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Settlement indices for 2015/16 fishing year for the red rock lobster (*Jasus edwardsii*)

New Zealand Fisheries Assessment Report 2017/05

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EXECUTIVE SUMMARY

Forman, J.S.; McKenzie, A.; Stotter, D.R. (2017). Settlement indices for 2015/16 fishing year for the red rock lobster (*Jasus edwardsii*).

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This report addresses objective one of the Ministry for Primary Industries project CRA201502B (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 2015/16 fishing year, two groups of collectors in Gisborne, Napier, and Castlepoint, four groups in Kaikoura, 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 2015/16 was notable for the record levels recorded in Moeraki which was eight times above its long-term mean. Settlement was also above average at Gisborne, Castlepoint, and Jackson Bay. For Jackson Bay, this is the sixth consecutive year of above average settlement. At Napier, settlement was just over the long-term mean and Kaikoura was just under the long-term mean. Halfmoon Bay had the lowest settlement of all sites recording just over half its mean settlement.

1. INTRODUCTION

Rock lobsters are one of New Zealand's most valuable fisheries. Understanding larval recruitment processes will greatly assist the management of this fishery because it may explain changes in levels of recruitment to the fishery and enable 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 fishery catch per unit effort (CPUE) for most fishery areas. The best correlations occur in fisheries with shorter intervals between settlement and recruitment, and in 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 encompass much of the main rock lobster fishing coast 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, 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. 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.

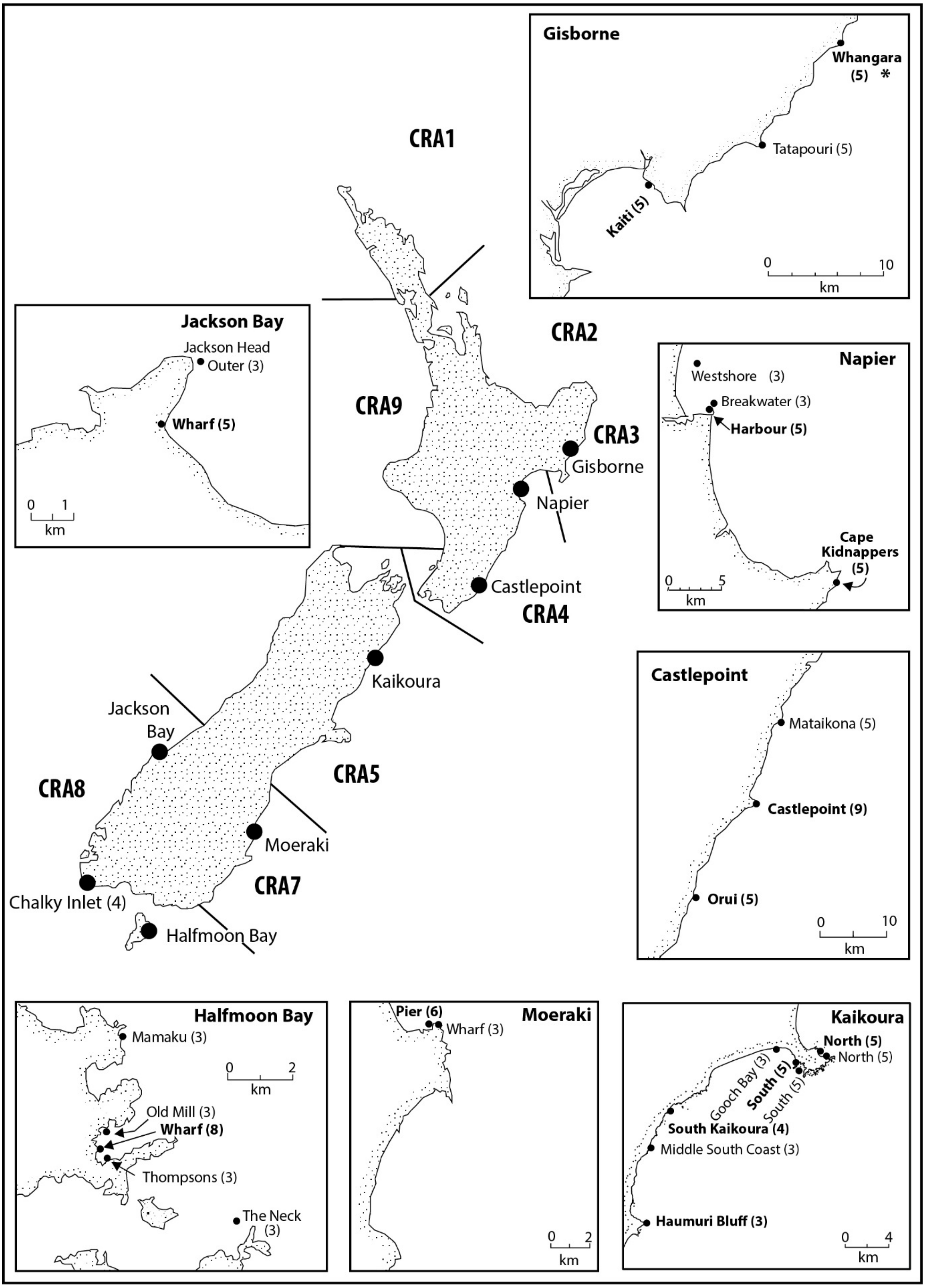

Figure 1: Map of New Zealand showing the location of collectors at the key monitoring sites (although not all groups are now checked). The sites that are checked are in bold and the number of collectors in that set is in brackets. Also shown are the CRA areas; CRA 6 is the Chatham Islands and CRA 10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

All standardisations before 2014 used settlement data based on the Calendar year. In contrast all standardisations presented here use the fishing year from 1 April to 31 March, with the year label being that 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’ 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 as settlement 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. Nonetheless, 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, for some standardisations the months used are restricted to those where counts are high. In some fishing years the number of samples is low, and the year is dropped from the standardisation if the number 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 was to:

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 been assigned to the previous month)
3. drop collectors with less 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 less than 10 samples
6. use a negative binomial model for the data
7. use year, month, and group (collector is not offered as an alternative to group) as the predictor variables in the standardisation

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 2015/16 fishing year (i.e. data is complete up to 31 March 2016).

3. RESULTS

3.1 Introduction

In the first part of this section detailed data characterisations and standardisations are presented for the sites at Napier and Castlepoint, both from CRA 4. A more detailed analysis was undertaken for these sites because their standardised indices were used as data inputs for the concurrent CRA 4 stock assessment (Appendix 1). These are followed by standardisation results for the other sites.

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 Napier data characterisation

At the Napier site 5 groups have been in place over time with a total of 20 collectors used. These groups are labelled 001, 002, ..., 005.

The number of samples by group and year is shown in Table 2. The sampling periods for the remaining collectors is shown graphically in Figure 2, and the total number of samples from each in Figure 3. Unstandardised puerulus indices are shown for each group in Figure 4.

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 all of the collectors from the 005 group (see Figure 3).

After filtering the remaining groups are 001, ..., 004. The number of samples for each year is shown in Table 3. There is sparse sampling 1985–1990 for the months October through to March, which the standardisation should adjust for (Figure 5). The number of zeros is not particularly high for the Napier site and under 40% (Figure 6). It was decided by the Rock Lobster Working Group that there was no need to subset the months to reduce the number of zeros for the standardisation.

3.3 Napier standardisation

All months of data were used for the standardisation, with a negative binomial standardisation model.

Group and month were chosen as standardisation predictors (in addition to the forced in year). The standardised index decreases from 1991 to 1999, increases for the following three years, then declines again until 2011 after which it increases slightly (Figure 7). Most of the difference between the raw and standardised indices is due to the group effect, which is adjusting for the different scale that the raw indices for NAP002 are on (Figure 8, see Figure 4).

The diagnostics show good agreement with the model assumptions (Figures 9–11).

Table 2: Number of puerulus samples at Napier by group and fishing year.

	NAP001	NAP002	NAP003	NAP004	NAP005
1979	52	0	0	0	0
1980	65	0	0	0	0
1981	66	0	0	0	0
1982	60	0	0	0	0
1983	48	0	0	0	0
1984	60	0	0	0	0
1985	36	0	0	0	0
1988	18	0	0	0	0
1989	36	0	0	0	0
1990	36	0	0	3	0
1991	60	21	0	26	0
1992	69	21	0	32	0
1993	69	17	0	33	0
1994	65	27	25	33	0
1995	59	29	41	30	0
1996	72	33	50	33	0
1997	71	24	65	36	0
1998	66	18	58	27	0
1999	72	6	55	27	0
2000	47	0	48	27	0
2001	65	0	61	21	33
2002	57	0	52	18	21
2003	66	0	54	0	0
2004	71	0	59	0	0
2005	72	0	53	0	0
2006	72	0	47	0	0
2007	53	0	40	0	0
2008	56	0	59	0	0
2009	60	0	59	0	0
2010	60	0	52	0	0
2011	60	0	53	0	0
2012	50	0	36	0	0
2013	50	0	50	0	0
2014	50	0	59	0	0
2015	55	0	59	0	0

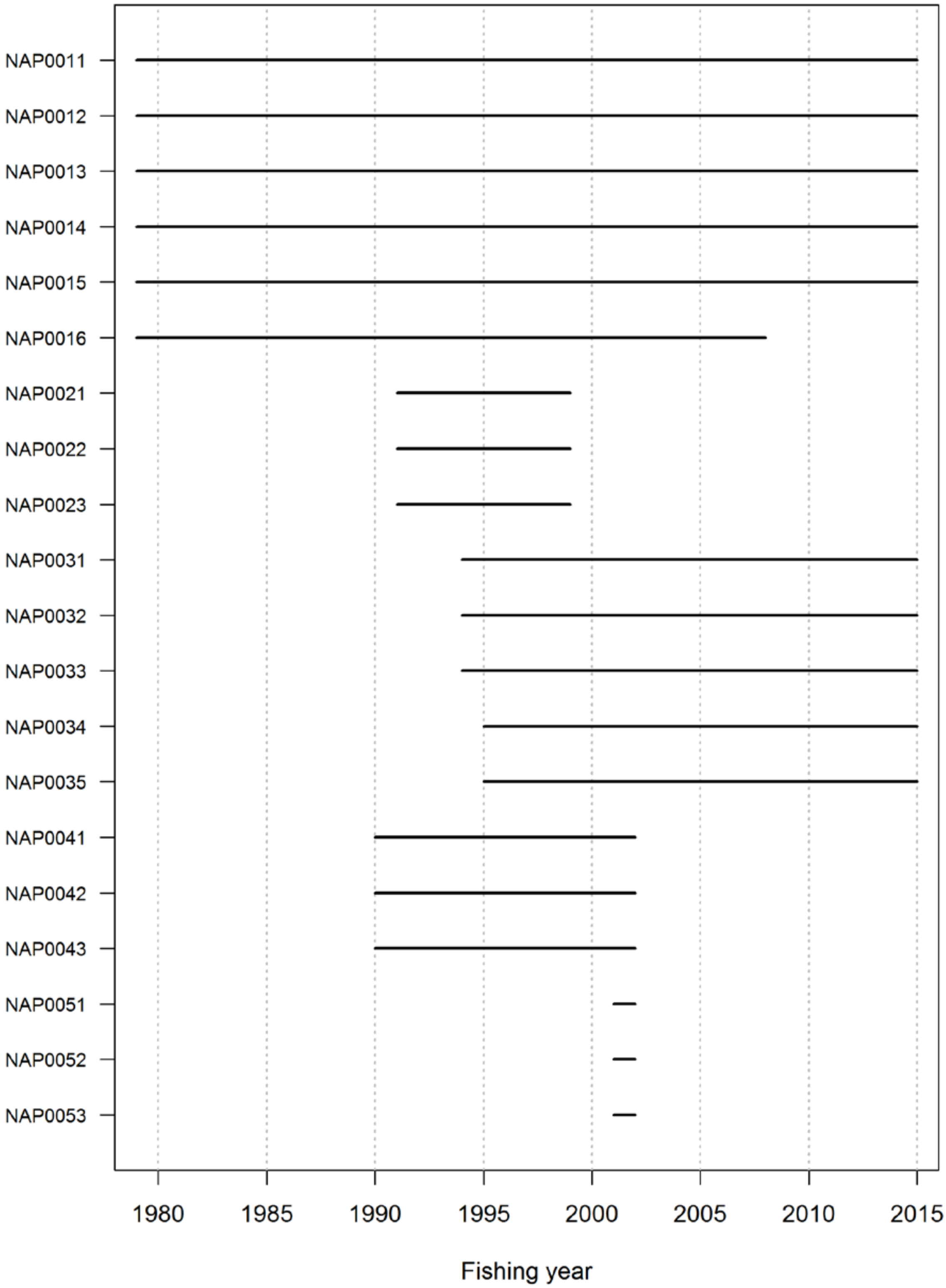

Figure 2: The fishing years over which the collectors in Napier have been in operation.

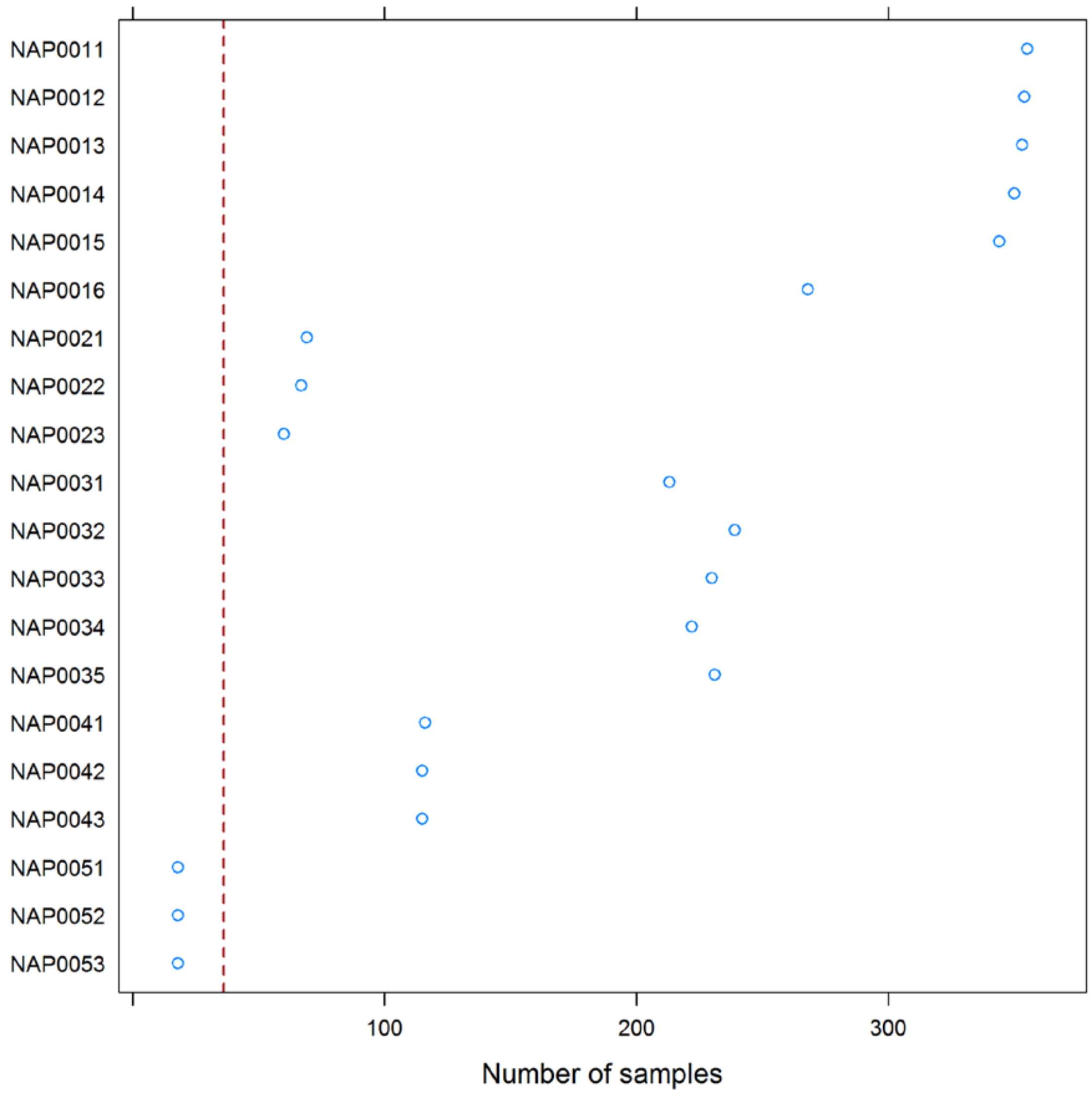

Figure 3: The total number of samples taken from each collector in Napier. The red dashed line at 36 samples represents the cut-off to include or not to include in the standardised data set.

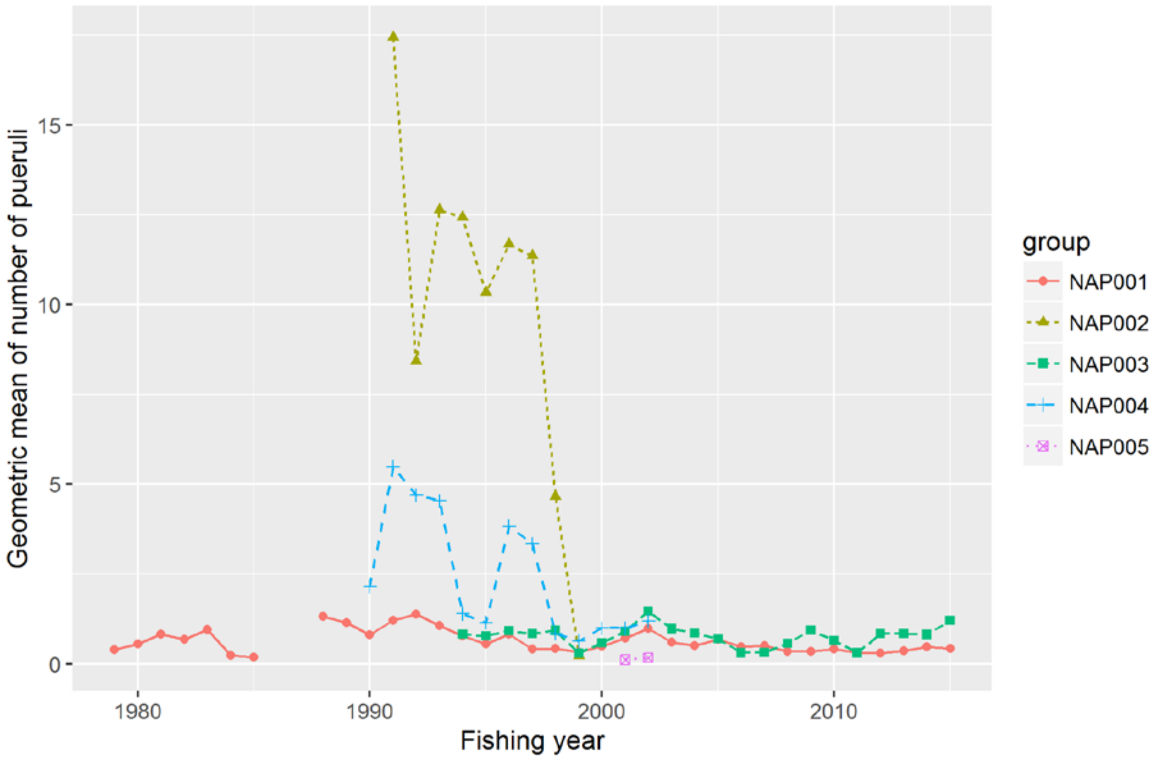

Figure 4: Geometric mean of the number of sampled pueruli. All samples from the groups are used.

Table 3: Napier standardisation data set. Number of puerulus samples by group and fishing year.

	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
2015	55	0	59	0	114

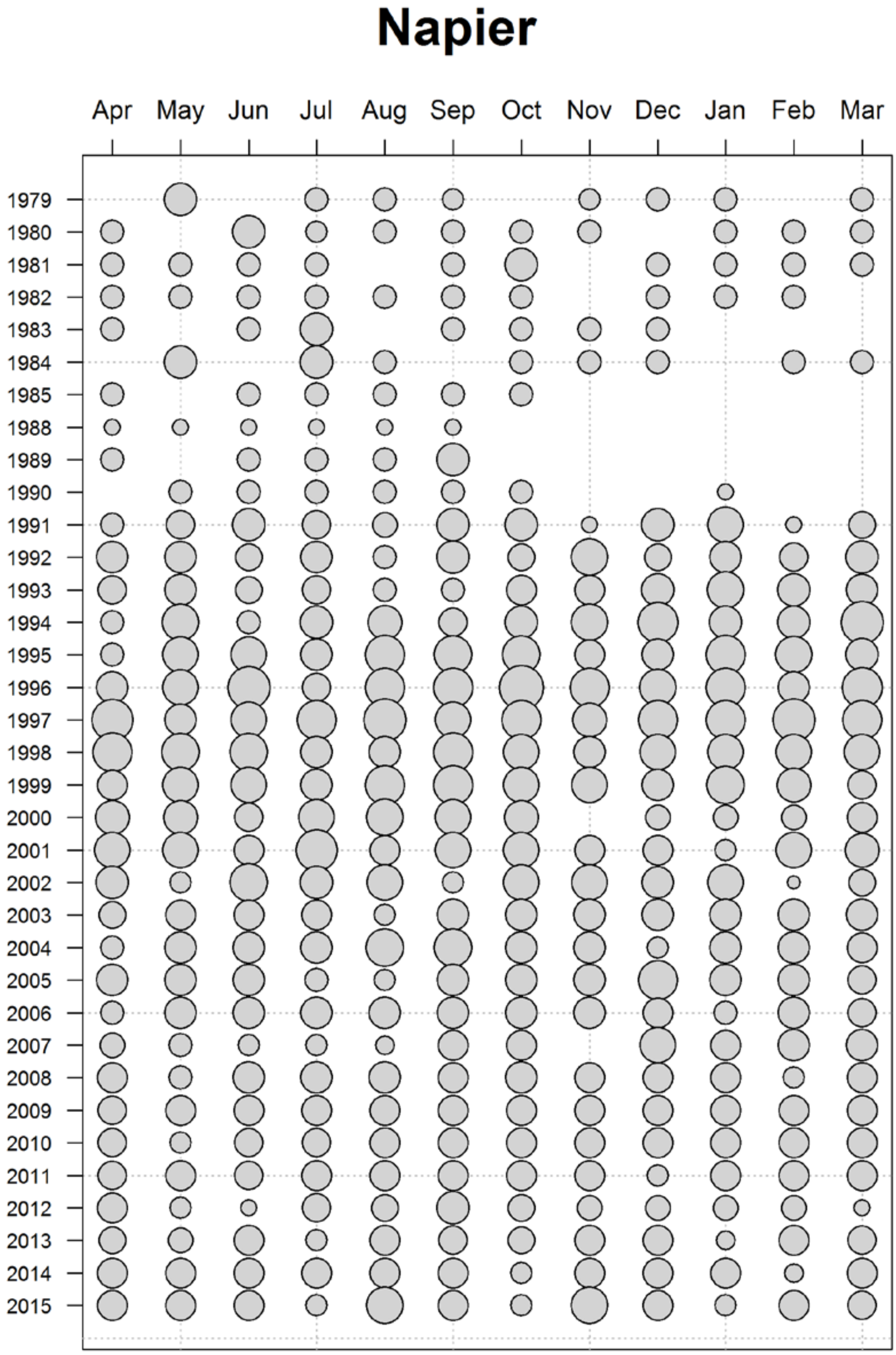

Figure 5: Number of samples by month and fishing year for Napier. The area of a circle is proportional to the number of samples, with a maximum value of 20.

