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Settlement indices for 2013 for the red rock lobster (*Jasus edwardsii*)

New Zealand Fisheries Assessment Report 2015/13

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EXECUTIVE SUMMARY

Forman, J.S.; McKenzie, A.; Stotter, D.R. (2015). Settlement indices for 2013 for the red rock lobster (*Jasus edwardsii*)

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This report addresses objective one of the Ministry for Primary Industries project CRA201202C (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 2013, two groups of collectors in Gisborne, Napier, Castlepoint, and 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. An annual raw and standardised index is produced from the groups of collectors at each site.

Additional data from industry collectors in Chalky Inlet and Kaikoura are also used. However, there was no data in 2013 for Chalky Inlet, and the number of industry samples from Kaikoura was small in 2013.

The Gisborne site (CRA 3) standardisation was explored in some detail, and the final standardisation used as a data input for the CRA 3 stock assessment.

Puerulus settlement in 2013 was notable for the extremely high levels recorded in Jackson Bay, where 18 times the normal number of pueruli were collected. This follows on from the very the high settlement recorded in 2012. To a much lesser extent, above average settlement was also recorded in Napier, Castlepoint, and Moeraki. Settlement was below average in Gisborne and Kaikoura, and close to average in Halfmoon Bay. Settlement in Gisborne continues to be low with 7 of the last 8 years below the long term mean.

1. INTRODUCTION

Rock lobsters support 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 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 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.

