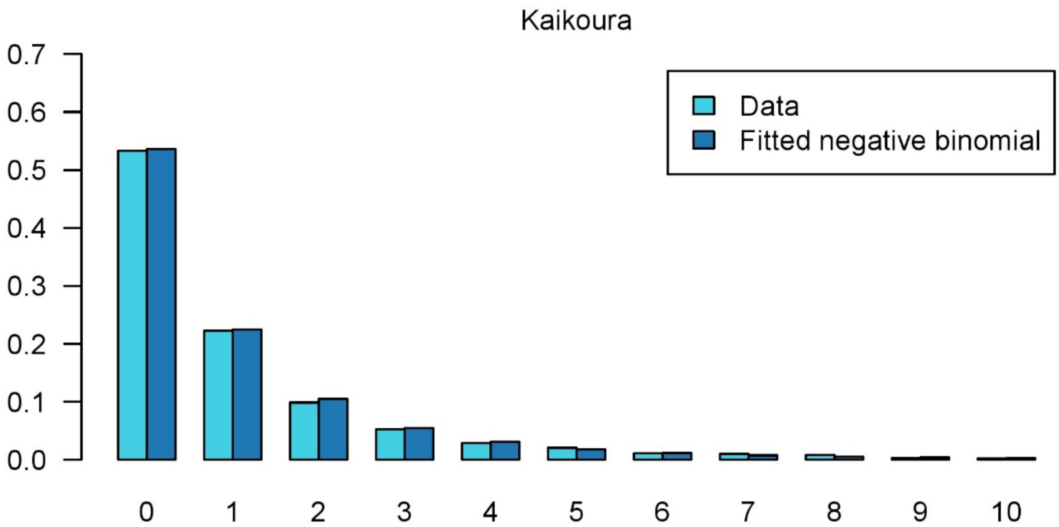

Figure 22: Data distribution and that from the fitted negative binomial for Kaikoura.

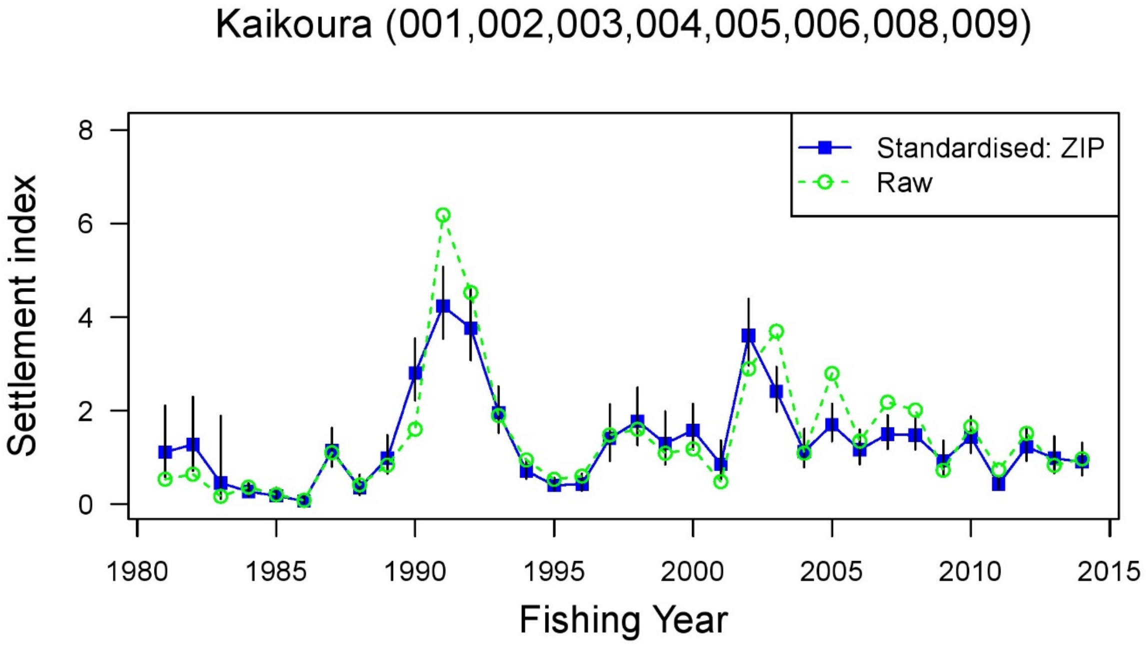

Figure 23: Zero Inflated Poisson (ZIP) model for Kaikoura data. Standardised and raw indices with 95% confidence intervals.

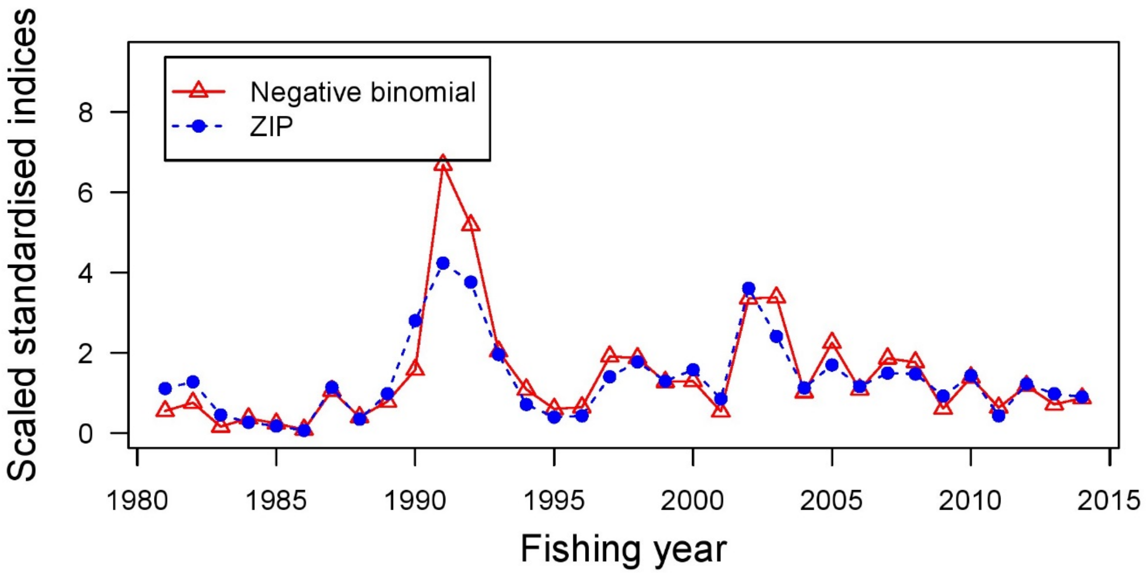

Figure 24: Using zero inflated Poisson (ZIP) instead of negative binomial for the standardisation of Kaikoura data.

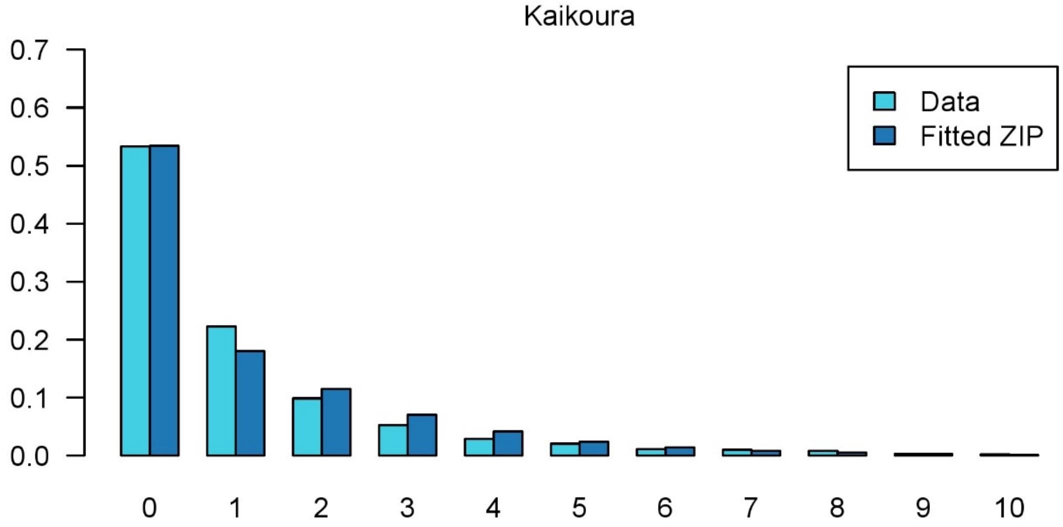

Figure 25: Data distribution and that from the fitted ZIP model for Kaikoura data.

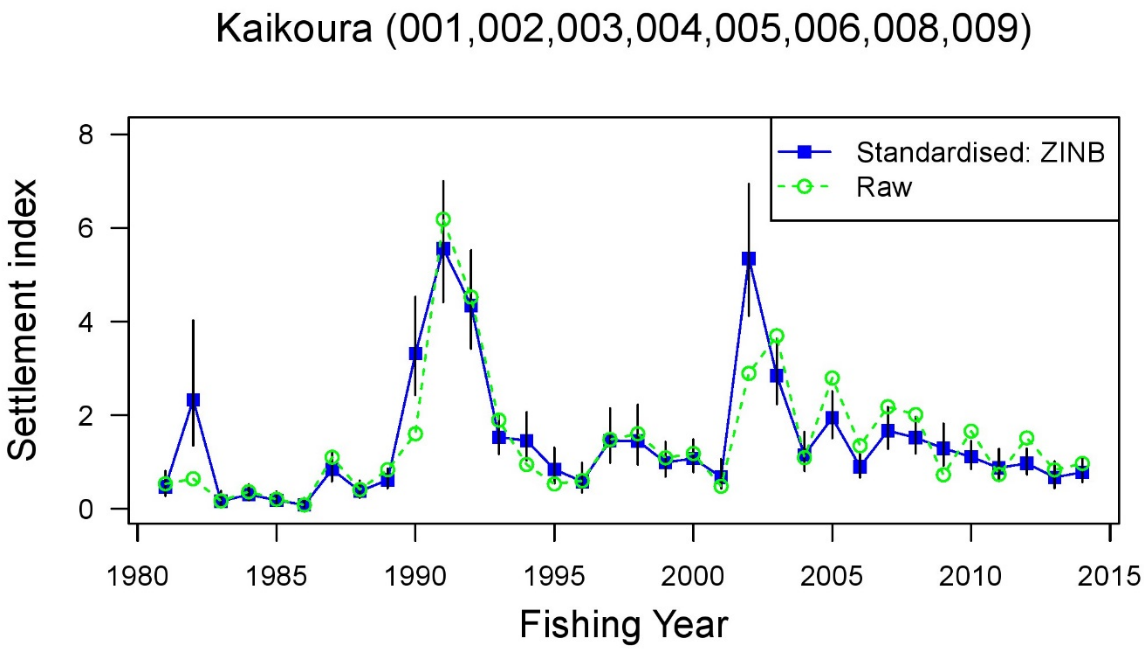

Figure 26: Zero-inflated negative binomial (ZINB) model for Kaikoura data. Standardised and raw indices with 95% confidence intervals.

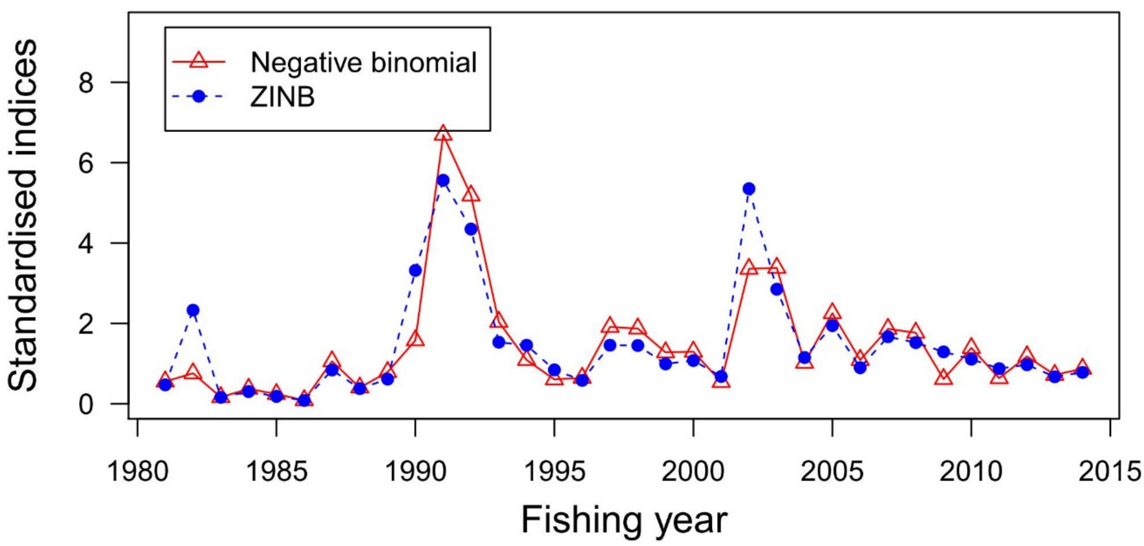

Figure 27: Using zero inflated negative binomial (ZINB) instead of negative binomial in the standardisation of Kaikoura data.

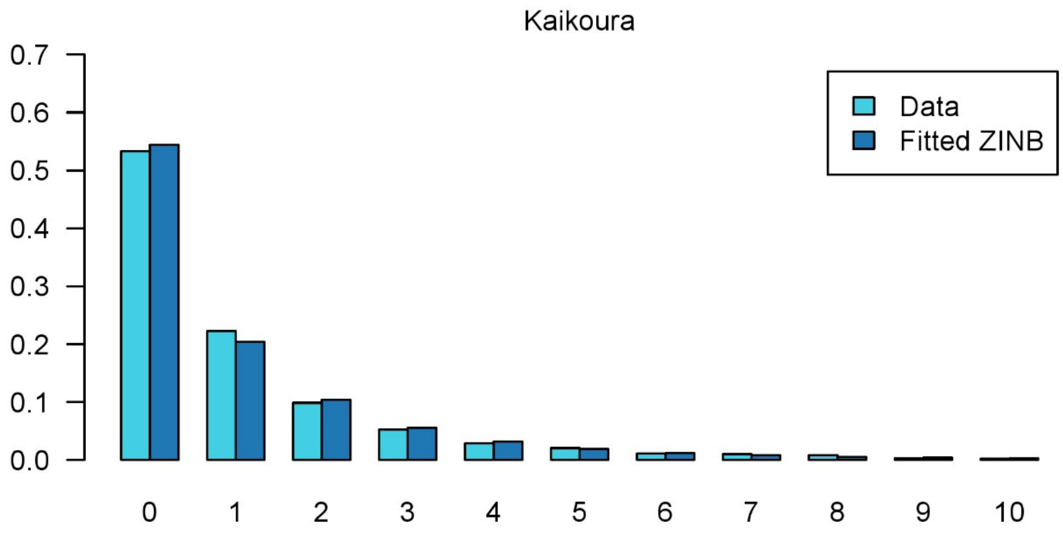

Figure 28: Data distribution and that from the ZINB model for Kaikoura data.

Table 6: AIC for three alternative standardisation models for Kaikoura data. All models had year, group, and month selected as predictor variables.

Model	AIC
Negative binomial	7 923
ZIP	8 158
ZINB	7 658

3.4 Moeraki data characterisation

Moeraki is the only site in the CRA 7 area with collectors, and henceforth in this document reference will be made to Moeraki instead of CRA 7 (Figure 1).

In the recent Moeraki standardisation two groups of collectors were used (002,007) and only collectors for which there are at least 36 samples have been used. In the following we look at the characteristics of sampling from the Moeraki collectors before any subsetting of the data is done

At the Moeraki site 7 groups have been in place at various times with a total of 43 collectors used. These groups are labelled 001, 002, ..., 007. The number of samples by group and year is shown in Table 7. The sampling periods for the collectors is shown graphically in Figure 29, and the total number of samples from each in Figure 30.

In previous standardisations the group of collectors 001, 003, and 004 have been dropped as they were inefficient at catching puerulus, leading to very high proportions of zeros in the samples (Figures 31–33).

Collectors are filtered for use in the standardisation with the requirement that they have at least 36 samples. This rule has the effect of dropping five collectors from 007, and all of the groups 005 and 006 (Figure 30). After dropping groups that are inefficient at catching puerulus, and filtering on the number of samples for a collector, the groups remaining are 002 and 007.

3.5 Moeraki puerulus settlement standardisation

3.5.1 Summary of Moeraki standardisation data

After dropping groups that are inefficient at sampling, and applying the criteria that there be a minimum of 36 samples for each collector, only collector groups 002 and 007 remain in the dataset. The number of samples for each year is shown in Table 8, with the months December through to February sporadically sampled (Figure 34). The highest settlement occurs from June to September (Figure 35).

Based on when the mean count value is highest, and the months with the highest proportion of non-zeros, the same months May–October were selected for the Moeraki standardisation as previously (see Forman et al. 2014). With subsetting on the months, the proportion of zeros drops, but is still higher than 0.7 (Figure 36). The remaining number of samples by year is shown in Table 9.

3.5.2 Initial standardisation

An initial standardisation was done using the quasi-Poisson model of the previous standardisation. Both group and month were offered to the standardisation as predictor variables, and accepted into the model. The resulting index is shown in Figure 37, with residual and quantile-quantile plots in Figures 38–40.

The fitted model has an estimated dispersion of 1.35 and fewer zeros than the data (Figure 41). The standardised and raw indices are very similar, with the small differences mainly due to the month effect in the standardisation (Figure 37, Figure 42). It makes little difference to the standardised index if collector is used instead of group in the standardisation (Figures 43–44).

3.5.3 Other standardisation models

An alternative model for overdispersed data is the negative binomial. For this model group and month were selected as predictor variables. The standardised index is very similar to that from the quasi-Poisson (Figures 45–46) however residual diagnostics are better for the negative binomial model than the quasi-Poisson in that they are smaller, and the quantiles are a better fit at the high end (Figures 47–49). The fitted negative binomial distribution has a size parameter of 3.18 and is a better fit to the data than the approximate quasi-Poisson plot (Figure 41, Figure 50).

Another way of dealing with the excess zeros in the data is to use zero-inflated models, either (i) a zero-inflated Poisson (ZIP), or (ii) a zero-inflated negative binomial (ZINB). However, both of these models gave singularity errors, and were not pursued any further.

Table 7: Number of puerulus samples at Moeraki by group and fishing year.

	MOE001	MOE002	MOE003	MOE004	MOE005	MOE006	MOE007
1982	8	0	0	0	0	0	0
1983	13	0	0	0	0	0	0
1984	11	0	0	0	0	0	0
1985	9	0	0	0	0	0	0
1986	12	0	17	0	0	0	0
1987	14	0	14	0	0	0	0
1988	20	0	12	0	0	0	0
1989	18	0	15	0	0	0	0
1990	23	5	0	0	0	0	0
1991	22	21	18	0	0	0	0
1992	15	17	17	21	0	0	0
1993	17	18	22	24	0	0	0
1994	23	18	14	19	0	0	0
1995	23	21	24	24	0	0	0
1996	18	24	21	21	0	0	0
1997	27	24	21	30	0	0	0
1998	9	24	0	18	0	0	0
1999	3	18	0	24	24	24	0
2000	0	30	0	27	33	21	0
2001	0	24	0	3	24	0	13
2002	0	30	0	0	12	0	12
2003	0	24	0	0	0	0	139
2004	0	12	0	0	0	0	169
2005	0	21	0	0	0	0	139
2006	0	9	0	0	0	0	77
2007	0	0	0	0	0	0	117
2008	0	0	0	0	0	0	122
2009	0	0	0	0	0	0	57
2010	0	0	0	0	0	0	67
2011	0	0	0	0	0	0	99
2012	0	0	0	0	0	0	70
2013	0	0	0	0	0	0	60
2014	0	0	0	0	0	0	54

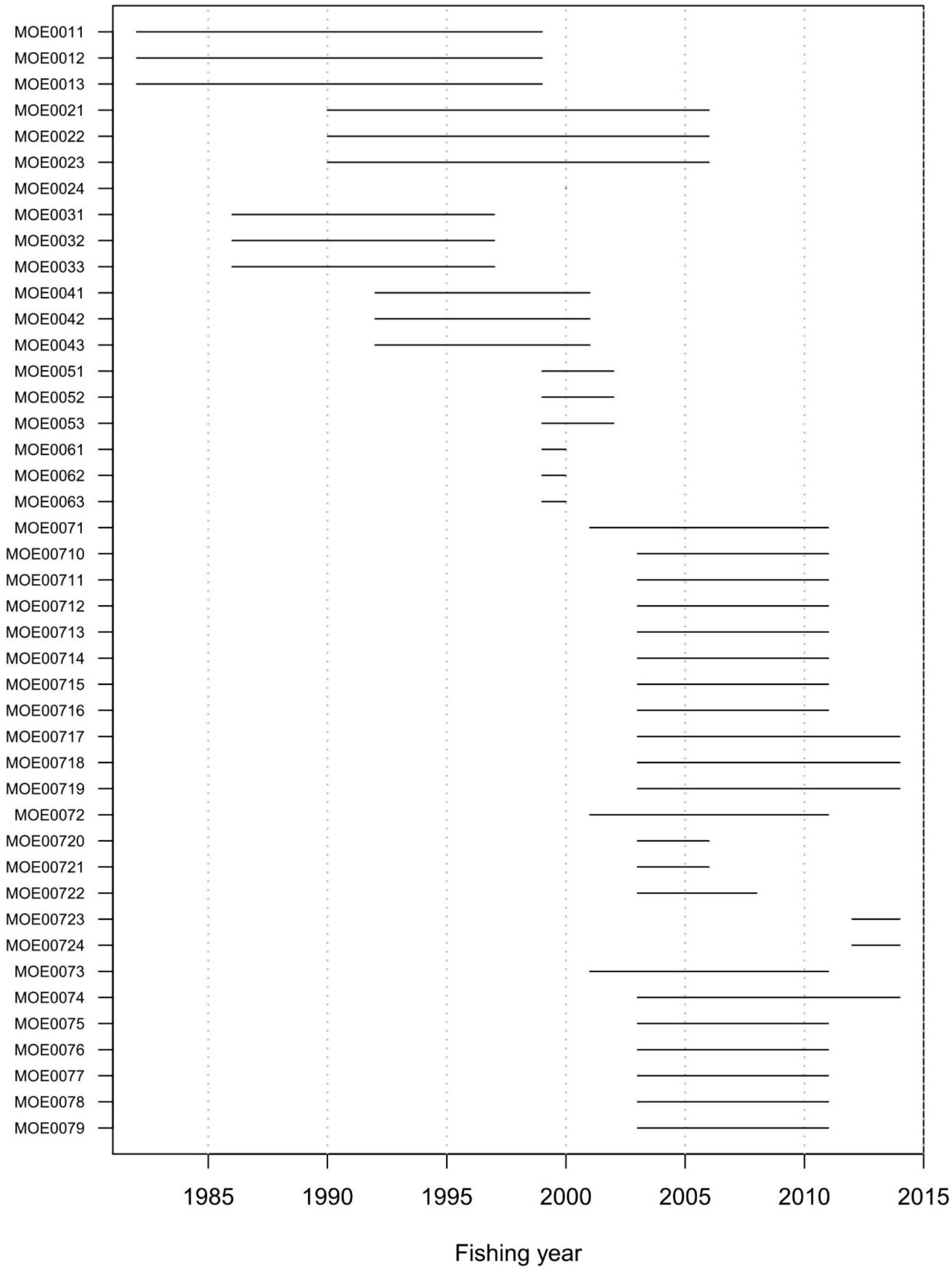

Figure 29: The fishing years over which the collectors have been in operation in Moeraki.

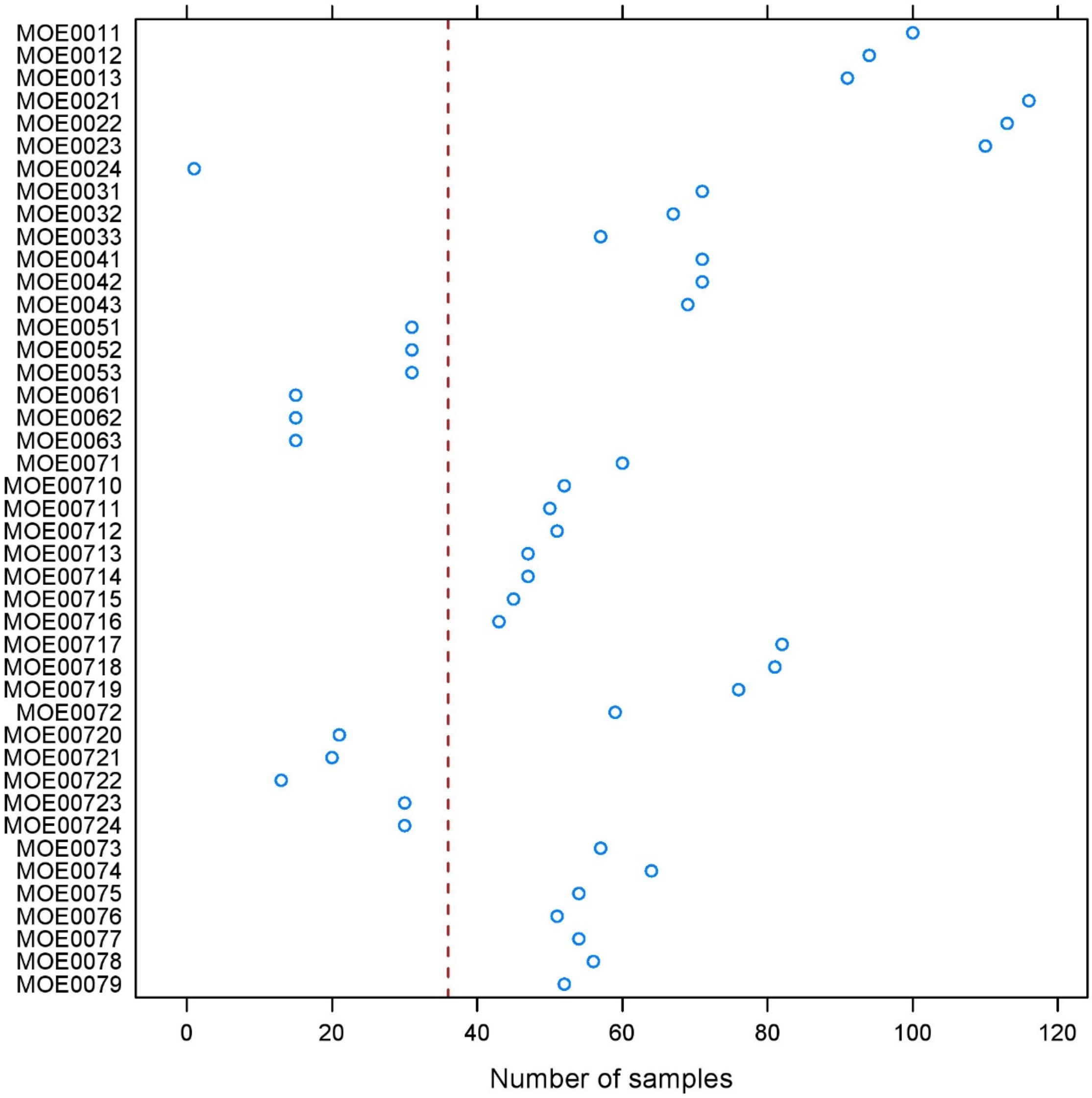

Figure 30: The total number of samples taken from each collector in Moeraki. The vertical dashed line is at 36 samples.

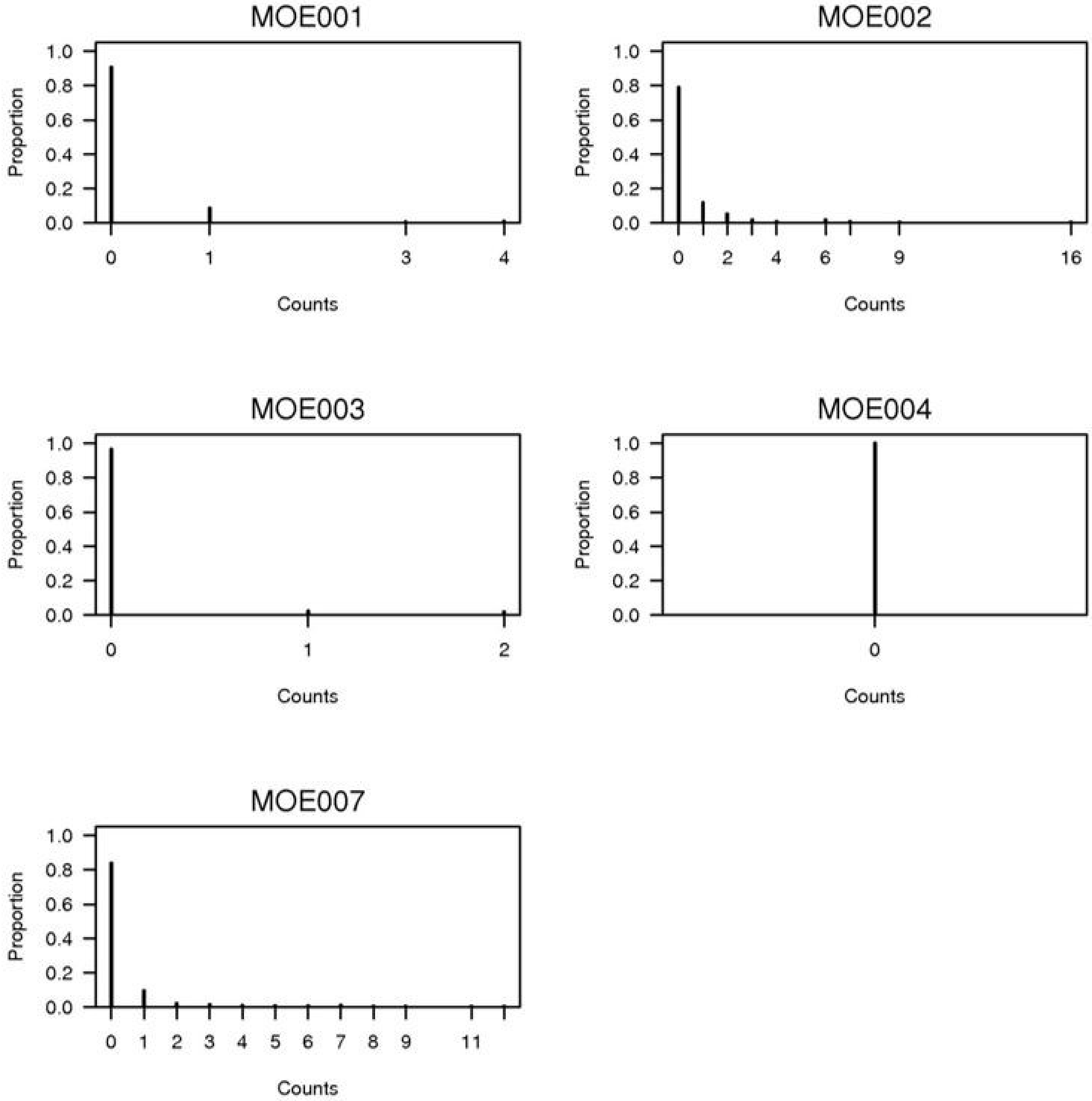

Figure 31: Number of pueruli counted in samples from Moeraki (only including collectors that have been sampled at least 36 times). Reproduced from figure A2 in (Forman et al. 2014).

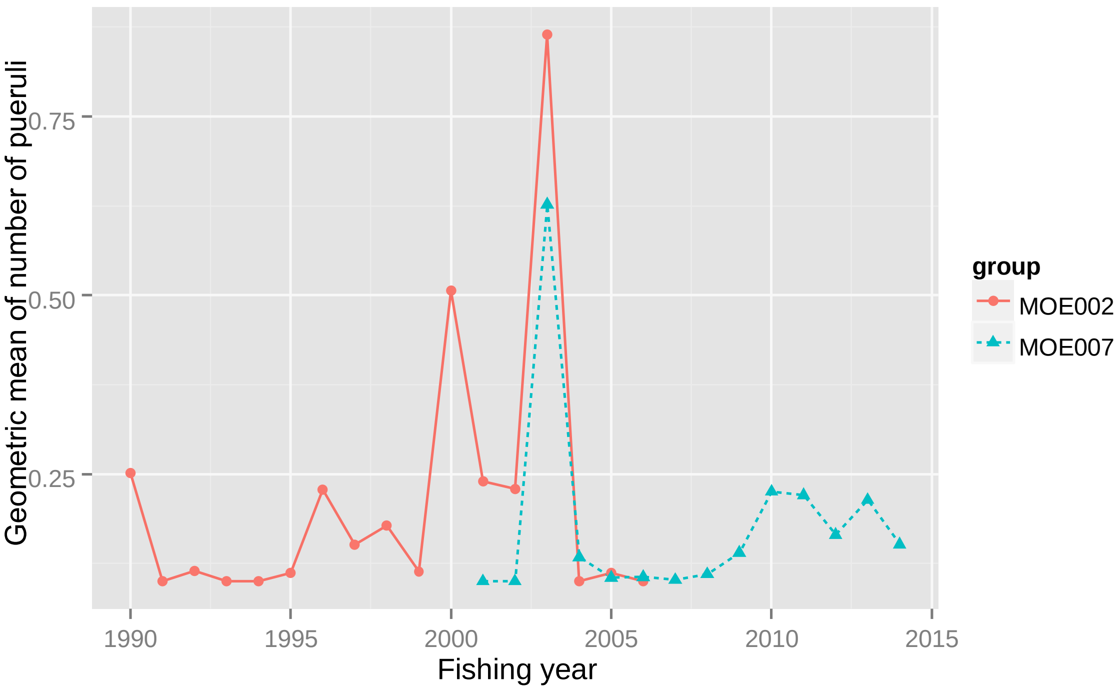

Figure 32: Geometric mean of number of sampled pueruli for groups used in the previous standardisation of Moeraki data.