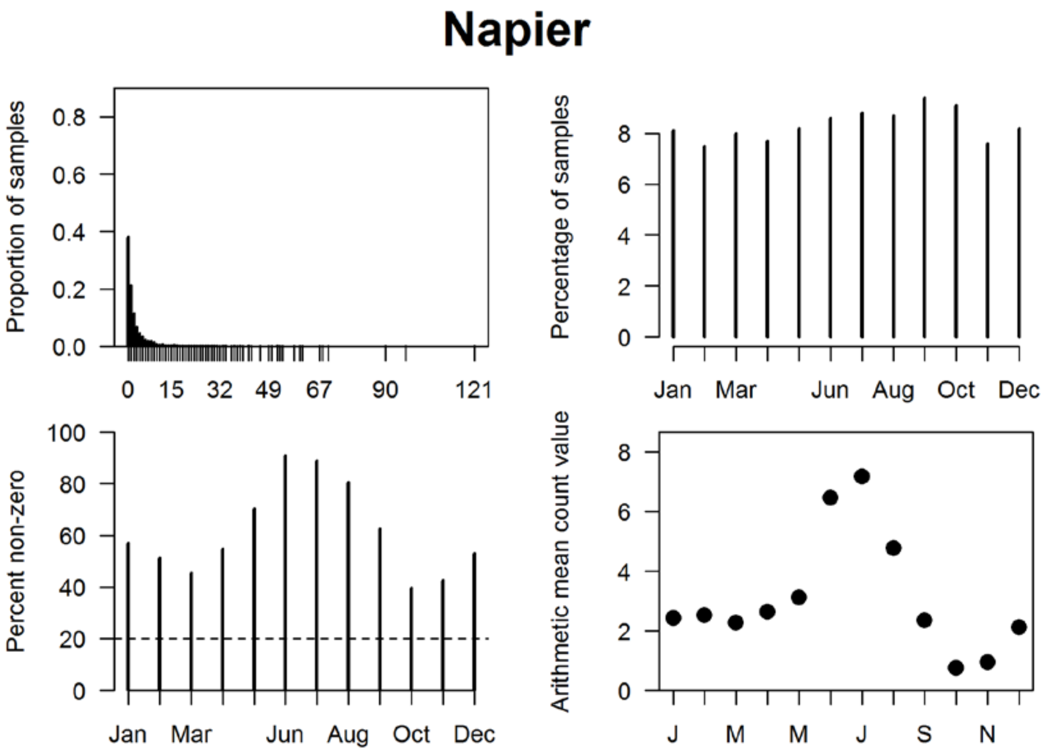

Figure 6: Characteristics of the Napier puerulus data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample.

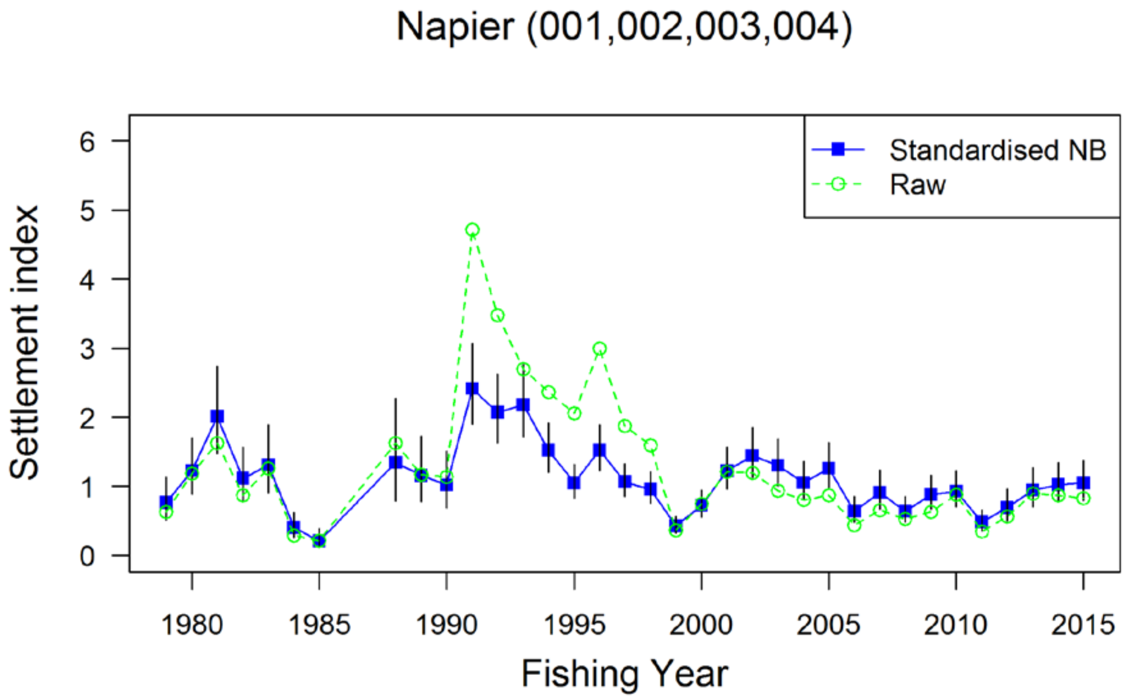

Figure 7: Negative binomial standardisation model for Napier. Standardised and raw indices with 95% confidence intervals.

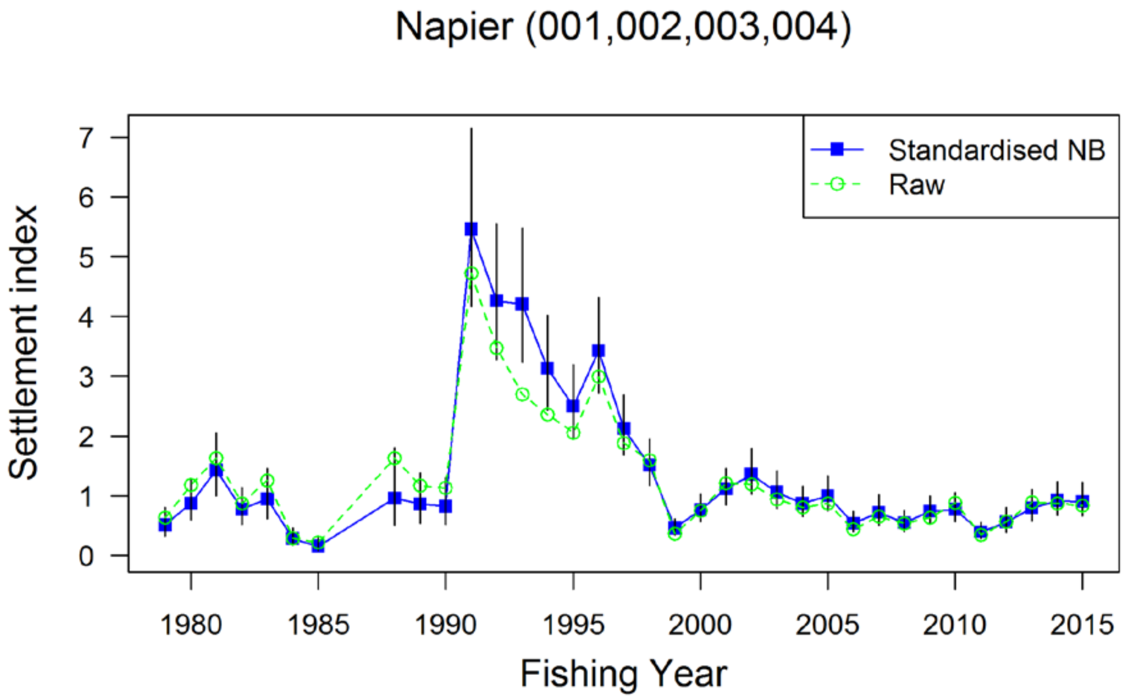

Figure 8: Negative binomial standardisation model for Napier, without group as a predictor variable. Standardised and raw indices with 95% confidence intervals.

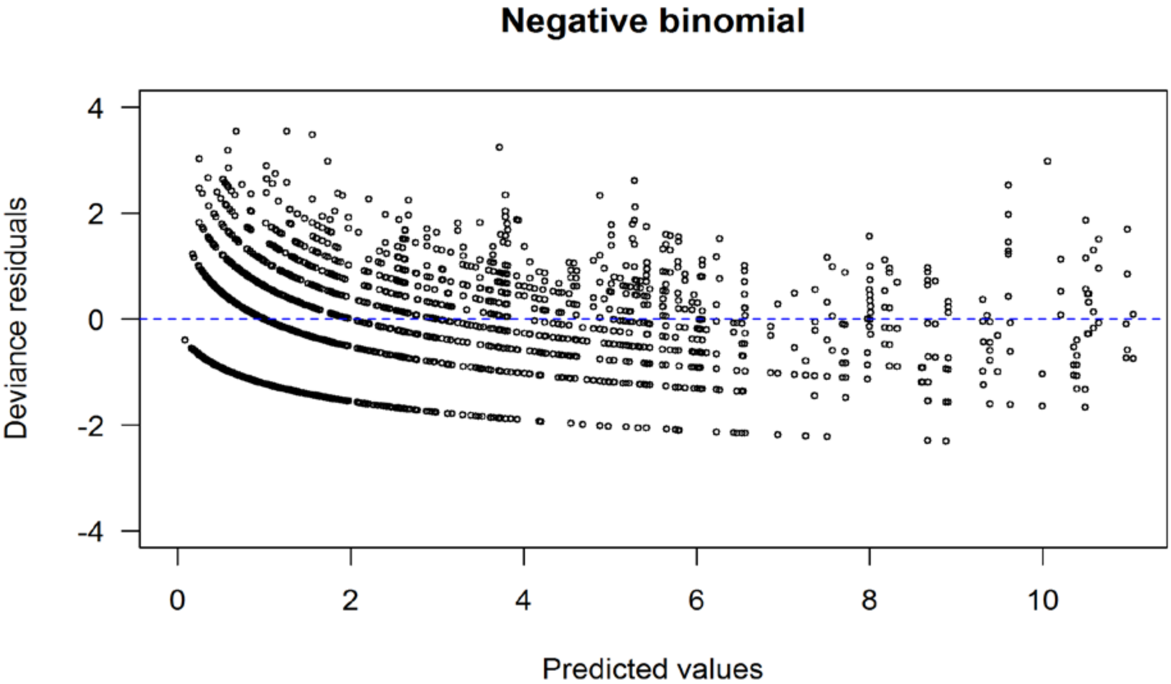

Figure 9: Deviance residuals for the Napier standardisation. The predicted values are in natural space.

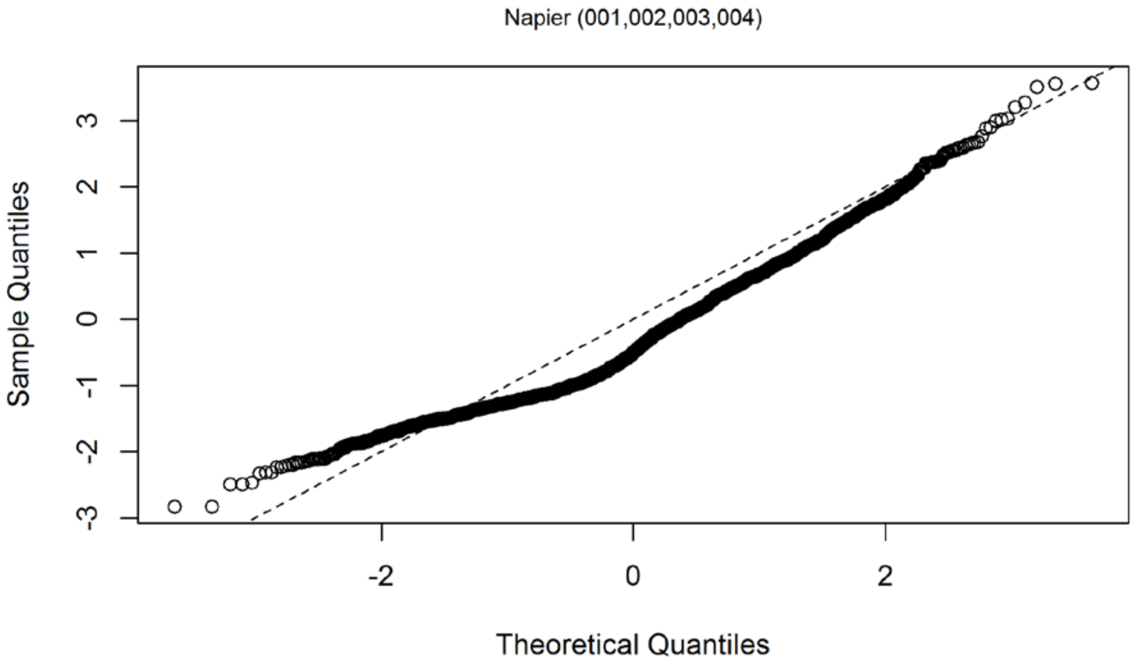

Figure 10: Quantile-quantile plot for the Napier standardisation.

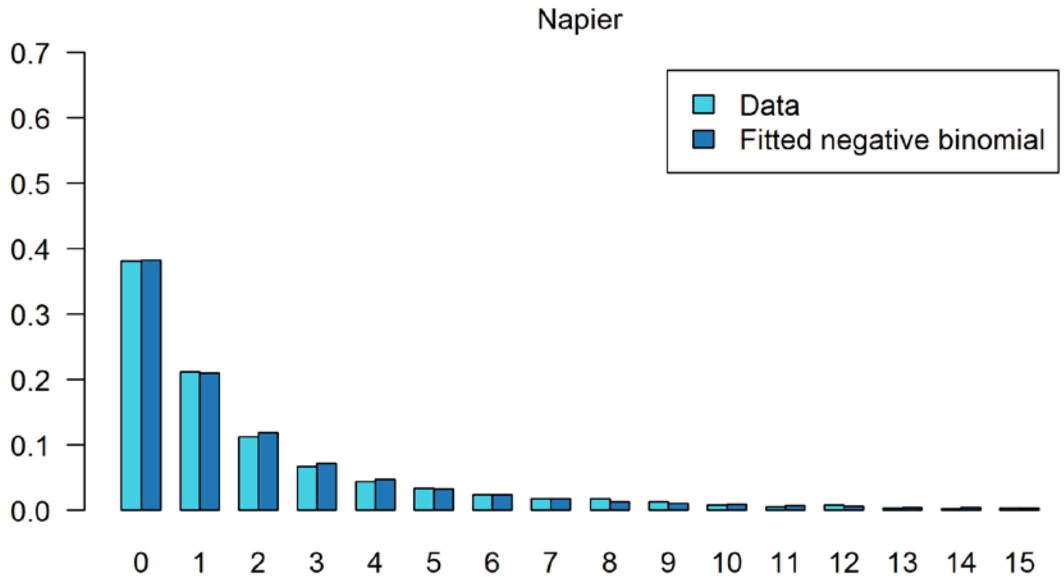

Figure 11: Data distribution and that from the fitted negative binomial for Napier.

3.4 Castlepoint data characterisation

At the Castlepoint site three groups have been in place over time with a total of 28 collectors used. These groups are labelled 001, 002, 003.

The number of samples by group and year is shown in Table 4. The sampling periods for the collectors is shown graphically in Figure 12, and the total number of samples from each in Figure 13. The unstandardised puerulus indices show similar patterns across the groups (Figure 14).

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 some of the early collectors in the 003 group (see Figure 13).

After filtering the remaining groups are the same (001, 002, 003) but without the early collectors in 003 (Table 5). There are some months missed for sampling before 1989 with only January– March sampled in 1982 (Figure 15). The number of zeros isn't particularly high and is less than 30% over all the data (Figure 16). It was decided by the Rock Lobster Working Group that there was no need to subset the months to reduce the number of zeros for the standardisation.

3.5 Castlepoint standardisation

All months of data were used for the standardisation, with a negative binomial standardisation model.

Group and month were chosen as standardisation predictors (in addition to the forced in year). The standardised index is somewhat irregular but generally higher in the period before 1998 compared to after this (Figure 17). Including all the data (i.e. the early CPT003 collectors as well) gives a different perspective on what settlement was in 1981 (Figure 18). The diagnostics show a good agreement with the model assumptions (Figures 19–21).

Table 4: Number of puerulus samples at Castlepoint by group and fishing year.

	CPT001	CPT002	CPT003
1981	0	0	9
1982	18	0	54
1983	68	0	66
1984	57	0	21
1985	41	0	0
1986	70	0	0
1987	66	0	0
1988	66	0	0
1989	67	0	0
1990	72	0	0
1991	72	17	16
1992	71	46	38
1993	70	63	61
1994	102	60	50
1995	97	48	37
1996	108	60	60
1997	108	60	55
1998	98	36	35
1999	116	18	65
2000	105	21	60
2001	99	36	53
2002	104	52	62
2003	99	51	55
2004	114	53	65
2005	107	60	60
2006	108	58	45
2007	106	50	0
2008	107	55	0
2009	99	55	0
2010	117	65	0
2011	108	60	0
2012	108	46	0
2013	117	70	0
2014	99	59	0
2015	105	59	0

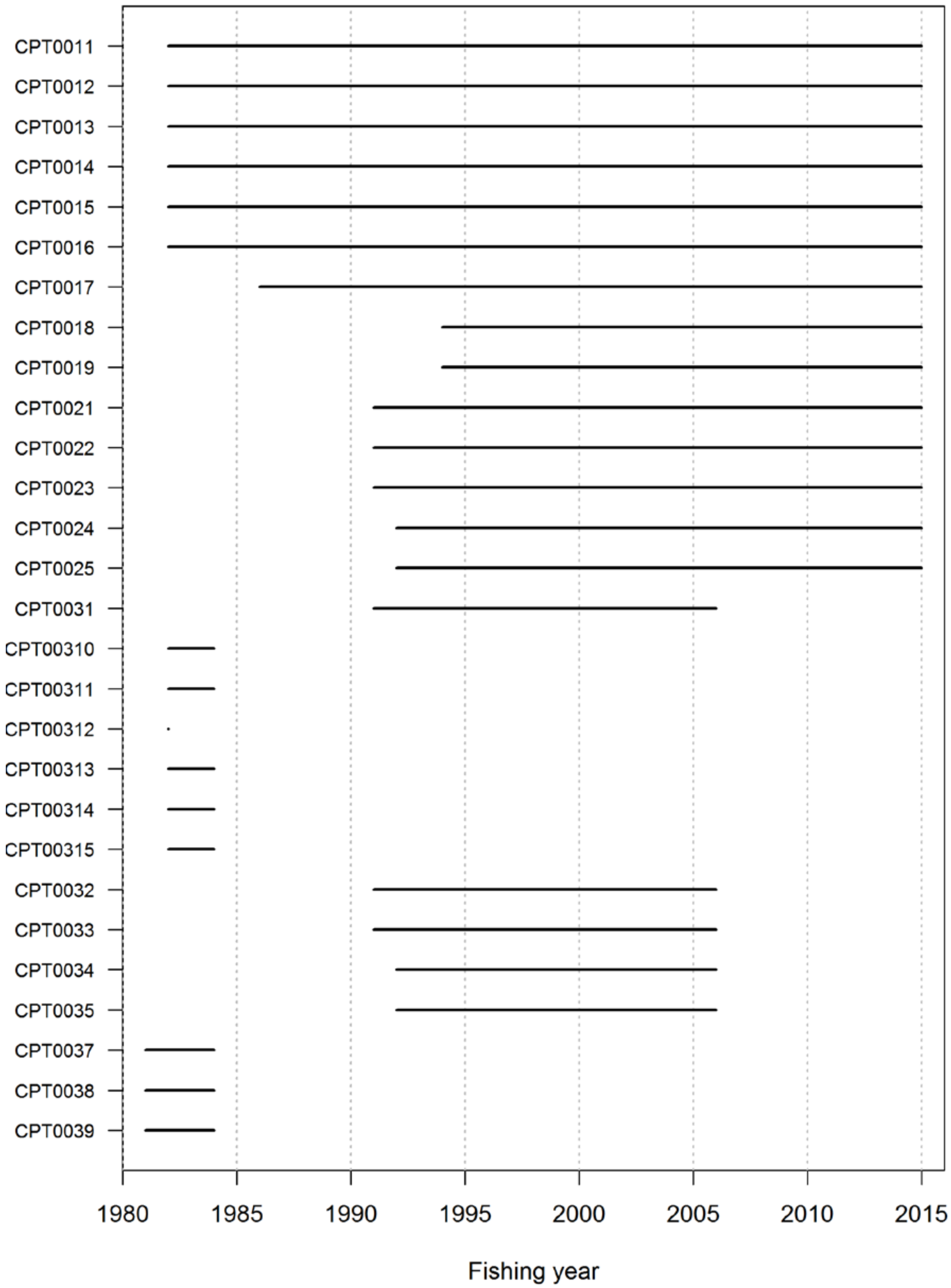

Figure 12: The fishing years over which the collectors in Castlepoint have been in operation.