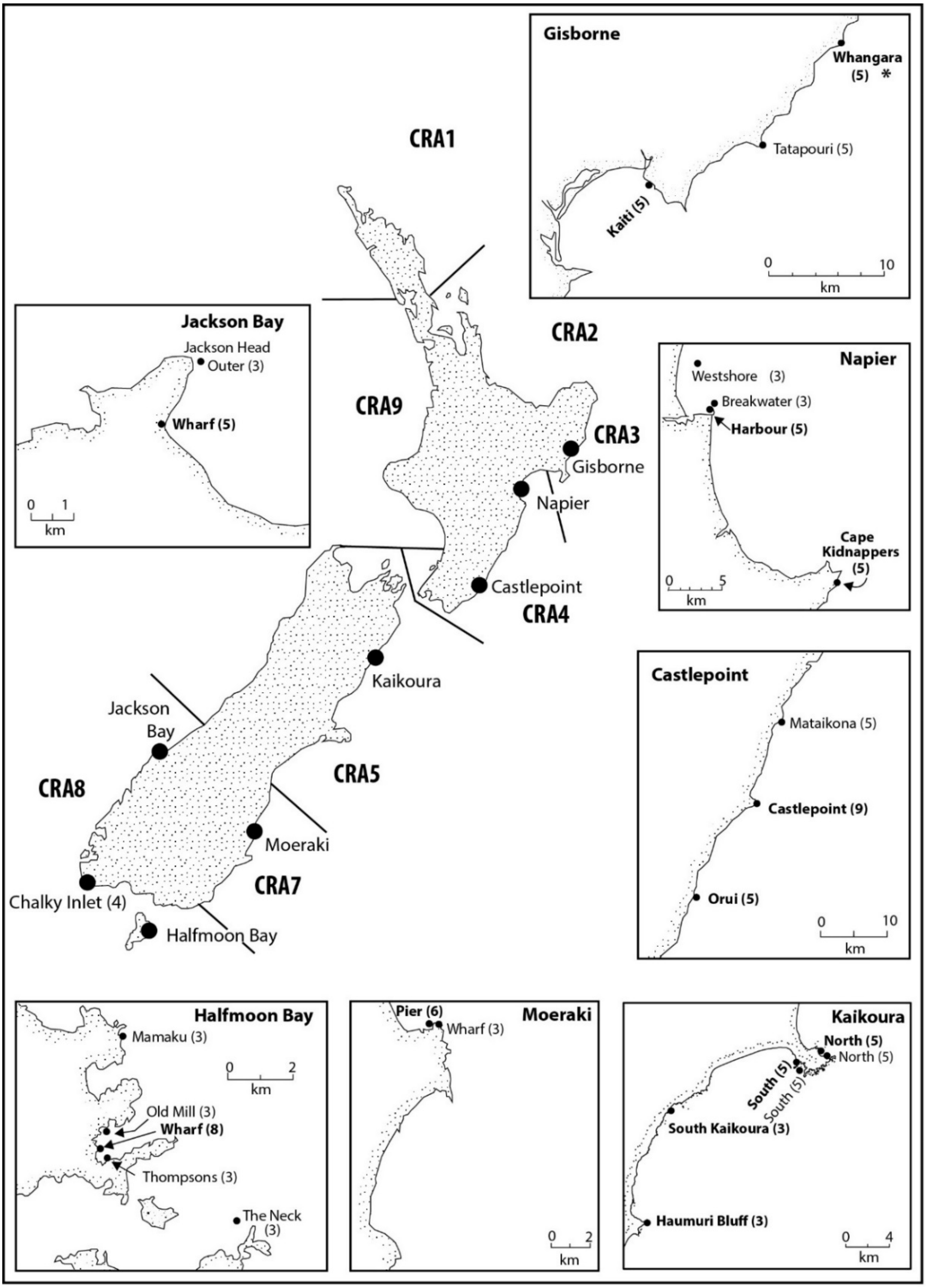

Figure 1: Map of New Zealand showing the location of collectors at the key monitoring sites (although not all groups are now checked). The sites that are checked are in bold and the number of collectors in that set is in brackets. Also shown are the CRA areas; CRA 6 is the Chatham Islands and CRA 10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

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, it was not considered reasonable to allocate the month of settlement to the nominal month.

Instead, 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.

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).

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 Poisson distribution with dispersion is assumed. All independent variables were treated as factors. The year variable was included in all models; the other independent variables (group/collector 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 Aikake Information Criterion (AIC) was included (Akaike 1974).

The standardisation method was the same as in previous years. Some recommendations were made in a review of the puerulus settlement program (Cockcroft 2011), including some aspects of the standardisation process, which are investigated in an in-depth look at the Gisborne standardisation for which the final standardisation method differed from the other sites (Section 3.3)

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 less than average settlement. For comparison, a raw form of these indices are also given (arithmetic mean for each year), which are also scaled to have an average value of 1 over all years.

3. RESULTS

3.1 Introduction

Results are shown first for the Gisborne site (data characterisation and standardisation). These are followed by the standardisation results for the other sites, and a discussion of settlement trends for all sites.

3.2 Gisborne data characterisation

3.2.1 Introduction

Gisborne is the only site in the CRA 3 area with collectors, and henceforth in this section reference will be made to Gisborne instead of CRA 3. The data set used is an extract from the *rocklob* database and is complete for the 2013 fishing year (i.e. data is complete up to 31 March 2014).

The Gisborne settlement was used as a data input for the CRA 3 stock assessment, for which there were specific requirements and background analyses requested (Appendix 1). As requested (and in contrast to previous standardisations) the year and month are assigned differently:

1. using the fishing year 1 April through to 31 March (in the CRA 3 puerulus index request the end date for the fishing year was inadvertently stated as 30 September). The fishing year label is the year in which April occurs. For example, 20 April 2004 is in the 2004 fishing year, while 11 Feb 2004 is in the 2003 fishing year.
2. the actual month in which a sample was used instead of samples taken up to the 7th of the month been assigned to the previous month.

In recent Gisborne standardisation three groups of collectors have been used (002, 003, 004) and only collectors for which at least 36 samples have been taken are included. In the following sections we look at the characteristics of sampling from the Gisborne collectors before any subsetting of the data is done.

3.2.2 Sampling characteristics

At the Gisborne site 10 groups of collectors have been in place at various times, and a total of 44 collectors have been used. These groups are labelled 001, 002, ..., 010. 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 GIS0103 represents the Gisborne site for group 010 and collector 3.

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

The group of collectors GIS005, GIS006, ..., GIS010 were exploratory groups of collectors sampled for a relatively short time. These were located in and around Gisborne wharf, although GIS010 may have been located in Anaura Bay (Jeff Forman, NIWA, pers. comm.). The main group of collectors GIS001, GIS002, GIS003, and GIS004 overlap in time with the groups GIS005, GIS006, and GIS007 for only one year (1987 for the GIS005 group). Because of this disjuncture, even though they show a degree of consistency (Figure 4) they cannot be combined in a standardisation to form a continuous series from 1979 to the present. The other exploratory groups, GIS008, GIS009, and GIS010 have a relatively small number of samples in each year (fewer than 30) and only cover a 2–3 year period.

The group GIS001 is a well sampled group and puerulus collections were done by diving in about 10 m of water near a wharf. However, the number of pueruli caught was considered anomalously high compared to other groups, and not reflective of pueruli settlement in the natural environment (Figure 5). Because of this the group has not been used in standardisations. A very high number of collected pueruli need not preclude a collector from being used in standardisations, as the standardisation procedure will scale the numbers to match with other collectors. Putting the yearly mean pueruli numbers for GIS001, GIS002, GIS003, and GIS004 on a similar scale indicates a good degree of correlation between the groups from 1991 until 1995, but less subsequently when 5 out of 8 of the changes in settlement rates for GIS001 (up or down) are in the opposite direction to the other groups (Figure 6).