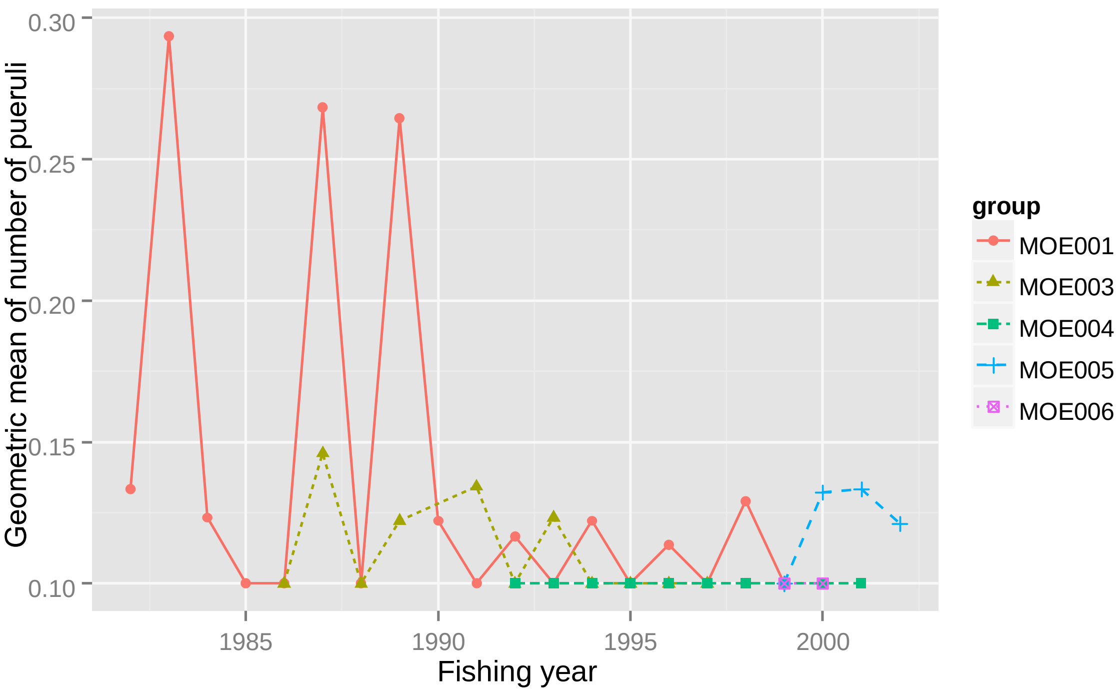

Figure 33: Geometric mean of number of sampled pueruli for groups not used in the previous standardisation of Moeraki data.

Table 8: Moeraki standardisation data set. Number of puerulus samples by group and fishing year.

	MOE002	MOE007	Total
1991	21	0	21
1992	17	0	17
1993	18	0	18
1994	18	0	18
1995	21	0	21
1996	24	0	24
1997	24	0	24
1998	24	0	24
1999	18	0	18
2000	29	0	29
2001	24	13	37
2002	30	12	42
2003	24	128	152
2004	12	147	159
2005	21	123	144
2006	9	73	82
2007	0	117	117
2008	0	121	121
2009	0	57	57
2010	0	67	67
2011	0	99	99
2012	0	48	48
2013	0	40	40
2014	0	36	36

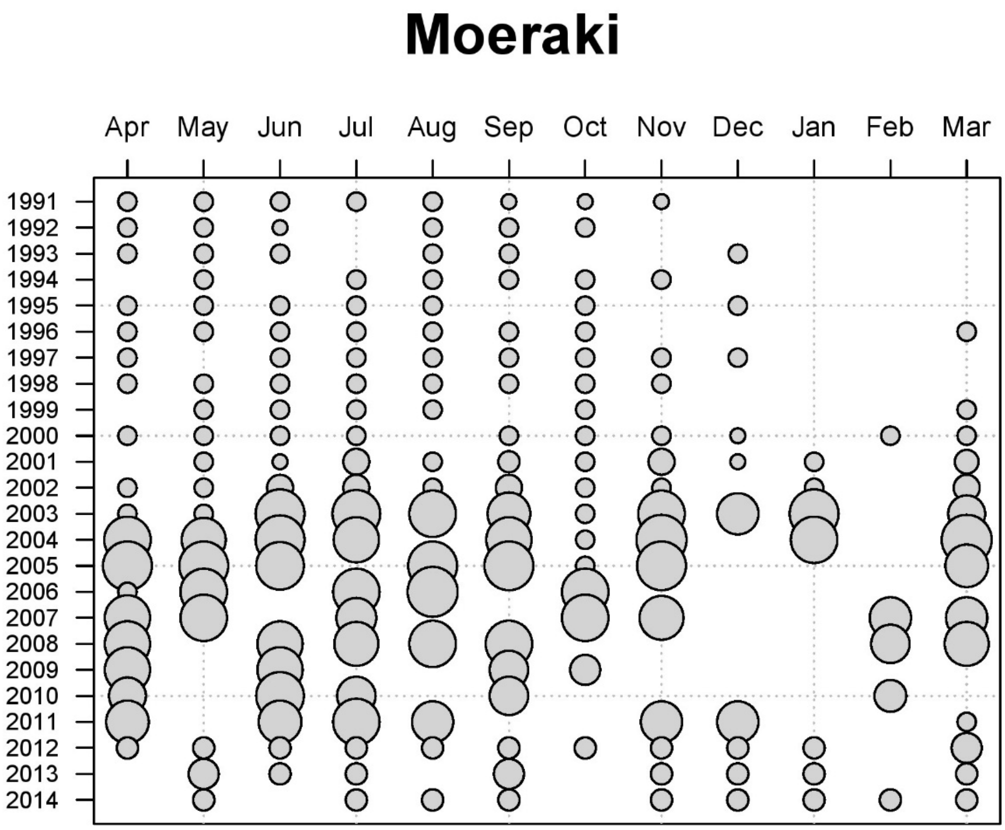

Figure 34: Number of samples by month and fishing year from Moeraki. The area of a circle is proportional to the number of samples, with a maximum value of 20.

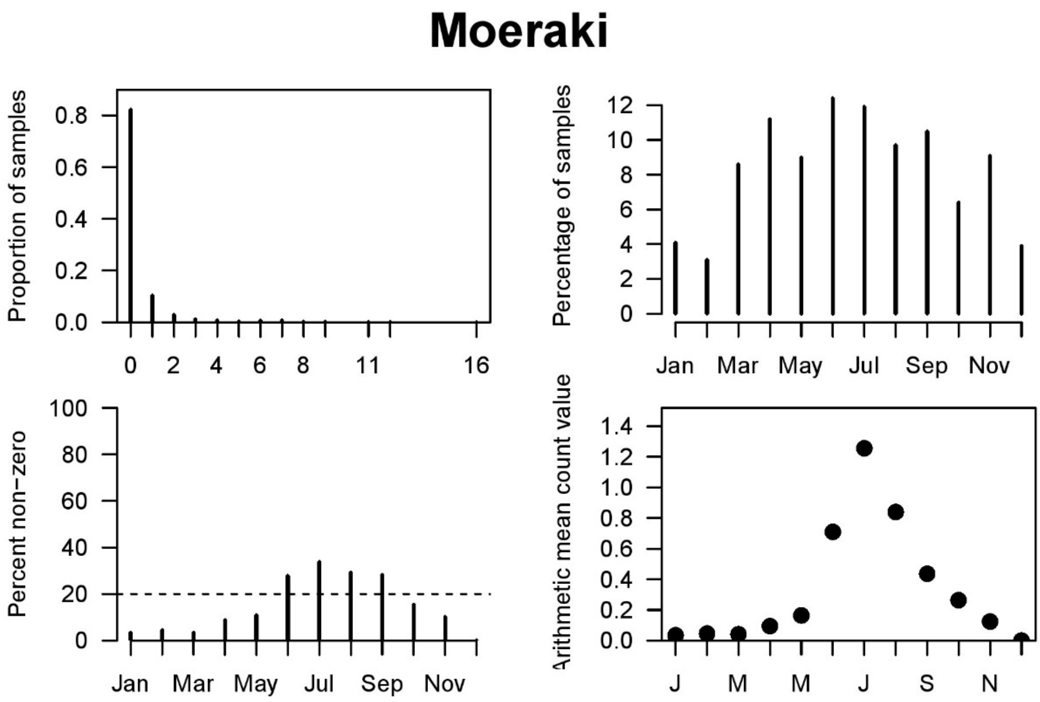

Figure 35: Characteristics of the Moeraki puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample.

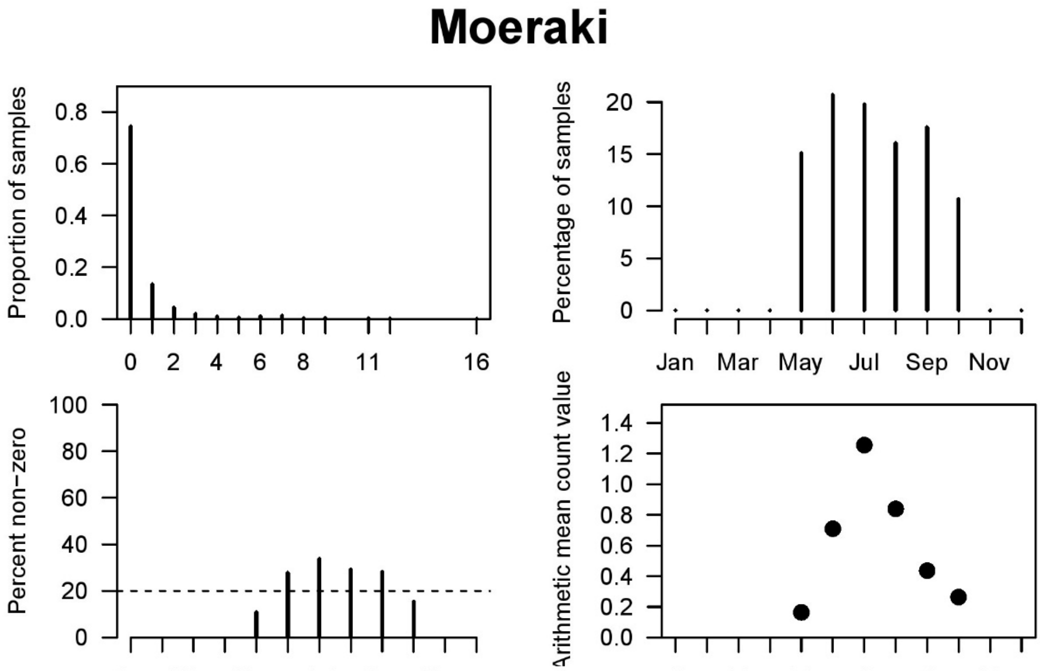

Figure 36: Characteristics of the Moeraki puerulus standardisation data restricted to the months May to October. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

Table 9: Number of puerulus samples at Moeraki by group and fishing year after restricting to the months May–September (inclusive).

	MOE002	MOE007	Total
1991	16	0	16
1992	14	0	14
1993	12	0	12
1994	15	0	15
1995	15	0	15
1996	18	0	18
1997	15	0	15
1998	18	0	18
1999	15	0	15
2000	15	0	15
2001	17	4	21
2002	18	9	27
2003	15	67	82
2004	6	71	77
2005	15	71	86
2006	6	73	79
2007	0	52	52
2008	0	73	73
2009	0	39	39
2010	0	46	46
2011	0	50	50
2012	0	24	24
2013	0	24	24
2014	0	16	16

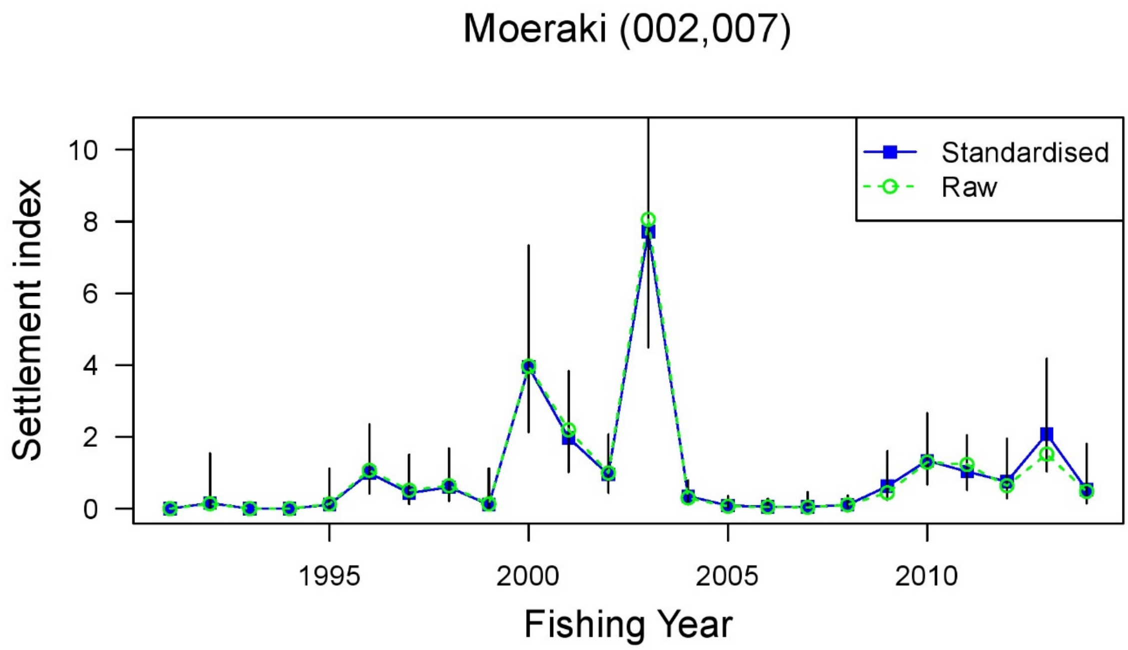

Figure 37: Standardised and raw indices of settlement from Moeraki with 95% confidence intervals. Indices are scaled to have a geometric mean of one. The standardisation model is quasi-Poisson.

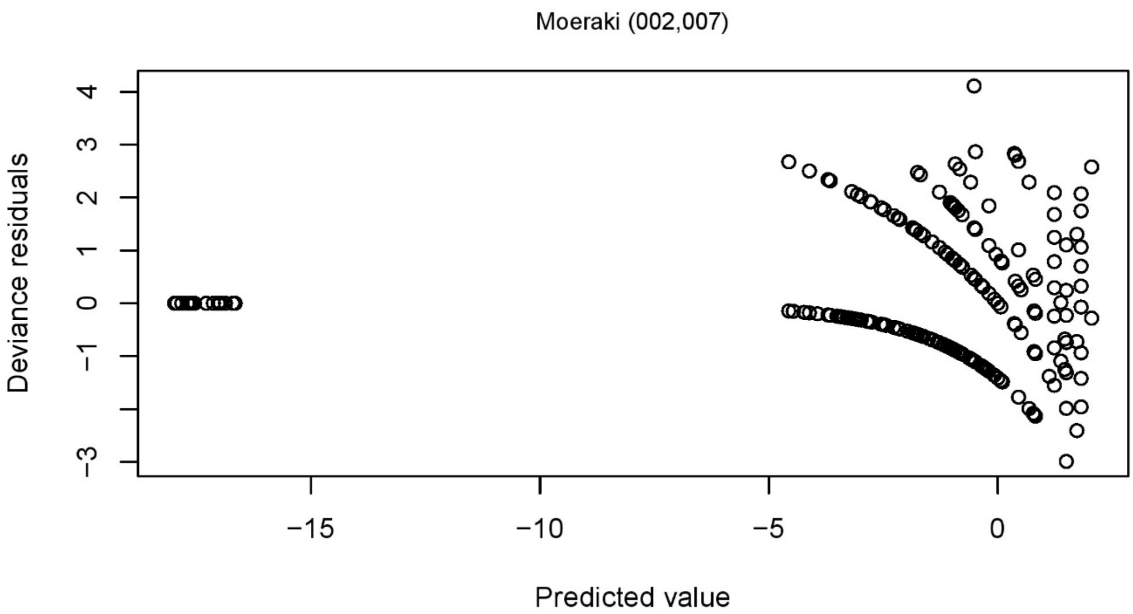

Figure 38: Residuals for the quasi-Poisson standardisation model for Moeraki. The predicted values are in log space.

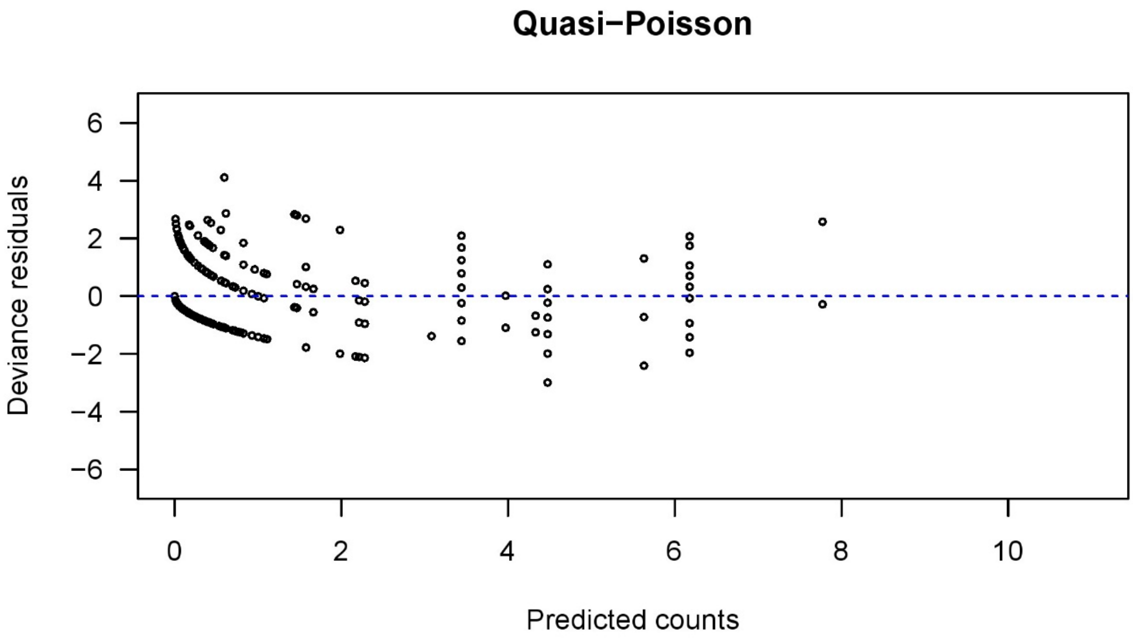

Figure 39: Deviance residuals for the quasi-Poisson model for Moeraki. Predicted counts are in natural space.

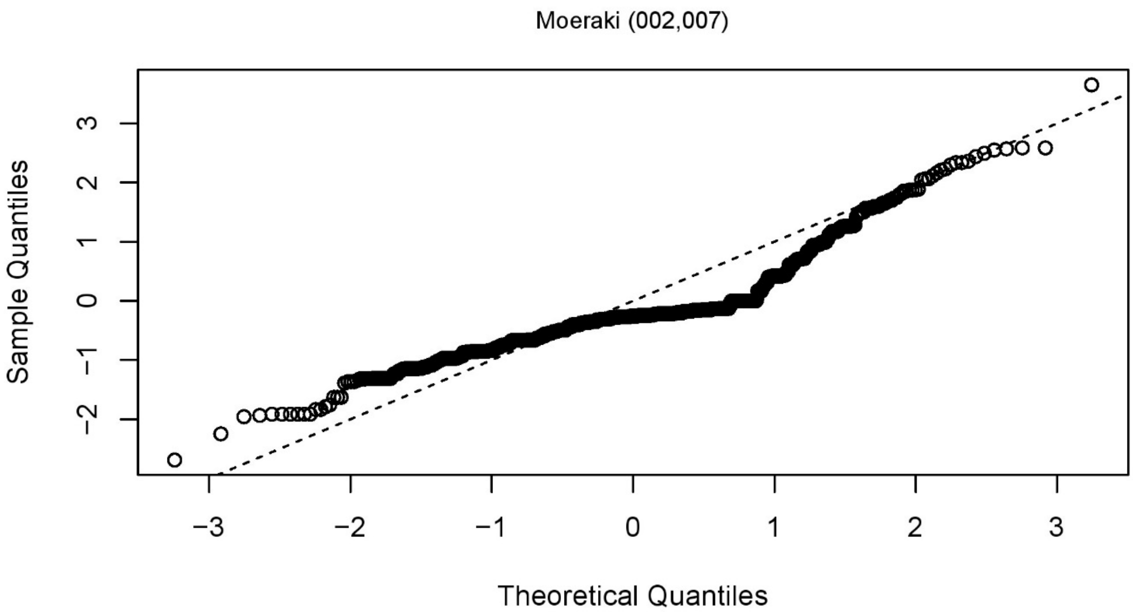

Figure 40: Quantile-quantile plot from the quasi-Poisson standardisation model for Moeraki.

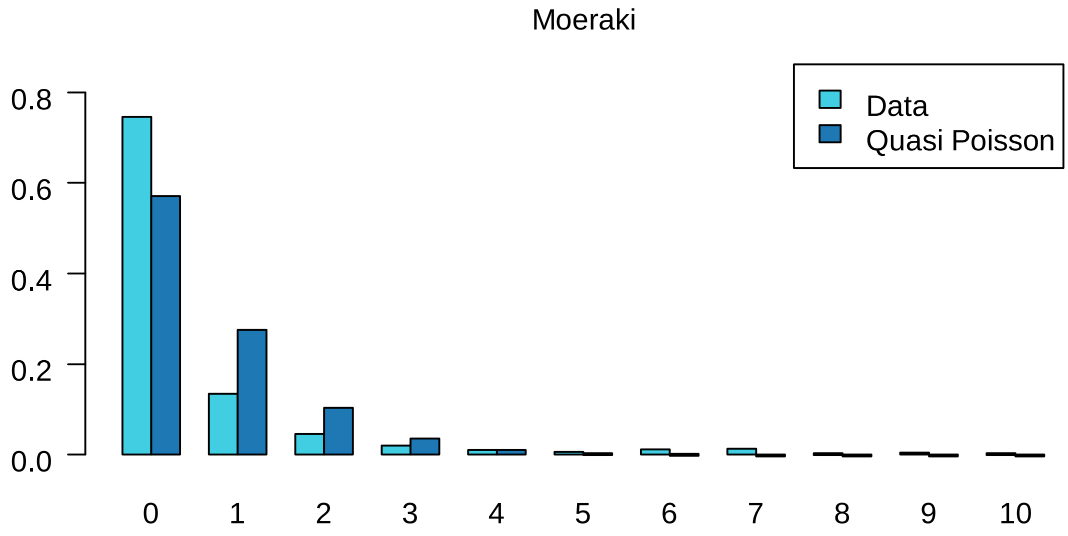

Figure 41: Data distribution and that from the fitted quasi-Poisson for Moeraki(approximated by a negative binomial).

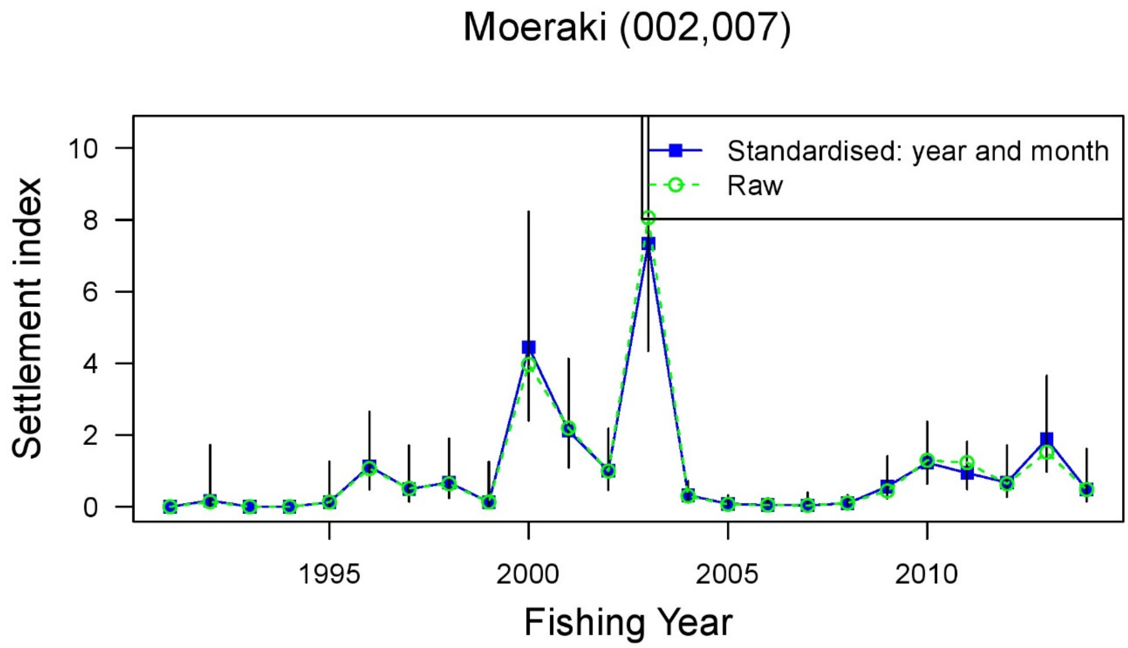

Figure 42: Effect on the standardisation indices for Moeraki of dropping group from the standardisation (thus using only year and month).

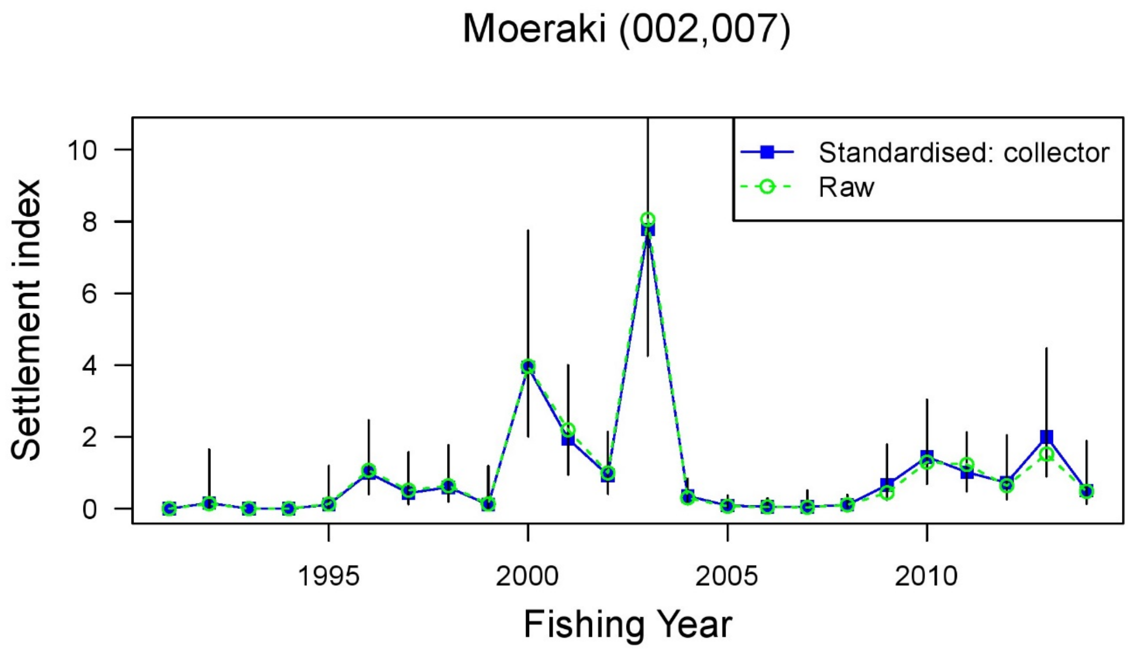

Figure 43: Using collector instead of group in the standardisation for Moeraki. Standardised and raw indices of settlement with 95% confidence intervals.

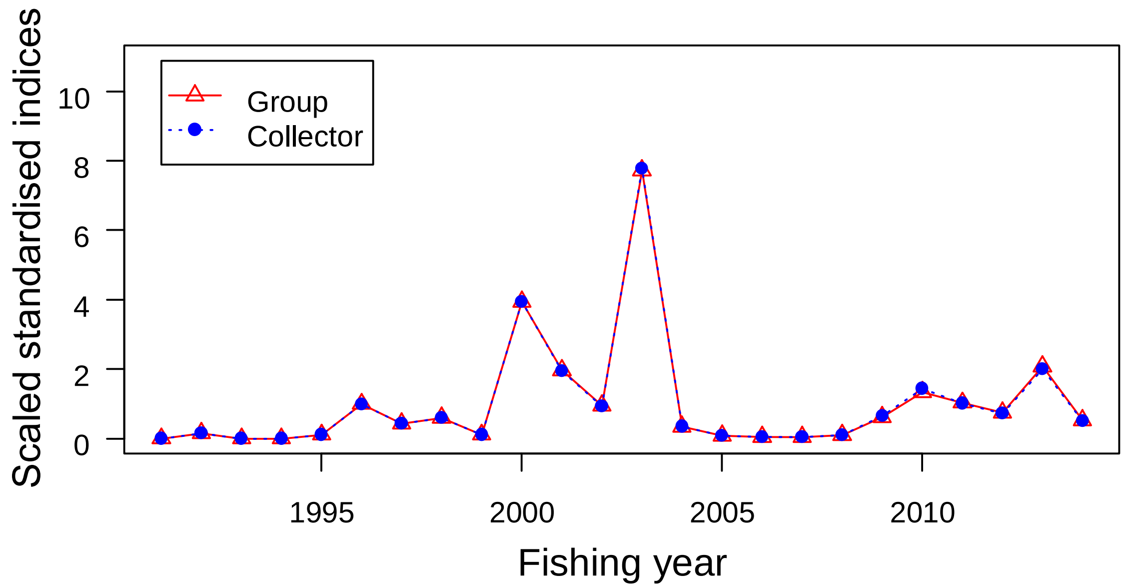

Figure 44: Using collector instead of group in the standardisation for Moeraki.

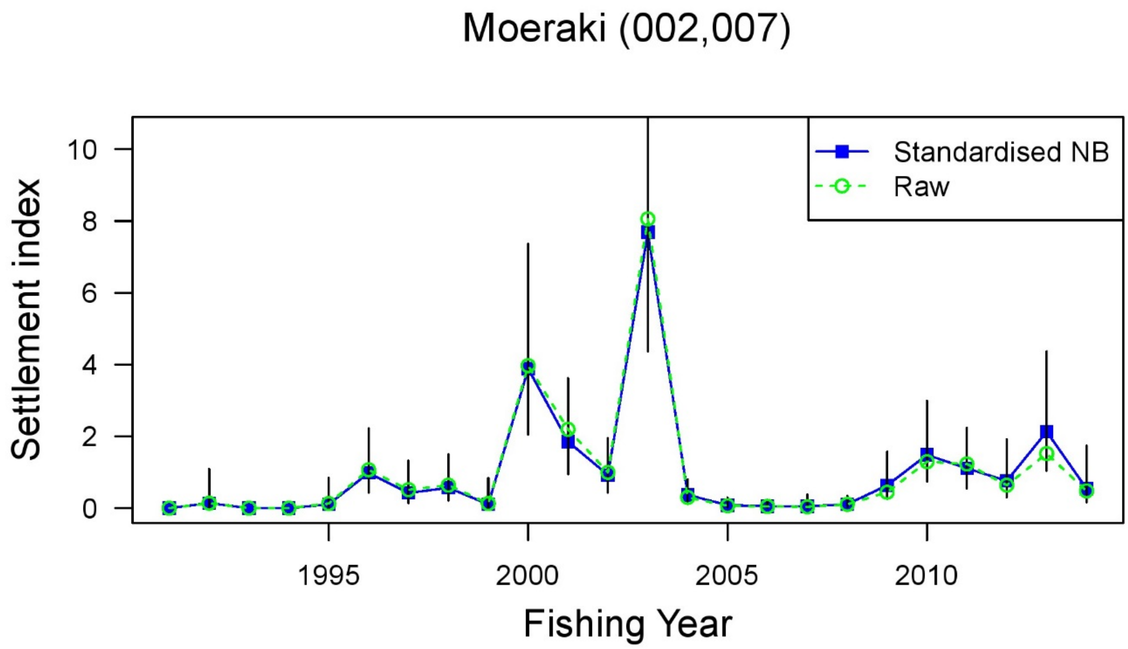

Figure 45: Negative binomial model for Moeraki. Standardised and raw indices with 95% confidence intervals.