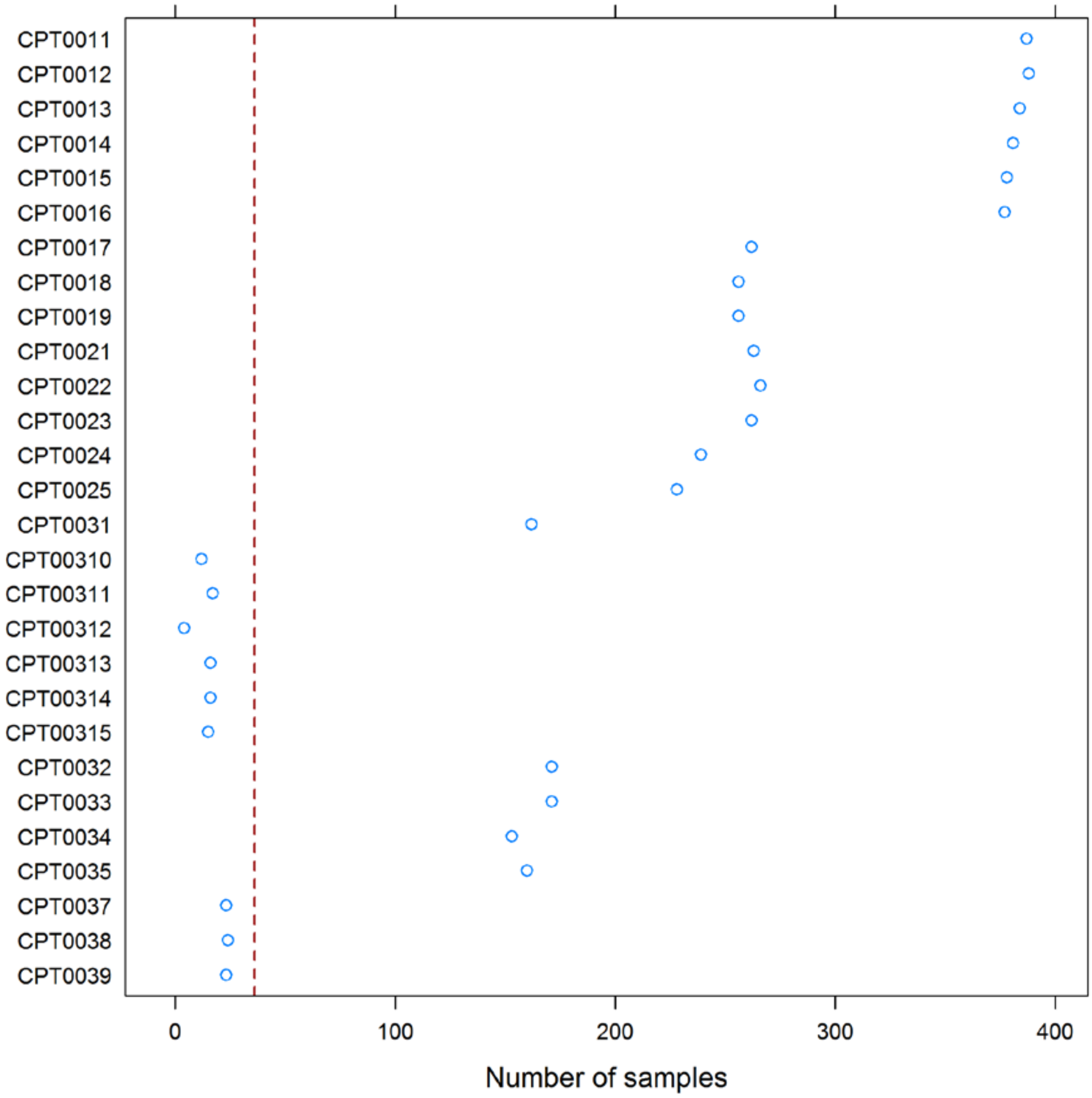

Figure 13: The total number of samples taken from each collector in Castlepoint. The red dashed line at 36 samples represents the cut-off to include or not to include in the standardised data set.

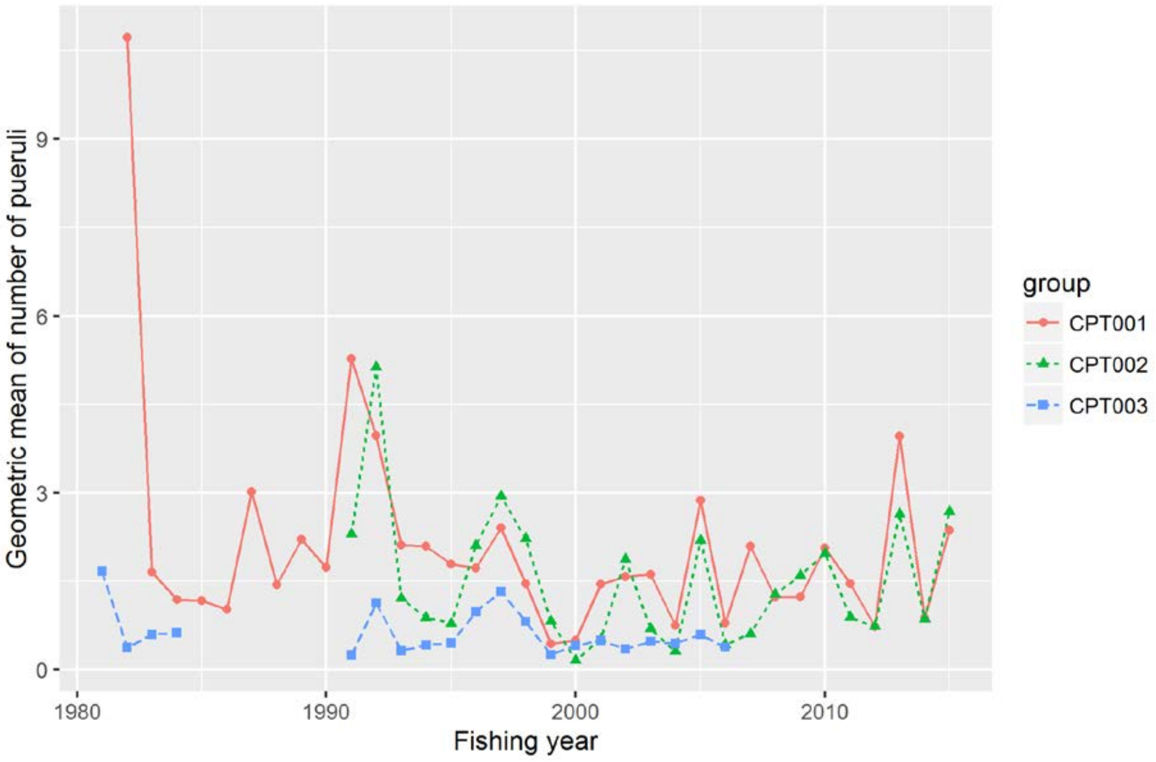

Figure 14: Geometric mean of the number of sampled pueruli for Castlepoint. All samples from the groups are used.

Table 5: Castlepoint standardisation data set. Number of puerulus samples by group and fishing year.

	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
2015	105	59	0	164

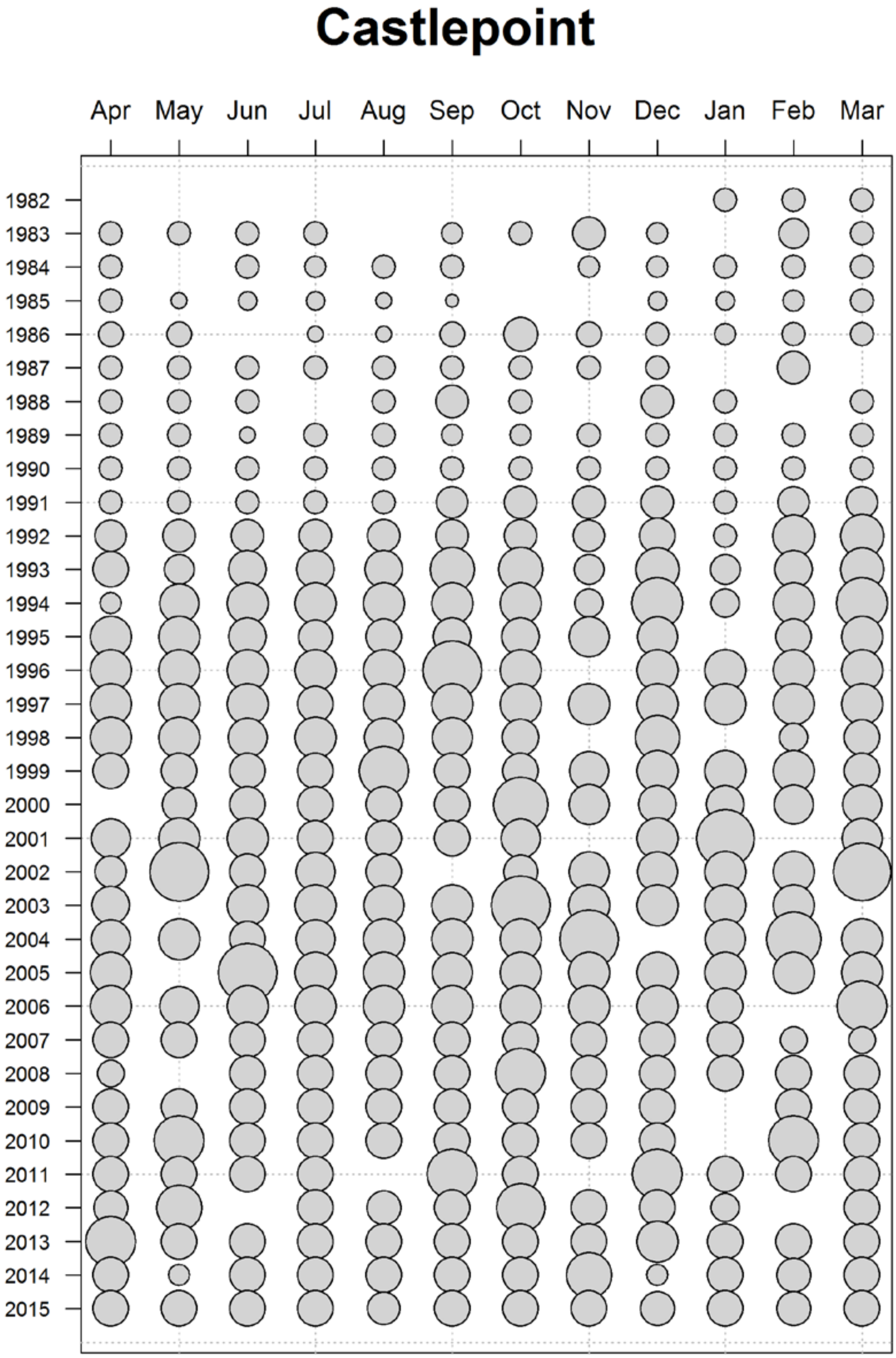

Figure 15: Number of samples by month and fishing year for Castlepoint. The area of a circle is proportional to the number of samples, with a maximum value of 20.

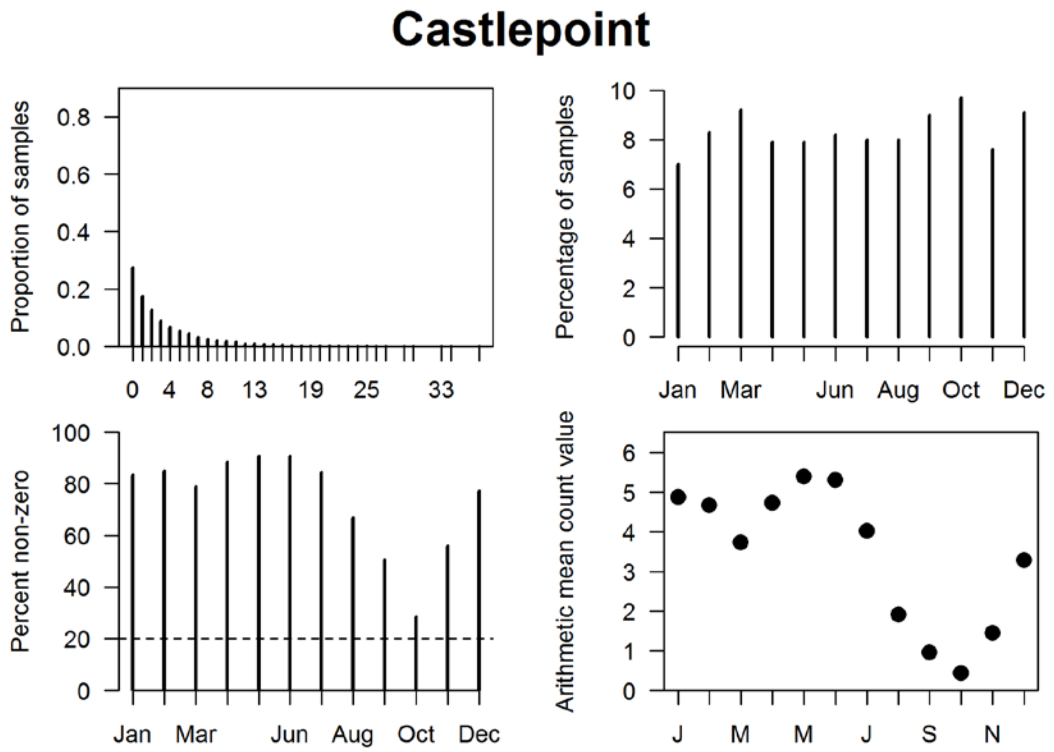

Figure 16: Characteristics of the Castlepoint puerulus data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the percentage of these that are non-zero. Count refers to the number of pueruli measured in a sample.

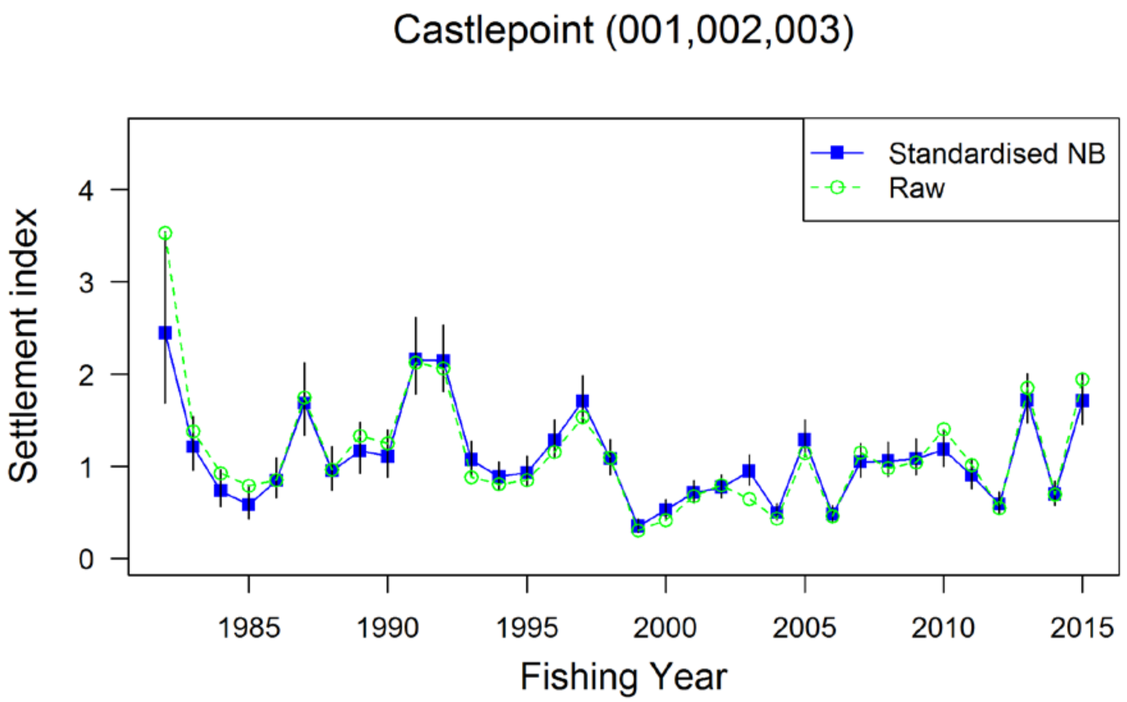

Figure 17: Negative binomial standardisation model for Castlepoint. Standardised and raw indices with 95% confidence intervals.

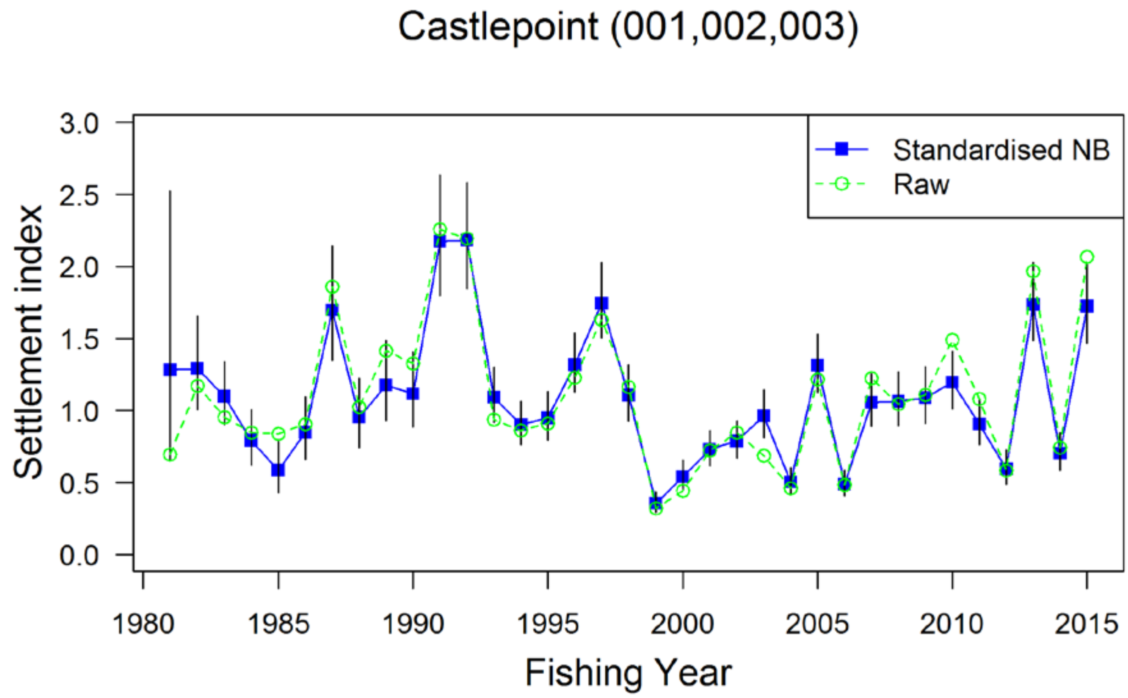

Figure 18: Negative binomial standardisation model for Castlepoint, using all the data. Standardised and raw indices with 95% confidence intervals.

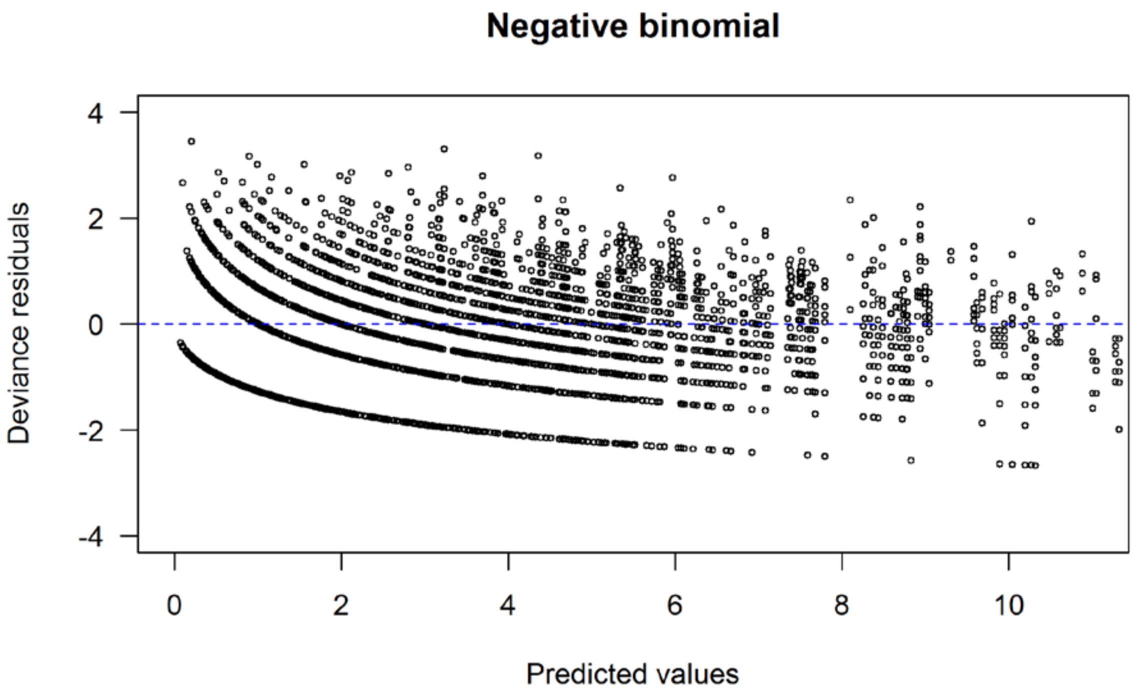

Figure 19: Deviance residuals for the Castlepoint standardisation. The predicted values are in natural space.