3.2.3 Impact of 36 samples subsetting rule

The rule that collectors are not used unless they have been sampled at least 36 times has little effect for the Gisborne site. If, as is currently done, the group of collectors GIS002, GIS003, and GIS004 are chosen to use for the standardisation, then all collectors from these groups easily satisfy this rule having being sampled at least 100 times each (Figure 3). Similarly if the GIS001 group was included in the standardisation - all collectors from this group have been sampled at least 150 times each.

3.2.1 Independence of collectors within groups

The counts from puerulus sampling follow a probability distribution, and independence for the collectors means that a sample from a collector is like an independent sample from this distribution. This means that if one collector records a high count, predictions of the puerulus count from another collector in the same group will not be improved.

The puerulus count distribution is likely to vary both monthly and annually (i.e. more puerulus settles in some months and years than others). Ideally, to investigate independence of the collectors one would use many samples from a given year and month. As this data is not available, independence is investigated at a yearly scale, the same scale on which the standardised indices are calculated.

To investigate the independence of collectors within groups we restrict data to the 1998 fishing year (which has a good number of samples) and groups used in the standardisation: GIS001, GIS002, and GIS003. The distribution of the puerulus counts from this data set is shown in Figure 7. We investigated independence graphically by plotting the puerulus counts from collectors against each other (for collectors sampled at the same time). This indicates that the collectors are not entirely independent in that high counts for one collectors enable one to predict that the counts will be high for the other collectors (Figure 8). However, the high counts are likely to be for months with high counts, reflecting an upward movement for the puerulus count distribution, making it difficult to discern to what extent this reflects lack of independence.

The effect of a lack of independence means that the “effective sample size” for the groups is less than the number of collectors would indicate. Two frameworks for dealing with this type of sampling (longitudinal, nested) are: (1) mixed-effects models, and (2) GEE (Generalized Estimating Equation) (see for example, Zuur et al. 2009). Both techniques would be worth exploring in future standardisations.

3.3 Gisborne puerulus settlement standardisation

3.3.1 Introduction

A generalised linear model framework is used, in which the response (dependent) variable is the log of numbers of settlers per collector sample and a Poisson distribution with dispersion is assumed. All independent variables were treated as factors. The year variable was included in all models; the other independent variables (group/collector and month) were added to the model in a stepwise process. At each step the variable that most improved the fit of the model as measured by the Aikake Information Criterion (AIC) was included (or to be more precise a quasi-AIC, QAIC). Some sensitivity analyses were performed on the initial model, and some alternative model structures were examined. The final standardisation model was decided upon by the Rock Lobster Working Group.

Following previous Gisborne standardisations the groups GIS002, GIS003, and GIS004 are used for the initial set of standardisations and explorations, though following review by the Rock Lobster Working Group the group GIS001 was incorporated into the final standardisation.

3.3.2 Summary of Gisborne standardisation data

The number of samples for the first year 1991 is only 13 (Table 3), and some months were not sampled (Figure 9). Other than during the early years, sampling is mostly spread over the months of highest settlement (May to September)(Figure 10).

3.3.1 Initial standardisation

The standardisation model selected the predictors: fishing year, month, and collector. The resultant index is shown in Figure 11, and residual and quantile-quantile plots are shown in Figures 12 and 13.

The data has more zeros and larger values than a Poisson distribution with the same mean puerulus count value (Figure 14). The estimated dispersion under the quasi-Poisson distribution is 2.82 and the associated distribution approximated by a negative binomial is a closer match to the data distribution (Figure 15).

Except for the 1992 and 1993 fishing years, the standardised and raw indices are very similar. The differences are mostly due to the collector effect in the standardisation (Figure 16), and in particular the group of collectors GIS002 for which the mean value is higher than the rest and from which most of the samples in 1992 and 1993 come (see Figure 5, Table 3).

It makes little difference to the standardised index if group is used instead of collector in the standardisation (Figures 17 and 18). If calendar year is used instead of fishing year the indices differ somewhat in 1993 (Figure 19), presumably due to the re-assignment of some samples to a different year (see Table 3).

Sometimes in standardisations a subset of the months is taken where most of the non-zero values occur. This is also useful when dealing with count data to reduce the number of zeros (if there seem to be a lot). For the Gisborne site most of the non-zero puerulus counts (and the highest ones) occur from May to September (see Figure 10) and a subset of data is taken from there. The same predictor variables are accepted into the standardisation and the index is similar to that without subsetting, except that the peaks are higher (Figure 20).