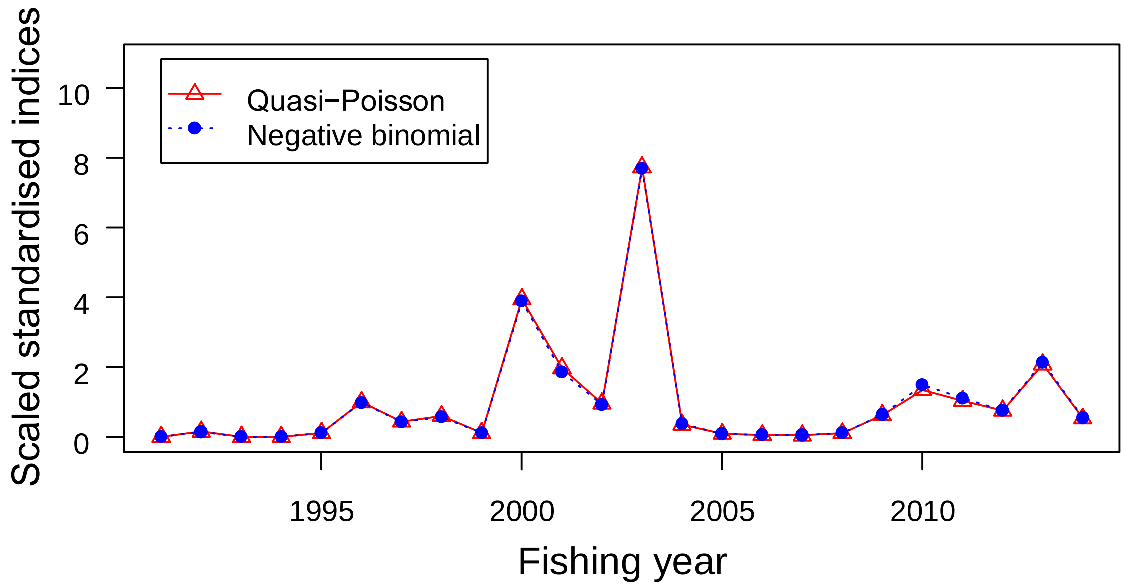

Figure 46: Using negative binomial instead of quasi-Poisson in the standardisation for Moeraki.

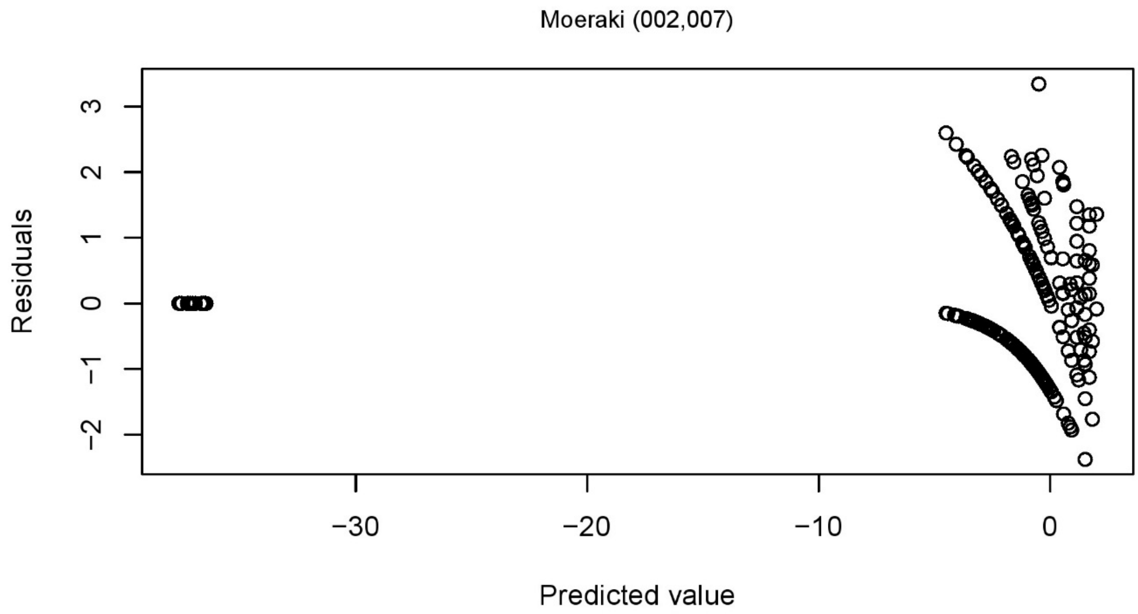

Figure 47: Residuals for negative binomial standardisation model for Moeraki. The predicted values are in log space.

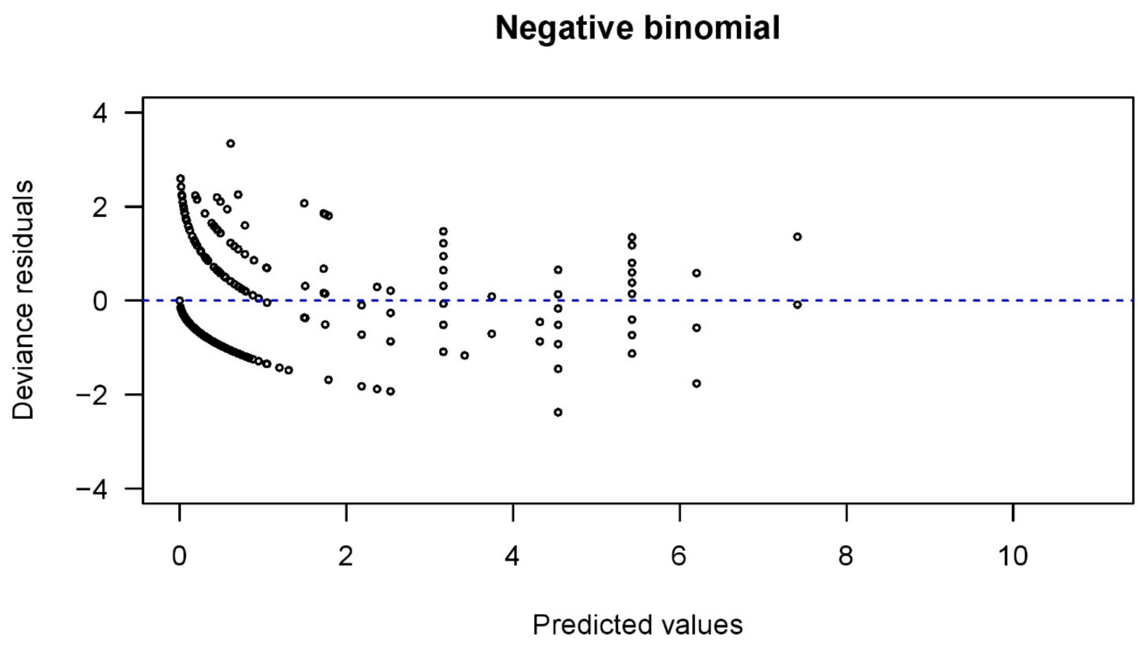

Figure 48: Deviance residuals for the negative binomial model for Moeraki. Predicted values are in natural space.

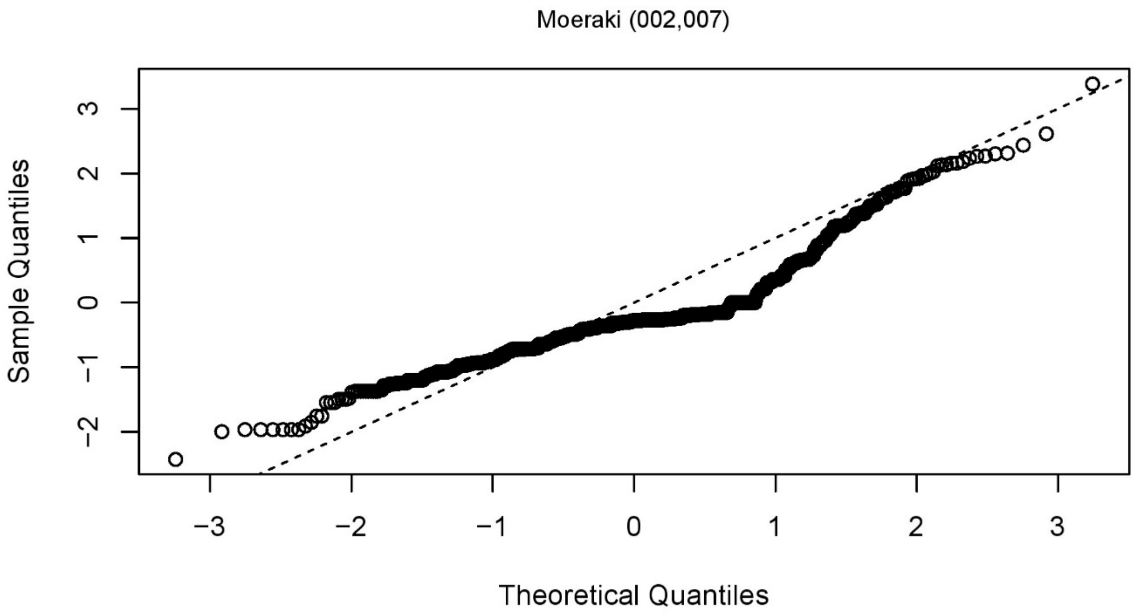

Figure 49: Quantile-quantile plot for the negative binomial standardisation model for Moeraki.

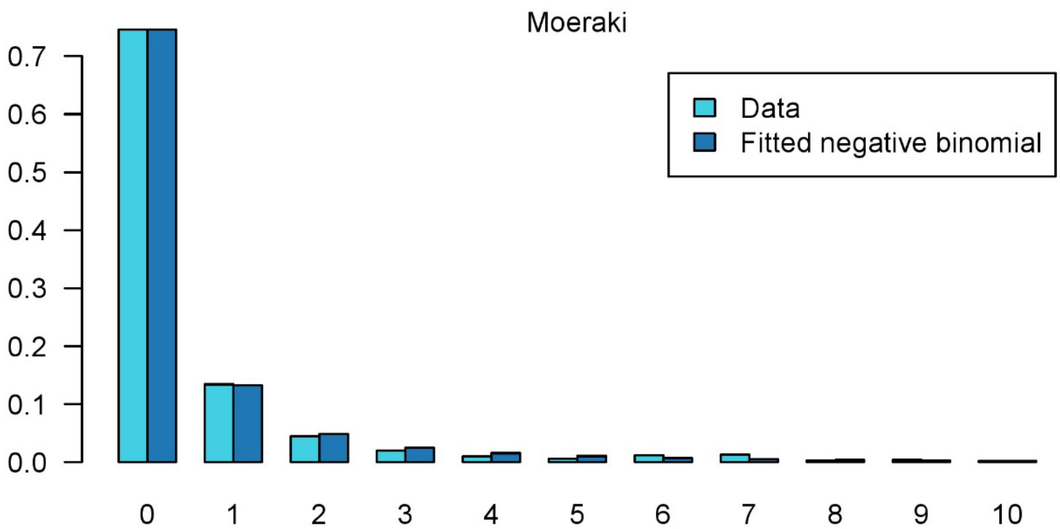

Figure 50: Data distribution and that from the fitted negative binomial model for Moeraki.

3.6 Jackson Bay

3.6.1 Sampling characteristics

At the Jackson Bay site five groups have been in place over time with a total of 29 collectors.

The number of samples by group and year is shown in Table 10. There was an early period of sampling for the groups 004 and 005 from 1981–1986, before more widespread sampling started again in 1999. Because of the large gap, all samples before 1999 were dropped. The sampling periods for the remaining collectors are shown graphically in Figure 51, and the total number of samples from each in Figure 52.

In previous standardisations the groups 003 and 004 were dropped as they were inefficient at capturing pueruli, giving many samples with zero counts (Figures 53–55). Arguably the 002 group could also be dropped under this criterion, but it was retained.

Collectors were filtered for use in the standardisation with the requirement that they have at least 36 samples. This rule has the effect of dropping the 005 group and one collector from the 001 group (see Figure 52).

After dropping groups and filtering, the remaining groups are 001 and 002. The number of samples for each year is shown in (Table 11), with less sampling in February, April, and May (Figure 56). Settlement is high throughout the year (Figure 57).

3.6.2 Negative binomial standardisation

All months of data were used for the standardisation. For the negative binomial model group and month were chosen as standardisation predictors (in addition to the year variable which was forced in). The standardised index increases rapidly from 2011 (Figure 58). Diagnostics are shown in Figures 59–61.

Table 10: Number of puerulus samples at Jackson Bay by group and fishing year.

	JKB001	JKB002	JKB003	JKB004	JKB005
1981	0	0	0	18	0
1982	0	0	0	52	0
1983	0	0	0	49	0
1984	0	0	0	37	29
1985	0	0	0	0	36
1986	0	0	0	0	11
1999	18	20	18	18	0
2000	48	34	34	30	24
2001	50	36	36	29	24
2002	48	30	30	18	30
2003	40	21	18	0	35
2004	38	24	0	0	0
2005	41	16	0	0	0
2006	23	4	0	0	0
2007	48	0	0	0	0
2008	36	0	0	0	0
2009	25	0	0	0	0
2010	23	0	0	0	0
2011	39	0	0	0	0
2012	52	0	0	0	0
2013	49	0	0	0	0
2014	48	0	0	0	0

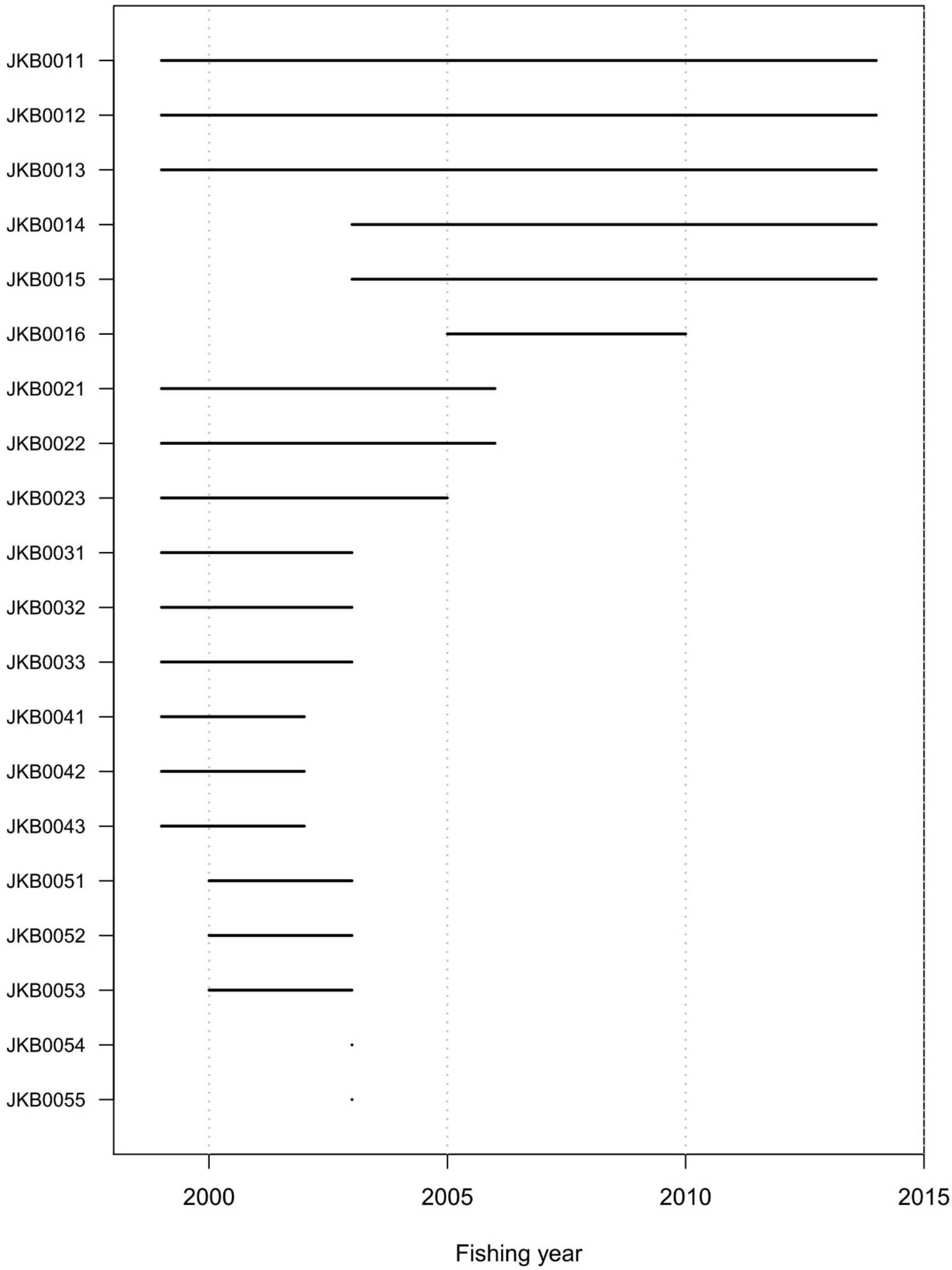

Figure 51: The fishing years over which the collectors have been in operation in Jackson Bay (from 1999 onwards).

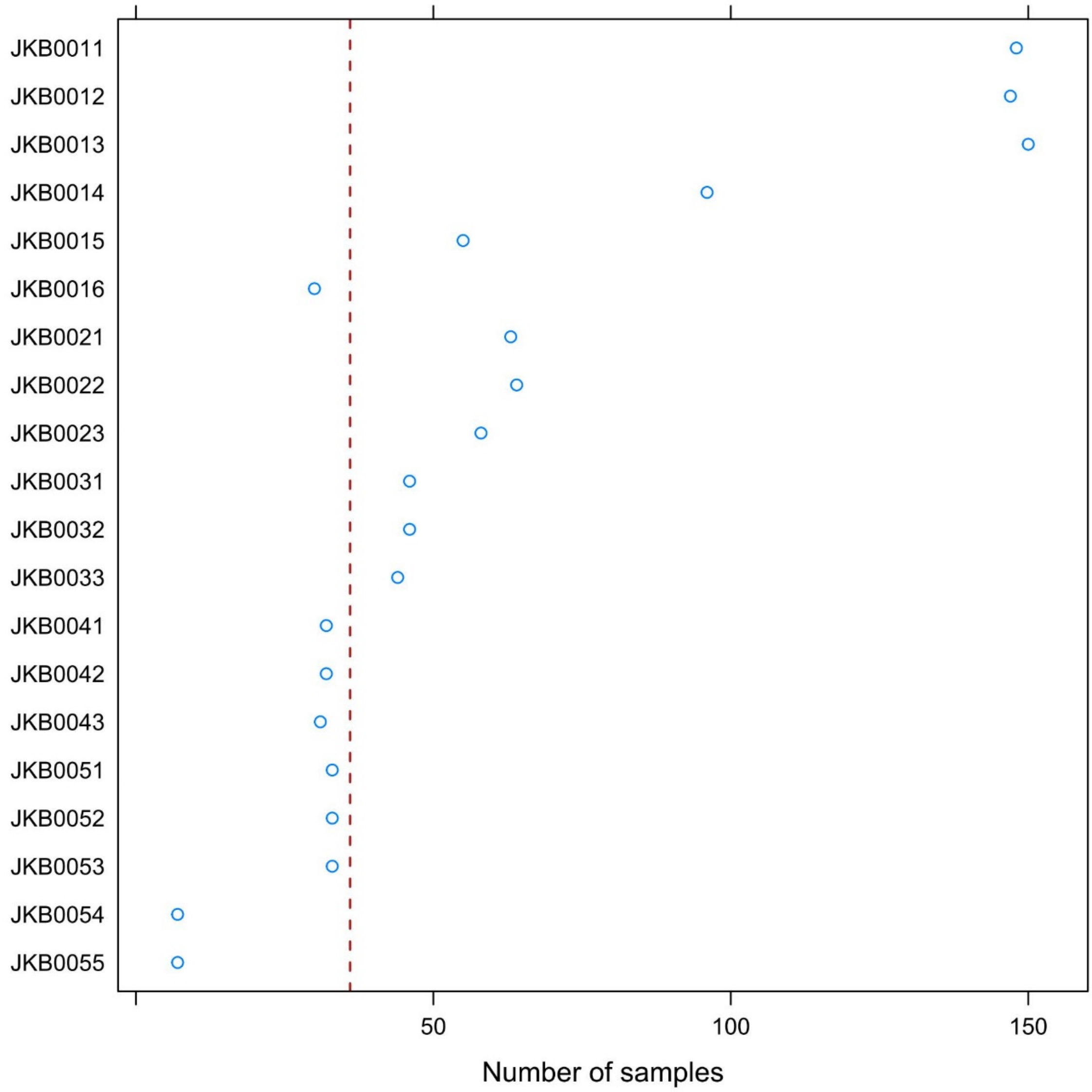

Figure 52: The total number of samples taken from each collector in Jackson Bay (from 1999 onwards). The vertical dashed line is at 36 samples.

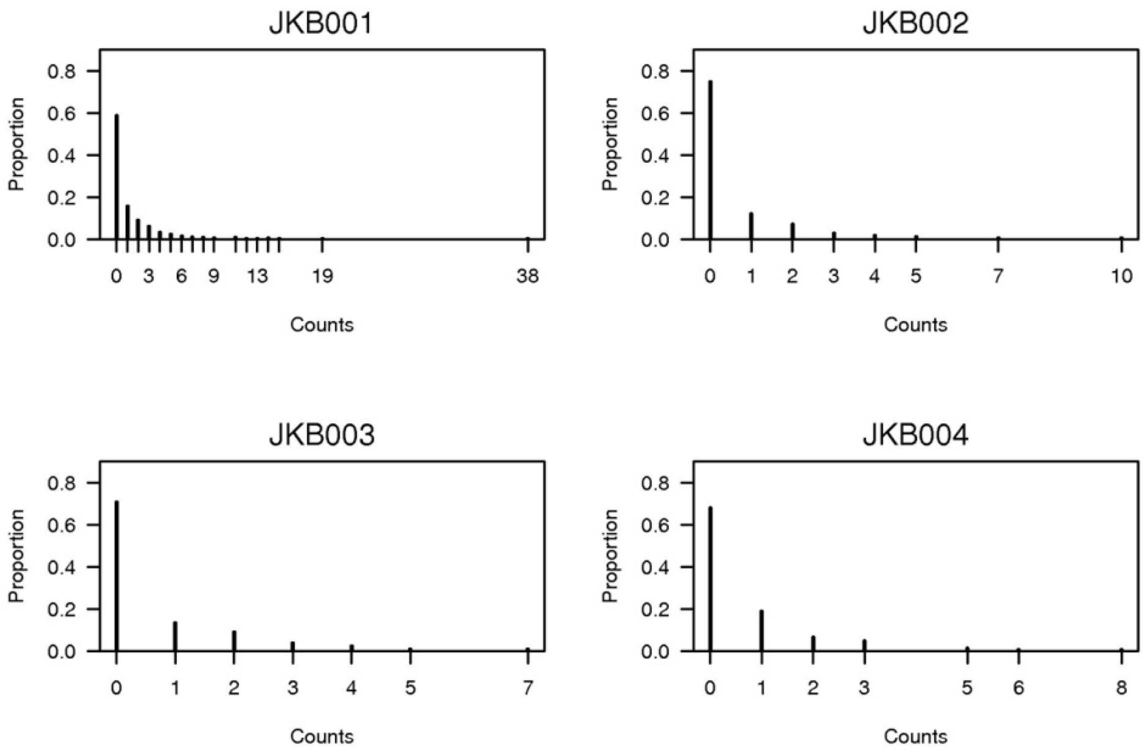

Figure 53: Number of pueruli counted in samples from Jackson Bay (only including collectors that have been sampled at least 36 times). Reproduced from figure A2 in Forman et al. (2014).

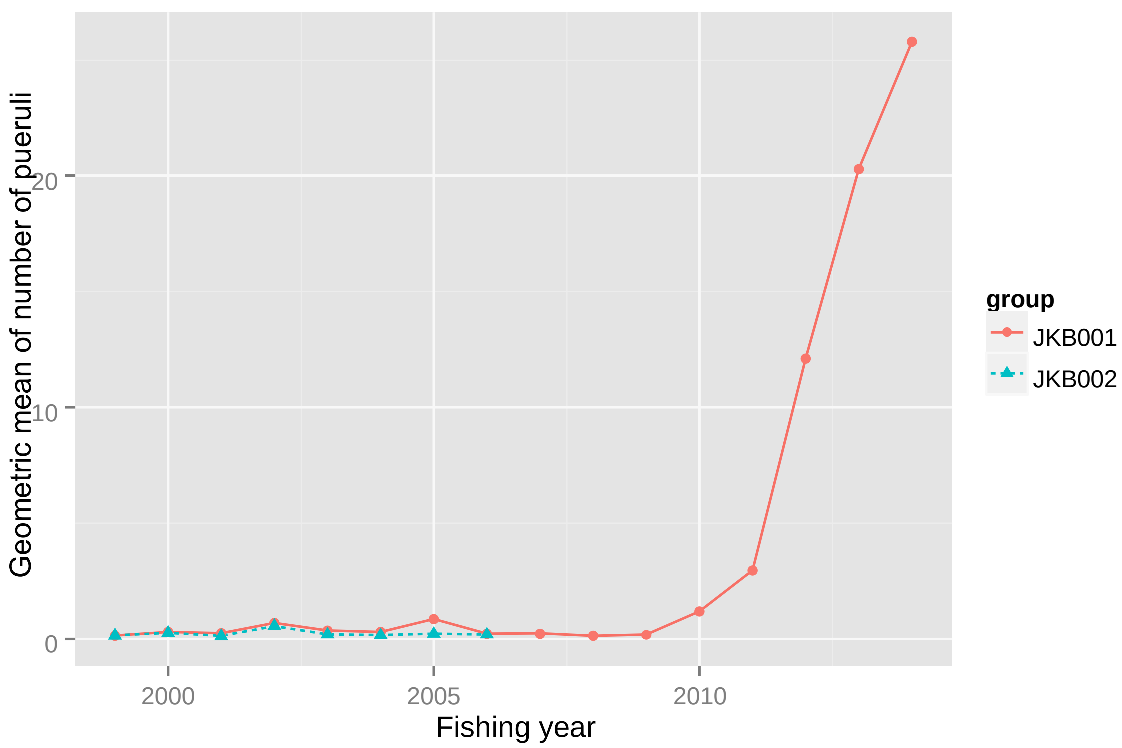

Figure 54: Geometric mean of the number of sampled pueruli for groups used in the previous standardisation for Jackson Bay. All samples for the groups are used.

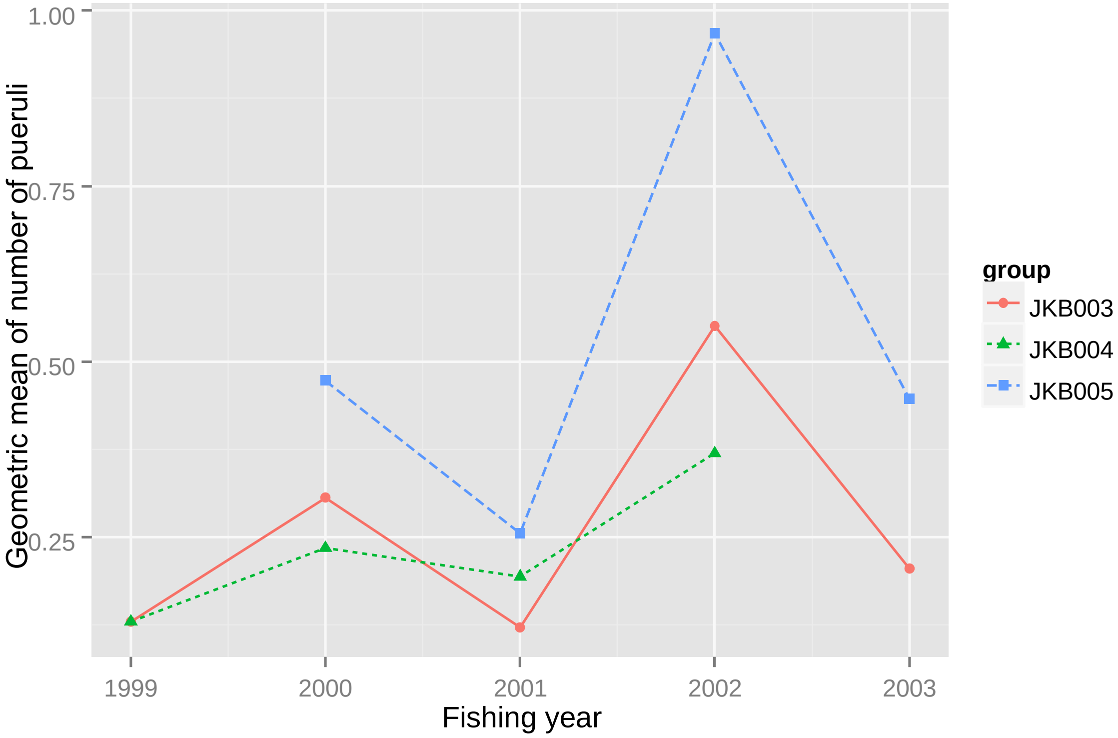

Figure 55: Geometric mean of the number of sampled pueruli for groups not used in the previous standardisation for Jackson Bay. All puerulus samples for the groups are used in this calculation.

Table 11: Jackson Bay standardisation data set for groups 001 and 002 (after filtering to ensure 36 samples). Number of puerulus samples by group and fishing year.

	Number of samples		
	JKB001	JKB002	Total
1999	18	20	38
2000	48	34	82
2001	50	36	86
2002	48	30	78
2003	40	21	61
2004	38	24	62
2005	35	16	51
2006	19	4	23
2007	40	0	40
2008	30	0	30
2009	20	0	20
2010	22	0	22
2011	39	0	39
2012	52	0	52
2013	49	0	49
2014	48	0	48

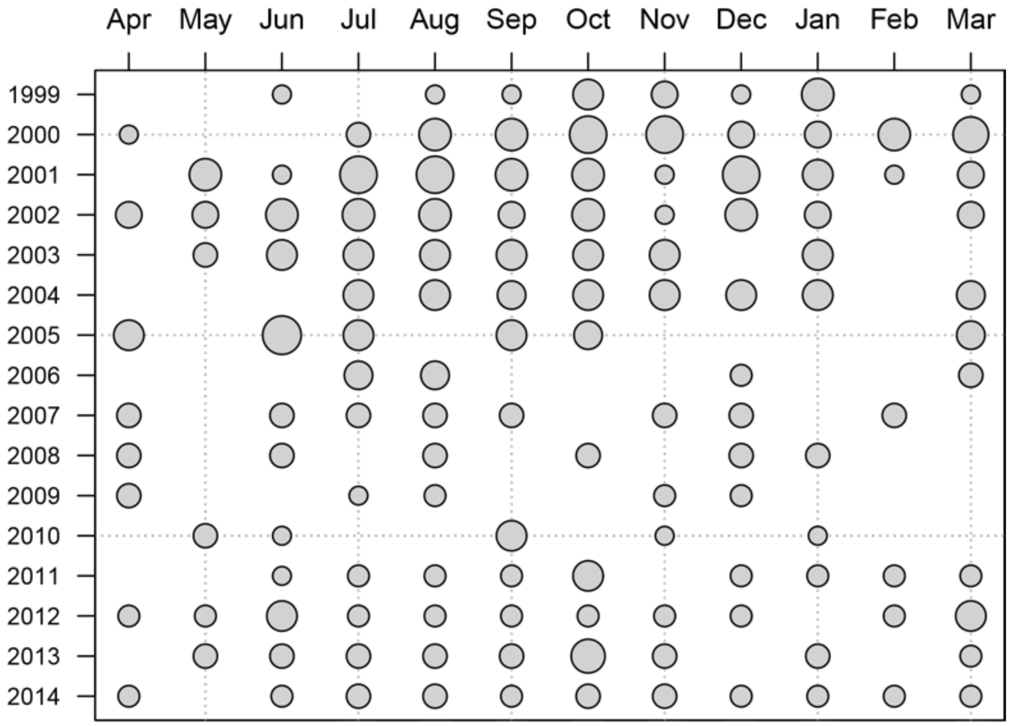

Figure 56: Number of samples by month and fishing year from Jackson Bay. The area of a circle is proportional to the number of samples, with a maximum value of 20.