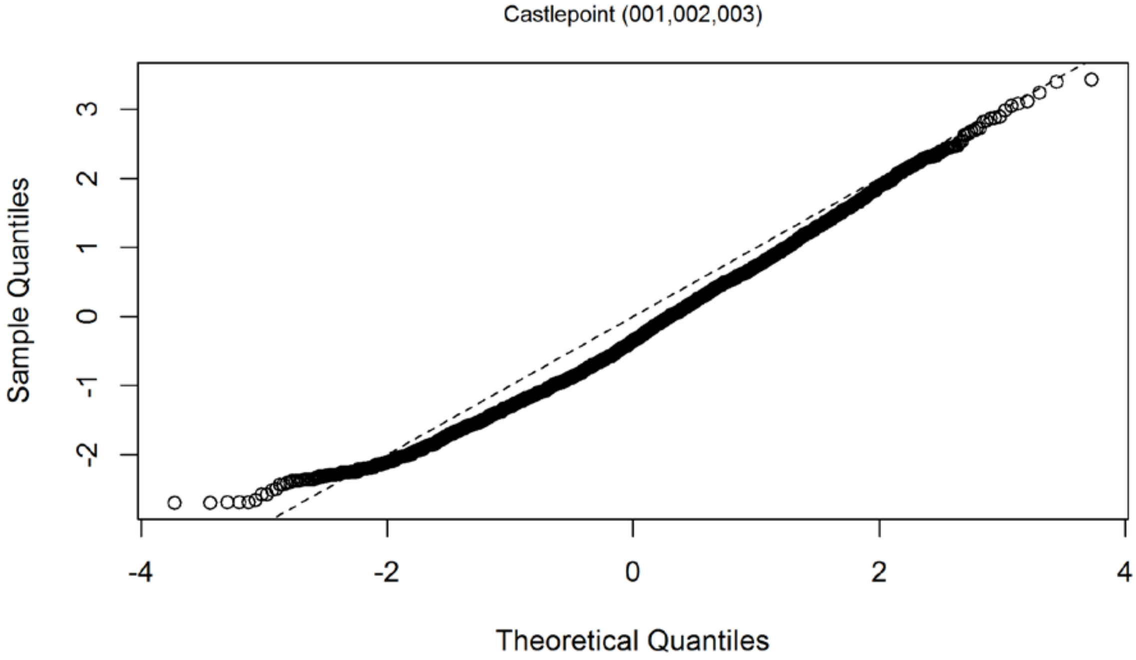

Figure 20: Quantile-quantile plot for the Castlepoint standardisation.

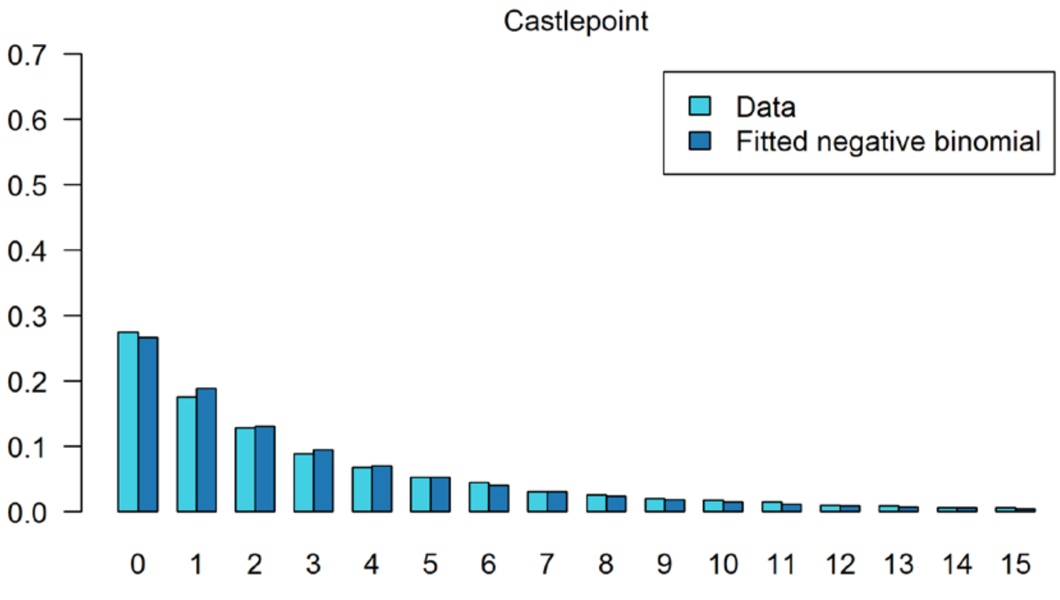

Figure 21: Data distribution and that from the fitted negative binomial for Castlepoint.

3.6 Standardised indices for other sites

The other sites are Gisborne (CRA 3), Kaikoura (CRA 5), Moeraki (CRA 7), Halfmoon Bay (CRA 8), and Jackson Bay (CRA 8). There was no new data for Chalky Inlet (CRA 8). The same standardisation method was used for these sites as Napier and Castlepoint (see Section 2.2 for more detail). To reduce the number of zeros a subset of months was used for many of the standardisations (Table 6).

For each site plots are given for puerulus data characteristics, standardised index, and standardisation diagnostics Figures 22–46 . Diagnostics look reasonable for all sites.

Table 6: Months for which data was used in standardisation.

Site	Months
Gisborne	May–September
Kaikoura	January–September
Moeraki	May–October
Halfmoon Bay	May–December
Jackson Bay	All

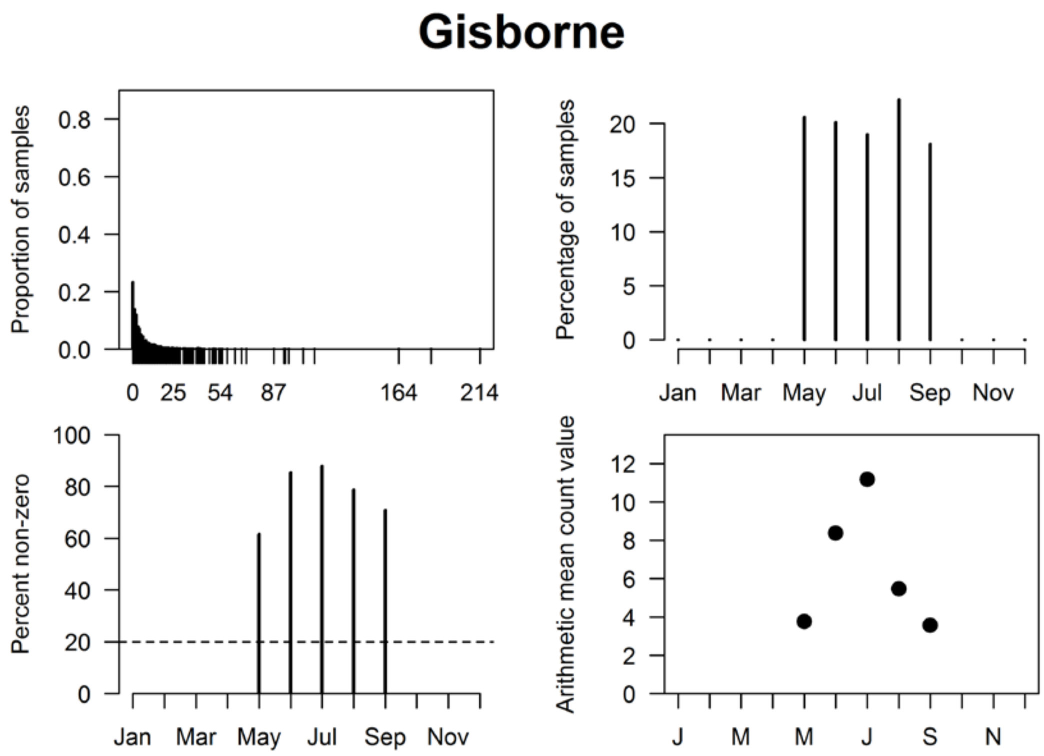

Figure 22: Characteristics of the Gisborne puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

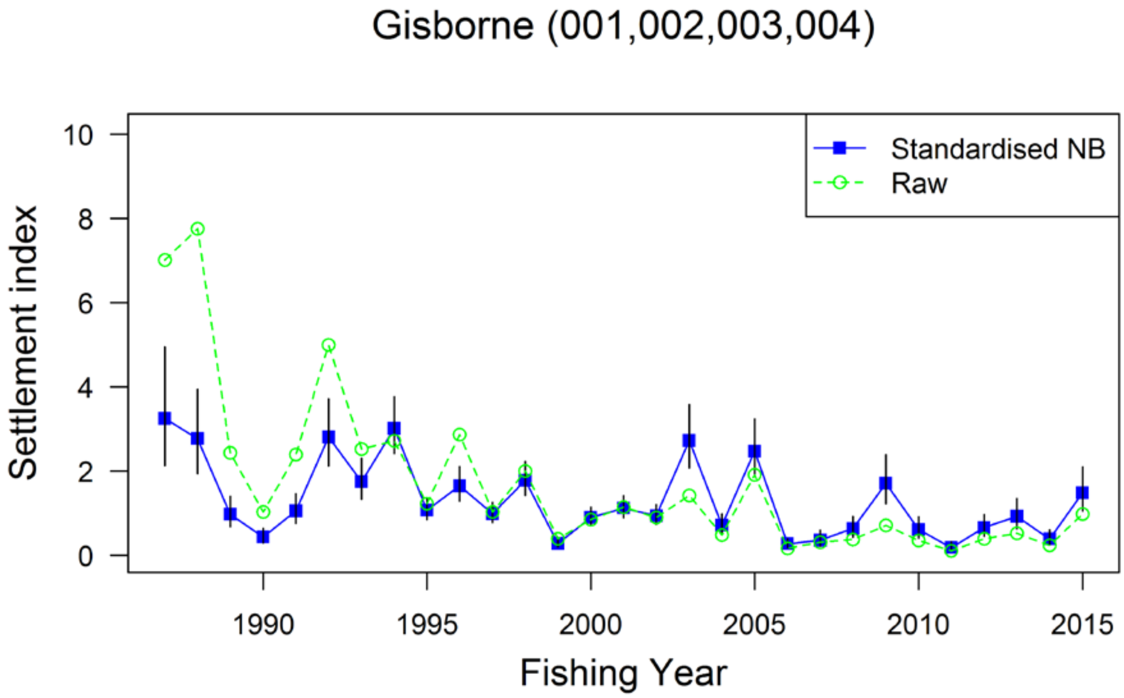

Figure 23: Standardised and raw indices with 95% confidence intervals for Gisborne.

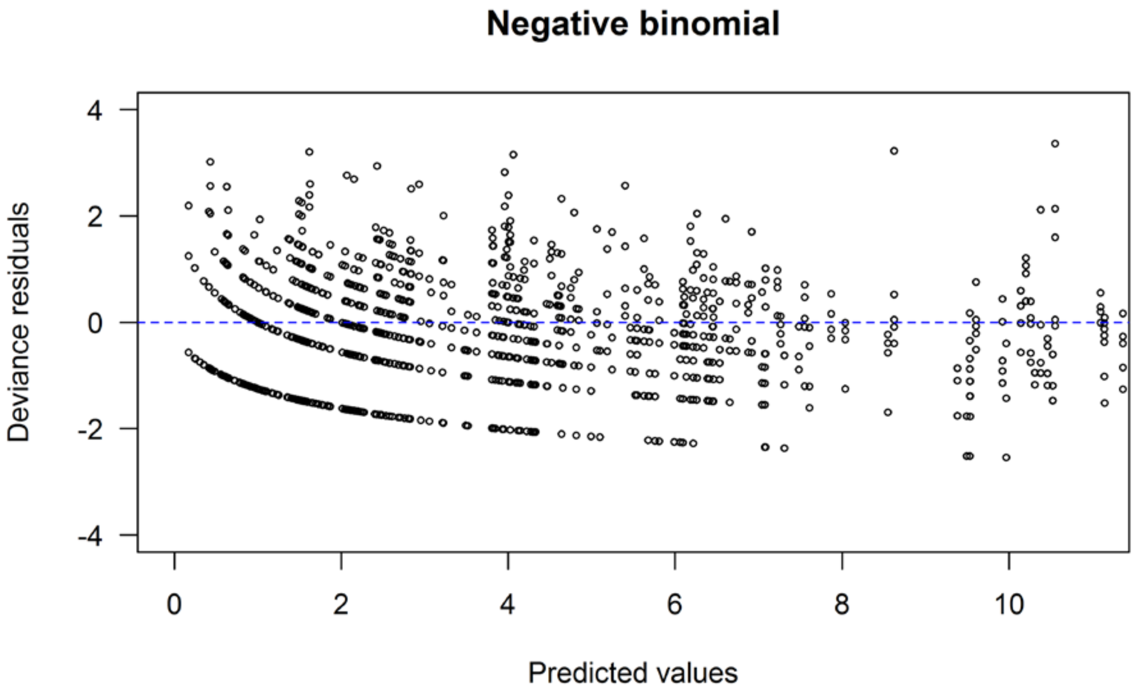

Figure 24: Deviance residuals for the negative binomial model and Gisborne site. Predicted values are in natural space.

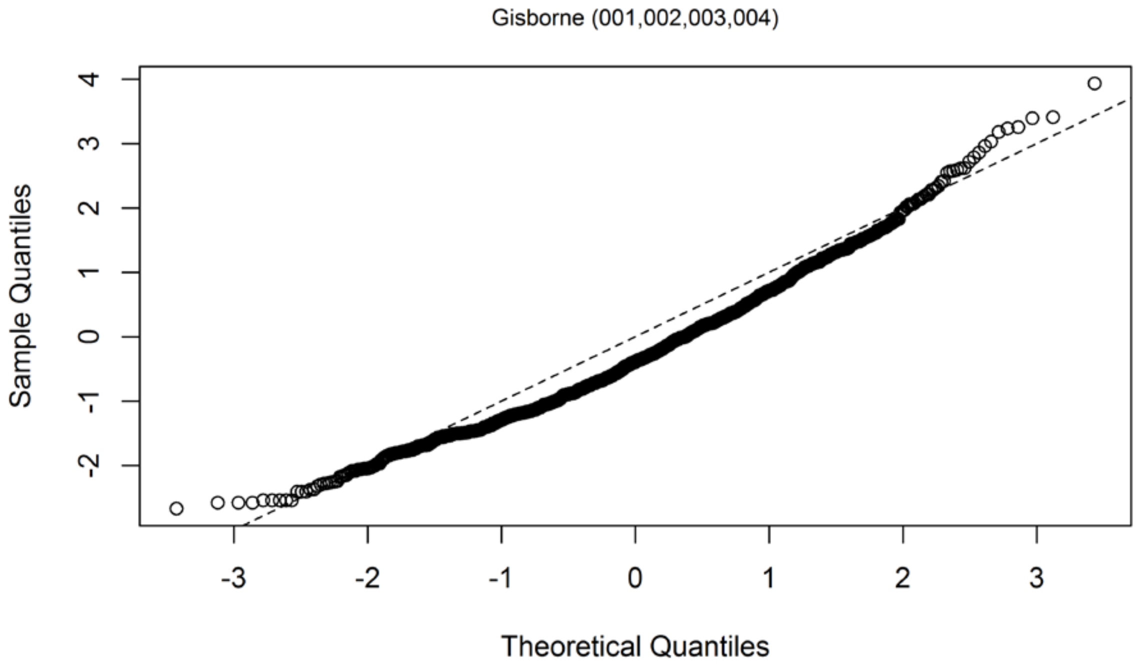

Figure 25: Quantile-quantile plot for the negative binomial standardisation model for Gisborne.

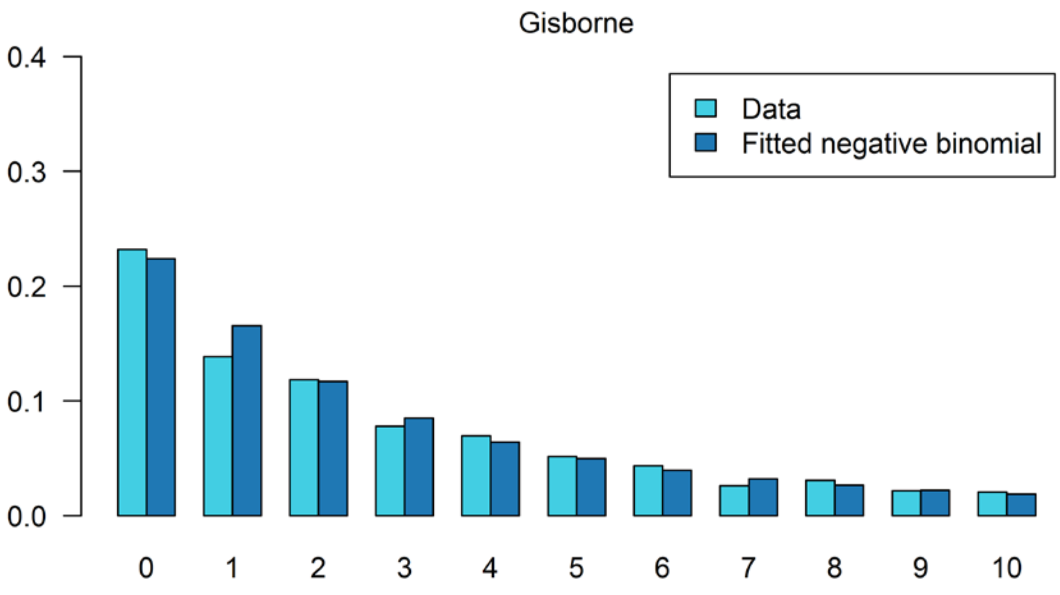

Figure 26: Data distribution and that from the fitted negative binomial model for Gisborne.

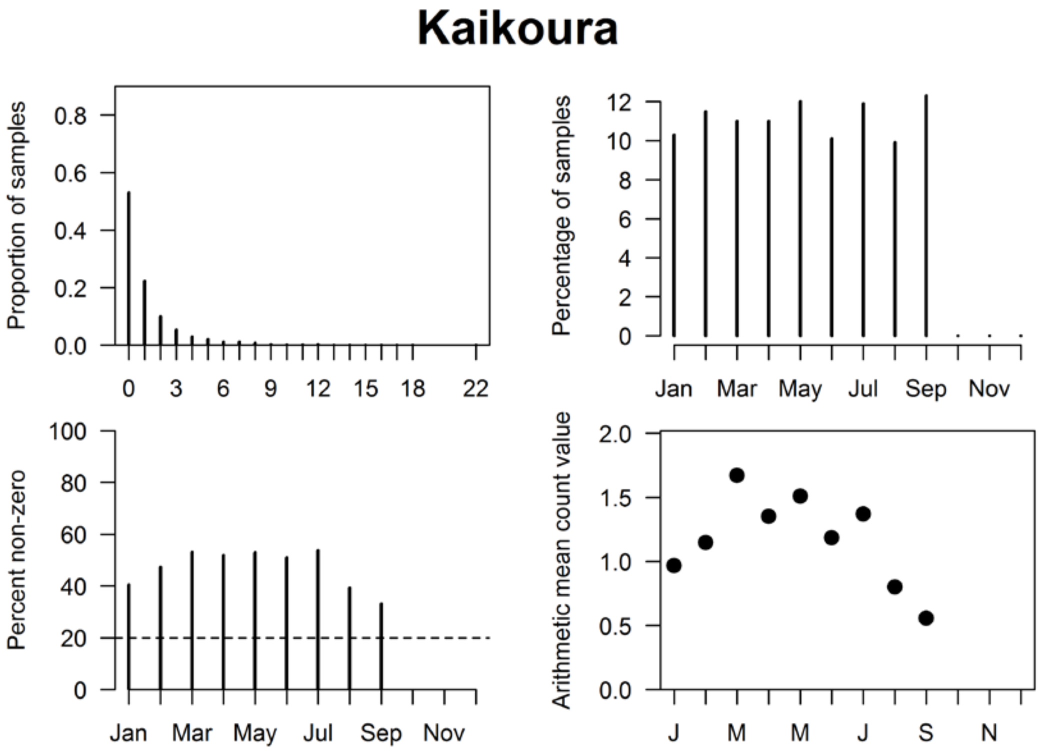

Figure 27: Characteristics of the Kaikoura puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

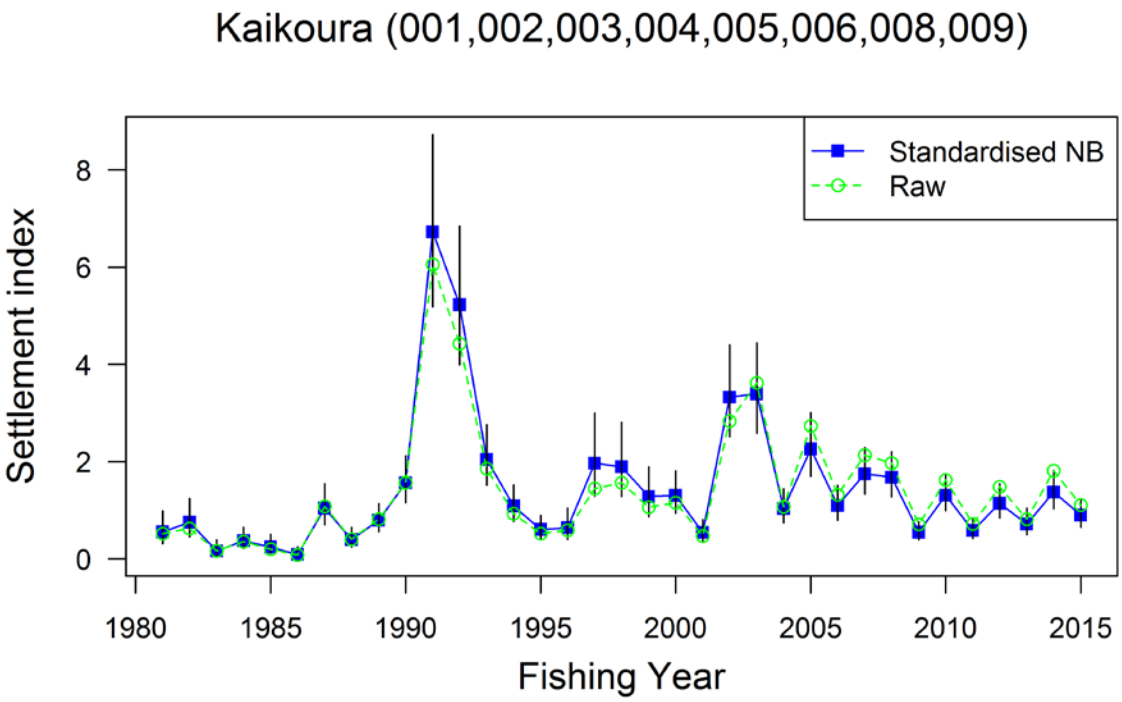

Figure 28: Standardised and raw indices for Kaikoura with 95% confidence intervals.

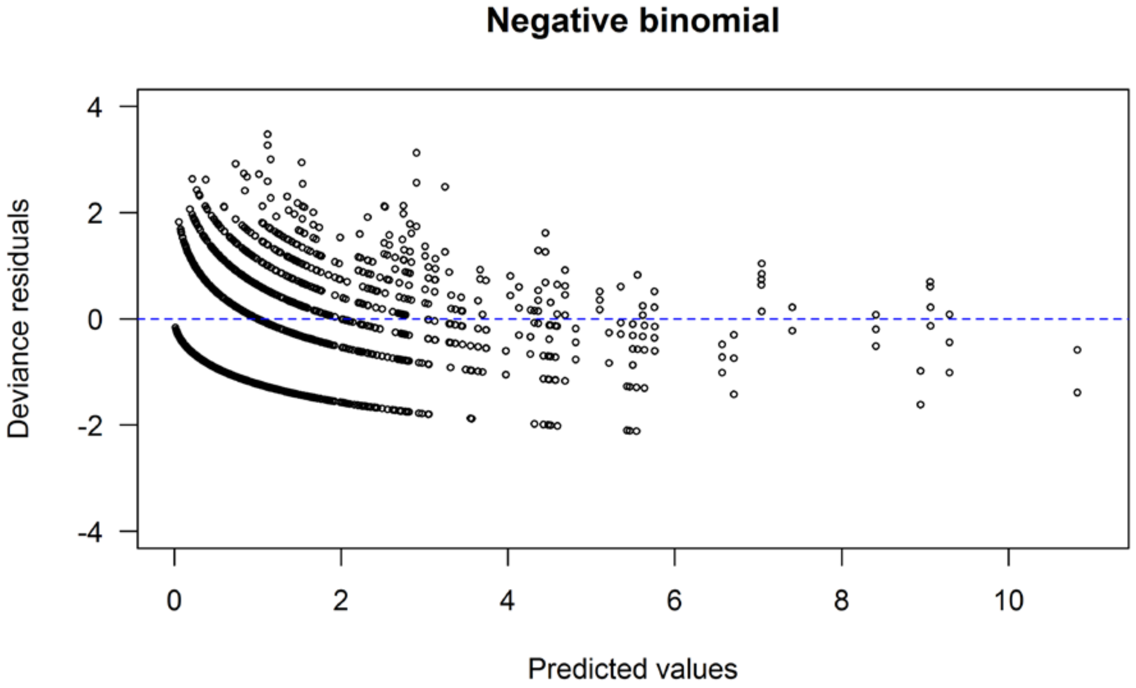

Figure 29: Deviance residuals for the Kaikoura site. Predicted values are in natural space.

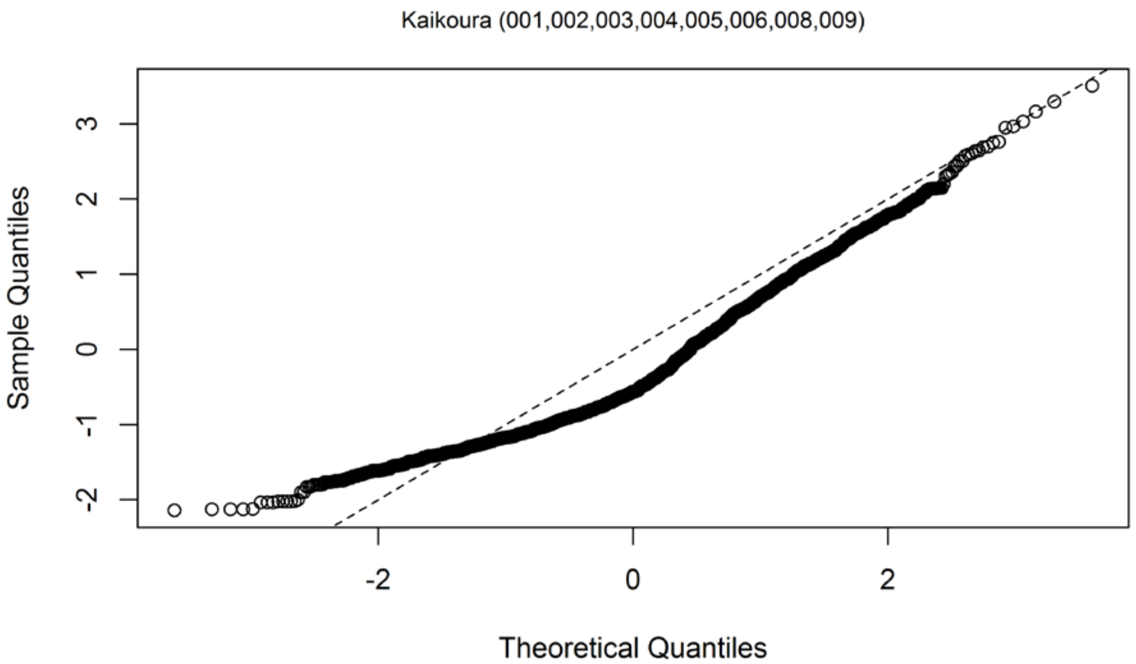

Figure 30: Quantile-quantile plot for Kaikoura.

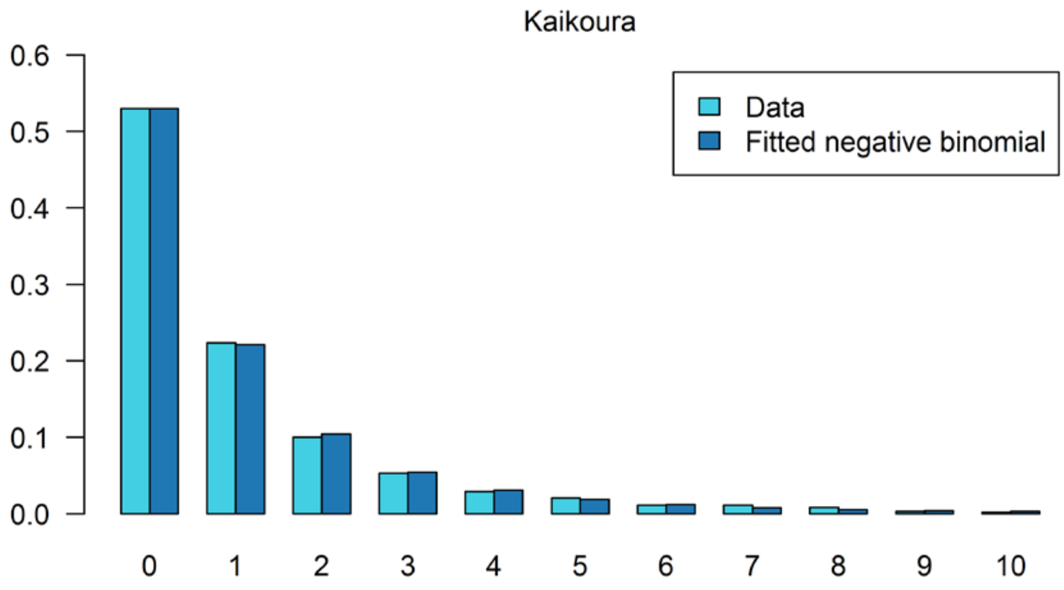

Figure 31: Data distribution and that from the fitted negative binomial for Kaikoura.

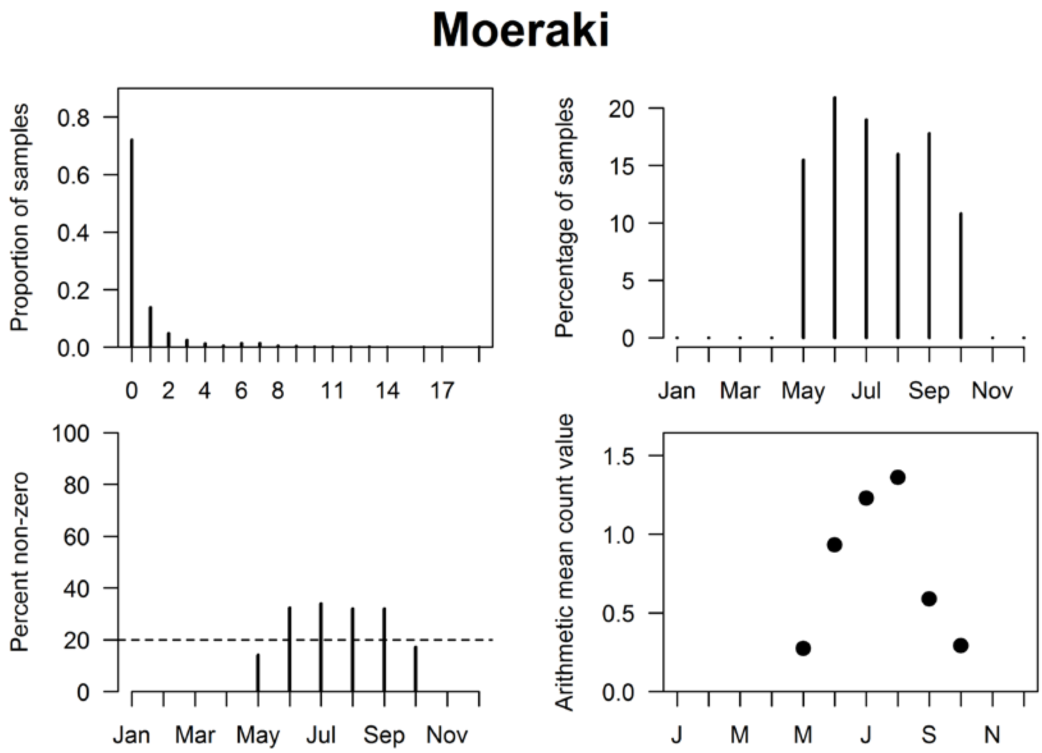

Figure 32: Characteristics of the puerulus standardisation data for Moeraki. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

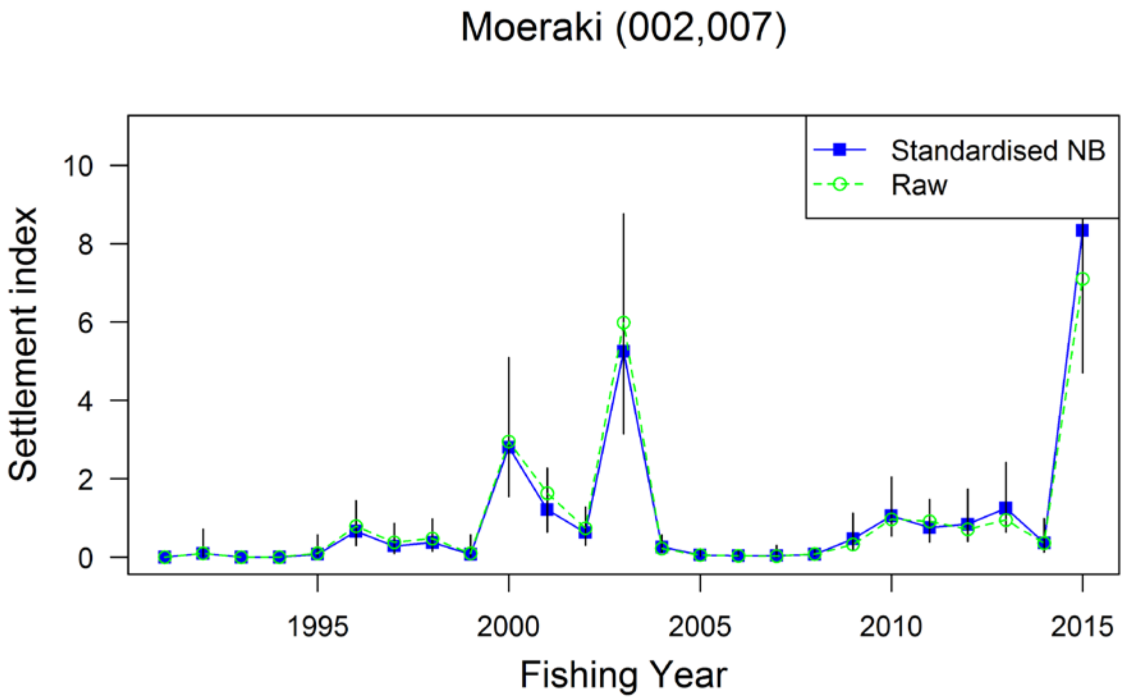

Figure 33: Standardised and raw indices with 95% confidence intervals for Moeraki.

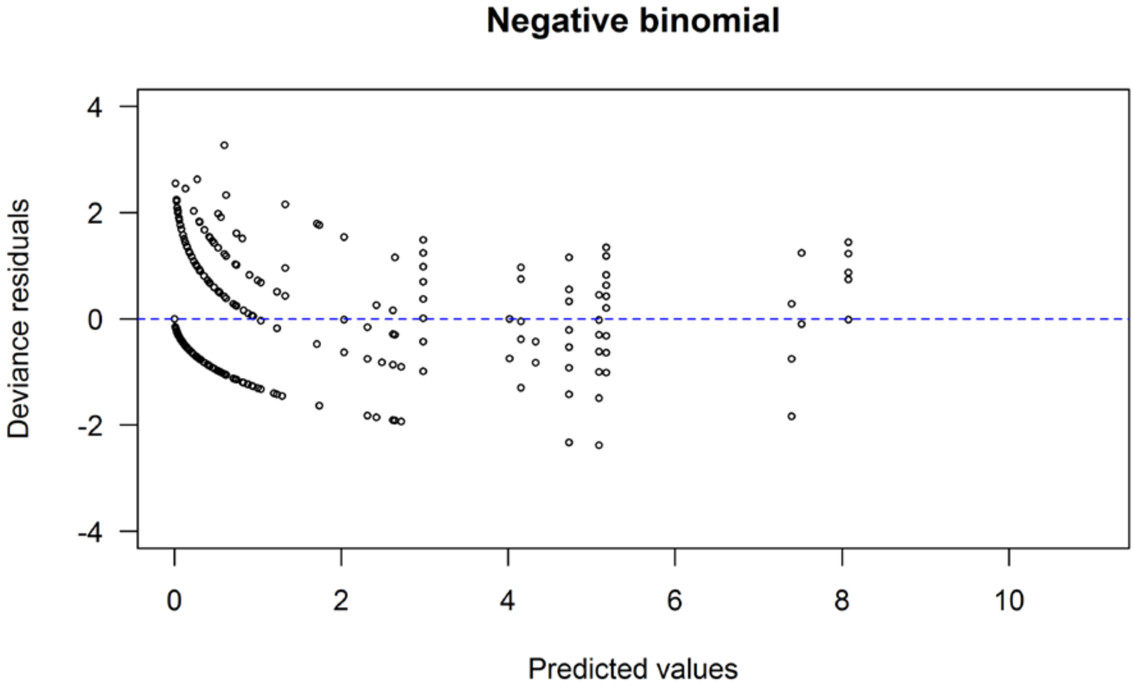

Figure 34: Deviance residuals for the negative binomial model for Moeraki. Predicted values are in natural space.

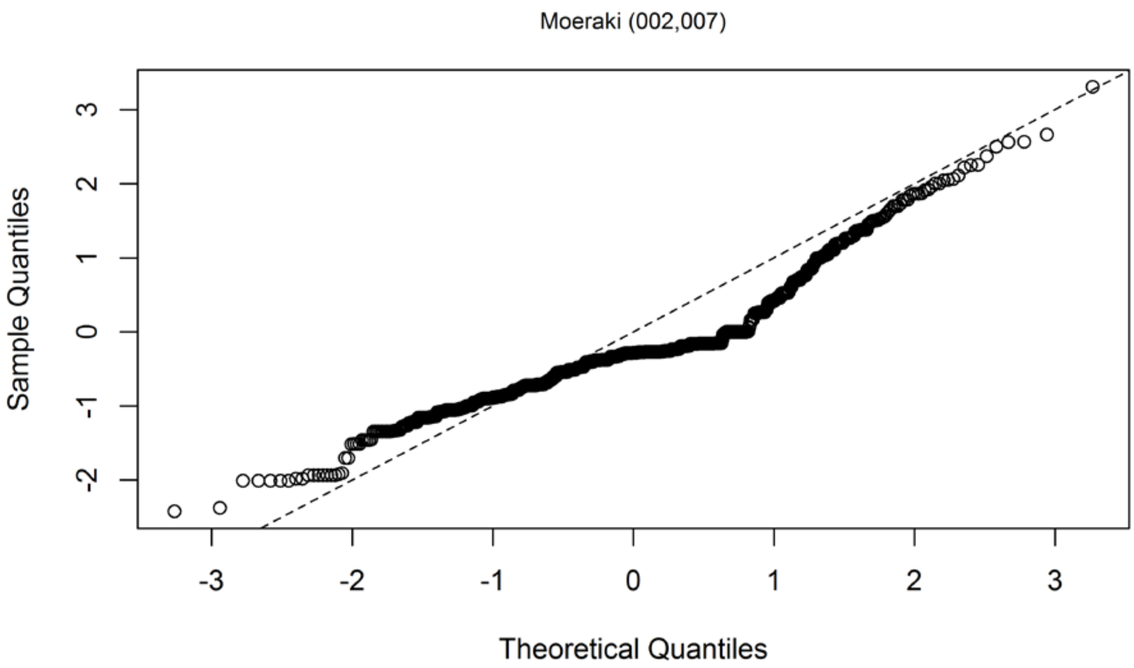

Figure 35: Quantile-quantile plot for the negative binomial standardisation model for Moeraki.

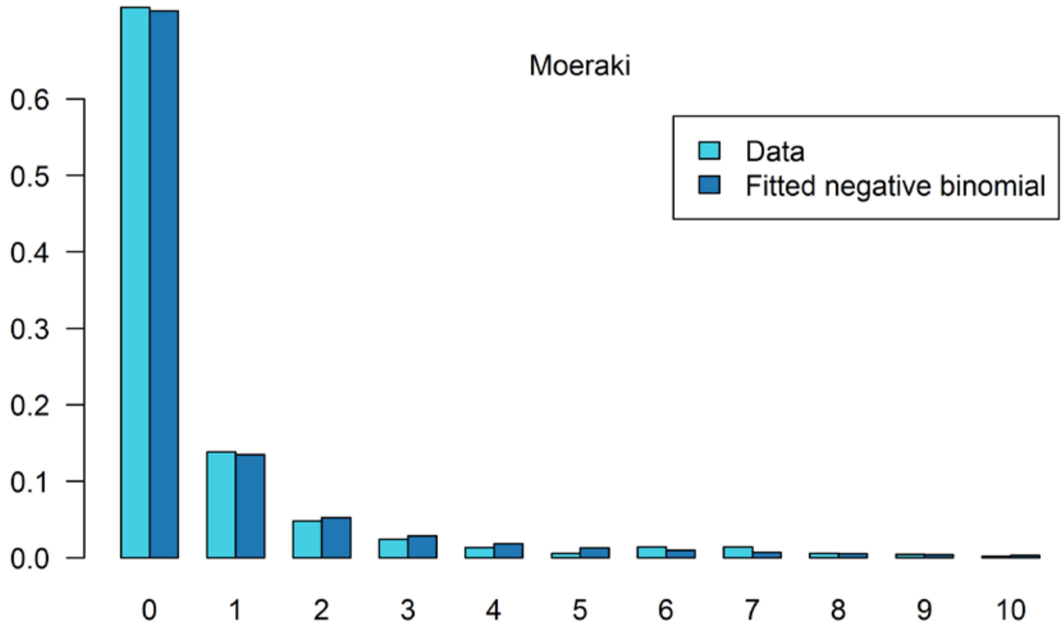

Figure 36: Data distribution for Moeraki and that from the fitted negative binomial.