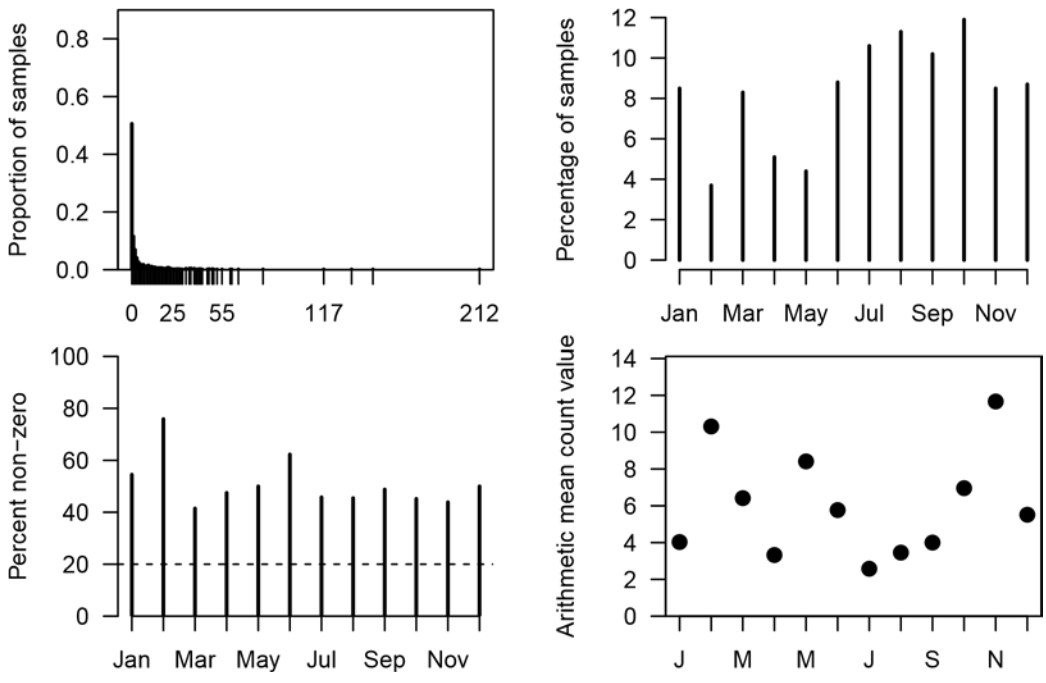

Figure 57: Characteristics of the Jackson Bay puerulus standardisation data for groups 001 and 002 (after filtering to ensure 36 samples). The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample.

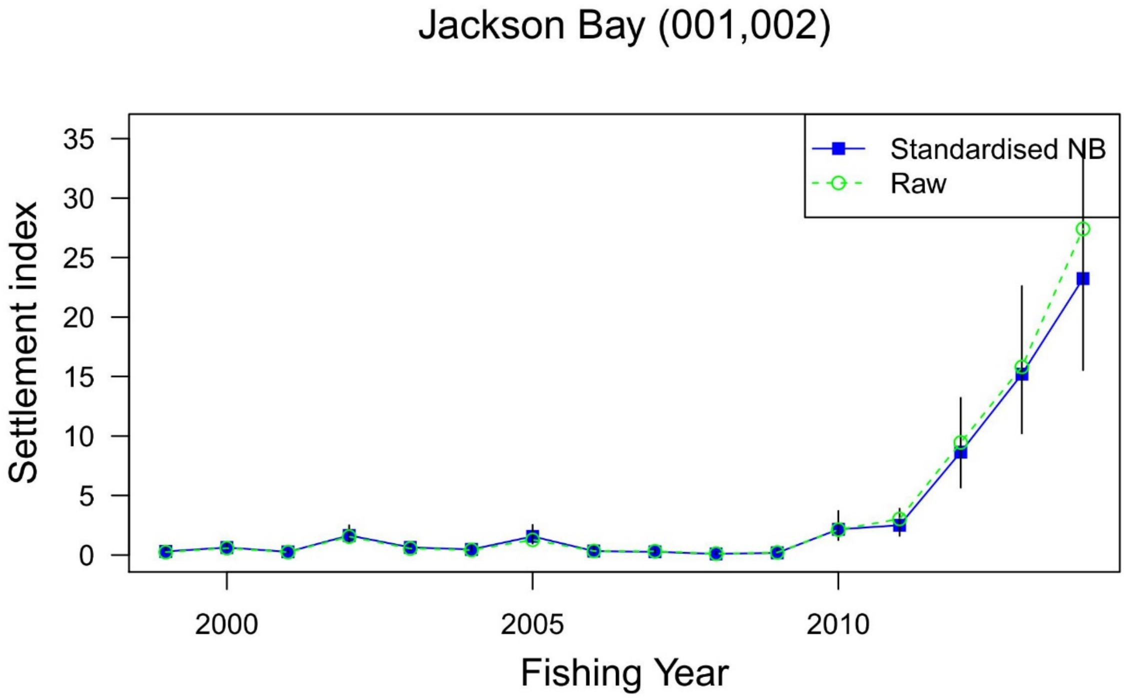

Figure 58: Negative binomial model for Jackson Bay. Standardised and raw indices with 95% confidence intervals.

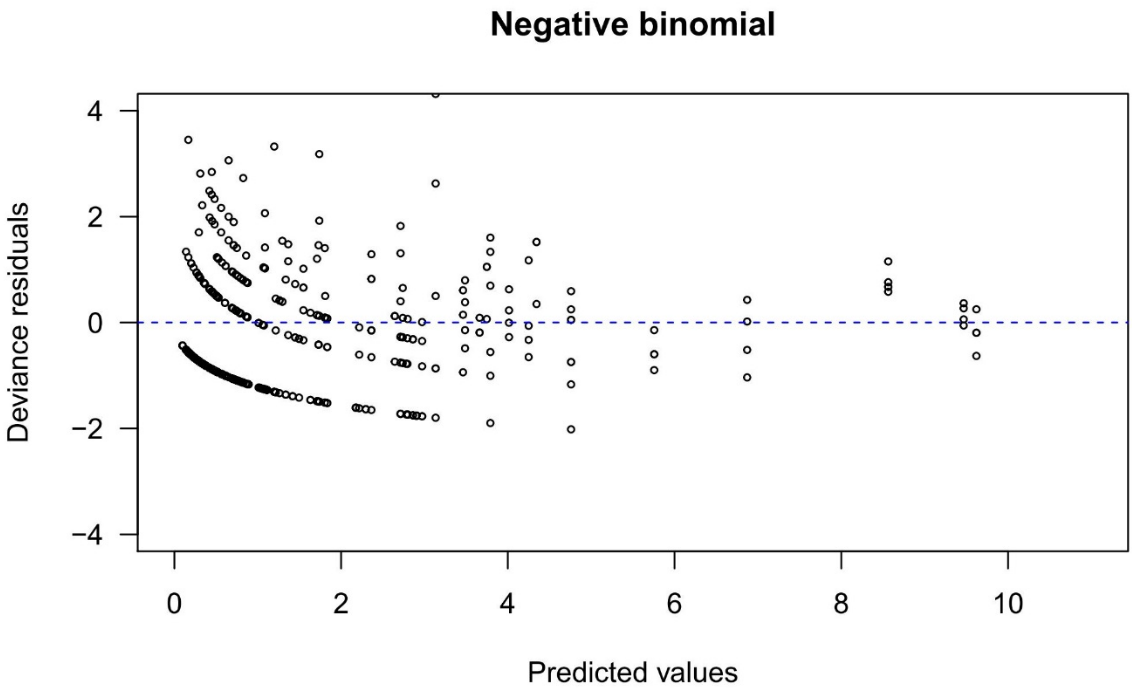

Figure 59: Deviance residuals for the negative binomial model for Jackson Bay. Predicted values are in natural space.

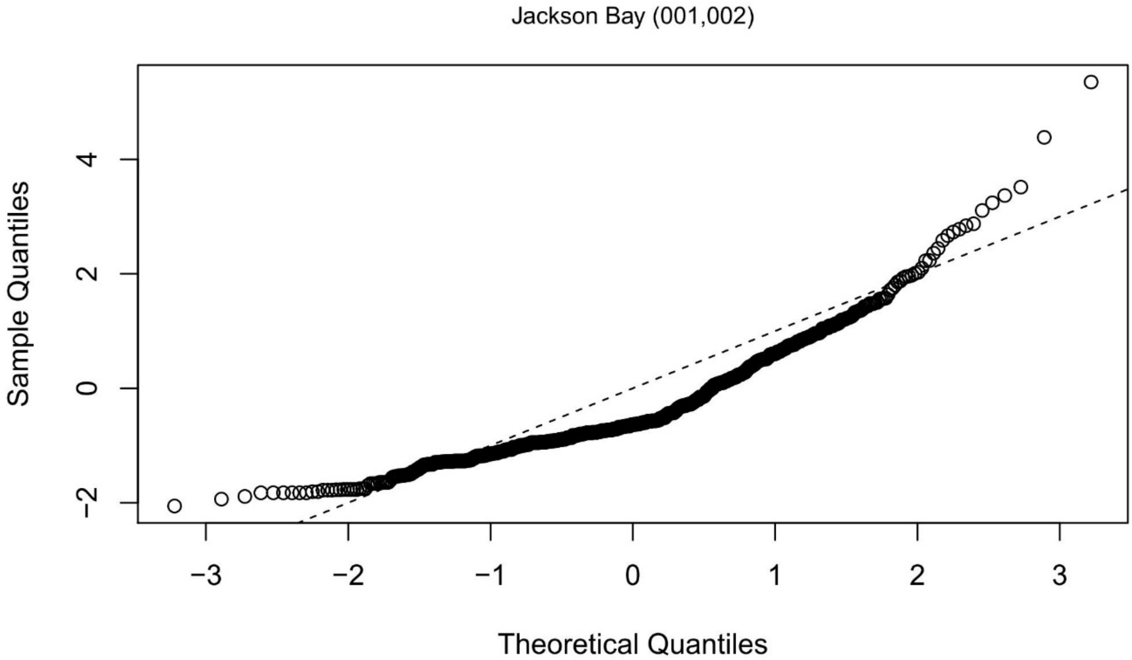

Figure 60: Quantile-quantile plot for the negative binomial standardisation model for Jackson Bay.

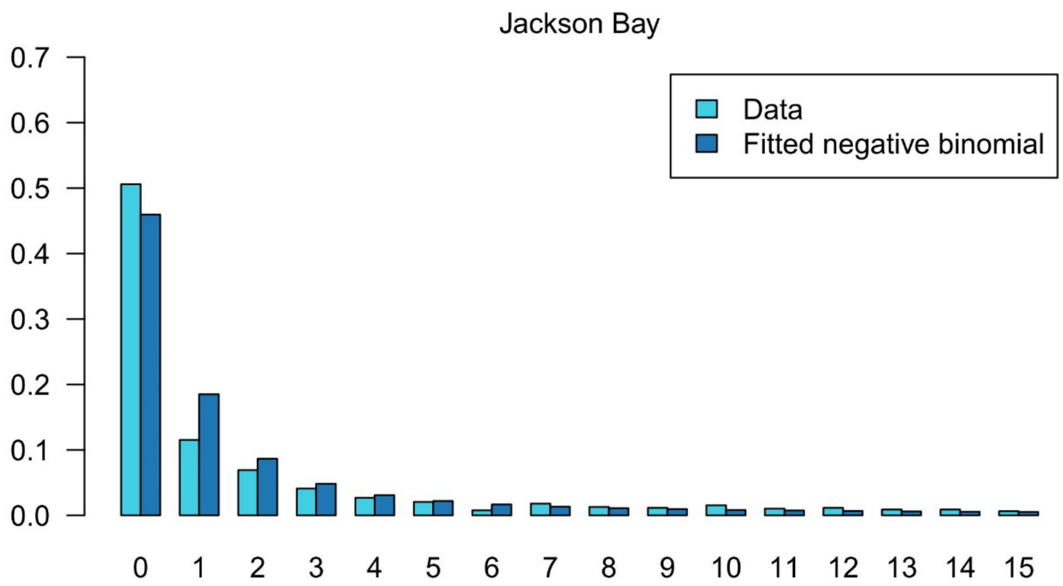

Figure 61: Data distribution and that from the fitted negative binomial for Jackson Bay.

3.7 Chalky Inlet

3.7.1 Sampling characteristics

At the Chalky Inlet site a single group 001 has been in place over time with a total of 6 collectors.

The number of samples by group and year is shown in Table 12. The sampling periods for the collectors is shown graphically in Figure 62, and the total number of samples from each in Figure 63. Settlement appears to have been higher in recent years (Figure 64).

Collectors are filtered for use in the standardisation with the requirement that they have at least 36 samples. No collectors are dropped using this rule (see Figure 63). However, the 2009 and 2014 years are dropped as they have fewer than 10 samples for the year (Table 13).

Sampling was lower from February through to June (Figure 65). Settlement was highest in winter (Figure 66).

3.7.2 Negative binomial standardisation

All months of data are used for the standardisation.

For the negative binomial model group and month were chosen as standardisation predictors (in addition to the variable year which was forced in). The standardised index shows an apparent jump in 2010 from a low in 2004 (Figure 67). Diagnostics are shown in Figures 68–70.

Table 12: Number of puerulus samples at Chalky Inlet by group and fishing year.

	CHI001
1985	12
1986	34
1987	25
1988	16
1989	22
1990	28
1991	18
1992	27
1993	18
1994	24
1995	18
1996	42
1997	48
1998	54
1999	30
2000	41
2001	36
2002	24
2003	30
2004	18
2009	8
2010	16
2011	15
2012	12
2014	6

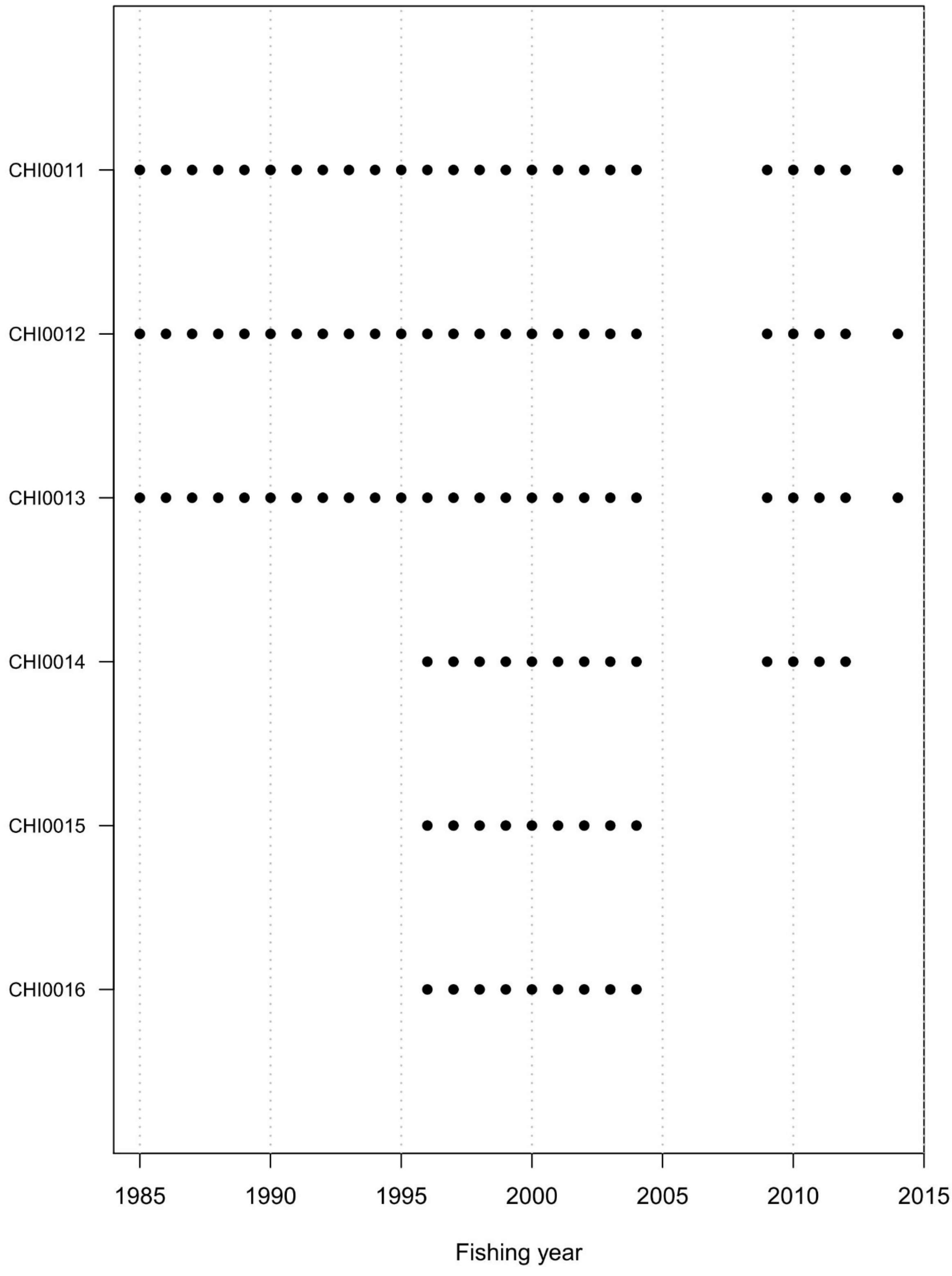

Figure 62: The fishing years over which the collectors have been in operation in Chalky Inlet.

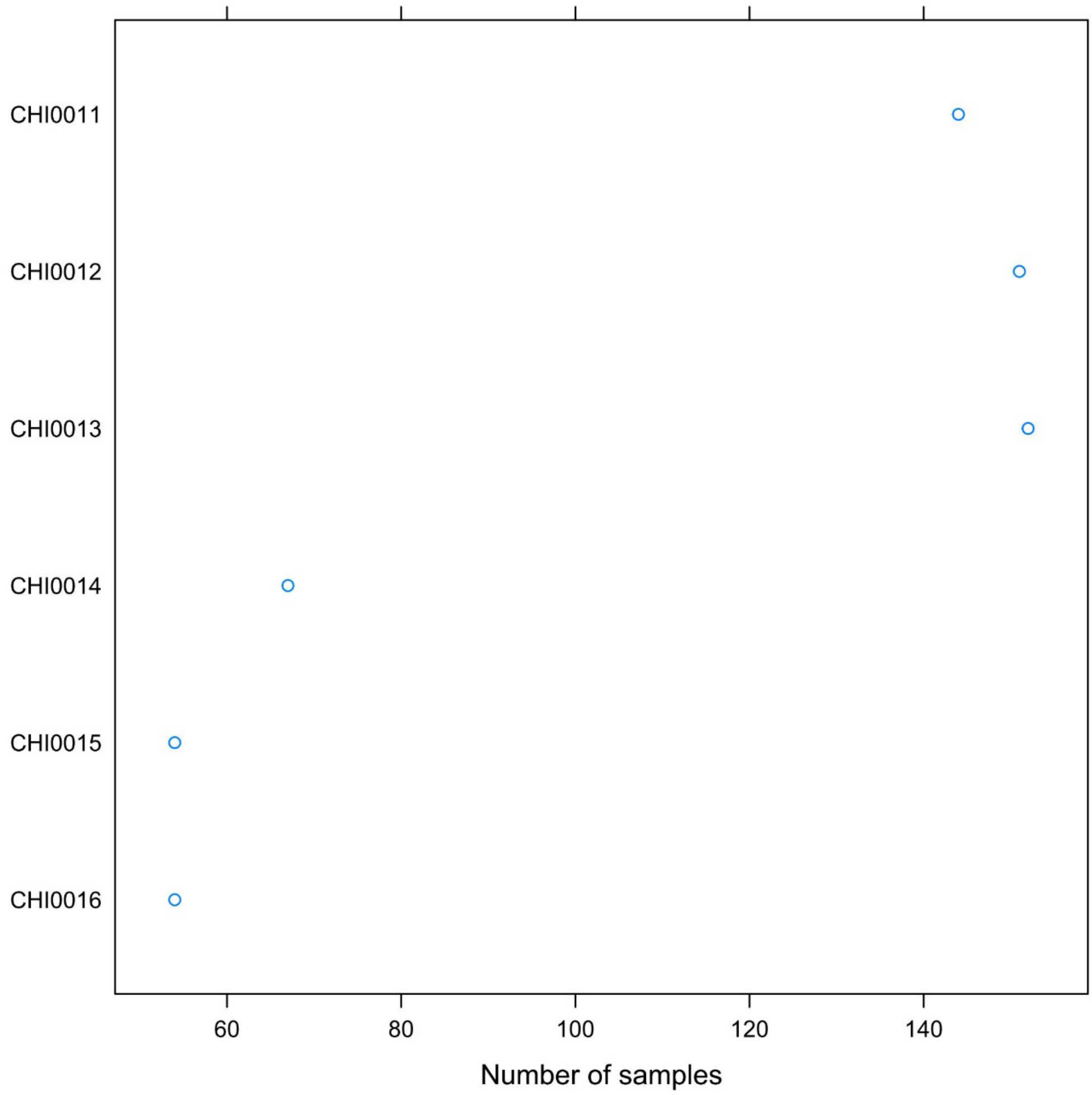

Figure 63: The total number of samples taken from each collector in Chalky Inlet.

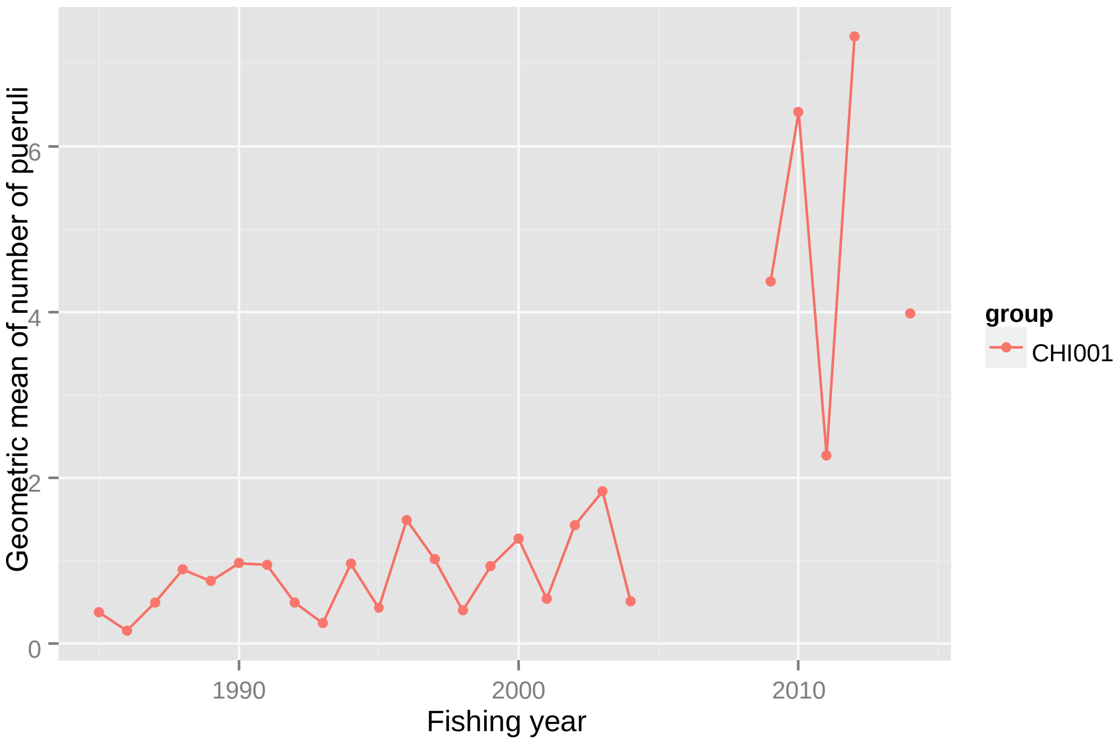

Figure 64: Geometric mean of number of sampled pueruli for the 001 group from Chalky Inlet (using all data).

Table 13: Chalky Inlet standardisation data set for the group 001. Number of puerulus samples by group and fishing year (with years with fewer than 10 samples removed).

	CHI001
1985	12
1986	34
1987	25
1988	16
1989	22
1990	28
1991	18
1992	27
1993	18
1994	24
1995	18
1996	42
1997	48
1998	54
1999	30
2000	41
2001	36
2002	24
2003	30
2004	18
2010	16
2011	15
2012	12

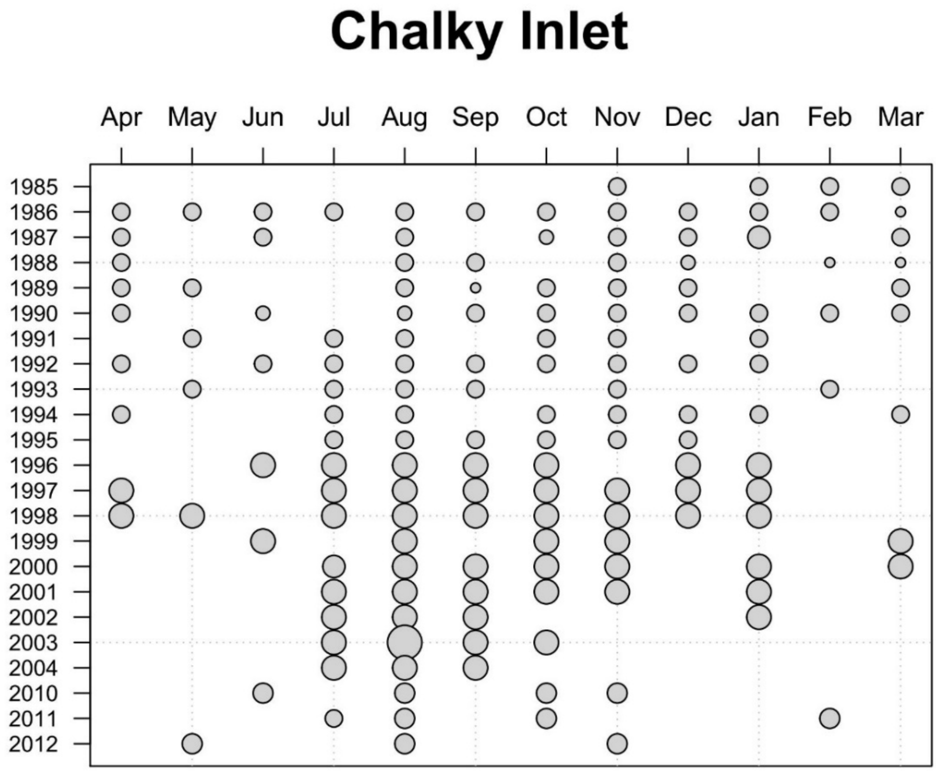

Figure 65: Number of samples by month and fishing year from Chalky Inlet. The area of a circle is proportional to the number of samples.

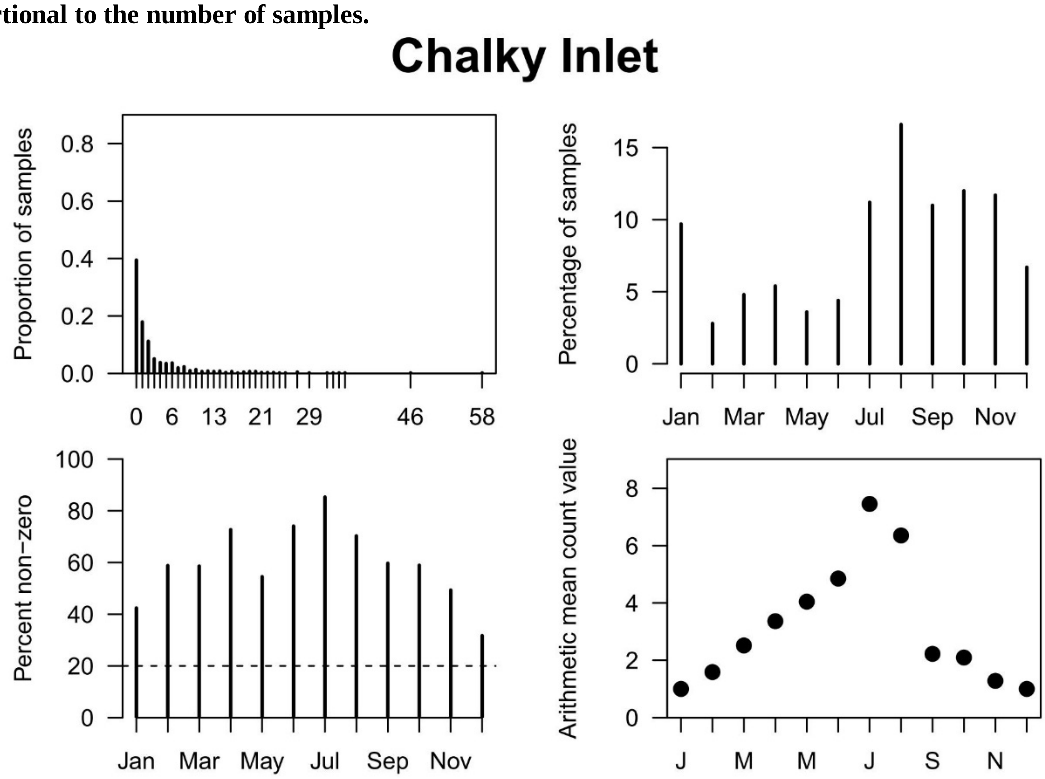

Figure 66: Characteristics of the Chalky Inlet puerulus data for the group 001. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample

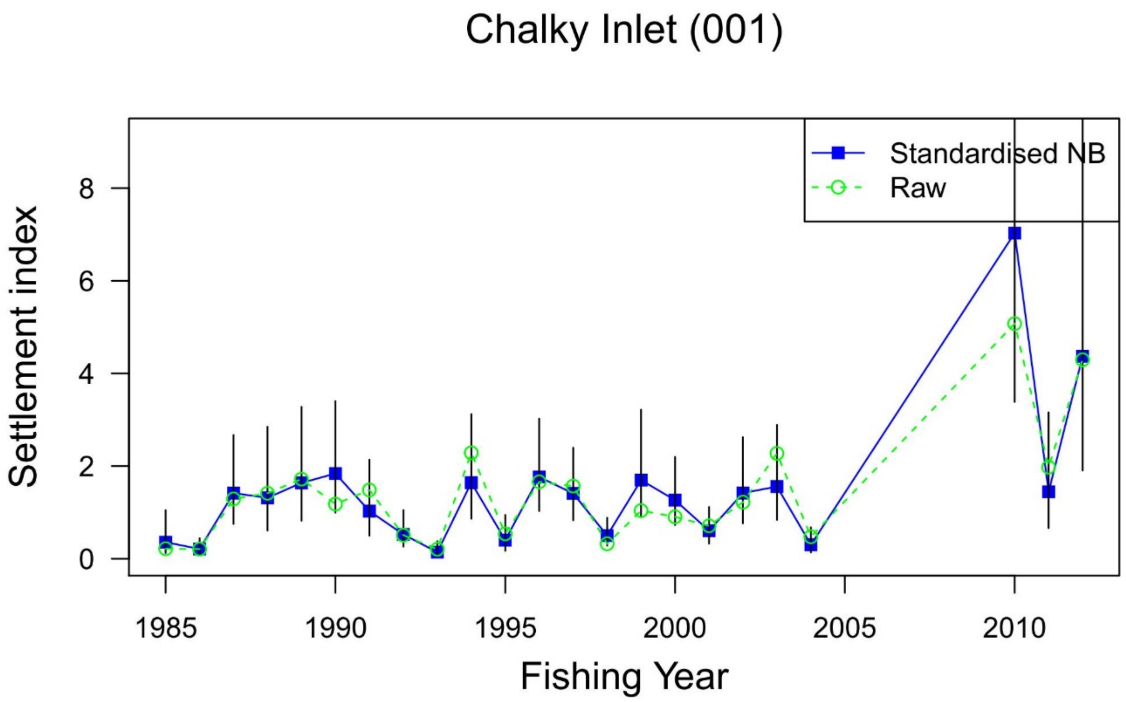

Figure 67: Negative binomial model for Chalky Inlet. Standardised and raw indices with 95% confidence intervals.