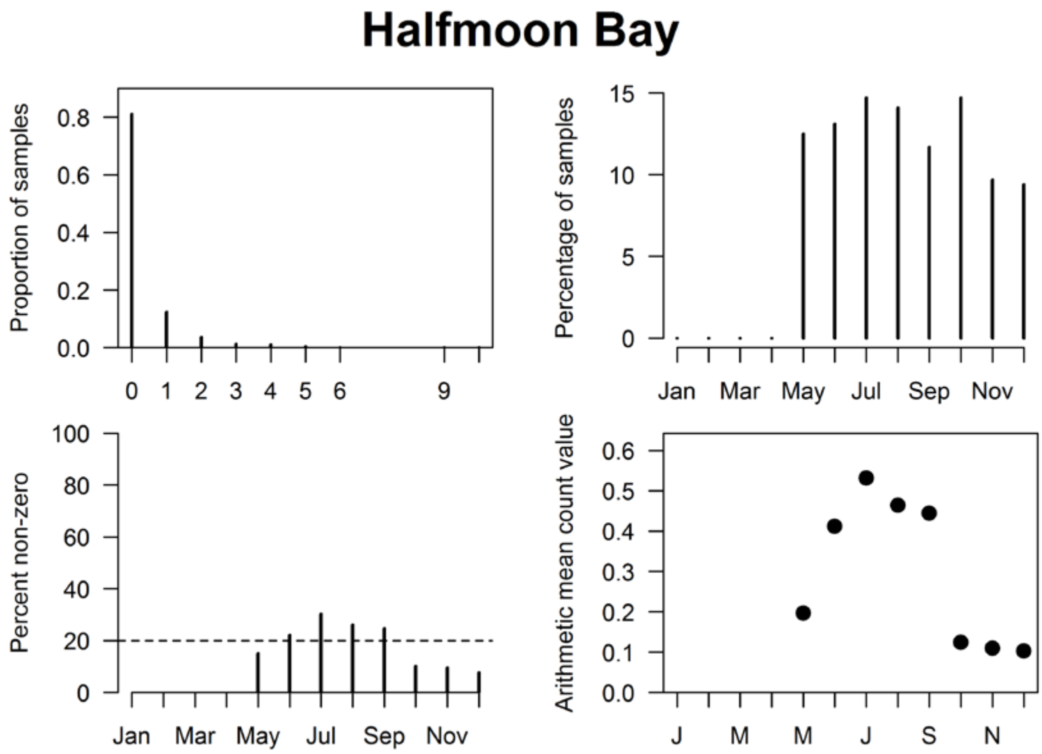

Figure 37: Characteristics of the puerulus standardisation data for Halfmoon Bay. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

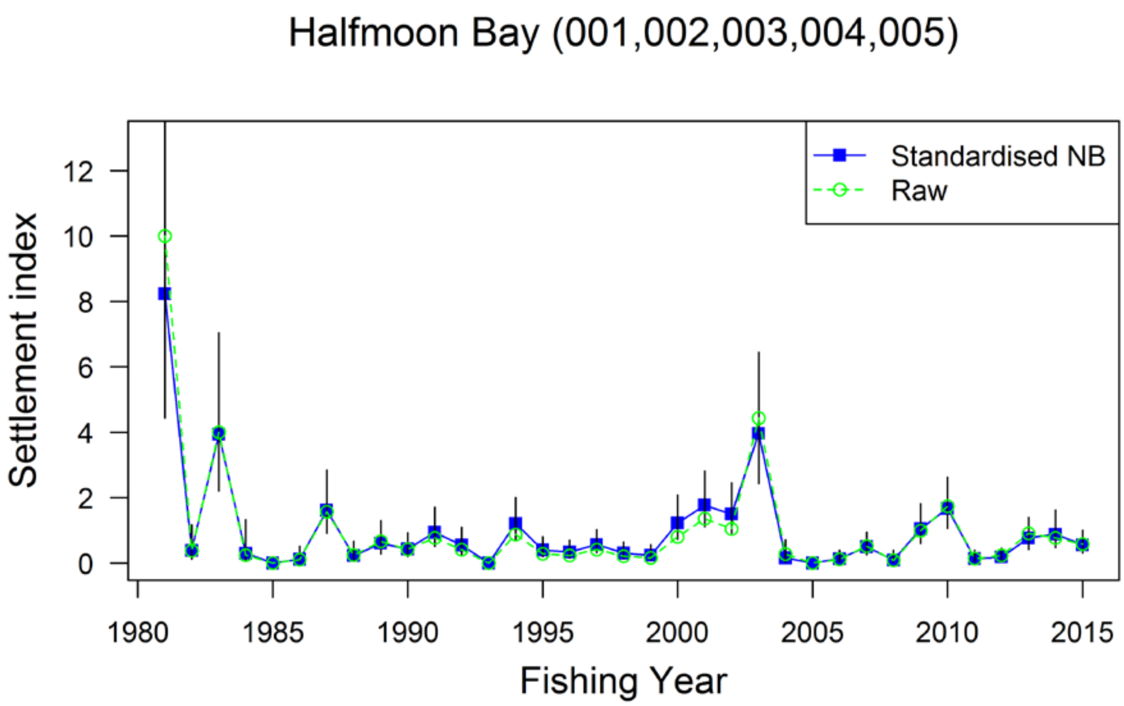

Figure 38: Standardised and raw indices for Halfmoon Bay with 95% confidence intervals.

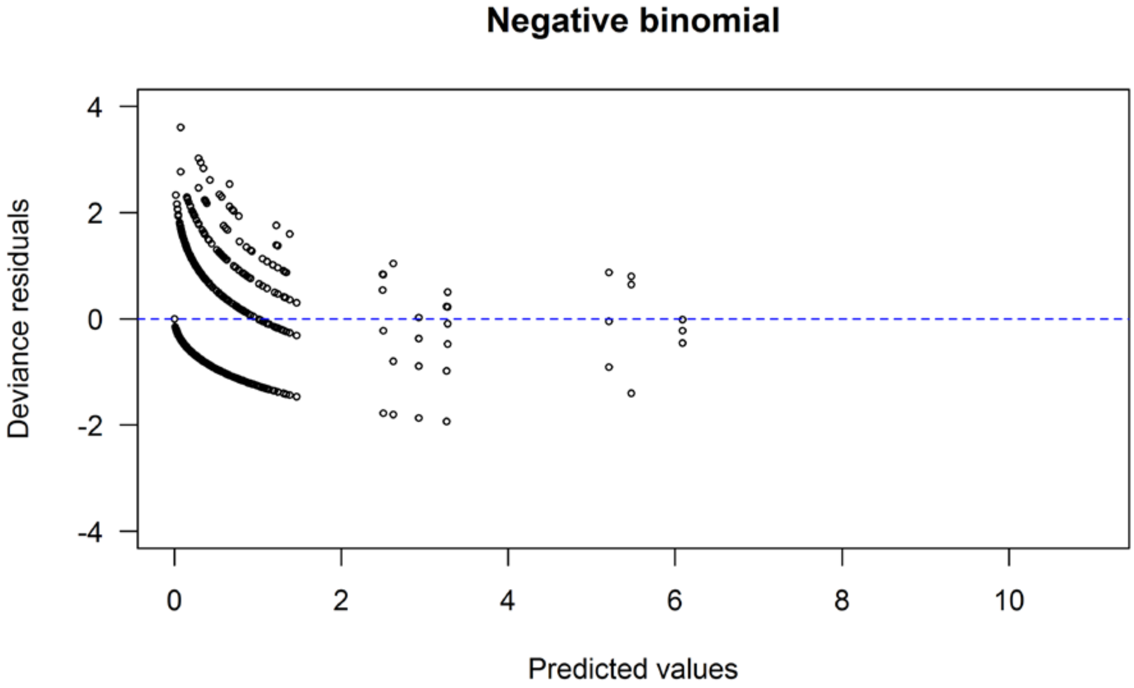

Figure 39: Deviance residuals for the negative binomial model at Halfmoon Bay site. Predicted values are in natural space.

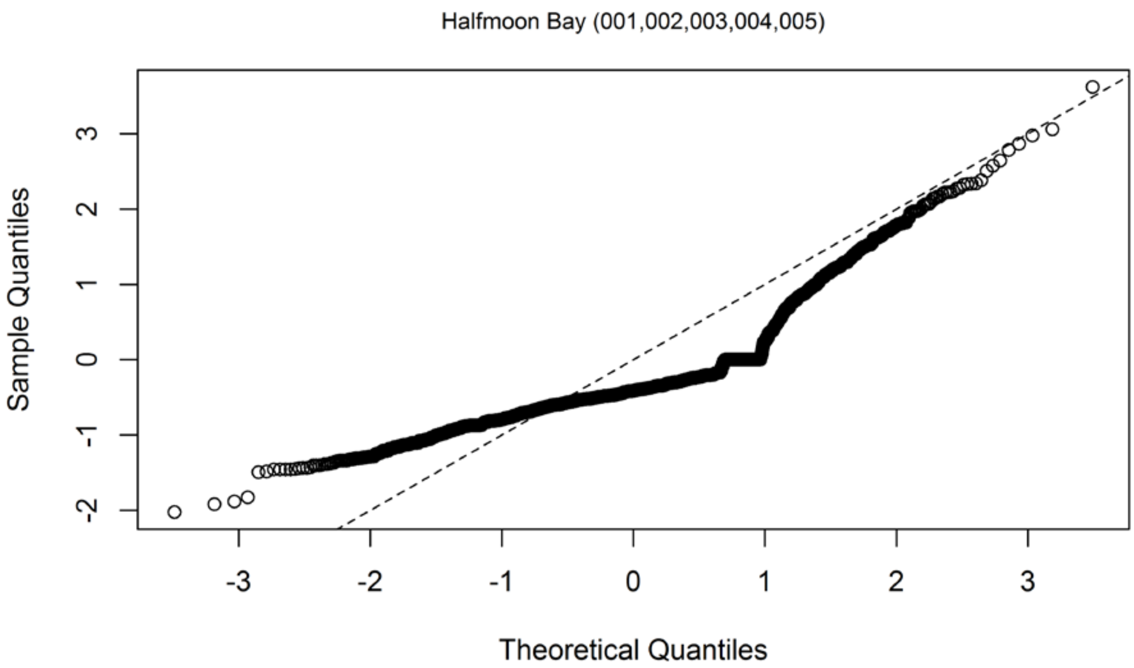

Figure 40: Quantile-quantile plot for the negative binomial standardisation model for Halfmoon Bay.

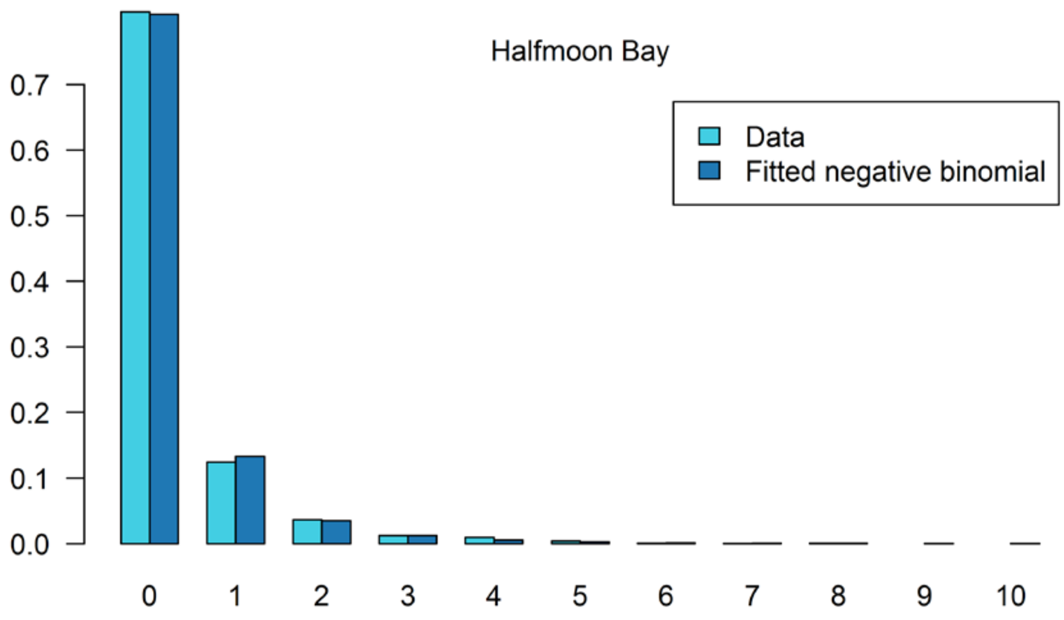

Figure 41: Data distribution and that from the fitted negative binomial model for Halfmoon Bay.

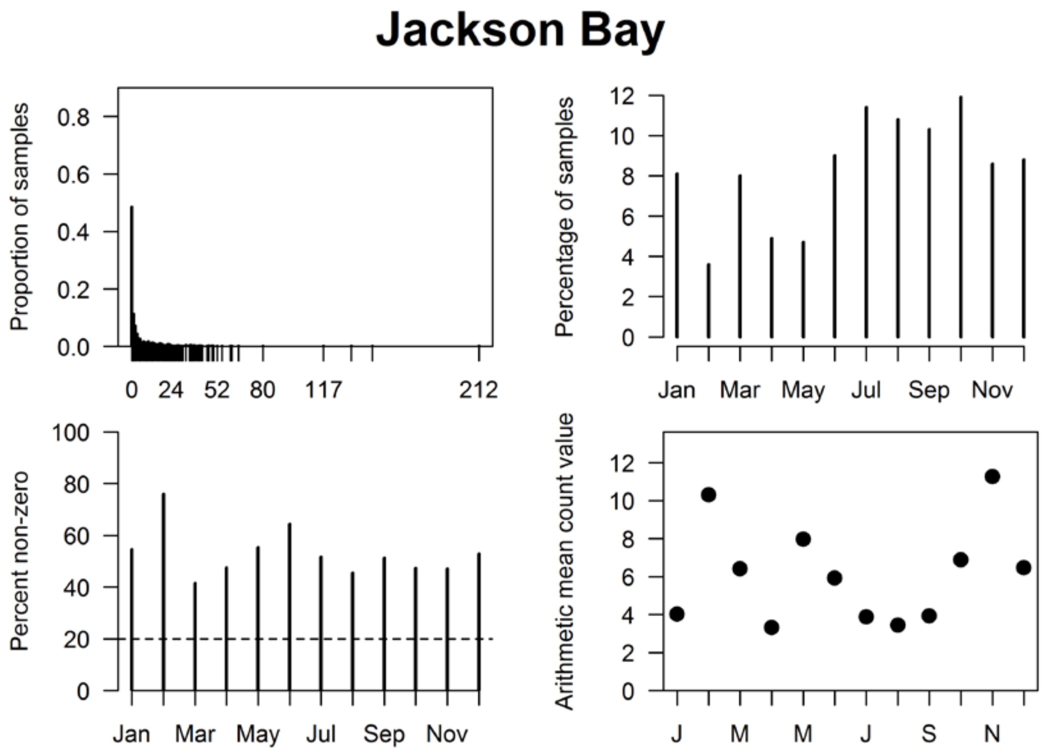

Figure 42: Characteristics of the puerulus standardisation data for Jackson Bay. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

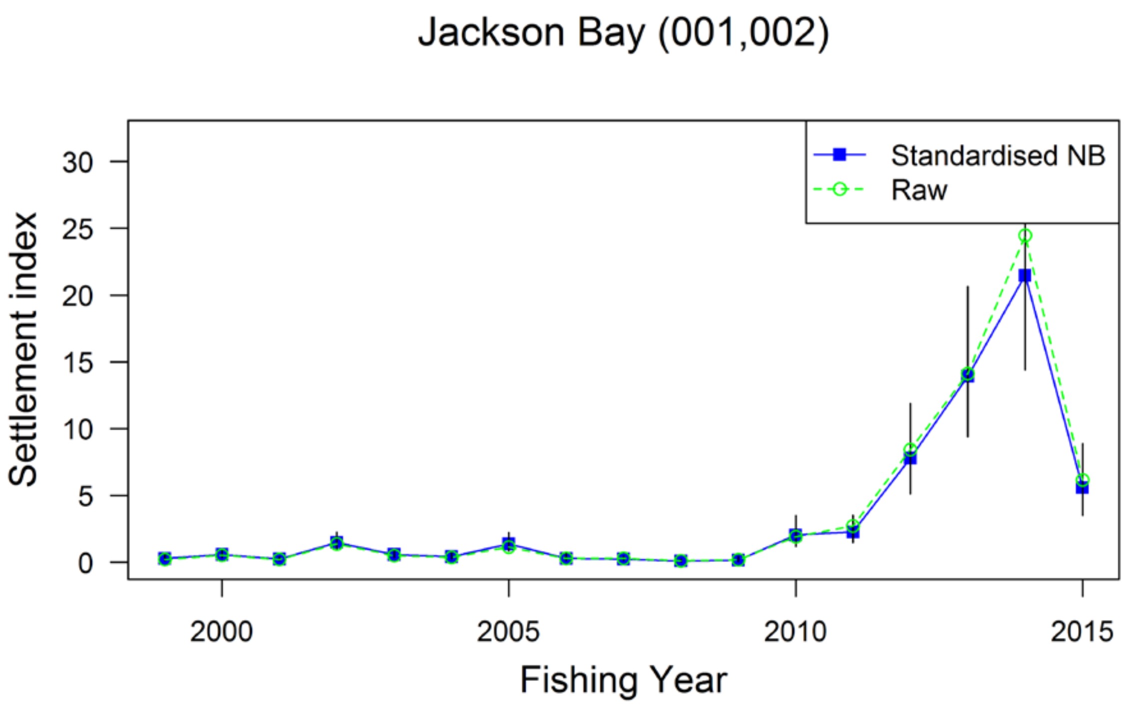

Figure 43: Standardised and raw indices for Jackson Bay with 95% confidence intervals.

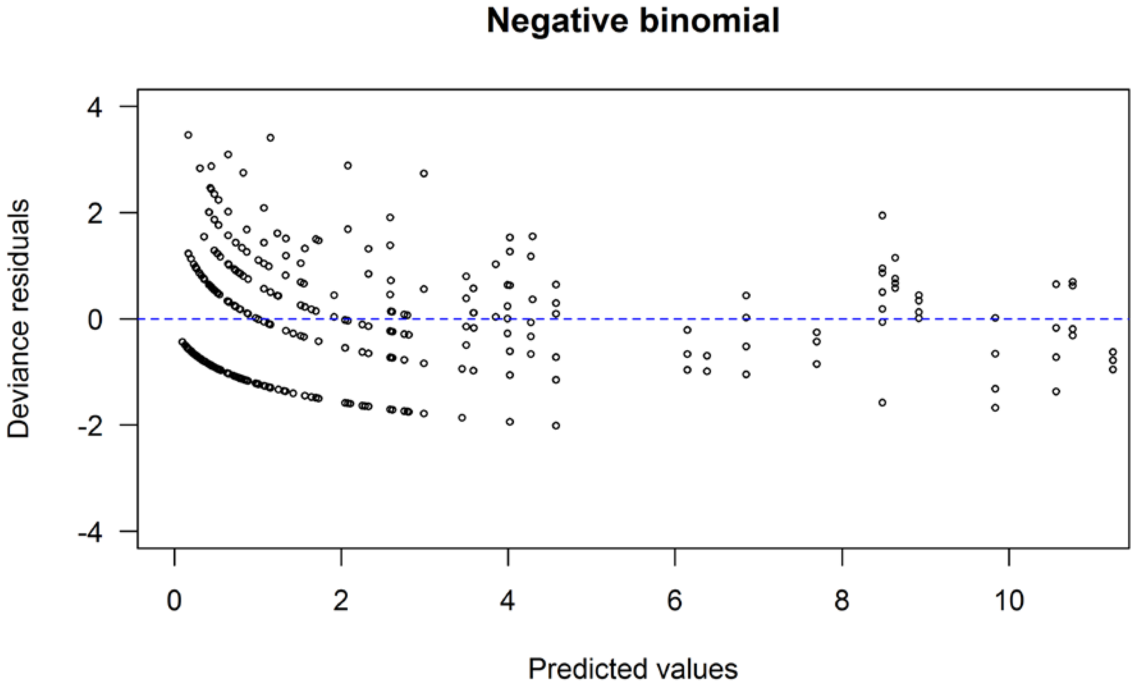

Figure 44: Deviance residuals for the negative binomial model for the Jackson Bay site. Predicted values are in natural space.

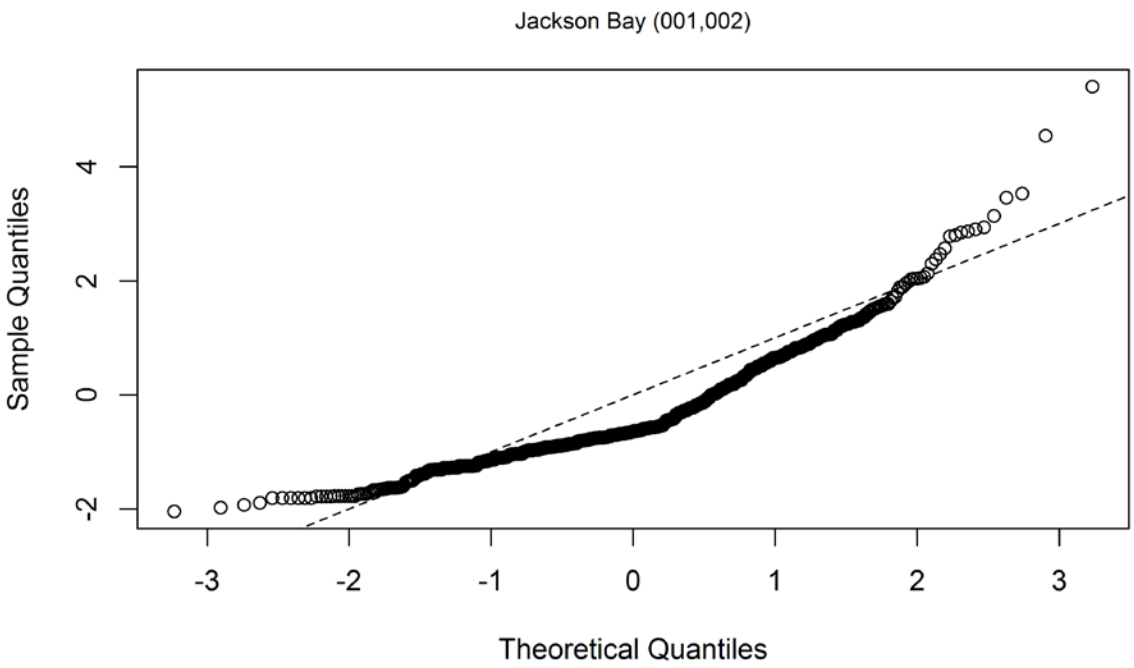

Figure 45: Quantile-quantile plot for the negative binomial standardisation model for Jackson Bay.