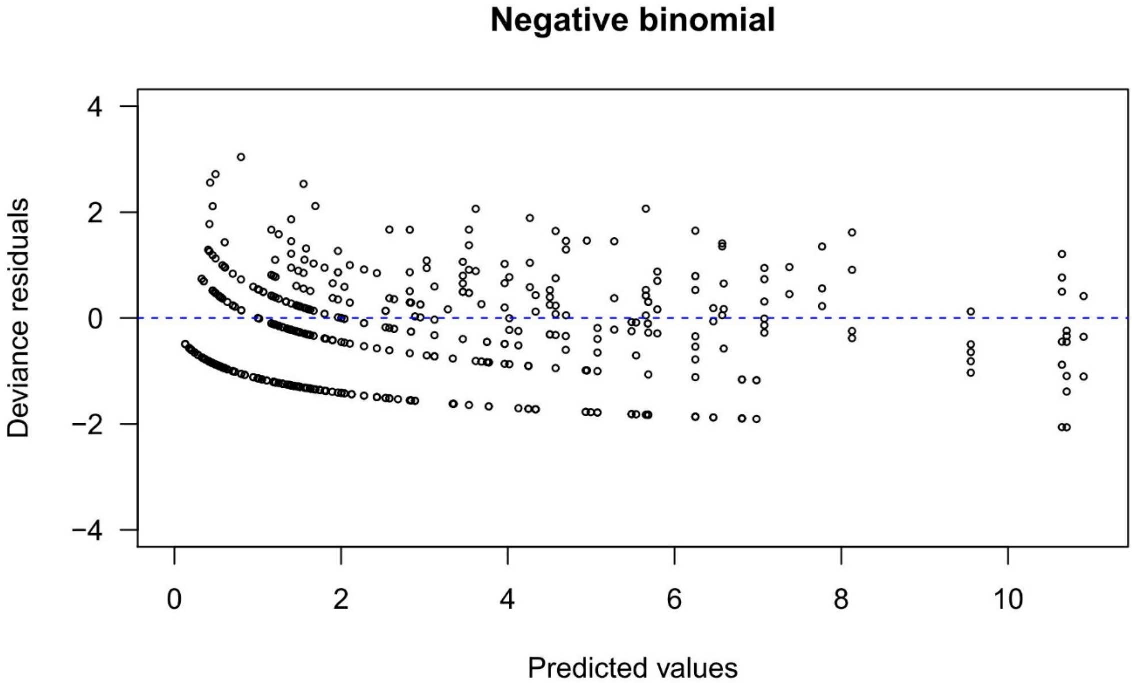

Figure 68: Deviance residuals for the negative binomial model for Chalky Inlet. Predicted values are in natural space.

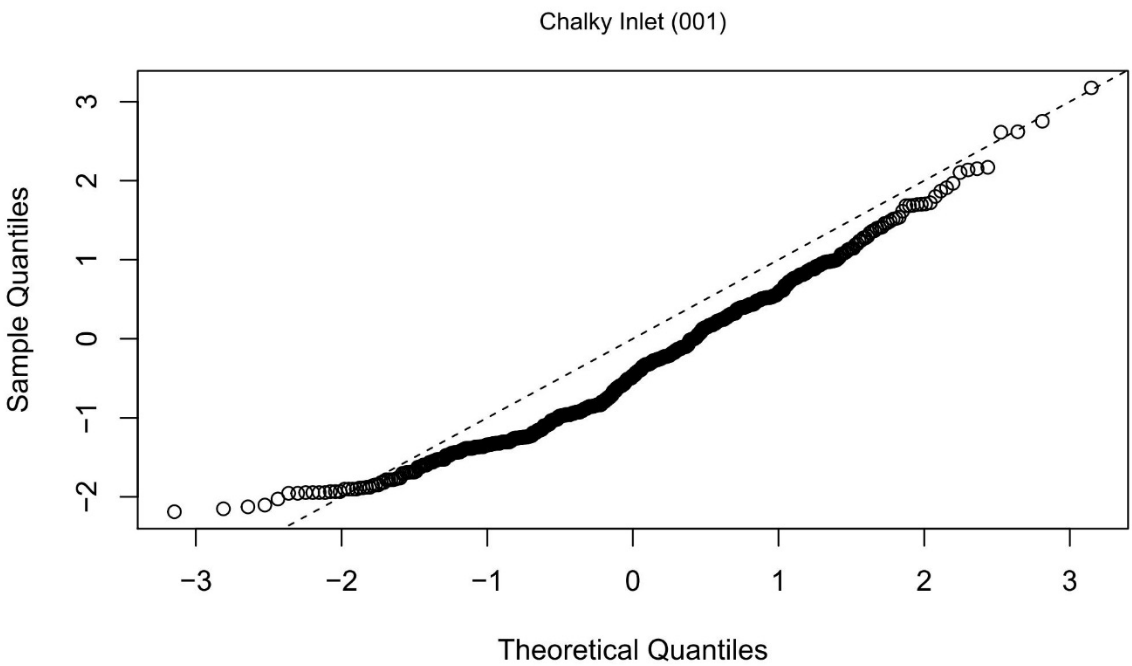

Figure 69: Quantile-quantile plot for the negative binomial standardisation model for Chalky Inlet.

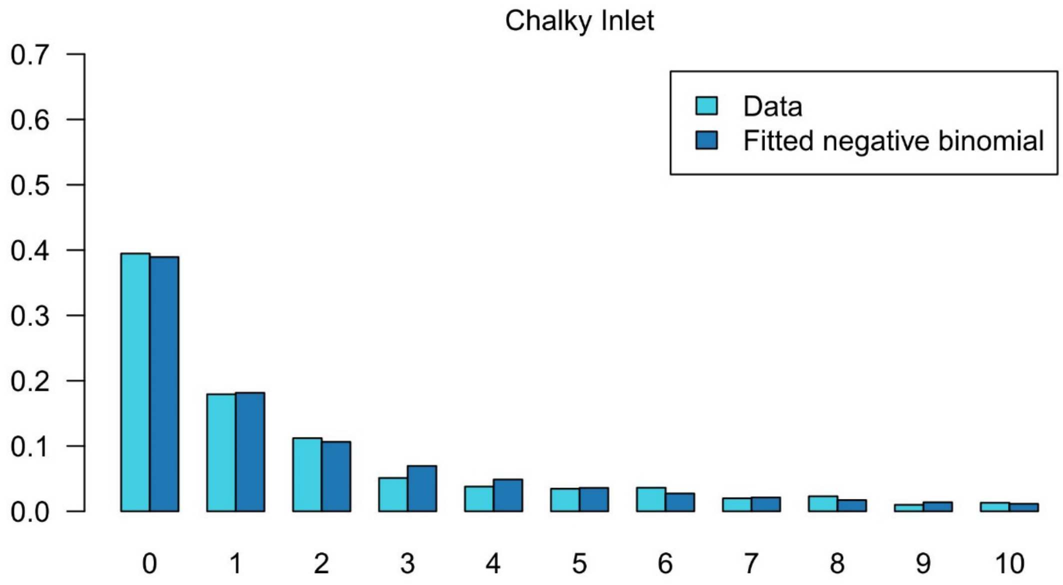

Figure 70: Data distribution and that from the fitted negative binomial model for Chalky Inlet.

3.8 Halfmoon Bay

3.8.1 Sampling characteristics

At the Halfmoon Bay site, seven groups have been in place over time with a total of 33 collectors.

The number of samples by group and year is shown in Table 14. The sampling time periods for the collectors is shown graphically in Figure 71, and the total number of samples from each in Figure 72. Raw average puerulus counts shows similar patterns across the groups used in the previous standardisation (Figure 73).

Collectors are filtered for use in the standardisation with the requirement that they have at least 36 samples. This rule drops groups 006 and 007 and some collectors from the other groups (see Figure 72).

After collector filtering the number of samples for each year is shown in Table 15. There was less sampling in January and February (Figure 74). Settlement was highest in winter (Figure 75).

3.8.2 Negative binomial standardisation

It was decided to use the months May–December (inclusive) for the standardisation, which dropped the proportion of zeros slightly to about 0.80 (Figure 76). The resulting numbers of samples by year is shown in Table 16. The number of samples is low for some years, and the first year (1980) is dropped as it has fewer than 10 samples.

For the standardisation, group and month were accepted as predictor variables (with the year variable forced in at the start). The resulting standardised index is shown in Figure 77. In the years 1985, 1993, 2005 all samples had zero puerulus counts (Figure 78) and the model was unable to estimate confidence intervals properly (it estimated very high upper confidence intervals, but these should be low since all counts were zero). Diagnostics are shown in Figures 79–81.

Table 14: Number of puerulus samples from Halfmoon Bay by group and fishing year.

	HMB001	HMB002	HMB003	HMB004	HMB005	HMB006	HMB007
1980	15	0	0	0	0	0	0
1981	21	0	0	0	0	0	0
1982	32	0	0	0	0	0	0
1983	27	0	0	0	0	0	0
1984	18	0	0	0	0	0	0
1985	21	0	0	0	0	0	0
1986	24	27	0	0	0	0	0
1987	36	21	0	0	0	0	0
1988	24	18	0	0	0	0	0
1989	21	18	0	0	0	0	0
1990	34	15	15	0	0	0	0
1991	30	24	24	3	3	0	0
1992	27	18	14	18	18	0	0
1993	33	27	27	26	22	0	0
1994	30	30	27	26	26	0	0
1995	30	21	21	21	21	0	0
1996	30	27	27	27	27	0	0
1997	30	24	24	24	24	0	0
1998	18	27	24	24	24	0	0
1999	15	27	27	27	27	0	0
2000	24	24	24	27	24	24	0
2001	36	24	24	24	24	6	3
2002	27	24	24	24	24	21	0
2003	66	0	0	0	0	0	0
2004	57	0	0	0	0	0	0
2005	84	0	0	0	0	0	0
2006	128	0	0	0	0	0	0
2007	105	0	0	0	0	0	0
2008	60	0	0	0	0	0	0
2009	69	0	0	0	0	0	0
2010	96	0	0	0	0	0	0
2011	96	0	0	0	0	0	0
2012	96	0	0	0	0	0	0
2013	72	0	0	0	0	0	0
2014	72	0	0	0	0	0	0

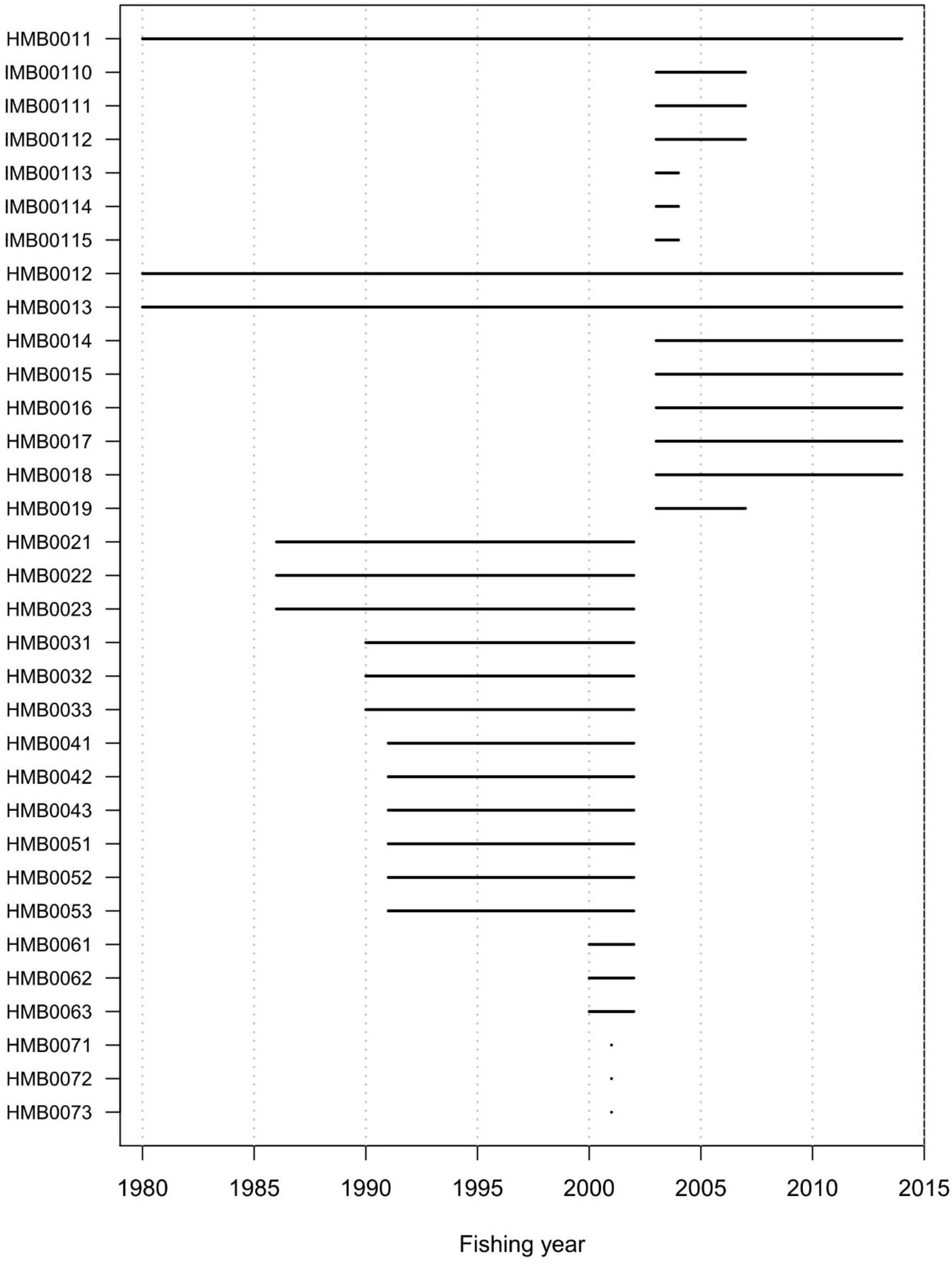

Figure 71: The fishing years over which the collectors have been in operation in Halfmoon Bay.

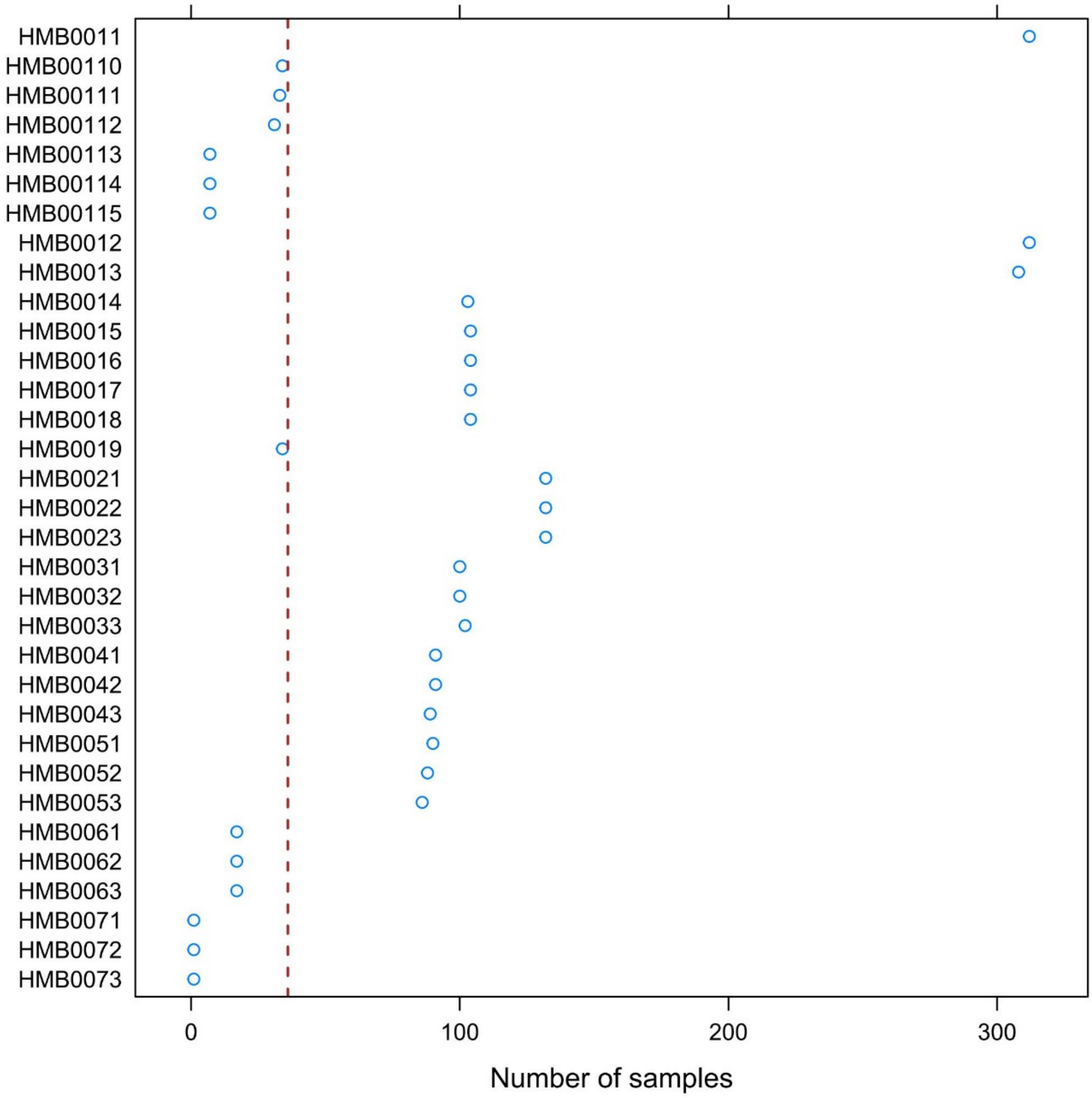

Figure 72: The total number of samples taken from each collector in Halfmoon Bay.

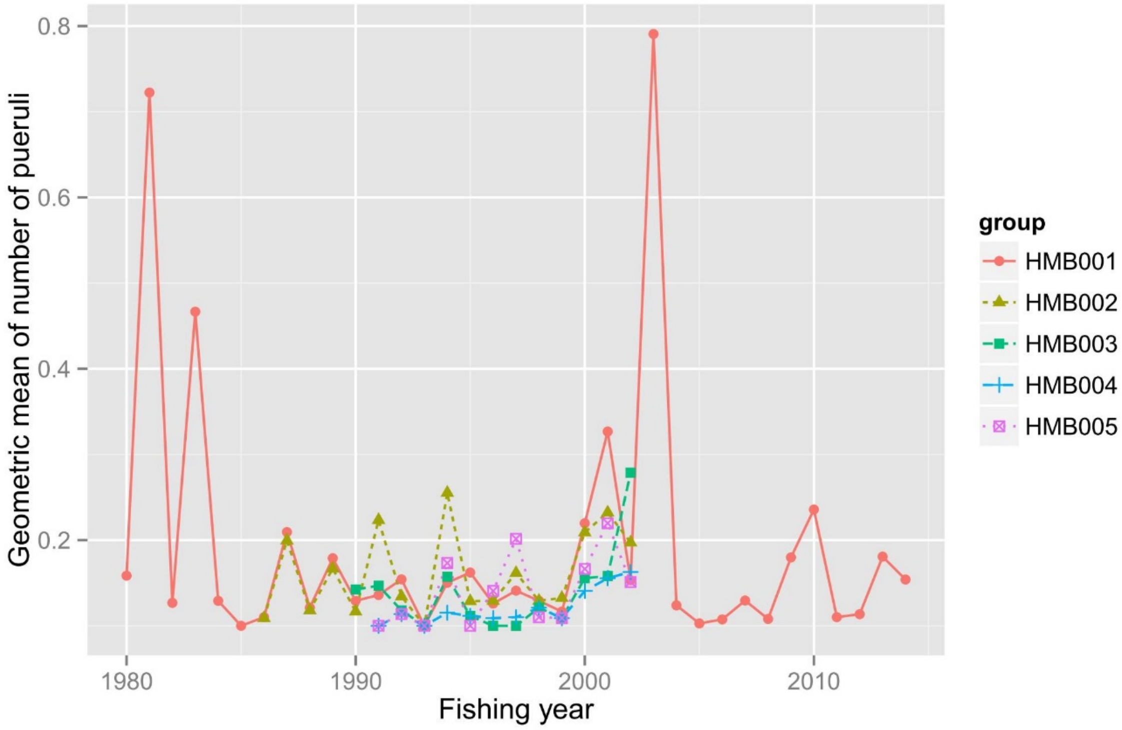

Figure 73: Geometric mean of number of sampled pueruli for groups used in the previous standardisation for Halfmoon Bay. All data for the groups is used.

Table 15: Halfmoon Bay standardisation data set for the groups 001 to 005 (after filtering to ensure 36 samples per collector). Number of puerulus samples by group and fishing year.

	HMB001	HMB002	HMB003	HMB004	HMB005	Total
1980	15	0	0	0	0	15
1981	21	0	0	0	0	21
1982	32	0	0	0	0	32
1983	27	0	0	0	0	27
1984	18	0	0	0	0	18
1985	21	0	0	0	0	21
1986	24	27	0	0	0	51
1987	36	21	0	0	0	57
1988	24	18	0	0	0	42
1989	21	18	0	0	0	39
1990	34	15	15	0	0	64
1991	30	24	24	3	3	84
1992	27	18	14	18	18	95
1993	33	27	27	26	22	135
1994	30	30	27	26	26	139
1995	30	21	21	21	21	114
1996	30	27	27	27	27	138
1997	30	24	24	24	24	126
1998	18	27	24	24	24	117
1999	15	27	27	27	27	123
2000	24	24	24	27	24	123
2001	36	24	24	24	24	132
2002	27	24	24	24	24	123
2003	38	0	0	0	0	38
2004	32	0	0	0	0	32
2005	56	0	0	0	0	56
2006	88	0	0	0	0	88
2007	73	0	0	0	0	73
2008	60	0	0	0	0	60
2009	69	0	0	0	0	69
2010	96	0	0	0	0	96
2011	96	0	0	0	0	96
2012	96	0	0	0	0	96
2013	72	0	0	0	0	72
2014	72	0	0	0	0	72

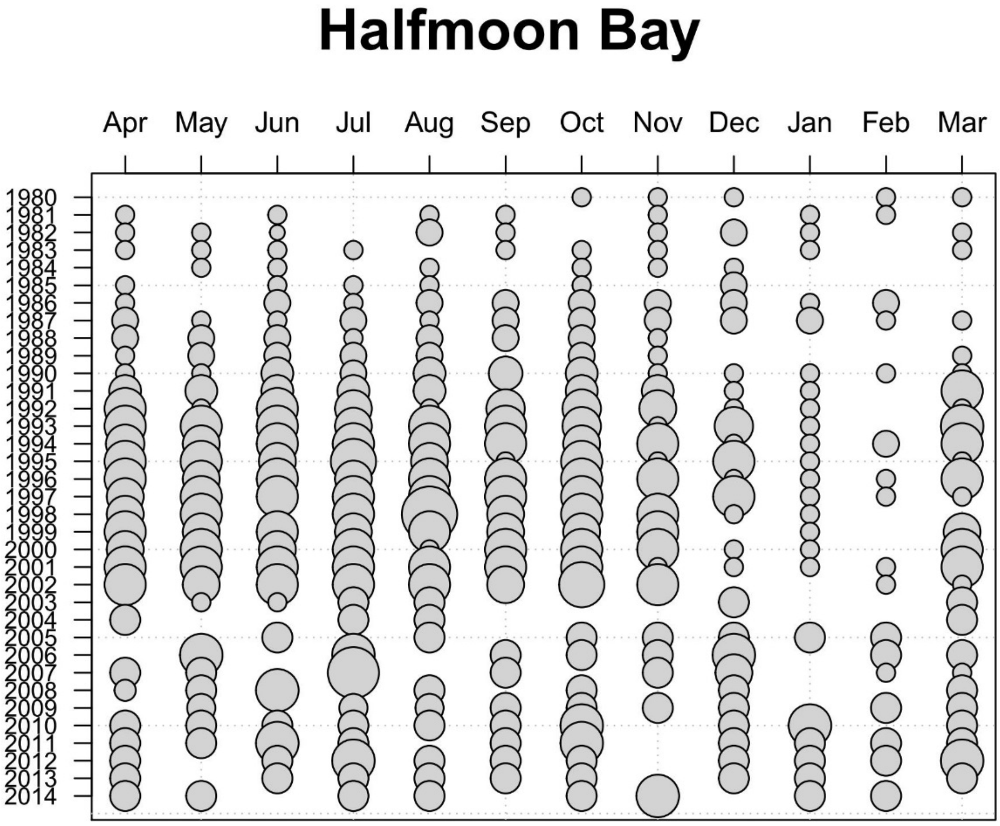

Figure 74: Number of samples by month and fishing year from Halfmoon Bay. The area of a circle is proportional to the number of samples.

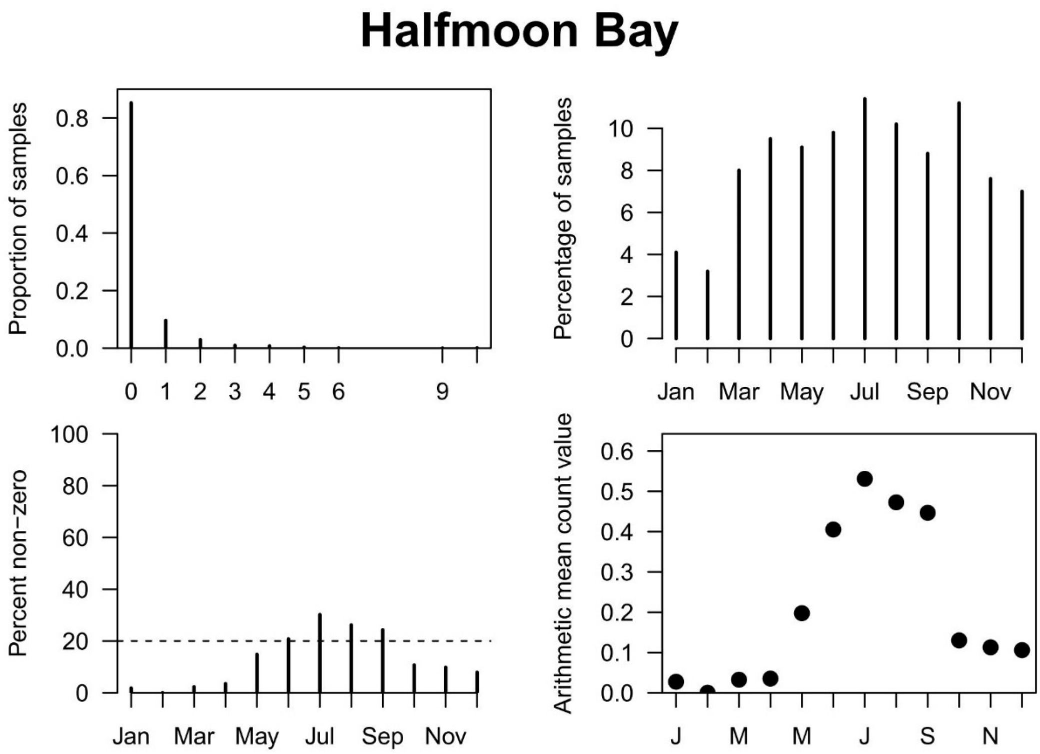

Figure 75: Characteristics of the Halfmoon Bay puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample

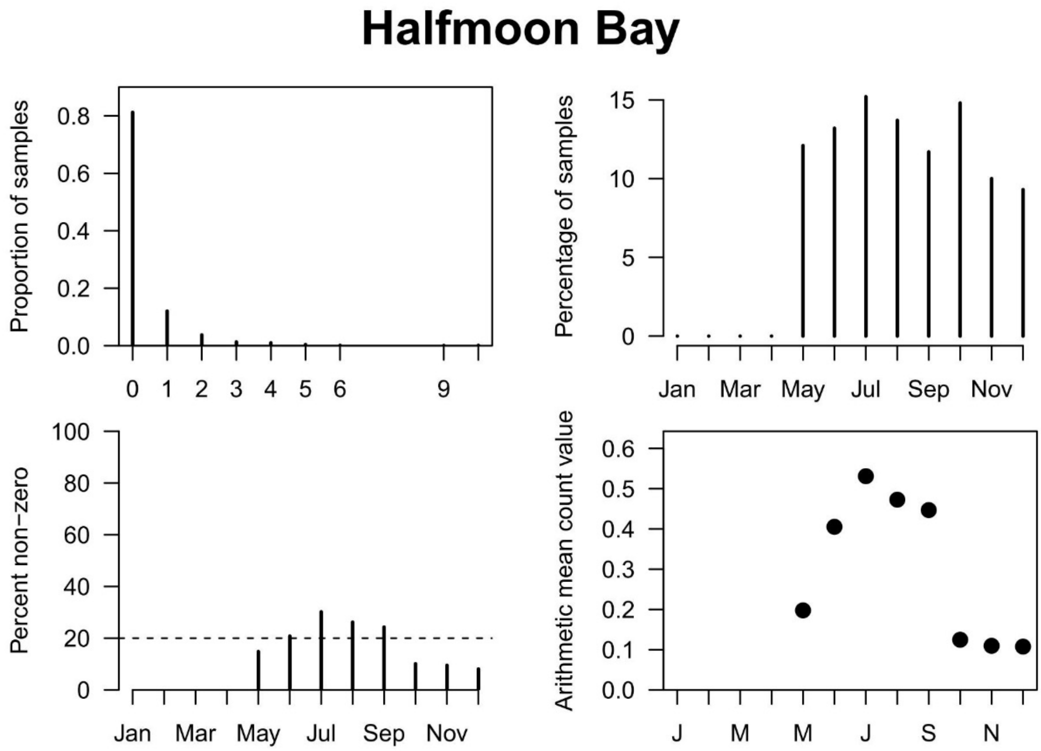

Figure 76: Characteristics of the Halfmoon Bay puerulus standardisation data after restricting to the months May to December (inclusive). The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

Table 16: Number of puerulus samples at Halfmoon Bay by group and fishing year after restricting data to the months May–December (inclusive).

	HMB001	HMB002	HMB003	HMB004	HMB005	Total
1980	9	0	0	0	0	9
1981	12	0	0	0	0	12
1982	23	0	0	0	0	23
1983	18	0	0	0	0	18
1984	18	0	0	0	0	18
1985	18	0	0	0	0	18
1986	18	21	0	0	0	39
1987	24	15	0	0	0	39
1988	21	15	0	0	0	36
1989	18	15	0	0	0	33
1990	22	15	15	0	0	52
1991	21	18	18	0	0	57
1992	18	15	11	15	15	74
1993	21	21	21	21	17	101
1994	18	21	21	21	21	102
1995	21	18	18	18	18	93
1996	18	21	21	21	21	102
1997	21	21	21	21	21	105
1998	15	24	21	21	21	102
1999	9	21	21	21	21	93
2000	18	18	18	21	18	93
2001	24	18	18	18	18	96
2002	18	21	21	21	21	102
2003	30	0	0	0	0	30
2004	16	0	0	0	0	16
2005	40	0	0	0	0	40
2006	72	0	0	0	0	72
2007	59	0	0	0	0	59
2008	48	0	0	0	0	48
2009	53	0	0	0	0	53
2010	64	0	0	0	0	64
2011	64	0	0	0	0	64
2012	56	0	0	0	0	56
2013	48	0	0	0	0	48
2014	48	0	0	0	0	48

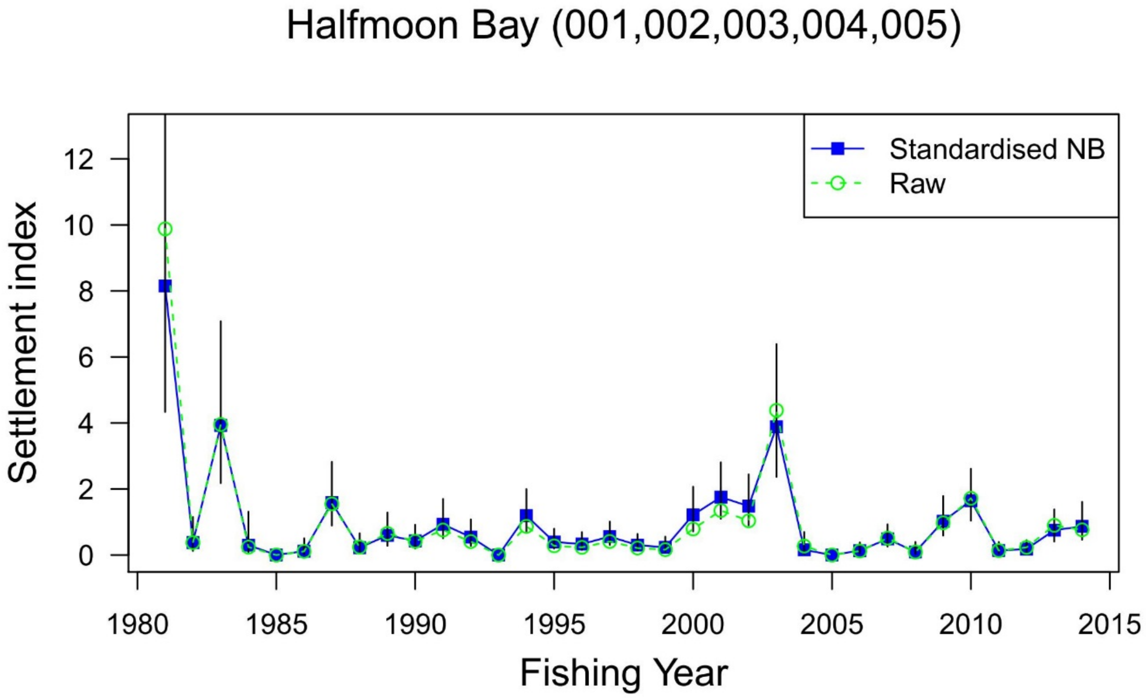

Figure 77: Negative binomial model for Halfmoon Bay. Standardised and raw indices with 95% confidence intervals.

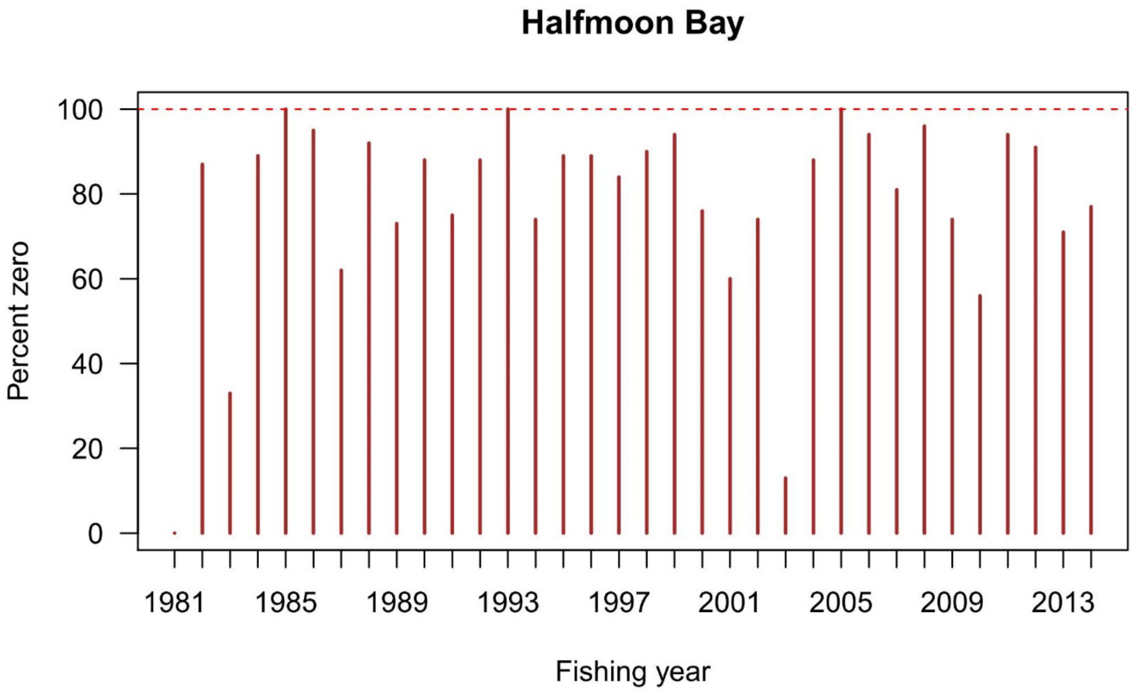

Figure 78: Percentage of zero counts by fishing year in Halfmoon Bay dataset.

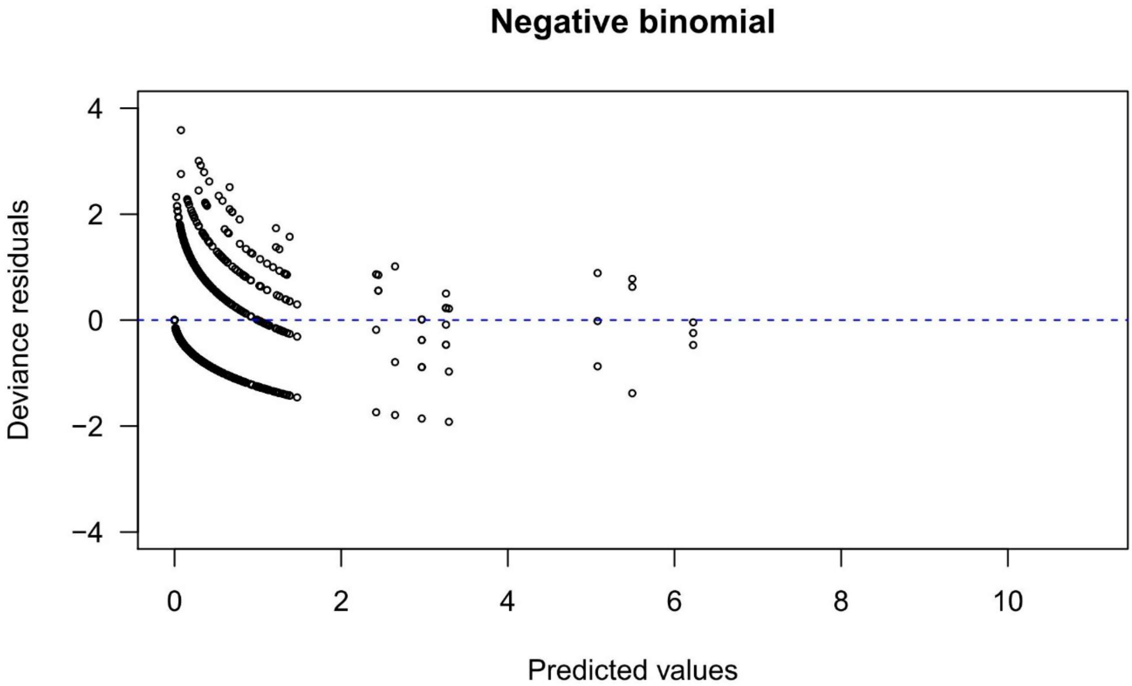

Figure 79: Deviance residuals for the negative binomial model for Halfmoon Bay. Predicted values are in natural space.

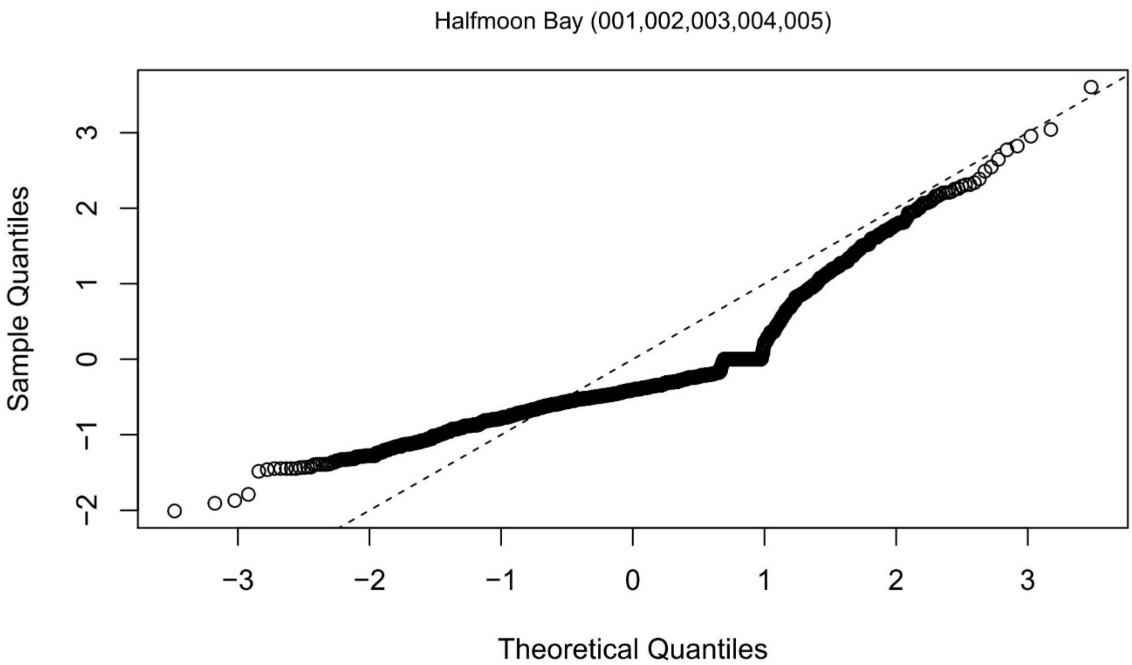

Figure 80: Quantile-quantile plot for the negative binomial standardisation model for Halfmoon Bay.

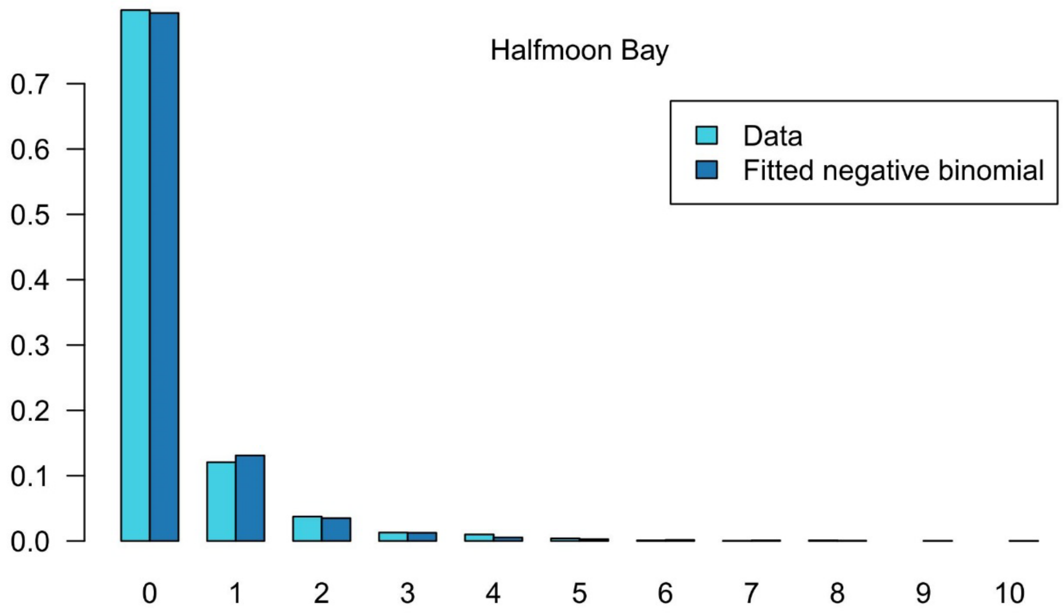

Figure 81: Data distribution and that from the fitted negative binomial model for Halfmoon Bay.

3.9 Standardised indices for other sites (Gisborne, Napier, Castlepoint)

For these sites the same standardisation method was used as the other sites, but with a negative binomial model only. For Gisborne a comprehensive examination of the standardisation was undertaken in 2014 (Forman et al. 2015), and the Rock Lobster Working Group decided upon the same standardisation methodology at the other sites in this document (with the months restricted to May to September inclusive). For Napier and Castlepoint the proportion of zero counts in the data is low and all months of data are used in the standardisations.

For Gisborne the puerulus data characteristics, standardised index, and standardisation diagnostics are shown in Figures 82–86. These are followed by the similar plots for Napier (Figures 87–91) and Castlepoint (Figures 92–96). Diagnostics look reasonable for all three sites.

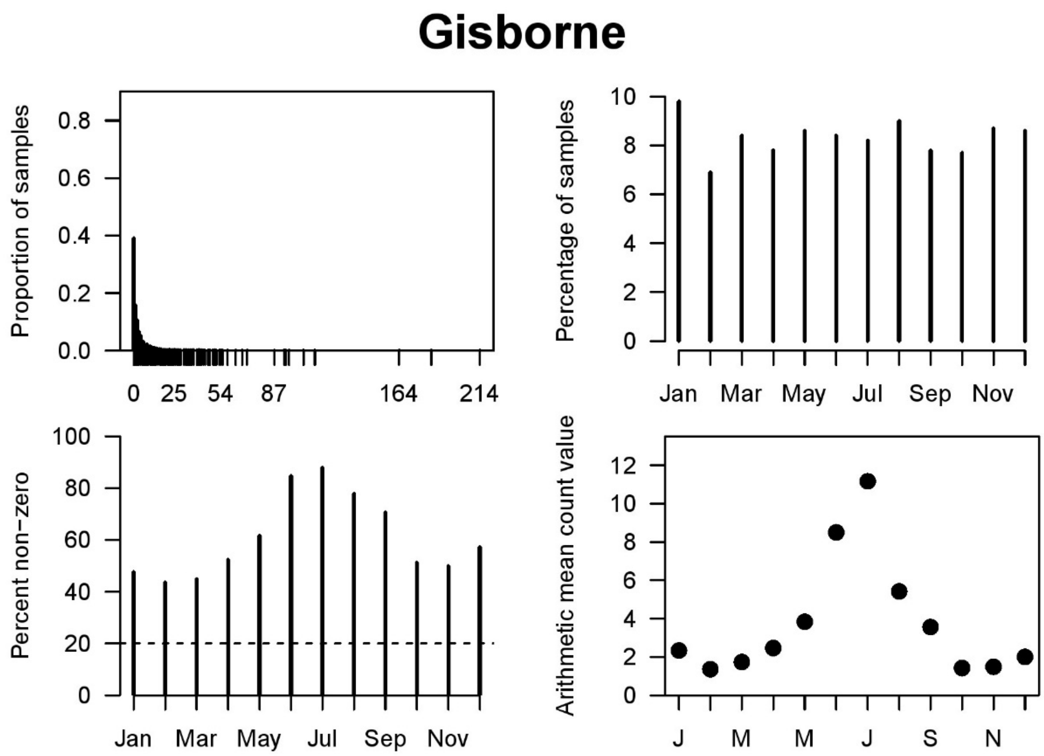

Figure 82: Characteristics of the Gisborne puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

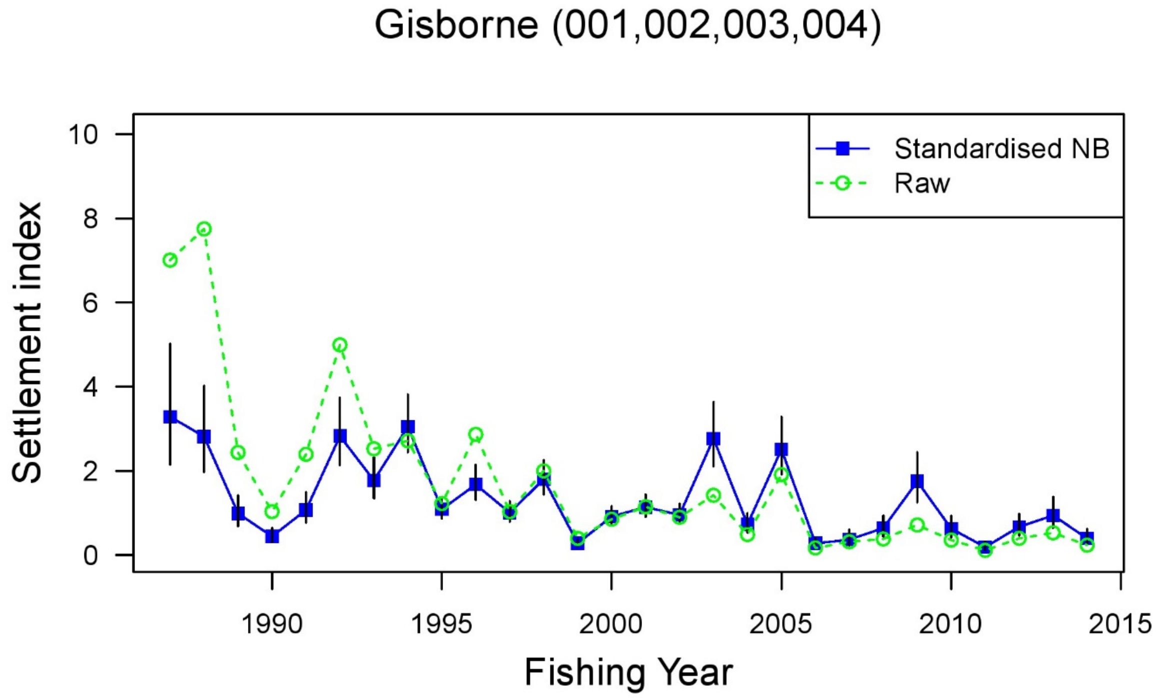

Figure 83: Standardised and raw indices of settlement from Gisborne with 95% confidence intervals.

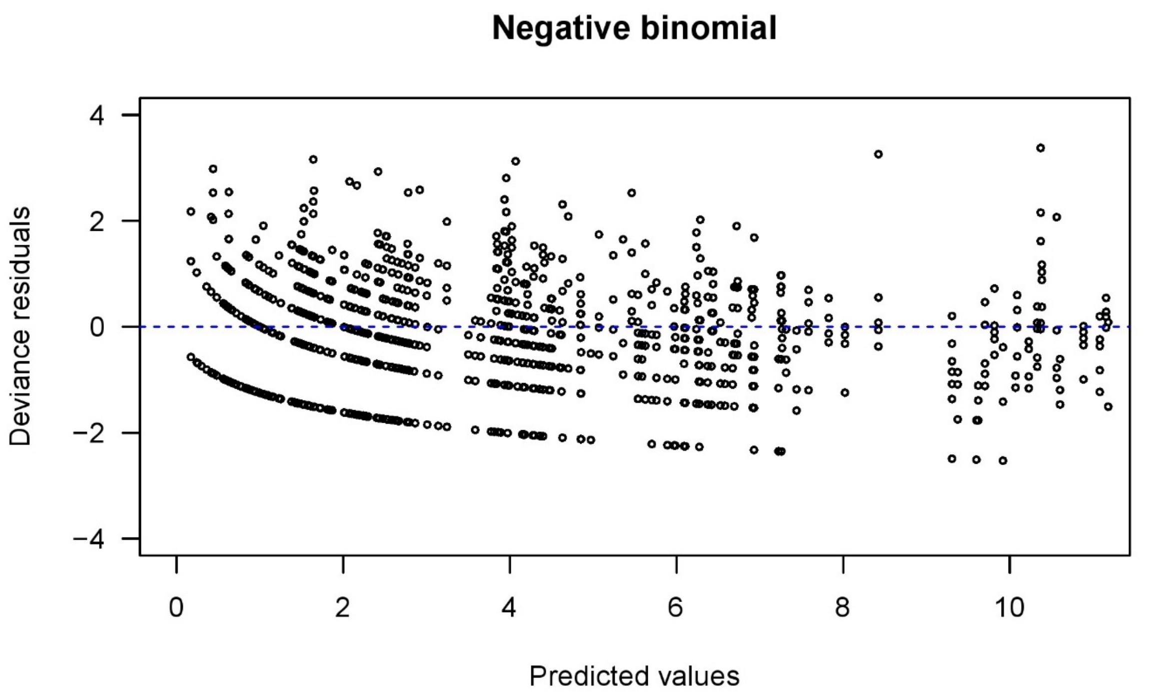

Figure 84: Deviance residuals for the negative binomial model for Gisborne. Predicted values are in natural space.

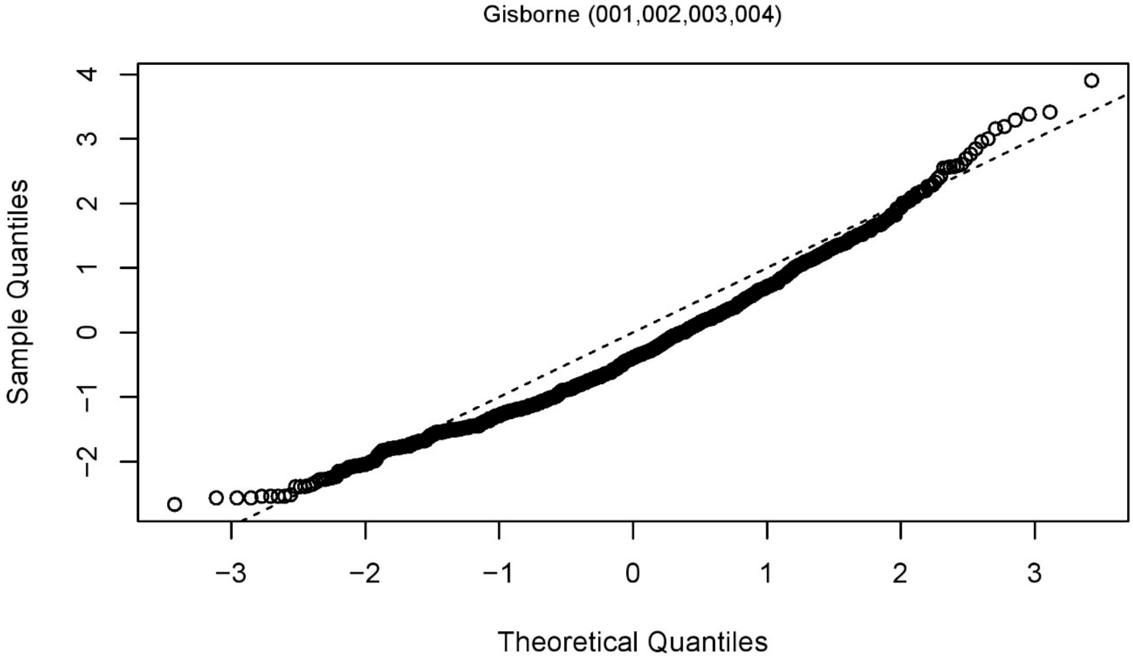

Figure 85: Quantile-quantile plot for the negative binomial standardisation model for Gisborne.

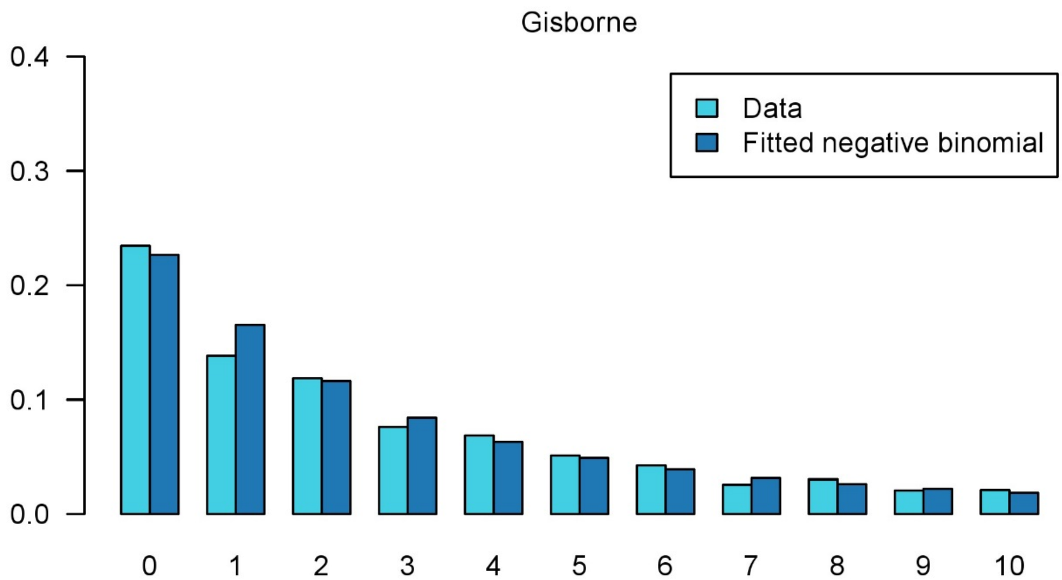

Figure 86: Data distribution and that from the fitted negative binomial model for Gisborne.

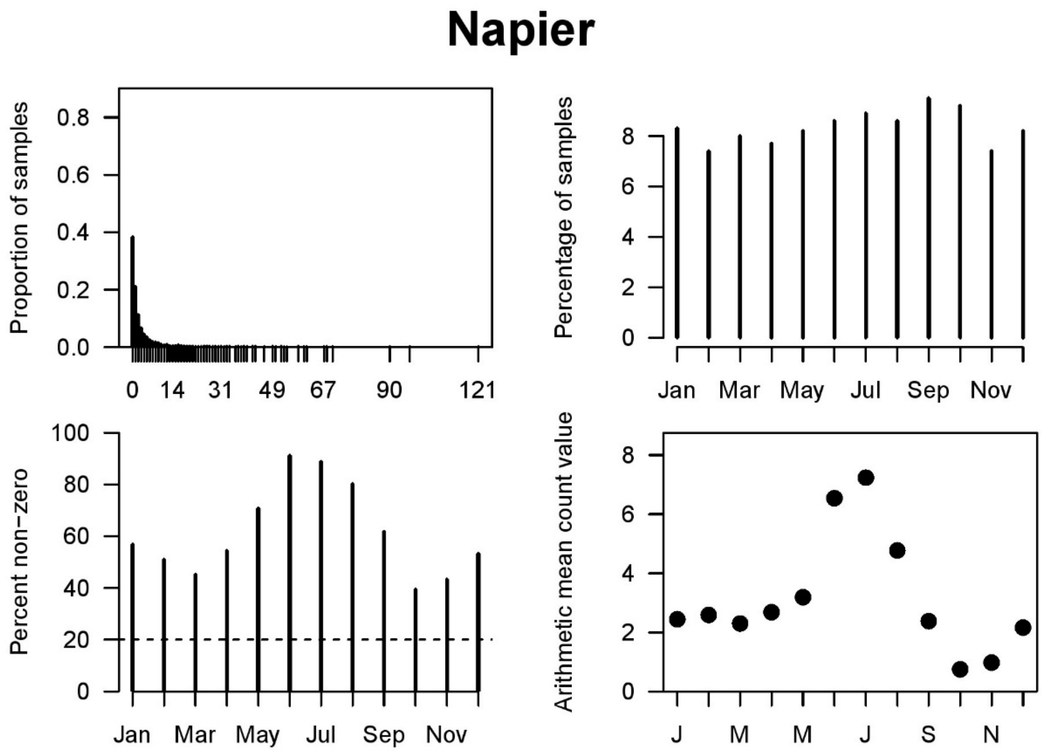

Figure 87: Characteristics of the Napier puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

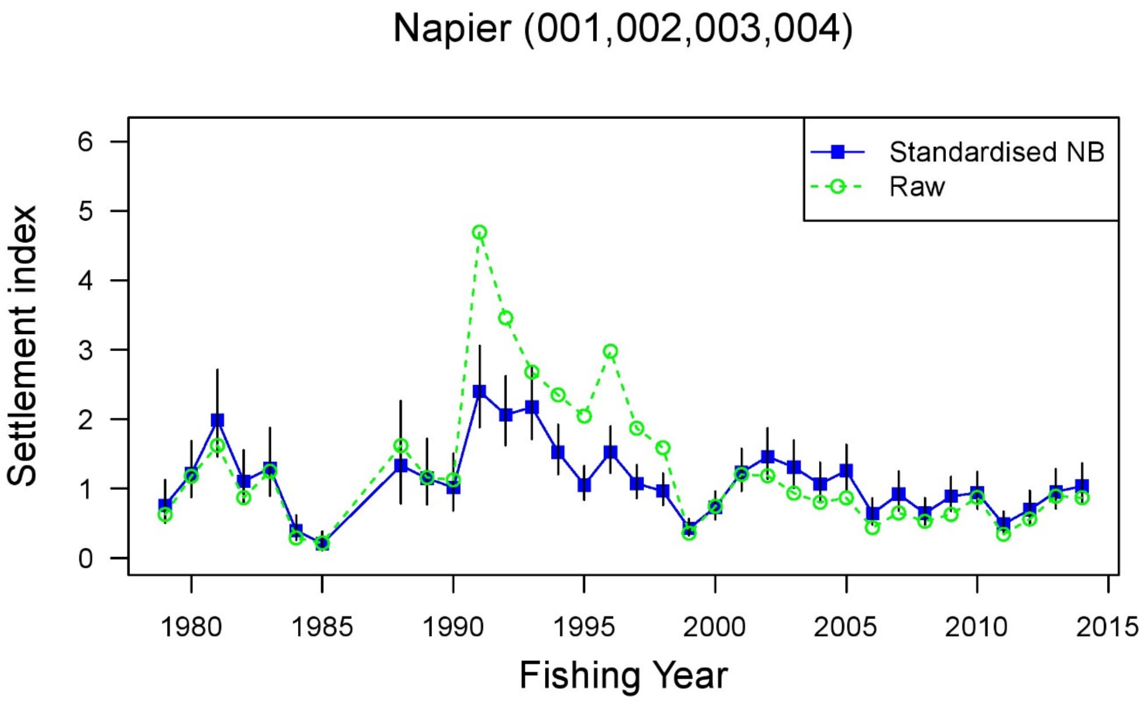

Figure 88: Standardised and raw indices of settlement from Napier with 95% confidence intervals.

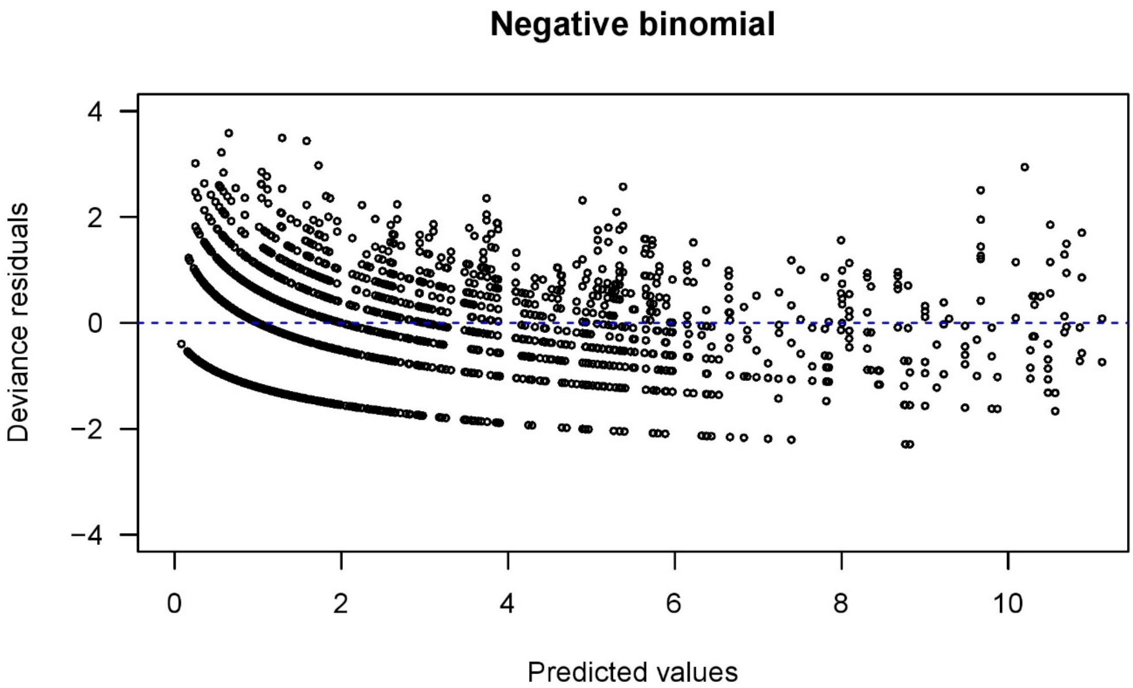

Figure 89: Deviance residuals for the negative binomial model for Napier. Predicted values are in natural space.