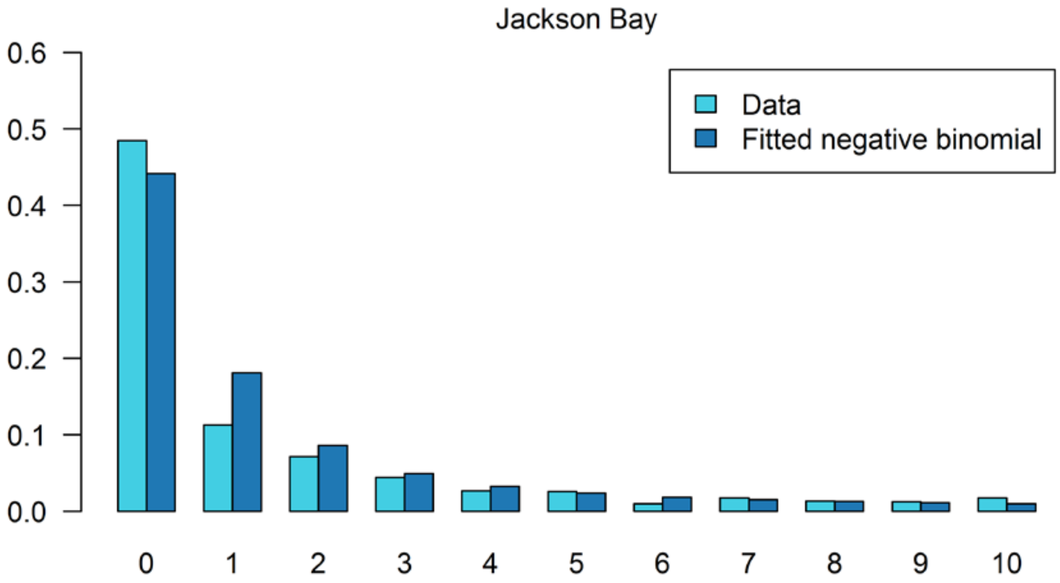

Figure 46: Data distribution and that from the fitted negative binomial for Jackson Bay.

4. SUMMARY AND DISCUSSION

The standardised indices for all sites are summarised in Table 7 (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 7: 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	–	0.77	–	–	–	–	–	–
1980	–	1.23	–	–	–	–	–	–
1981	–	2.01	–	0.55	–	8.24	–	–
1982	–	1.12	2.44	0.75	–	0.39	–	–
1983	–	1.31	1.21	0.16	–	3.95	–	–
1984	–	0.40	0.74	0.37	–	0.30	–	–
1985	–	0.21	0.58	0.24	–	0.00	0.36	–
1986	–	–	0.85	0.09	–	0.12	0.21	–
1987	3.25	–	1.68	1.04	–	1.61	1.42	–
1988	2.77	1.34	0.95	0.40	–	0.23	1.31	–
1989	0.97	1.16	1.17	0.79	–	0.60	1.64	–
1990	0.44	1.02	1.11	1.56	–	0.43	1.84	–
1991	1.05	2.41	2.16	6.72	0.00	0.94	1.03	–
1992	2.81	2.07	2.14	5.22	0.09	0.55	0.52	–
1993	1.75	2.18	1.07	2.04	0.00	0.00	0.14	–
1994	3.01	1.52	0.89	1.08	0.00	1.21	1.64	–
1995	1.07	1.05	0.93	0.60	0.07	0.40	0.40	–
1996	1.65	1.52	1.29	0.64	0.66	0.34	1.76	–
1997	0.99	1.07	1.71	1.97	0.28	0.57	1.41	–
1998	1.78	0.96	1.08	1.90	0.38	0.31	0.50	–
1999	0.28	0.43	0.35	1.28	0.07	0.24	1.70	0.28
2000	0.90	0.72	0.53	1.30	2.81	1.23	1.26	0.57
2001	1.12	1.23	0.71	0.54	1.21	1.77	0.60	0.24
2002	0.94	1.45	0.77	3.33	0.63	1.50	1.42	1.48
2003	2.73	1.30	0.95	3.39	5.25	3.96	1.56	0.57
2004	0.72	1.05	0.50	1.03	0.26	0.16	0.30	0.42
2005	2.47	1.26	1.29	2.26	0.06	0.00	–	1.36
2006	0.27	0.64	0.48	1.09	0.04	0.14	–	0.28
2007	0.36	0.92	1.05	1.75	0.04	0.50	–	0.24
2008	0.64	0.64	1.06	1.68	0.07	0.09	–	0.09
2009	1.71	0.88	1.08	0.55	0.47	1.04	–	0.16
2010	0.61	0.93	1.18	1.31	1.05	1.67	7.03	2.03
2011	0.18	0.48	0.90	0.58	0.75	0.14	1.44	2.27
2012	0.66	0.70	0.59	1.14	0.84	0.18	4.37	7.79
2013	0.92	0.94	1.72	0.72	1.25	0.77	–	13.92
2014	0.39	1.02	0.70	1.37	0.37	0.88	–	21.47
2015	1.49	1.05	1.71	0.90	8.34	0.56	–	5.57

Gisborne

Settlement at Gisborne in 2015/16 was above the long-term mean and ends a five year series of below average settlement (Figure 47). Whangara recorded higher levels of settlement than Kaiti but both sites had a similar monthly settlement pattern and both peaked in July (Figure 48).

Napier

Settlement at Napier was just below the long-term mean. Over the last ten years, settlement has been close to or below the long-term mean, and no significantly high settlement has occurred since the 1990s (Figure 49). There was a sharp increase in settlement at Cape Kidnappers in June and July but it was low over the rest of the settlement period. At Napier Port, settlement was low throughout the year. (Figure 50).

Castlepoint

For the second time in three years settlement at Castlepoint was above the long-term mean. (Figure 51). Levels of settlement between Castlepoint and Orui were very similar. Settlement at Orui and Castlepoint both had a winter peak in June 2015 and a summer peak in January 2016 (Figure 52). The January peak at Castlepoint was almost twice the previous record set back in 1983 and four times the average settlement for that month.

Kaikoura

Kaikoura was just below the long-term mean (Figure 53). North Bay, South Bay, and Haumuri Bluff had similar levels of settlement with South Kaikoura recording much higher levels over summer (Figure 54).

Moeraki

Record levels of settlement were recorded at Moeraki, eight times above the long-term mean (Figure 55). Most of the settlement occurred from April to August with July the peak month (Figure 56).

Halfmoon Bay

Settlement was below the long-term mean in Halfmoon Bay (Figure 57). There were two small peaks in June and August (Figure 58).

Chalky Inlet

No new data were received in 2015/16.

Jackson Bay

Settlement, although well down from the previous two years of extreme highs, was still well above average in Jackson Bay (Figure 59). There were two peak periods, in June and December (Figure 60). The very low settlement from January to March was a probably a result of very high rainfall during this period causing the salinity in the bay to drop. These data were therefore not used in the final settlement index.

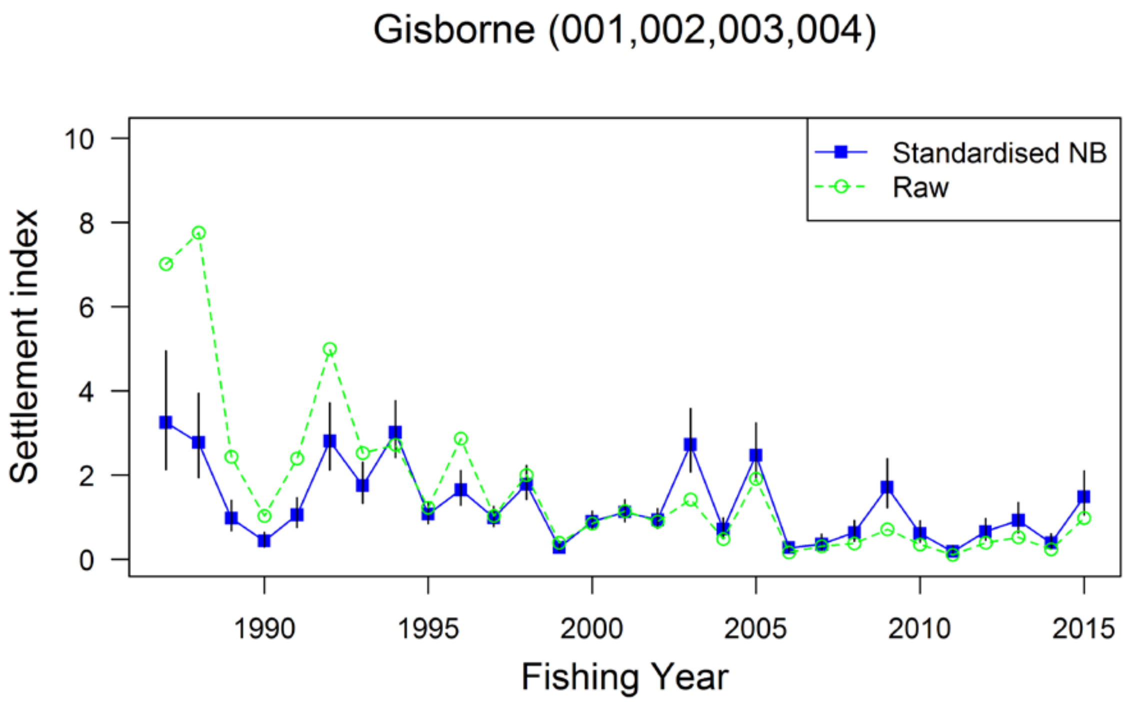

Figure 47: Gisborne–standardised and raw indices of annual settlement with 95% confidence intervals.

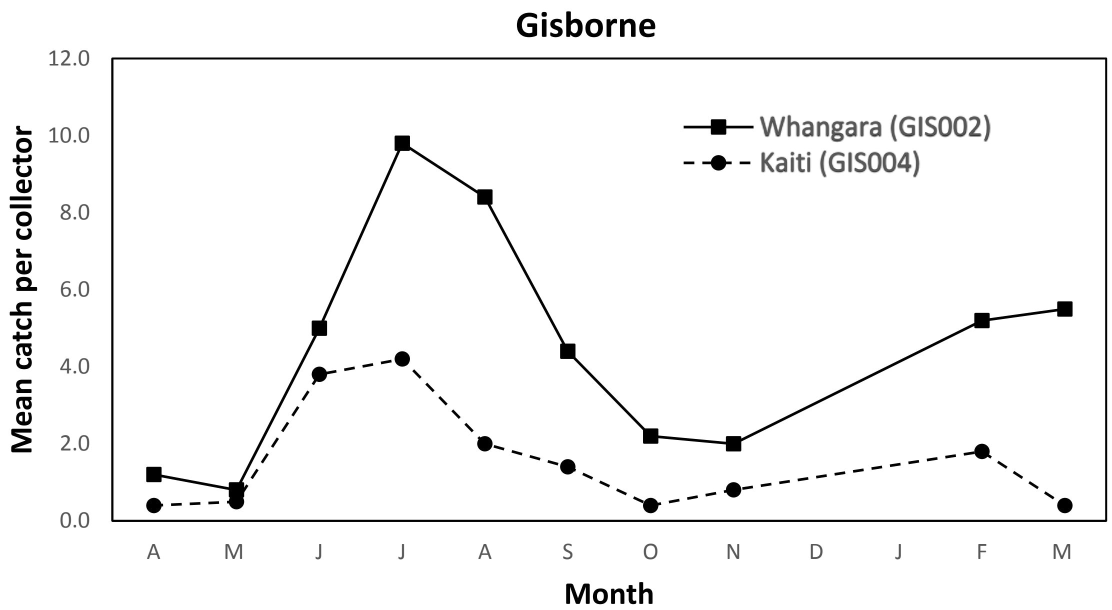

Figure 48: Whangara and Kaiti monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

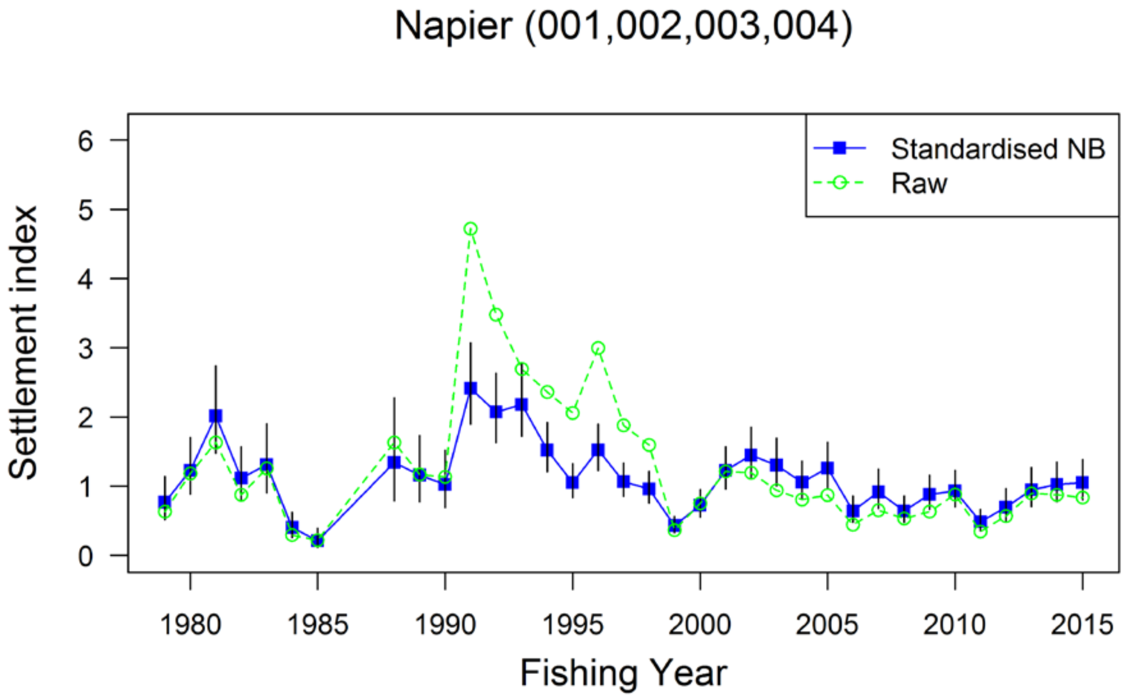

Figure 49: Napier—standardised and raw indices of annual settlement with 95% confidence intervals. Note that there were no checks in 1986–87.

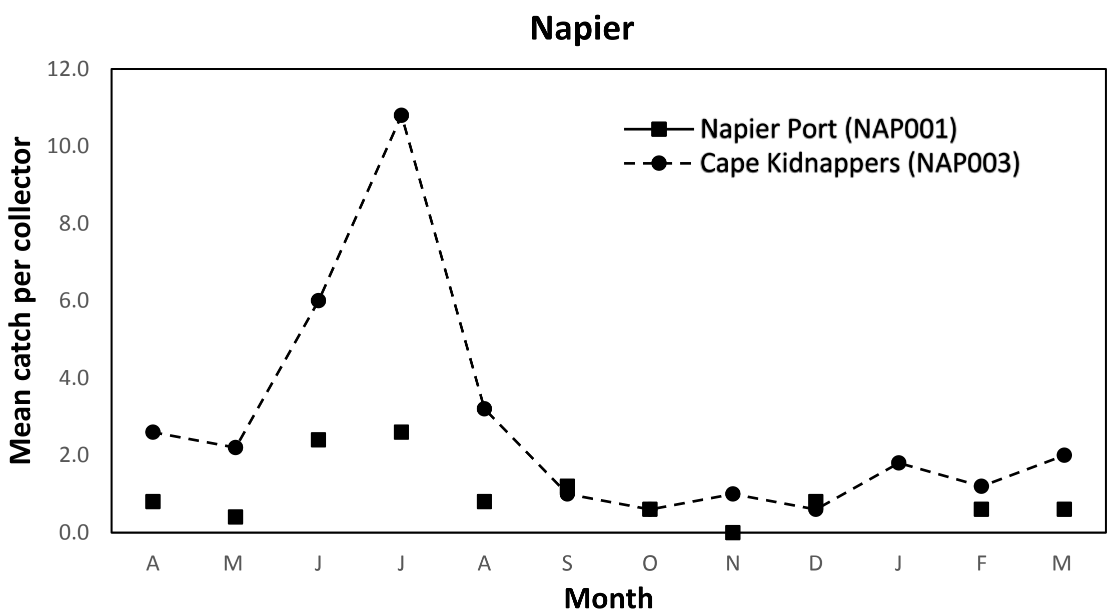

Figure 50: Napier Port and Cape Kidnappers monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

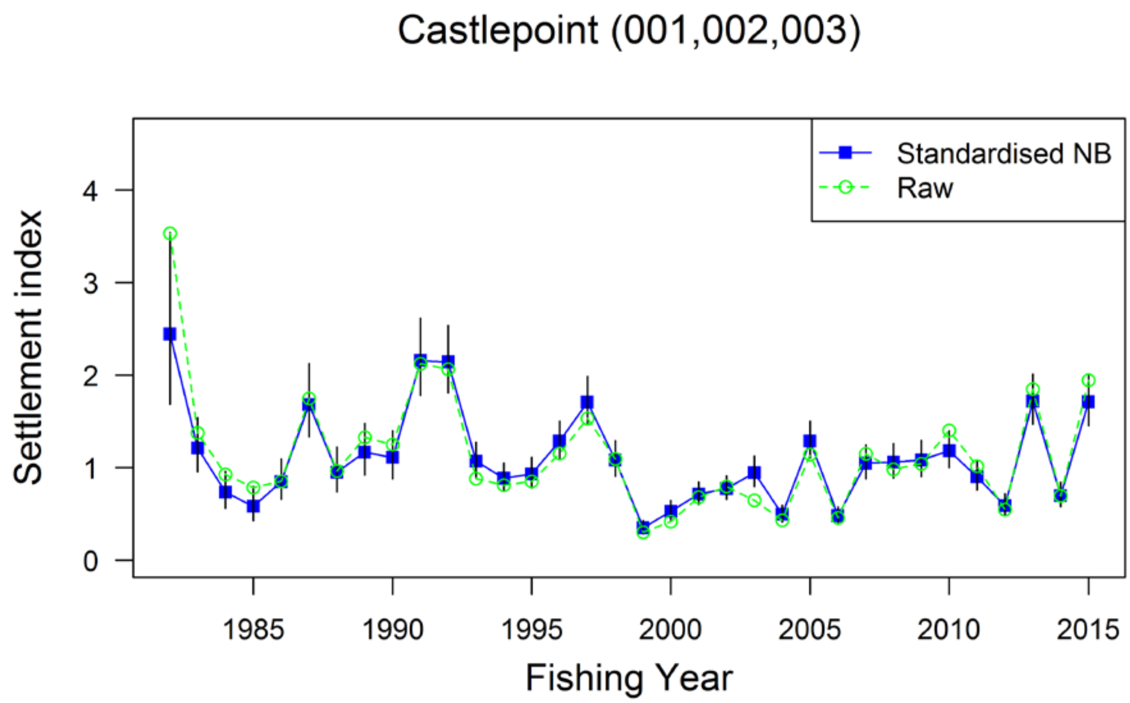

Figure 51: Castlepoint—standardised and raw indices of annual settlement with 95% confidence intervals.

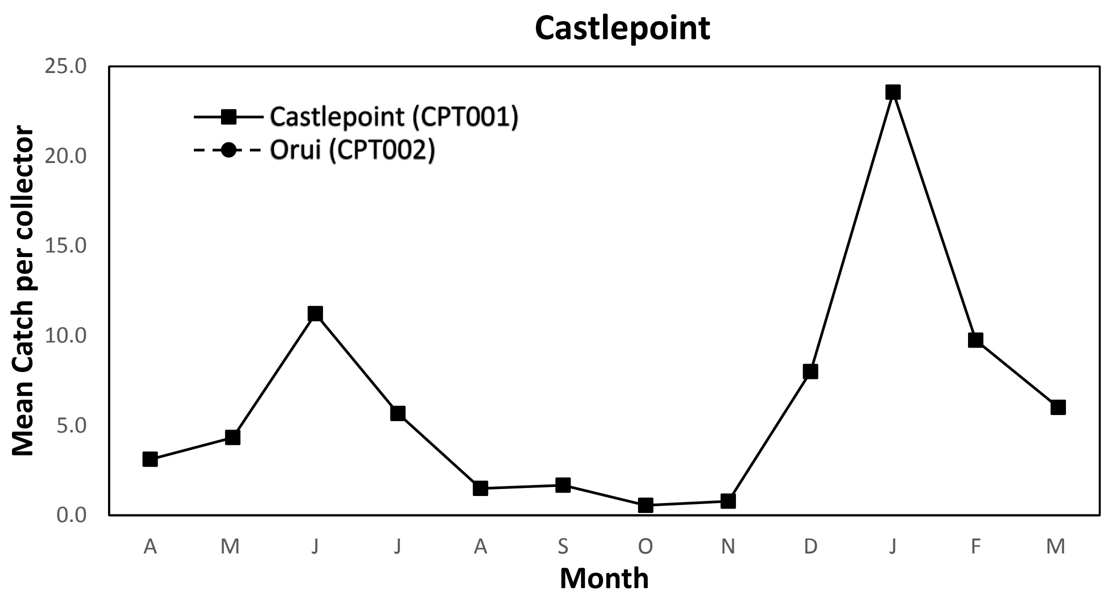

Figure 52: Castlepoint and Orui monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

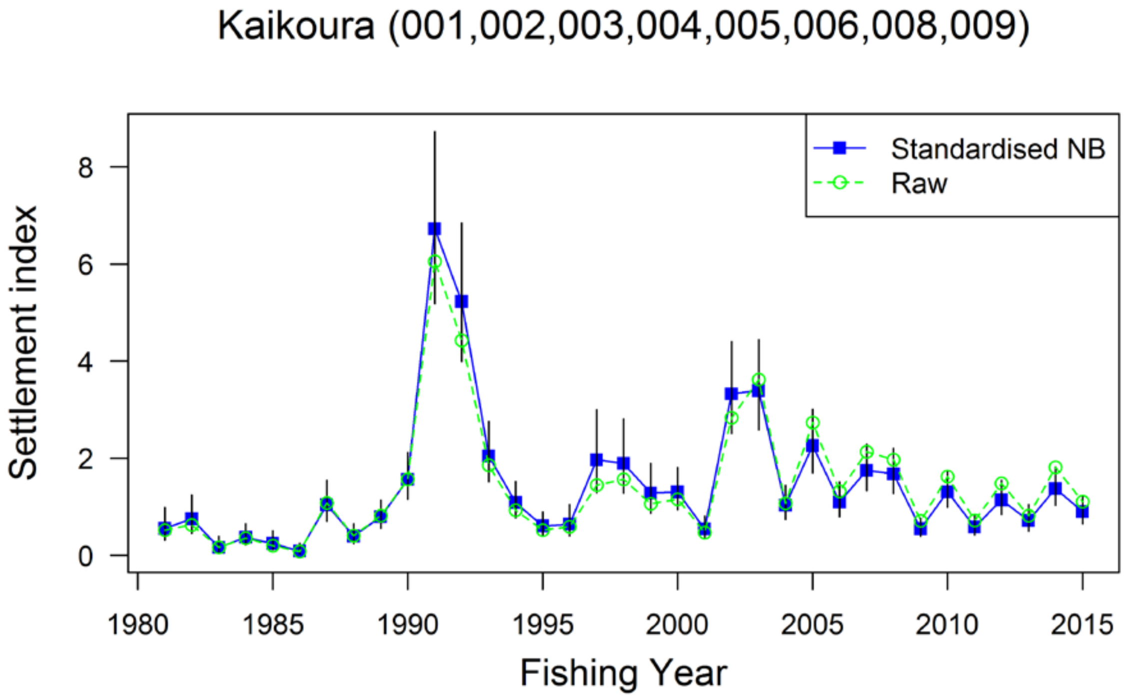

Figure 53: Kaikoura—standardised and raw indices of annual settlement with 95% confidence intervals.