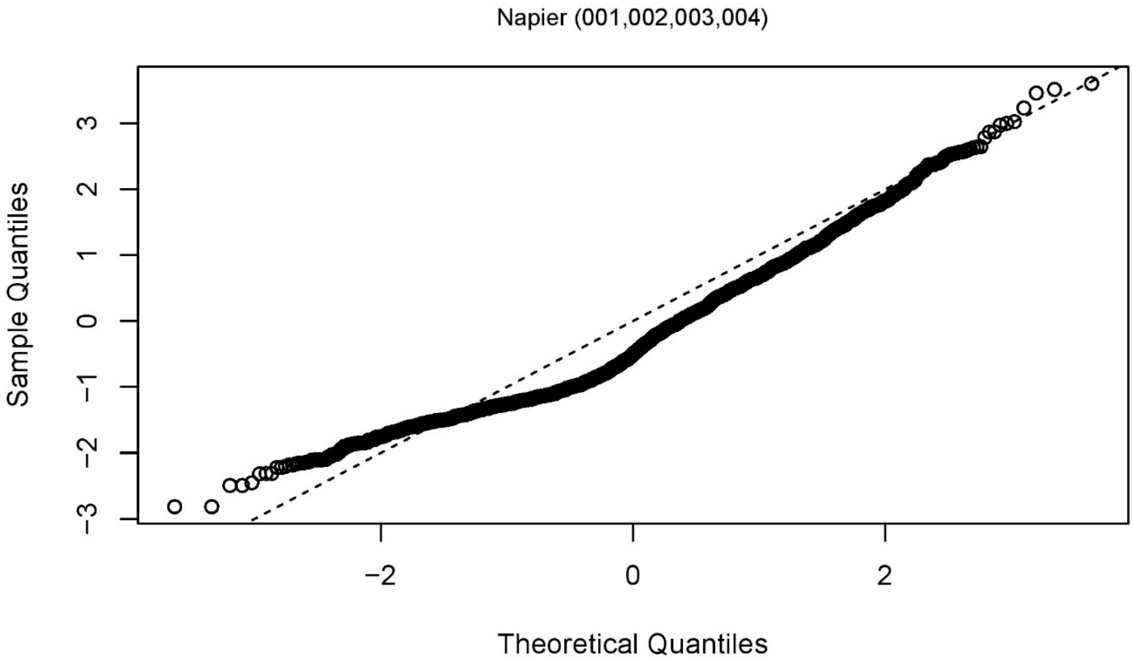

Figure 90: Quantile-quantile plot for the negative binomial standardisation model for Napier.

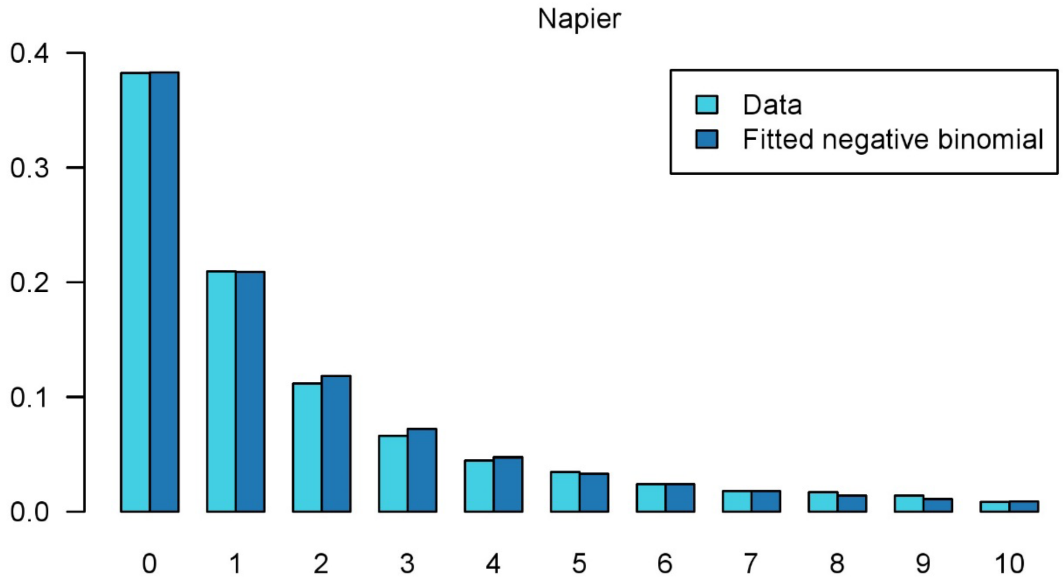

Figure 91: Data distribution and that from the fitted negative binomial model for Napier.

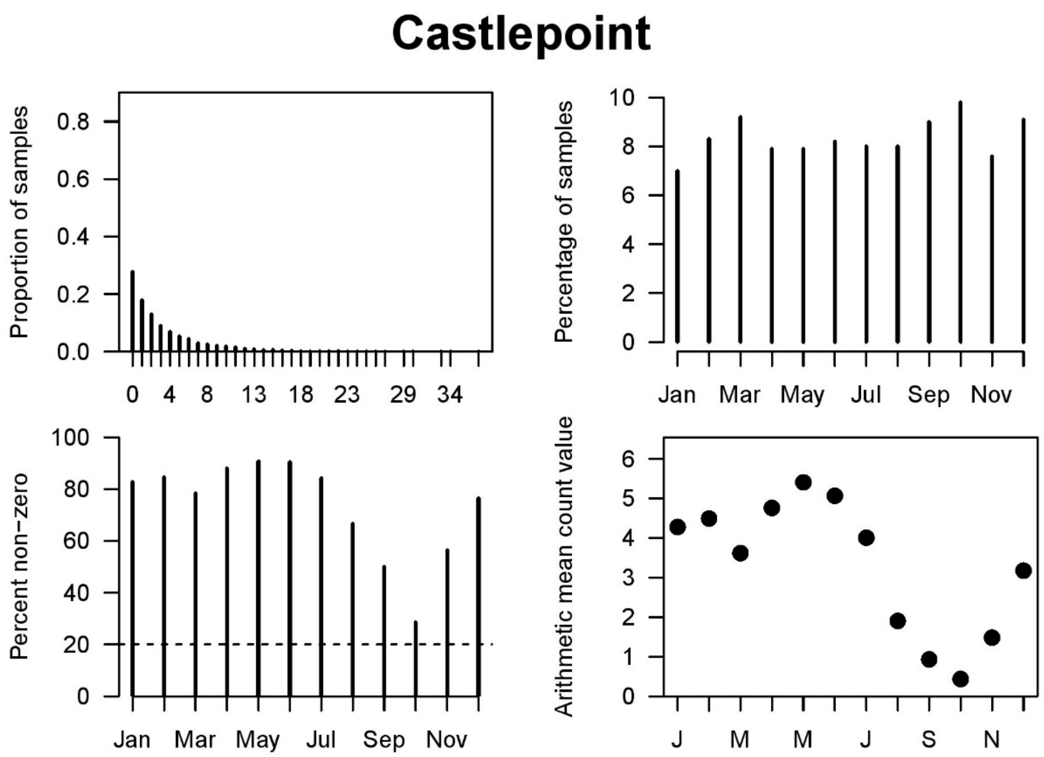

Figure 92: Characteristics of the Castlepoint puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

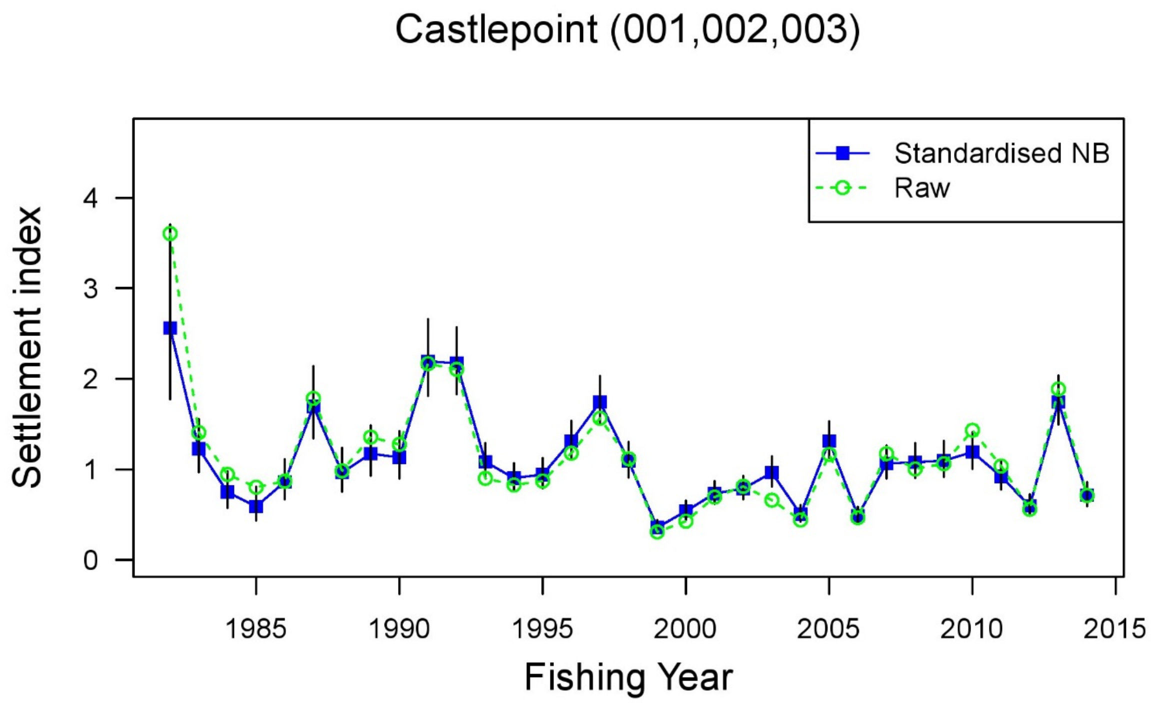

Figure 93: Standardised and raw indices of settlement from Castlepoint with 95% confidence intervals.

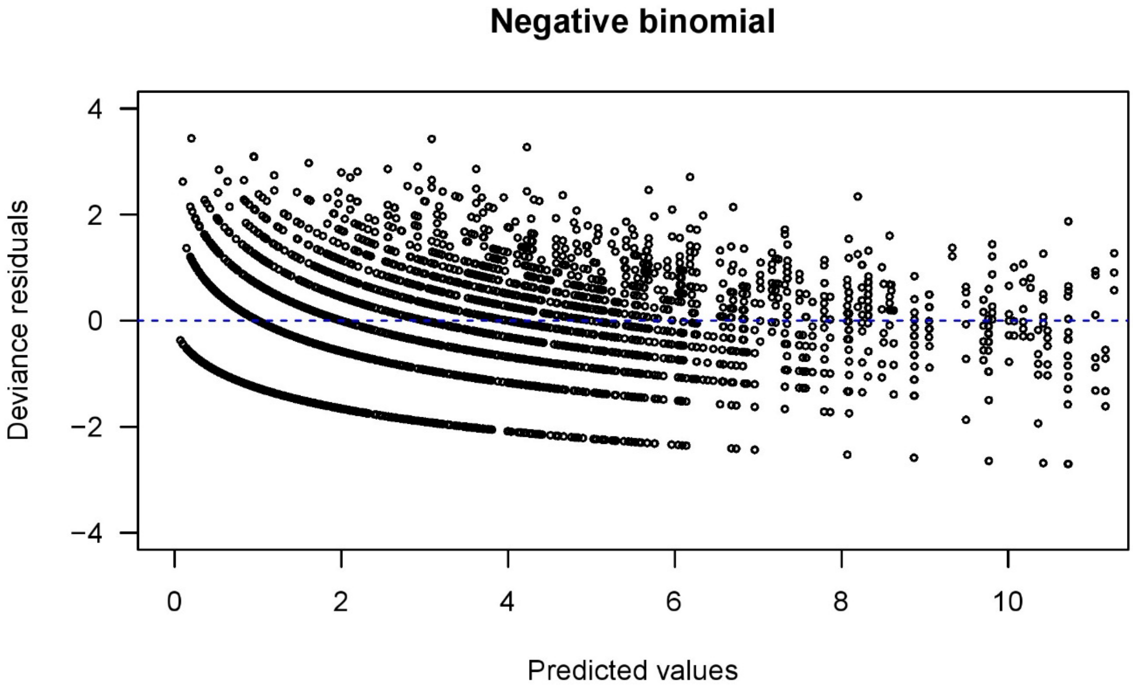

Figure 94: Deviance residuals for the negative binomial model for Castlepoint. Predicted values are in natural space.

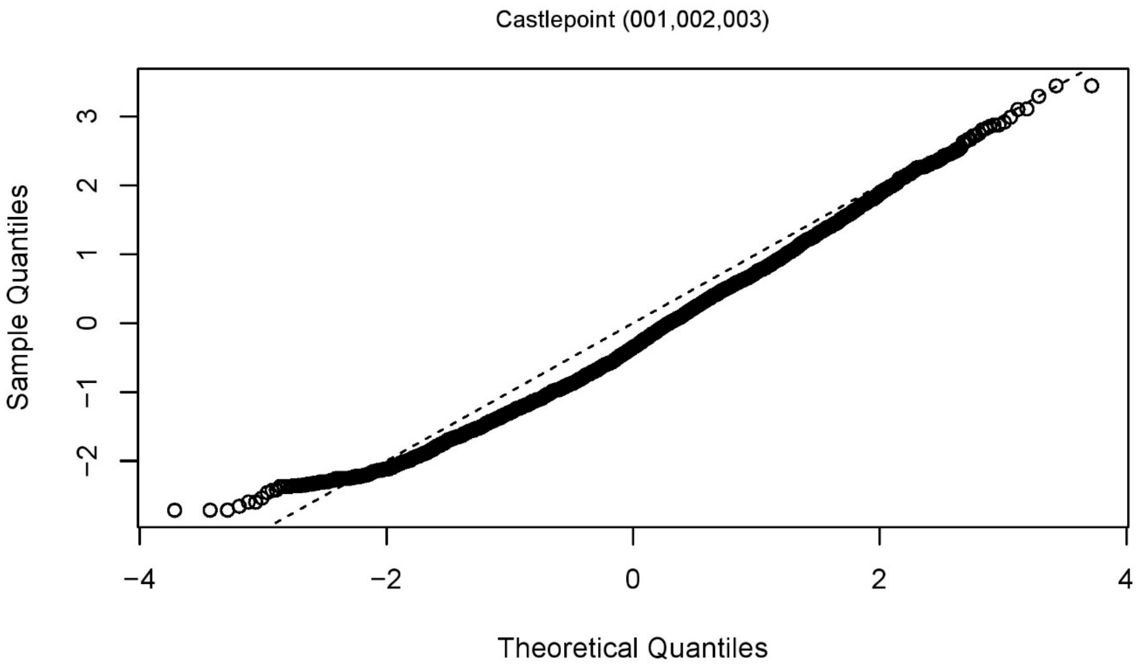

Figure 95: Quantile-quantile plot for the negative binomial standardisation model for Castlepoint.

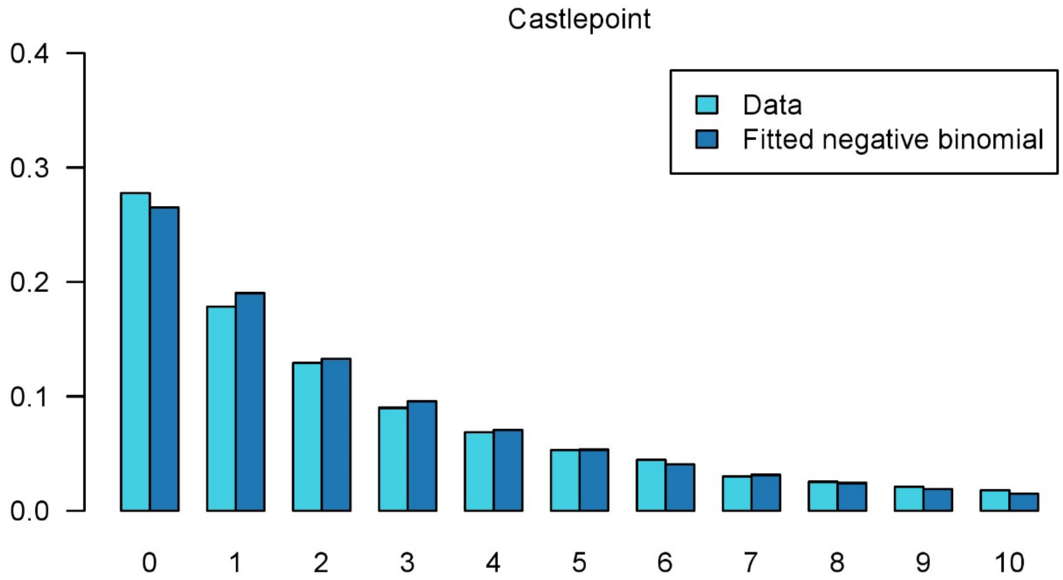

Figure 96: Data distribution and that from the fitted negative binomial model for Castlepoint.

4. SUMMARY AND DISCUSSION

The standardised indices for all sites are summarised in Table 17 (and the plots that follow), and the yearly number of samples for each site is given in Appendix 2. In the rest of this section trends over time for each site are discussed, and monthly puerulus settlement for currently operating collectors is plotted.

Table 17: Standardised annual indices for each site. Year is fishing year 1 April–31 March. '–': no usable sampling was done; 0.00: no observed settlement.

	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikoura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Chalky Inlet CRA 8	Jackson Bay CRA 8
1979	–	0.76	–	–	–	–	–	–
1980	–	1.22	–	–	–	–	–	–
1981	–	1.99	–	0.55	–	8.15	–	–
1982	–	1.10	2.56	0.76	–	0.38	–	–
1983	–	1.30	1.23	0.16	–	3.93	–	–
1984	–	0.40	0.75	0.37	–	0.30	–	–
1985	–	0.21	0.59	0.24	–	0.00	0.36	–
1986	–	–	0.86	0.09	–	0.12	0.21	–
1987	3.28	–	1.70	1.05	–	1.58	1.42	–
1988	2.82	1.33	0.96	0.40	–	0.22	1.31	–
1989	0.99	1.15	1.17	0.79	–	0.60	1.64	–
1990	0.44	1.02	1.13	1.58	–	0.43	1.84	–
1991	1.07	2.40	2.19	6.69	0.00	0.93	1.03	–
1992	2.83	2.06	2.17	5.18	0.14	0.54	0.52	–
1993	1.77	2.17	1.08	2.04	0.00	0.00	0.14	–
1994	3.05	1.52	0.90	1.09	0.00	1.19	1.64	–
1995	1.09	1.05	0.94	0.60	0.11	0.40	0.40	–
1996	1.67	1.53	1.31	0.64	0.98	0.33	1.76	–
1997	1.00	1.07	1.74	1.91	0.42	0.56	1.41	–
1998	1.80	0.96	1.09	1.87	0.57	0.30	0.50	–
1999	0.28	0.43	0.36	1.28	0.11	0.23	1.70	0.30
2000	0.91	0.73	0.54	1.30	3.88	1.22	1.26	0.63
2001	1.14	1.23	0.73	0.54	1.85	1.75	0.60	0.26
2002	0.95	1.46	0.79	3.36	0.92	1.48	1.42	1.65
2003	2.77	1.31	0.96	3.38	7.68	3.89	1.56	0.64
2004	0.73	1.06	0.50	1.02	0.37	0.16	0.30	0.47
2005	2.51	1.26	1.31	2.25	0.08	0.00	–	1.56
2006	0.28	0.64	0.49	1.09	0.05	0.13	–	0.33
2007	0.36	0.92	1.06	1.86	0.05	0.49	–	0.27
2008	0.64	0.65	1.08	1.77	0.11	0.09	–	0.10
2009	1.75	0.89	1.10	0.61	0.64	1.02	–	0.18
2010	0.62	0.94	1.19	1.39	1.49	1.65	7.03	2.16
2011	0.19	0.49	0.92	0.64	1.11	0.14	1.44	2.50
2012	0.67	0.70	0.60	1.18	0.76	0.18	4.37	8.65
2013	0.94	0.96	1.74	0.72	2.13	0.75	–	15.20
2014	0.39	1.04	0.72	0.87	0.55	0.87	–	23.23

Gisborne

Settlement at Gisborne in 2014/15 was well below the long-term mean. This is a continuation of a series of below average settlement for the region. With the exception of 2009, eight of the last nine years have been below average (Figure 97). Similar settlement patterns and levels were observed at Whangara and Kaiti with settlement peaking at both sites in August with another smaller peak in January (Figure 98).

Napier

Settlement at Napier was only just above the long-term mean. Over the last nine years, settlement has been close to or below the long-term mean, and no significantly high settlement has occurred since the 1990s (Figure 99). Settlement at Napier Port and Cape Kidnappers peaked in July (Figure 100).

Castlepoint

For the third time in four years settlement at Castlepoint was below the long-term mean. Other than 2013 and 2005, settlement has been average to below average since 1998 (Figure 101). Levels of settlement between Castlepoint and Orui were generally consistent. Settlement at Orui and Castlepoint peaked in January (Figure 102).

Kaikoura

Kaikoura was just below the long term mean (Figure 103). All four groups had similar levels of settlement up until the last three months (between January and March) where South Kaikoura recorded much higher levels (Figure 104).

Moeraki

Settlement at Moeraki was below the long term mean (Figure 105) and sporadic over most of the fishing year (Figure 106).

Halfmoon Bay

Settlement was below the long-term mean in Halfmoon Bay (Figure 107), peaking in May (Figure 108).

Chalky Inlet

Very little data were received in 2014/15 (see Table 12).

Jackson Bay

Extraordinarily high levels of settlement were recorded at Jackson Bay in 2014/15 surpassing the record settlement from the previous year (Figure 109). Settlement was lowest in June with about 5 pueruli per collector (slightly lower than the highest settlement month from Castlepoint or Napier) and peaked in November with an average of about 120 puerulus per collector. From December to March settlement was consistently high, averaging about 30 to 40 puerulus per collector per month (Figure 110).

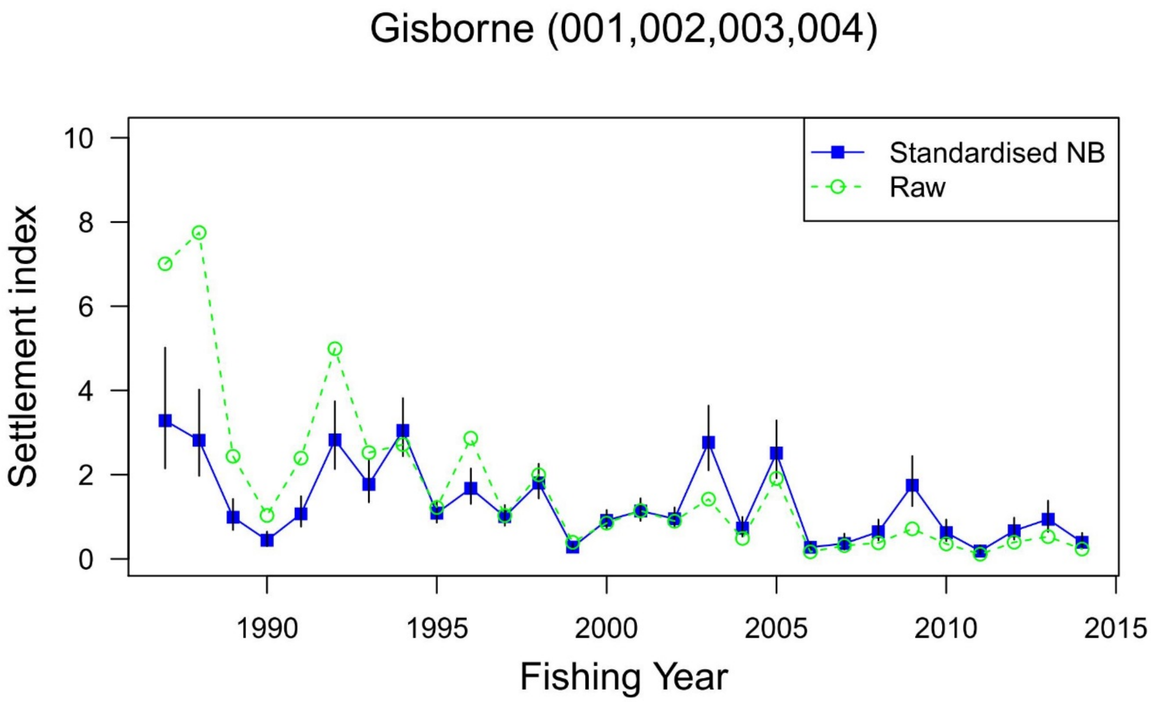

Figure 97: Gisborne–standardised and raw indices of annual settlement with 95% confidence intervals.

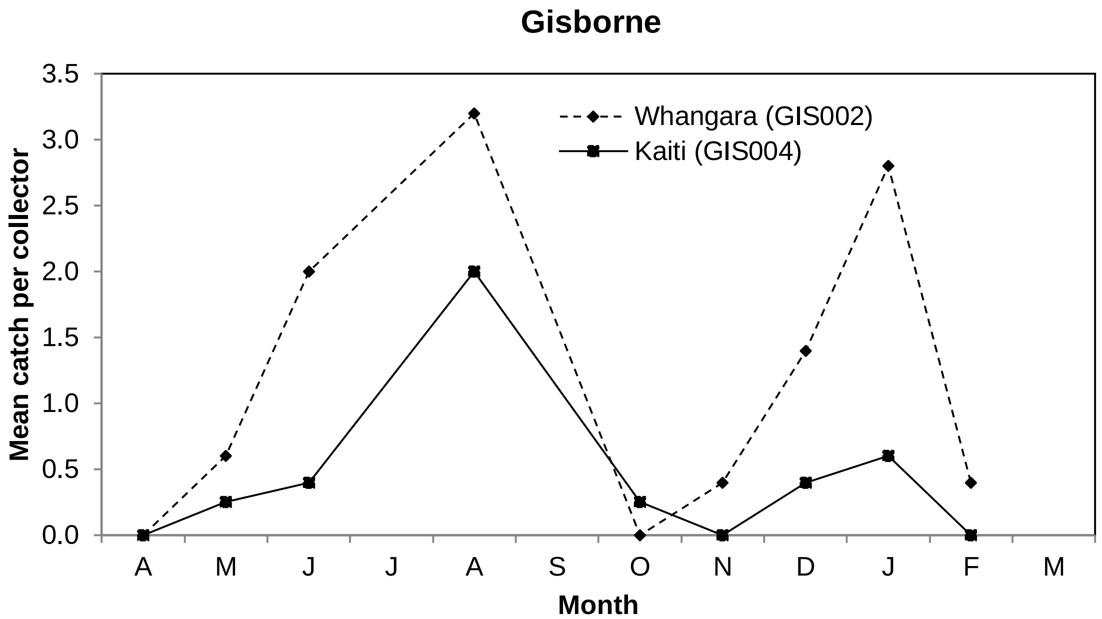

Figure 98: Whangara and Kaiti monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

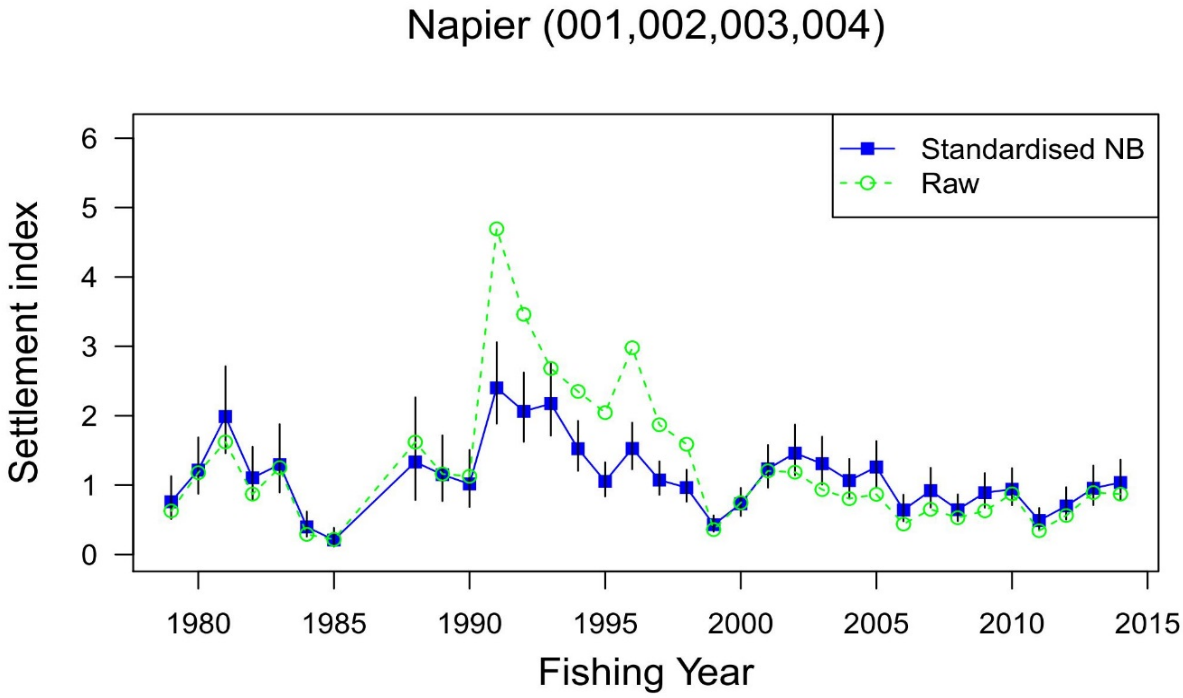

Figure 99: Napier—standardised and raw indices of annual settlement with 95% confidence intervals. Note that there were no checks in 1986–87.

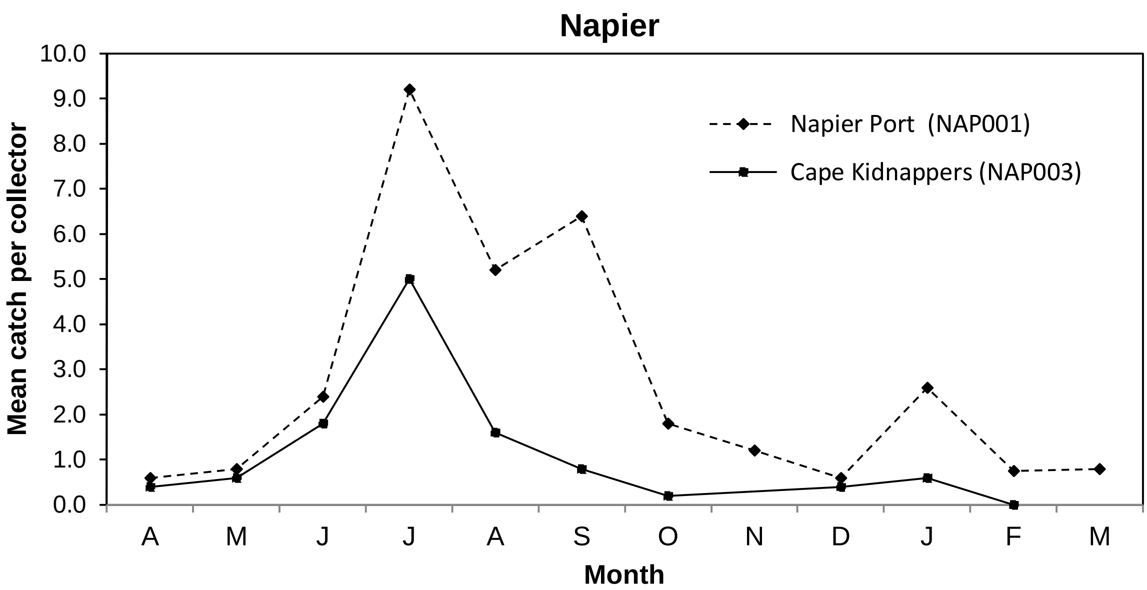

Figure 100: Napier harbour and Cape Kidnappers monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

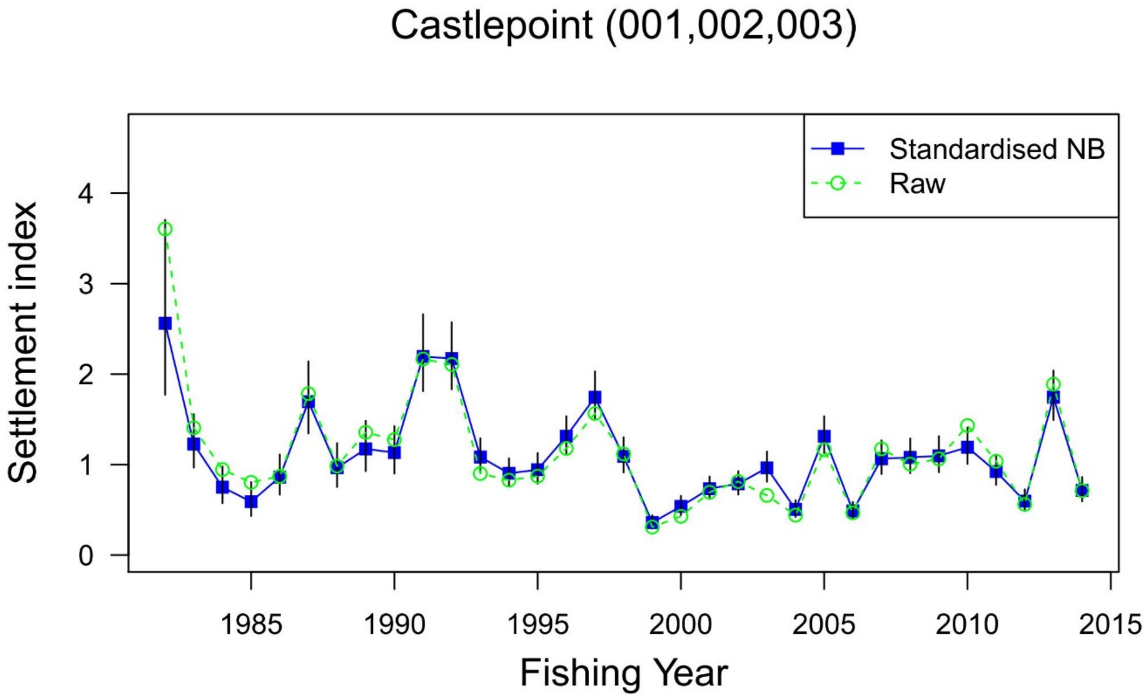

Figure 101: Castlepoint—standardised and raw indices of annual settlement with 95% confidence intervals.