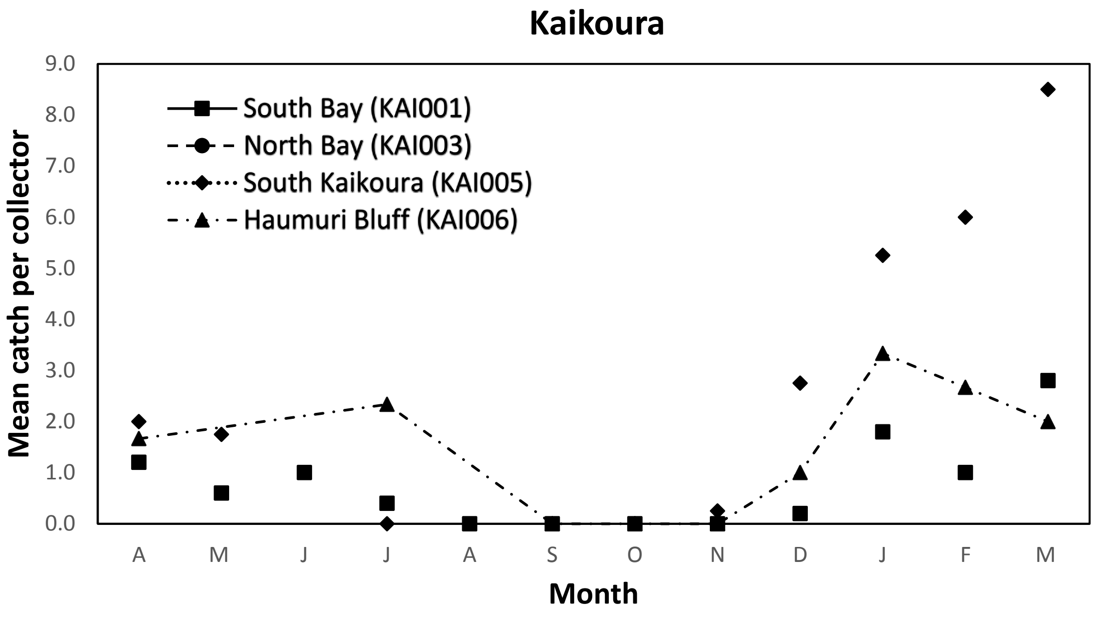

Figure 54: South Bay and North Bay monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

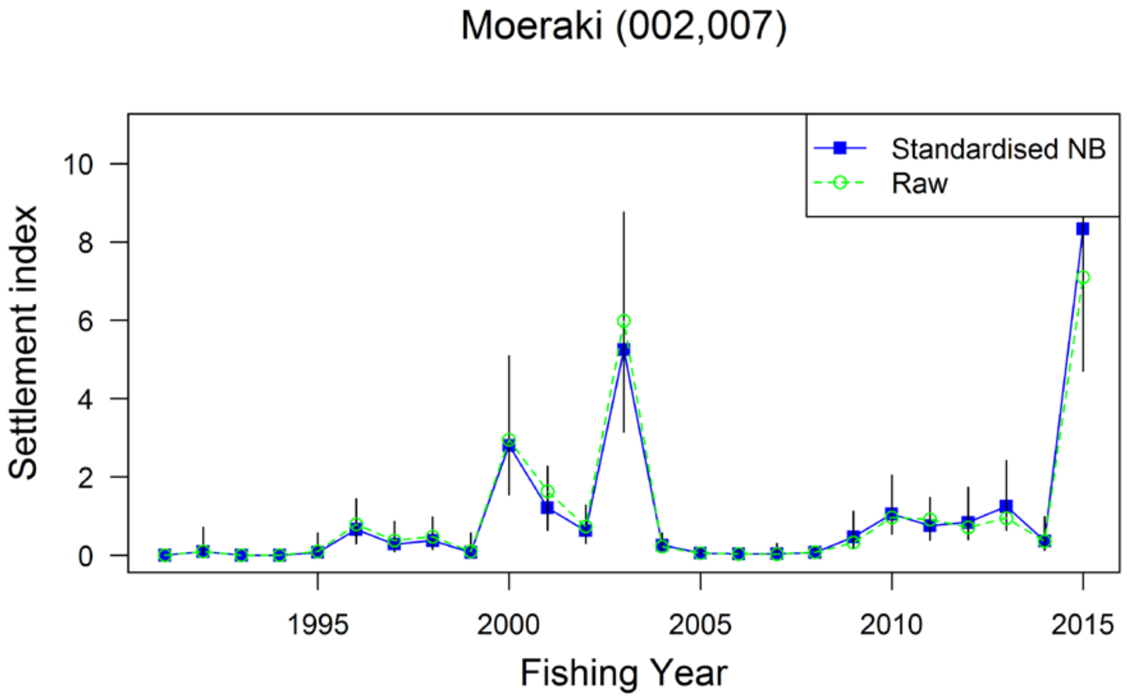

Figure 55: Moeraki—standardised and raw indices of annual settlement with 95% confidence intervals.

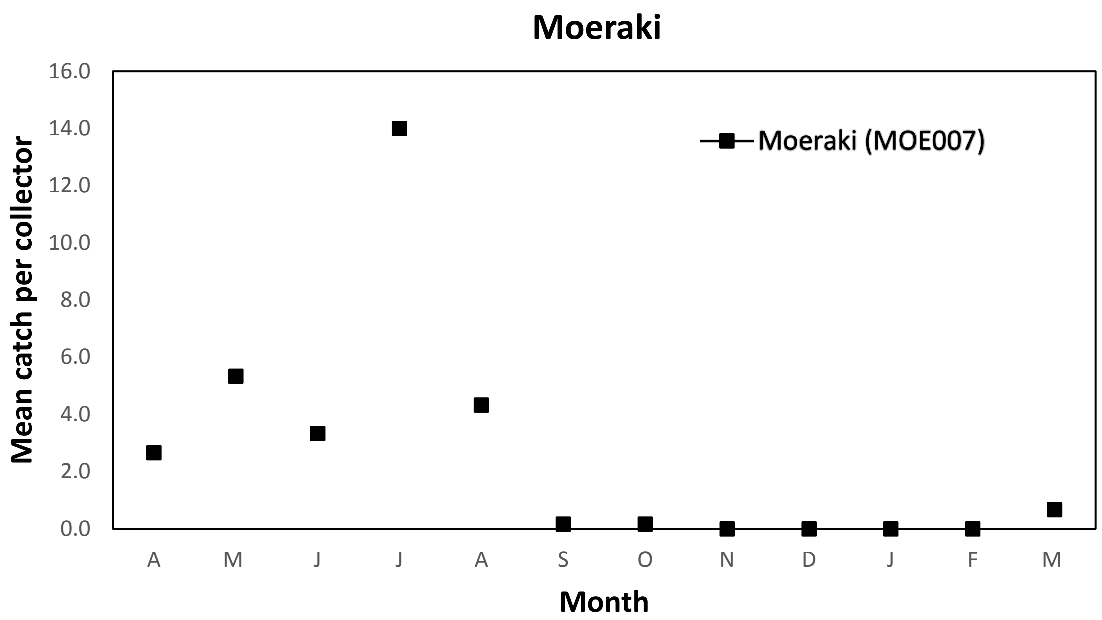

Figure 56: Moeraki monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii pueruli* plus juveniles less than 14.5 mm carapace length per collector.

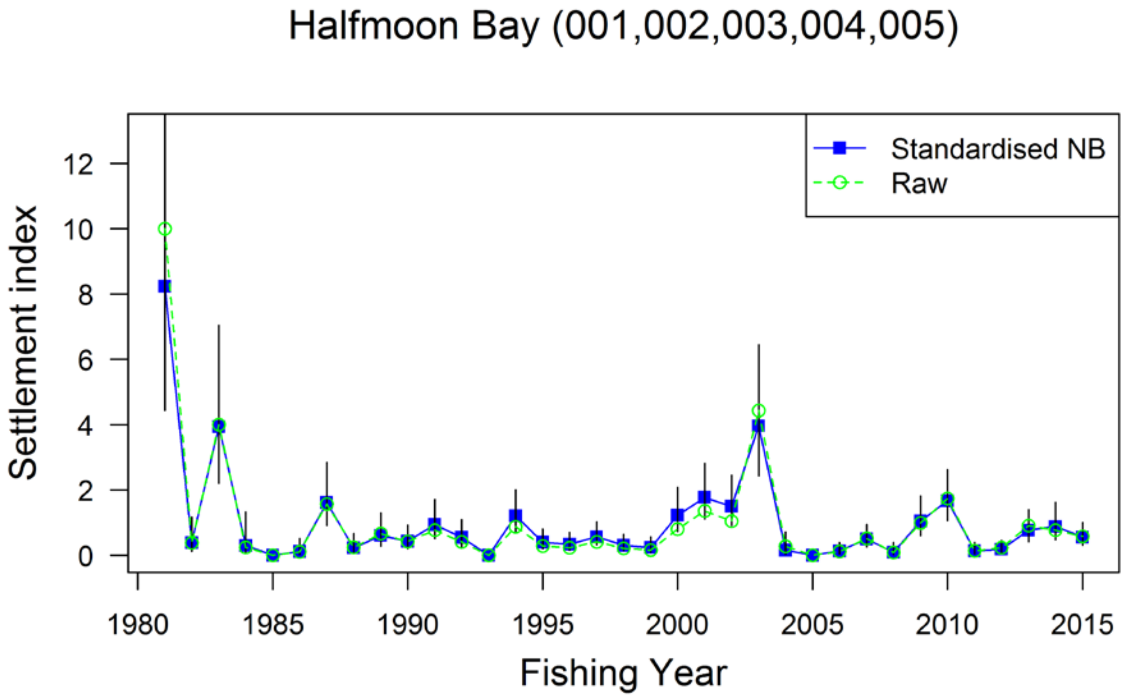

Figure 57: Halfmoon Bay—standardised and raw indices of annual settlement with 95% confidence intervals. The 95% confidence bounds were large because of high collector catch variability and the data not fitting the standardisation model well because of the large number of zero catches.

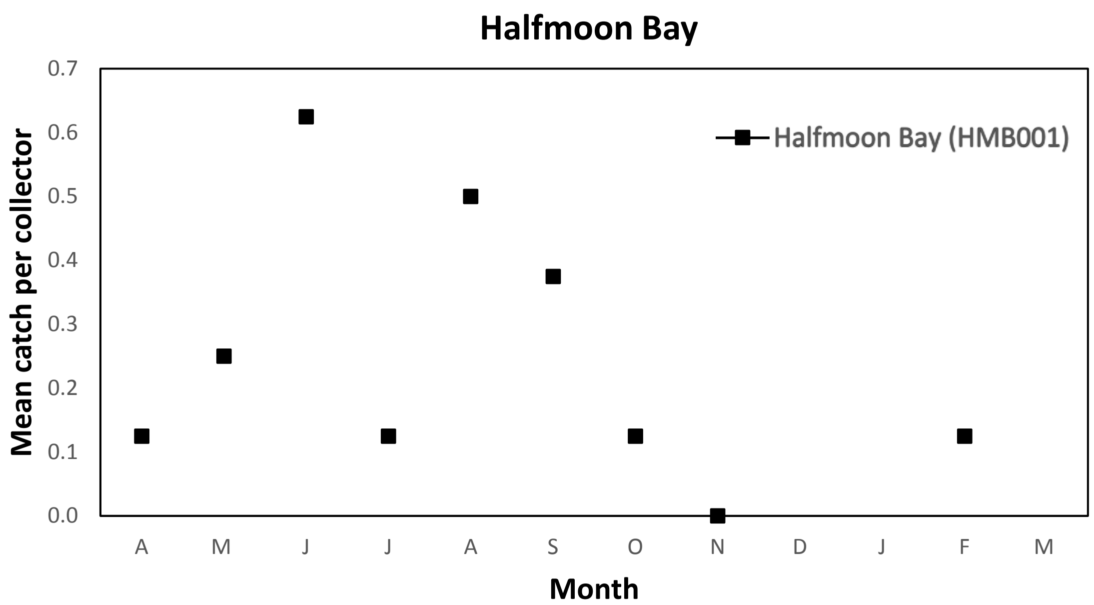

Figure 58: Halfmoon Bay monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

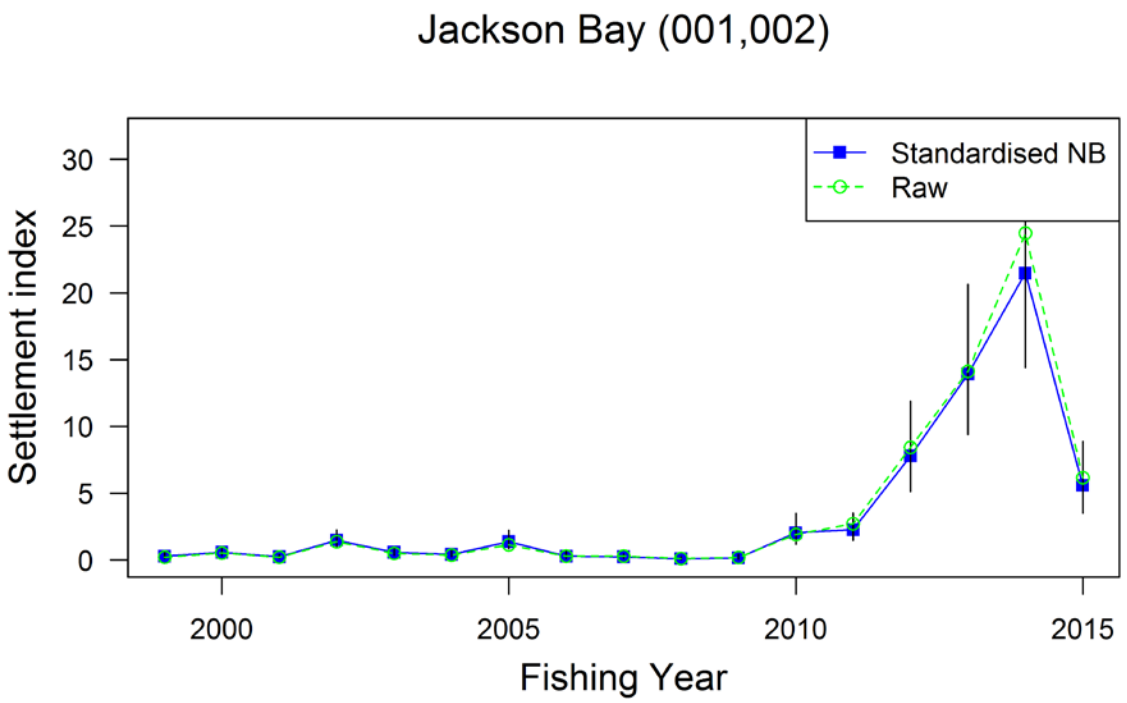

Figure 59: Jackson Bay—standardised and raw indices of annual settlement with 95% confidence intervals.

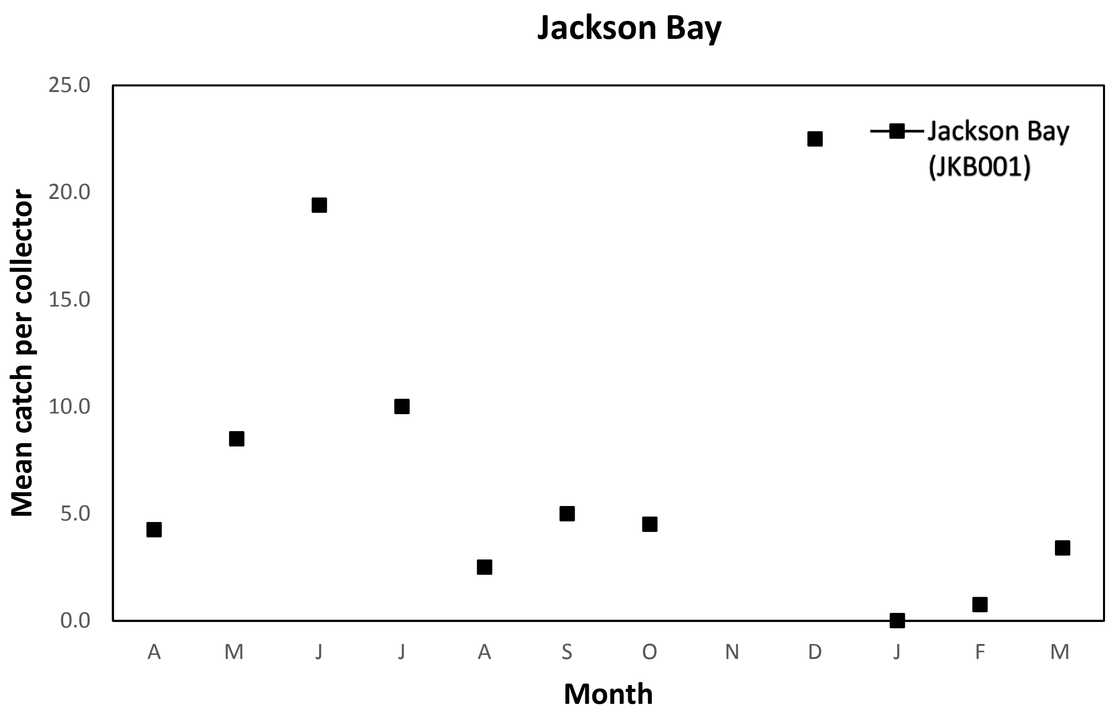

Figure 60: Raw monthly settlement, 2015/16 fishing year. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

5. CONCLUSIONS

After eleven years of average to below average settlement, Moeraki produced record levels of settlement. Settlement at Jackson Bay, although reduced from the previous two years, was also well above the long-term mean making it six years in a row of above average settlement with the previous two years being exceptionally high. Above average settlement was also recorded at Gisborne and Castlepoint. Only Halfmoon Bay and to a lesser extent Kaikoura recorded below average settlement.

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

NZ ROCK LOBSTER INDUSTRY COUNCIL LTD

Ka whakapai te kai o te moana

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CC: Dr. R.J. Hurst, Chief Scientist, NIWA
CC: Dr. Julie Hills, Chair, Rock Lobster Fishery Assessment WG, MPI
CC: ECs

July 11th 2016

PUERULUS INDICES FOR 2016 STOCK ASSESSMENT

Dear Andy:

This year the rock lobster stock assessment will be done for CRA 4. The stock assessment team therefore needs annual standardised indices for this stock, based on the fishing year 1 April through 30 March.

As for previous indices, 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, if that concern is applicable.

We will need to see a characterisation of the data from CRA 4 – how many collectors in what groups in what locations for which periods – so that we can be assured that appropriate groups have been used for the standardisation. For some of these stocks, zeroes are a problem, and we support using only the peak settlement months, if they are apparent. Last year's results suggest that negative binomial error is appropriate if the diagnostics are acceptable.

The first RLFAWG meeting is on 20 September. Because we would like to be comfortable with the puerulus index by that date, we request a preliminary document from NIWA by 01 September. We will need a table of the annual indices.

Please address any queries to myself or to Dr. Paul Breen at:
bb26@inspire.net.nz

Thanks in advance. Yours sincerely on behalf of the assessment team

Daryl R Sykes

NZ Rock Lobster Industry Council Ltd

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 less than 36 samples and fishing years with less 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
2015	0	20	0	19	39

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
2015	55	0	59	0	114

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
2015	105	59	0	164

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	24	24	0	0	128
2015	45	0	45	0	12	9	0	0	111

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	36	36
2013	0	36	36
2014	0	24	24
2015	0	36	36

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
2015	64	0	0	0	0	64

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
2015	34	0	34