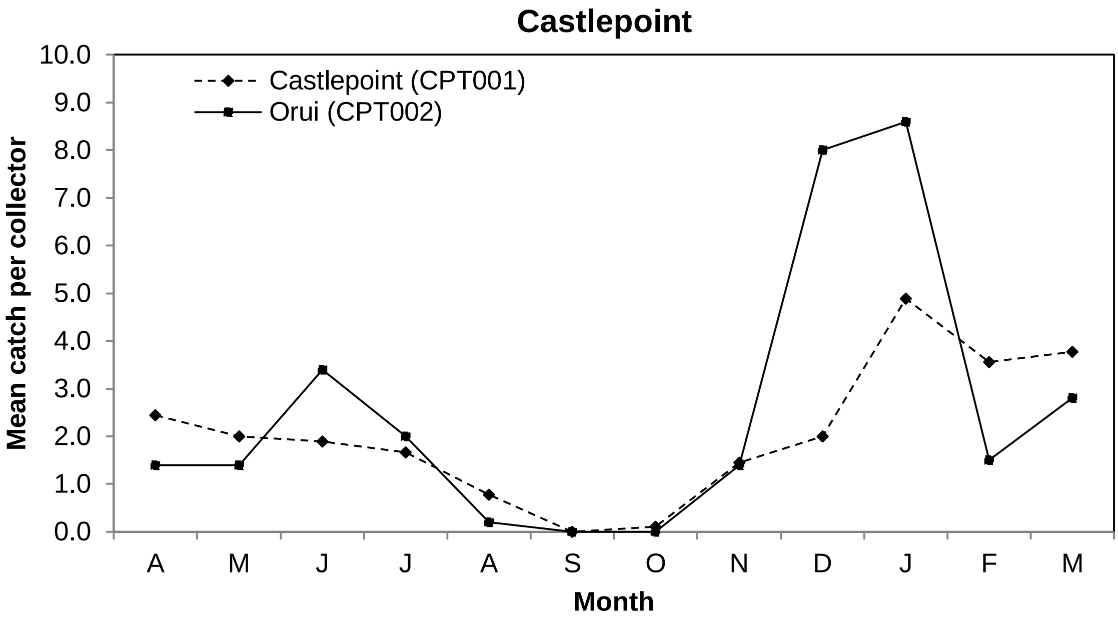

Figure 102: Castlepoint and Orui monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

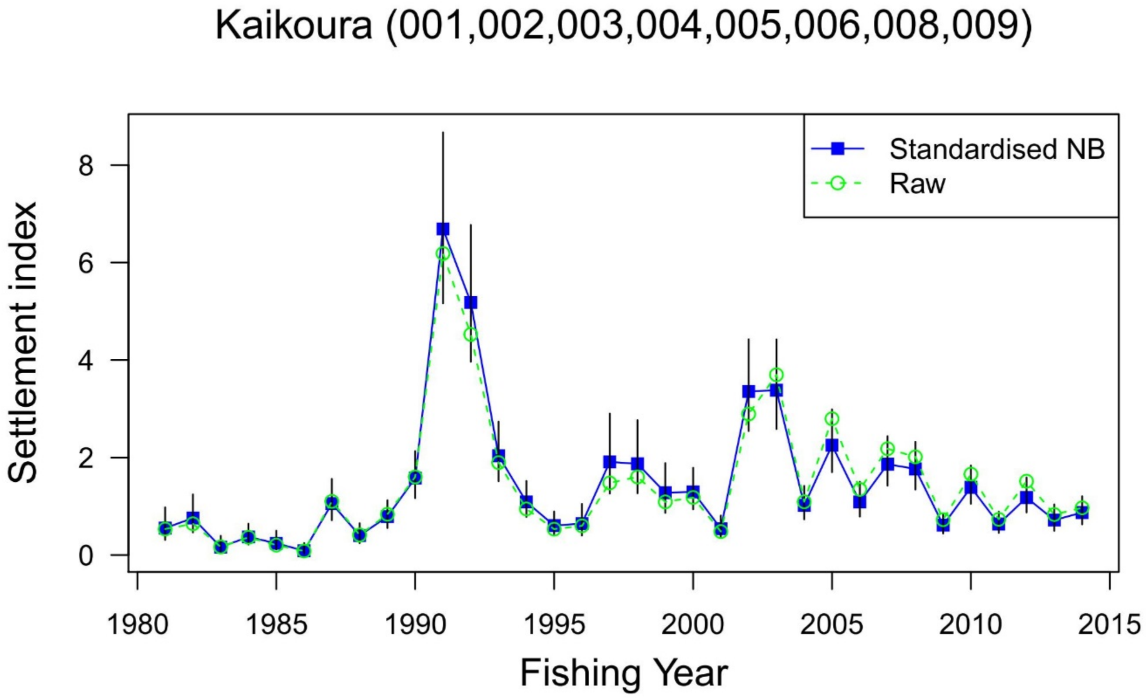

Figure 103: Kaikoura—standardised and raw indices of annual settlement with 95% confidence intervals.

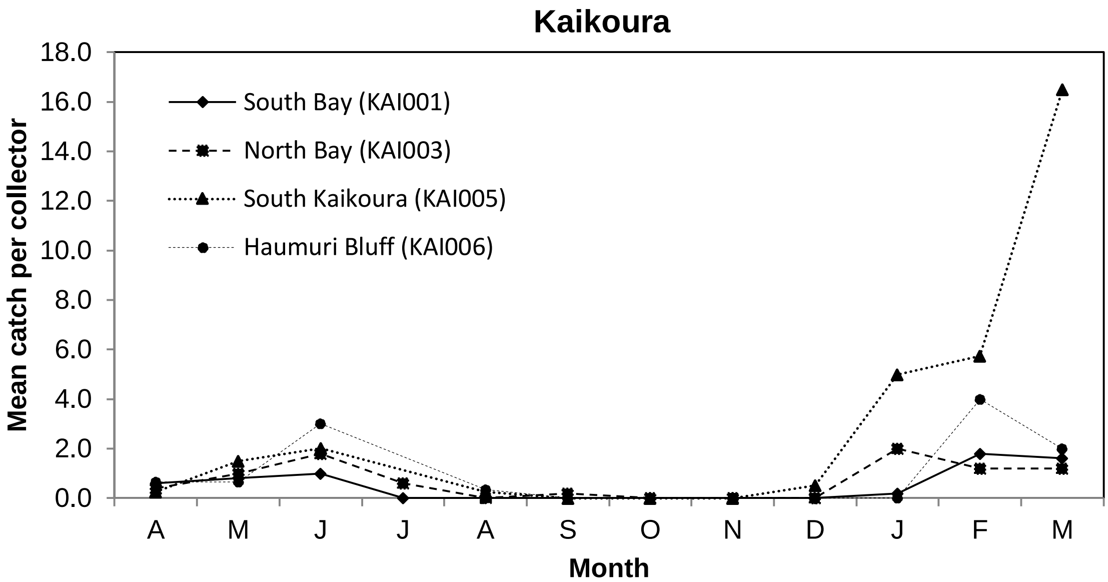

Figure 104: South Bay and North Bay monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

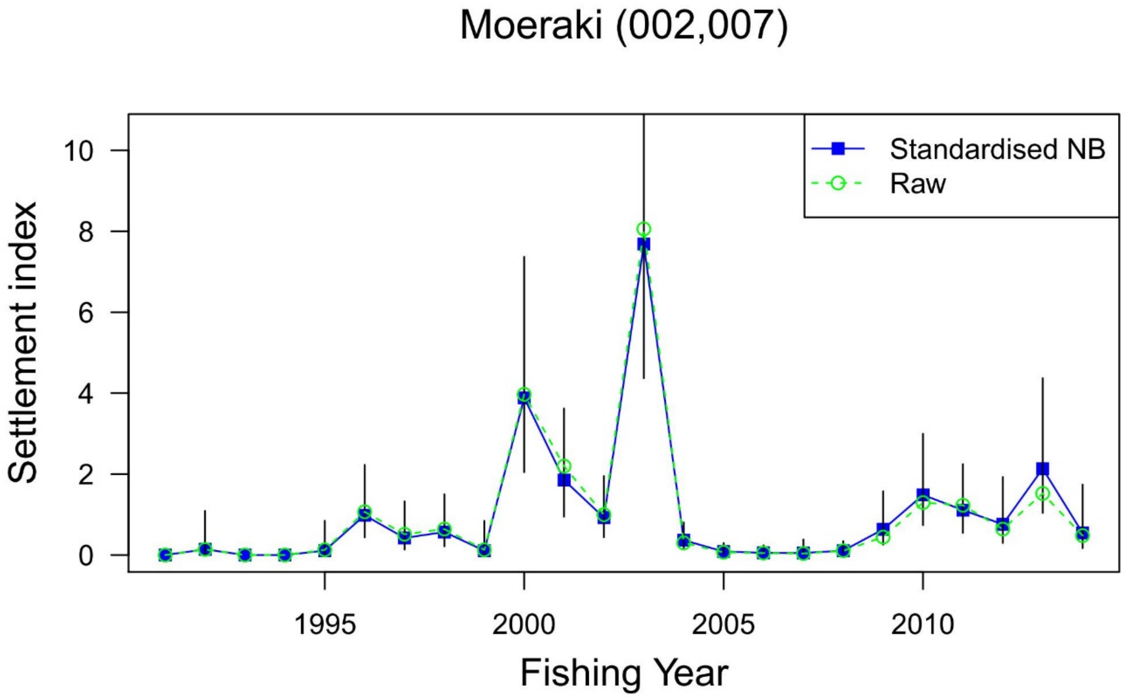

Figure 105: Moeraki—standardised and raw indices of annual settlement with 95% confidence intervals.

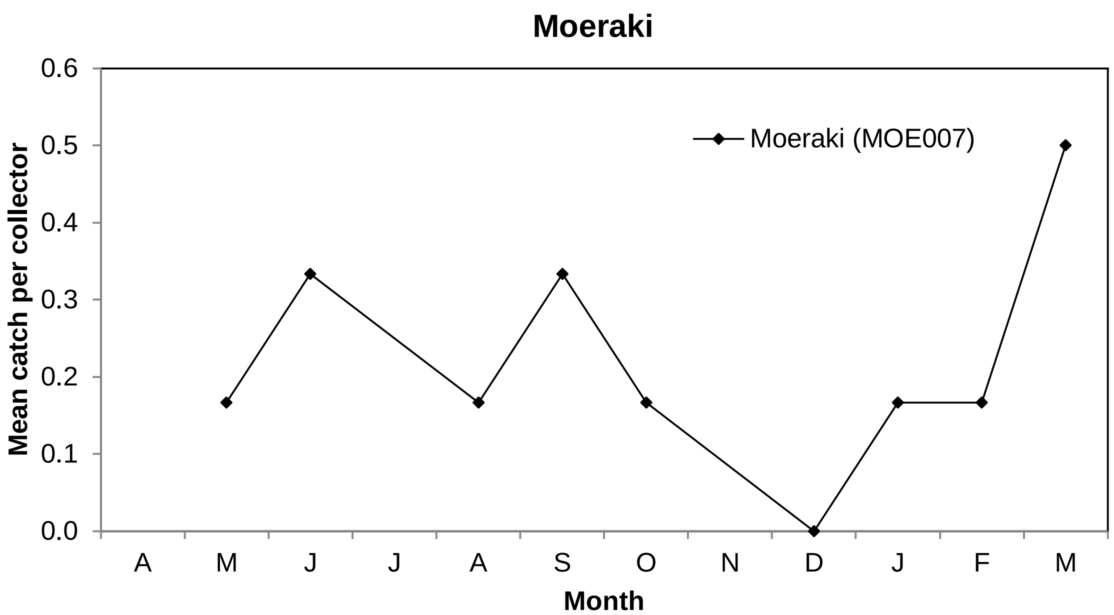

Figure 106: Moeraki monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

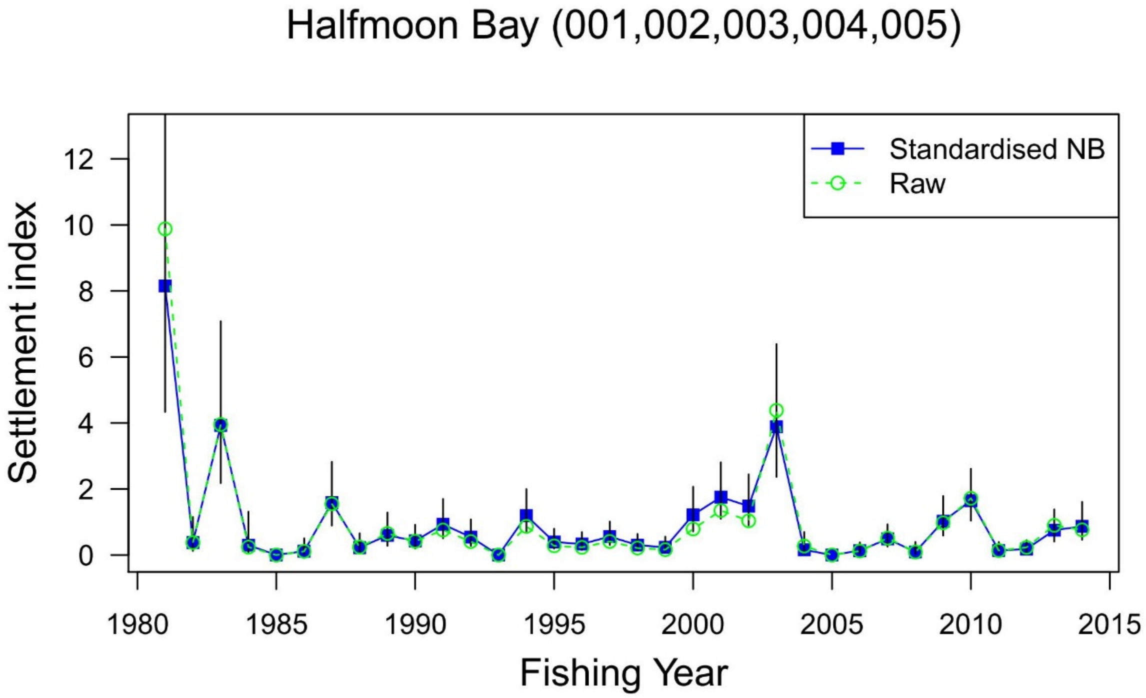

Figure 107: Halfmoon Bay—standardised and raw indices of annual settlement with 95% confidence intervals. The 95% confidence bounds were large because of high collector catch variability and the data not fitting the standardisation model well because of the large number of zero catches.

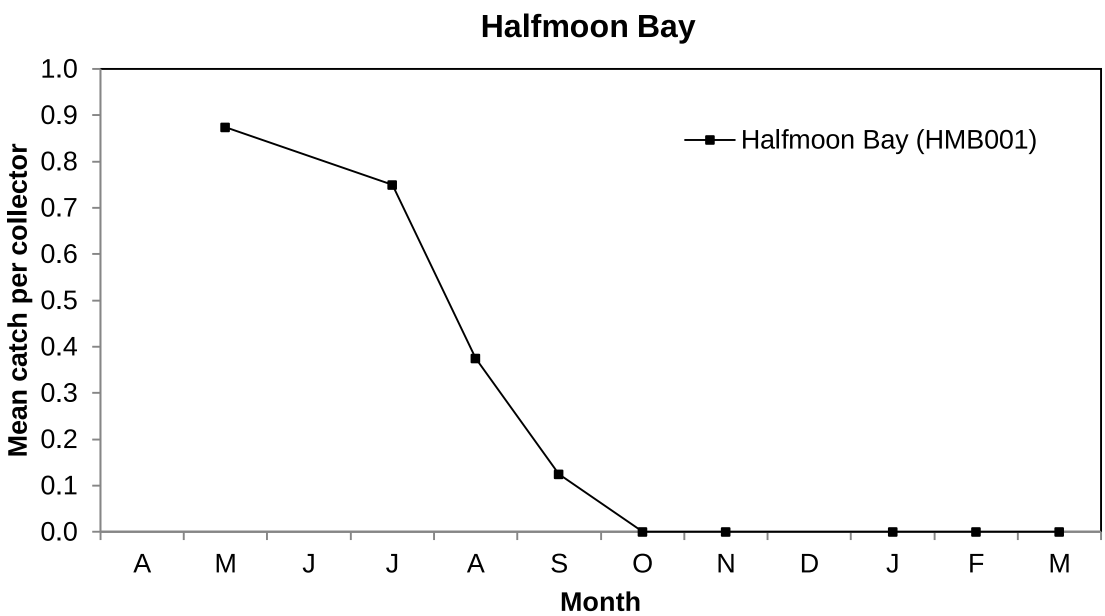

Figure 108: Halfmoon Bay monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

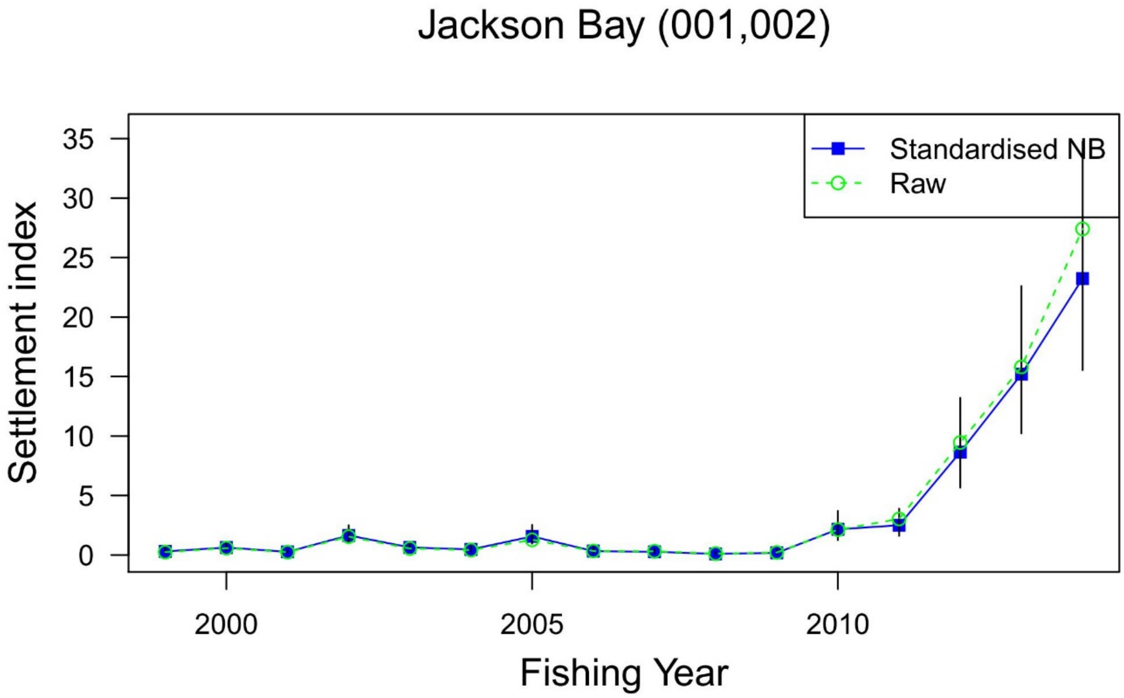

Figure 109: Jackson Bay—standardised and raw indices of annual settlement with 95% confidence intervals.

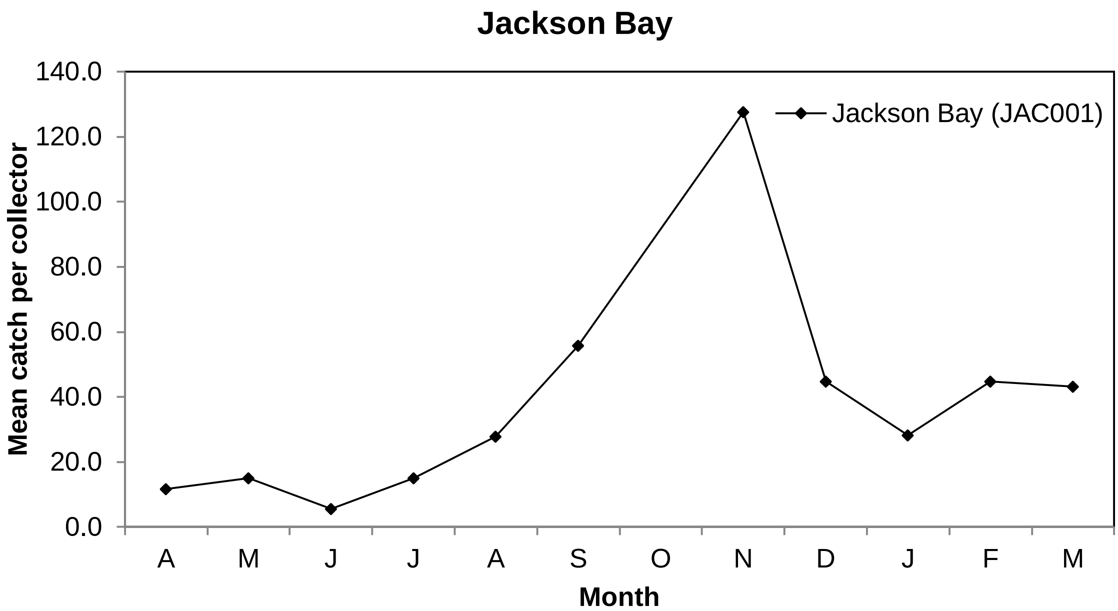

Figure 110: Raw monthly settlement, 2014/15 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

5. CONCLUSIONS

Jackson Bay (CRA 8) has continued its record run of extremely high levels of settlement with 23 times the normal settlement being recorded during the year. In contrast, Halfmoon Bay (CRA 8), has been below the long-term mean for the last four years. Moeraki (CRA 7) had about half the normal settlement and Kaikoura (CRA 5) was just below the long-term mean.

In the North Island, only Napier (CRA 4) had settlement close to the long-term mean. The other sites, Gisborne (CRA 5) and Castlepoint (CRA 4), were below the long-term mean. This continues (with the exception of Castlepoint in 2013 where settlement was moderately high) a succession of mostly below average settlement for the last five years at these sites.

For Gisborne, Napier, and Castlepoint the puerulus index is potentially a signal for recruited abundance 4–6 years into the future (Booth & McKenzie 2008). For other sites estimated intervals from settlement to recruitment in the fishery are 4–5 years (Moeraki) or 6–8 years (Halfmoon Bay).

6. ACKNOWLEDGMENTS

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Appendix 1: Request for puerulus standardisations

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Ka whakapai te kai o te moana

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PUERULUS INDICES FOR 2015 STOCK ASSESSMENT

Dear Andy:

This year the rock lobster stock assessments will be done for CRA 5, CRA 7 and CRA 8. The stock assessment team will therefore need annual standardised indices for each of these three stocks, based on the fishing year 1 April through 30 March.

As for last year's index, we would like the standardisation to be done using the date of the actual check.

We noted last year that a 36-check threshold is used: collectors are not used unless they have been checked at least 36 times. Because there is potential for data to be discarded by this rule, we would like to see some exploration of the effect of this rule where appropriate.

We will need to see a characterisation of the data from each stock – how many collectors in what groups in what locations for which periods – so that we can assess which groups should be used for the standardisation.

For some of these stocks, zeroes are a problem, and last year's CRA 3 index used only the peak settlement months. We support this approach.

The first RLFAWG meeting is on 22 September. Because we would like to be comfortable with the puerulus index by that date, we request a preliminary document from NIWA by 1 September.

Yours sincerely on behalf of the assessment team

Daryl R Sykes

NZ Rock Lobster Industry Council Ltd

In the standardisation request for Gisborne (CRA 3) in 2014 there was an additional aspect (Forman et al. 2015, Appendix 1). This is shown below, and a query was made as to what extent this should be revisited:

"*As discussed in the meeting, we would like to see analyses that investigate whether collectors represent independent samples within each group, exploration of the effects of grouping in different ways, and fits based on alternative error structure assumptions (e.g. delta log*-normal)."

The reply was:

1. The review recommended: Methods to reduce the large number of zeros in the settlement data in CRA7 and CRA8 should be investigated. This could include using only the information from the peak settlement periods and examining alternate model fit distributions to these data. The model with best diagnostics for standardization could then be used.

2. Last years puerulus standardisation investigated several alternative distributions: the Poisson, quasi-Poisson, zero-inflated Poisson and negative binomial. For CRA 3 we accepted the negative binomial but this exploration needs to be done on a stock-by-stock basis.

3. Similarly, last year there was an exploration of group vs. collector and this seems essential to do on a stock-by-stock basis.

I believe that these comments provide good guidance in response to your question “To what extent would you like to revisit these analyses and decisions?”

Appendix 2: Number of samples by fishing year and group

Summary of the number of puerulus samples taken by fishing year and group. This is for the final data sets used in the puerulus standardisation after dropping collectors with fewer than 36 samples and fishing years with fewer than 10 samples.

Table A1: Gisborne.

	GIS001	GIS002	GIS003	GIS004	Total
1987	15	0	0	0	15
1988	23	0	0	0	23
1989	25	0	0	0	25
1990	25	0	0	0	25
1991	25	5	0	0	30
1992	24	17	0	0	41
1993	25	20	0	0	45
1994	25	20	25	23	93
1995	25	24	25	25	99
1996	25	20	0	25	70
1997	25	20	23	25	93
1998	25	25	25	25	100
1999	20	25	21	18	84
2000	23	25	25	25	98
2001	24	25	25	25	99
2002	20	25	19	25	89
2003	0	18	19	30	67
2004	0	20	20	25	65
2005	0	25	19	25	69
2006	0	23	24	30	77
2007	0	24	0	0	24
2008	0	20	0	25	45
2009	0	18	0	25	43
2010	0	15	0	25	40
2011	0	20	0	20	40
2012	0	20	0	25	45
2013	0	20	0	15	35
2014	0	20	0	18	38

Table A2: Napier.

	NAP001	NAP002	NAP003	NAP004	Total
1979	52	0	0	0	52
1980	65	0	0	0	65
1981	66	0	0	0	66
1982	60	0	0	0	60
1983	48	0	0	0	48
1984	60	0	0	0	60
1985	36	0	0	0	36
1988	18	0	0	0	18
1989	36	0	0	0	36
1990	36	0	0	3	39
1991	60	21	0	26	107
1992	69	21	0	32	122
1993	69	17	0	33	119
1994	65	27	25	33	150
1995	59	29	41	30	159
1996	72	33	50	33	188
1997	71	24	65	36	196
1998	66	18	58	27	169
1999	72	6	55	27	160
2000	47	0	48	27	122
2001	65	0	61	21	147
2002	57	0	52	18	127
2003	66	0	54	0	120
2004	71	0	59	0	130
2005	72	0	53	0	125
2006	72	0	47	0	119
2007	53	0	40	0	93
2008	56	0	59	0	115
2009	60	0	59	0	119
2010	60	0	52	0	112
2011	60	0	53	0	113
2012	50	0	36	0	86
2013	50	0	50	0	100
2014	50	0	59	0	109

Table A3: Castlepoint.

	CPT001	CPT002	CPT003	Total
1982	18	0	0	18
1983	68	0	0	68
1984	57	0	0	57
1985	41	0	0	41
1986	70	0	0	70
1987	66	0	0	66
1988	66	0	0	66
1989	67	0	0	67
1990	72	0	0	72
1991	72	17	16	105
1992	71	46	38	155
1993	70	63	61	194
1994	102	60	50	212
1995	97	48	37	182
1996	108	60	60	228
1997	108	60	55	223
1998	98	36	35	169
1999	116	18	65	199
2000	105	21	60	186
2001	99	36	53	188
2002	104	52	62	218
2003	99	51	55	205
2004	114	53	65	232
2005	107	60	60	227
2006	108	58	45	211
2007	106	50	0	156
2008	107	55	0	162
2009	99	55	0	154
2010	117	65	0	182
2011	108	60	0	168
2012	108	46	0	154
2013	117	70	0	187
2014	99	59	0	158

Table A4: Kaikoura.

	KAI001	KAI002	KAI003	KAI004	KAI005	KAI006	KAI008	KAI009	Total
1981	15	0	15	0	0	0	15	0	45
1982	18	0	18	0	0	0	18	0	54
1983	15	0	15	0	0	0	18	0	48
1984	21	0	21	0	0	0	24	0	66
1985	18	0	17	0	0	0	24	0	59
1986	21	0	20	0	0	0	24	0	65
1987	24	0	24	0	0	0	27	0	75
1988	24	6	24	0	0	0	18	9	81
1989	24	24	27	0	0	0	0	27	102
1990	27	27	27	0	0	0	0	27	108
1991	27	24	27	0	0	0	0	24	102
1992	21	21	21	21	0	0	0	21	105
1993	24	24	24	24	0	0	0	15	111
1994	26	27	27	27	0	0	0	0	107
1995	27	27	27	27	0	0	0	0	108
1996	15	15	15	15	0	0	0	0	60
1997	12	12	12	9	0	0	0	0	45
1998	12	12	15	15	0	0	0	0	54
1999	15	15	18	18	0	0	0	0	66
2000	26	26	27	27	0	0	0	0	106
2001	27	27	27	27	0	0	0	0	108
2002	27	24	27	26	0	0	0	0	104
2003	45	0	45	0	0	0	0	0	90
2004	44	0	45	0	0	0	0	0	89
2005	45	0	45	0	0	0	0	0	90
2006	45	0	45	0	0	0	0	0	90
2007	45	0	50	0	12	9	0	0	116
2008	45	0	44	0	20	18	0	0	127
2009	44	0	45	0	24	21	0	0	134
2010	45	0	45	0	21	15	0	0	126
2011	45	0	45	0	15	15	0	0	120
2012	45	0	40	0	11	6	0	0	102
2013	39	0	40	0	3	3	0	0	85
2014	40	0	40	0	15	15	0	0	110

Table A5: Moeraki.

	MOE002	MOE007	Total
1991	16	0	16
1992	14	0	14
1993	12	0	12
1994	15	0	15
1995	15	0	15
1996	18	0	18
1997	15	0	15
1998	18	0	18
1999	15	0	15
2000	15	0	15
2001	17	4	21
2002	18	9	27
2003	15	67	82
2004	6	71	77
2005	15	71	86
2006	6	73	79
2007	0	52	52
2008	0	73	73
2009	0	39	39
2010	0	46	46
2011	0	50	50
2012	0	24	24
2013	0	24	24
2014	0	16	16

Table A6: Halfmoon Bay.

	HMB001	HMB002	HMB003	HMB004	HMB005	Total
1981	12	0	0	0	0	12
1982	23	0	0	0	0	23
1983	18	0	0	0	0	18
1984	18	0	0	0	0	18
1985	18	0	0	0	0	18
1986	18	21	0	0	0	39
1987	24	15	0	0	0	39
1988	21	15	0	0	0	36
1989	18	15	0	0	0	33
1990	22	15	15	0	0	52
1991	21	18	18	0	0	57
1992	18	15	11	15	15	74
1993	21	21	21	21	17	101
1994	18	21	21	21	21	102
1995	21	18	18	18	18	93
1996	18	21	21	21	21	102
1997	21	21	21	21	21	105
1998	15	24	21	21	21	102
1999	9	21	21	21	21	93
2000	18	18	18	21	18	93
2001	24	18	18	18	18	96
2002	18	21	21	21	21	102
2003	30	0	0	0	0	30
2004	16	0	0	0	0	16
2005	40	0	0	0	0	40
2006	72	0	0	0	0	72
2007	59	0	0	0	0	59
2008	48	0	0	0	0	48
2009	53	0	0	0	0	53
2010	64	0	0	0	0	64
2011	64	0	0	0	0	64
2012	56	0	0	0	0	56
2013	48	0	0	0	0	48
2014	48	0	0	0	0	48

Table A7: Jackson Bay.

	JKB001	JKB002	Total
1999	18	20	38
2000	48	34	82
2001	50	36	86
2002	48	30	78
2003	40	21	61
2004	38	24	62
2005	35	16	51
2006	19	4	23
2007	40	0	40
2008	30	0	30
2009	20	0	20
2010	22	0	22
2011	39	0	39
2012	52	0	52
2013	49	0	49
2014	48	0	48