3.3.2 Other standardisation models

An alternative model for overdispersed data is the negative binomial. Using AIC, the negative binomial model gives the same predictor variables as the quasi-Poisson model (fishing year, month, collector) and gives a similar index but with some differences in the early years and in 2005 (Figures 21 and 22). Diagnostics are better for the residuals in that they are smaller and there is less of a funnel pattern. The quantiles also look better at the higher end (Figures 23 and 24).

The fitted negative binomial distribution (Figure 25) has a size parameter of 1.28 and looks similar to the approximate quasi Poisson plot (see Figure 15). In both there are more zeros in the data than in the model, and a zero-inflated model could account for this. Trying a zero-inflated negative binomial model resulted in singularity problems, but a zero-inflated Poisson (ZIP) model was more successful (using the zeroinfl function from the pscl package). The predictor variables selected by AIC were the same as for the quasi-Poisson (year, month, collector) giving an index similar to that from the quasi-Poisson (Figures 26–27). The AIC for the ZIP model was 10 000 compared with 8800 for the negative binomial model, indicating that the negative binomial model provides a much better fit.

One potential reason for apparent overdispersion in Poisson regression is outliers in the data, for example a small number of high values can drive up the mean value parameter, leading to an apparent excess of zeros in the data. For the Gisborne data most of the counts are small, but there a few very high values (see Figure 10). Removing values greater than 15 drops 1.4 percent of the data. However, the dispersion parameter only drops from 2.82 to 2.17 and overdispersion is still evident in the distribution (Figure 28).

3.3.1 Final standardisation model

The data and puerulus standardisations above for Gisborne were presented to the Rock Lobster Working Group. As a data input to the CRA 3 stock assessment, it was decided by the working group to use a standardised index:

1. Based on the groups GIS001, GIS002, GIS003, and GIS004
2. Restricting data to that from May to September (inclusive)
3. Using a negative-binomial model for the standardisation
4. Using as the predictor variables in the standardisation year, month, and group

For this data set the number of samples by group and year is shown in Table 4. Further characteristics of the sampling and data are shown in Figure 29.

The raw and standardised indices are shown in Figure 30. Diagnostics are good and are shown in Figures 31 and 32. The differences between the raw and standardised indices is almost entirely due to the group effect (Figures 33 and 34).

Table 2: Number of puerulus samples in CRA 3 by group and fishing year.

	GIS001	GIS002	GIS003	GIS004	GIS005	GIS006	GIS007	GIS008	GIS009	GIS010
1978	0	0	0	0	0	0	6	0	0	0
1979	0	0	0	0	0	0	69	0	0	0
1980	0	0	0	0	20	0	72	0	0	0
1981	0	0	0	0	34	0	74	0	0	0
1982	0	0	0	0	21	10	34	0	0	0
1983	0	0	0	0	14	27	0	0	0	0
1984	0	0	0	0	23	48	0	0	0	0
1985	0	0	0	0	30	38	0	0	0	0
1986	0	0	0	0	21	0	0	0	0	0
1987	34	0	0	0	6	0	0	0	0	0
1988	53	0	0	0	0	0	0	0	0	0
1989	49	0	0	0	0	0	0	0	0	0
1990	60	0	0	0	0	0	0	0	0	0
1991	60	13	0	0	0	0	0	21	15	0
1992	58	41	0	0	0	0	0	27	18	0
1993	49	54	3	0	0	0	0	0	0	0
1994	60	55	50	52	0	0	0	0	0	0
1995	60	44	60	60	0	0	0	0	0	0
1996	55	40	35	55	0	0	0	0	0	0
1997	60	50	58	60	0	0	0	0	0	0
1998	65	59	60	65	0	0	0	0	0	0
1999	46	59	55	48	0	0	0	0	0	0
2000	57	58	60	60	0	0	0	0	0	0
2001	59	60	60	60	0	0	0	0	0	3
2002	45	60	42	55	0	0	0	0	0	3
2003	5	53	46	65	0	0	0	0	0	0
2004	0	50	47	57	0	0	0	0	0	0
2005	0	45	39	55	0	0	0	0	0	0
2006	0	58	43	50	0	0	0	0	0	0
2007	0	53	0	20	0	0	0	0	0	0
2008	0	54	0	55	0	0	0	0	0	0
2009	0	53	0	55	0	0	0	0	0	0
2010	0	50	0	50	0	0	0	0	0	0
2011	0	44	0	64	0	0	0	0	0	0
2012	0	50	0	50	0	0	0	0	0	0
2013	0	55	0	30	0	0	0	0	0	0

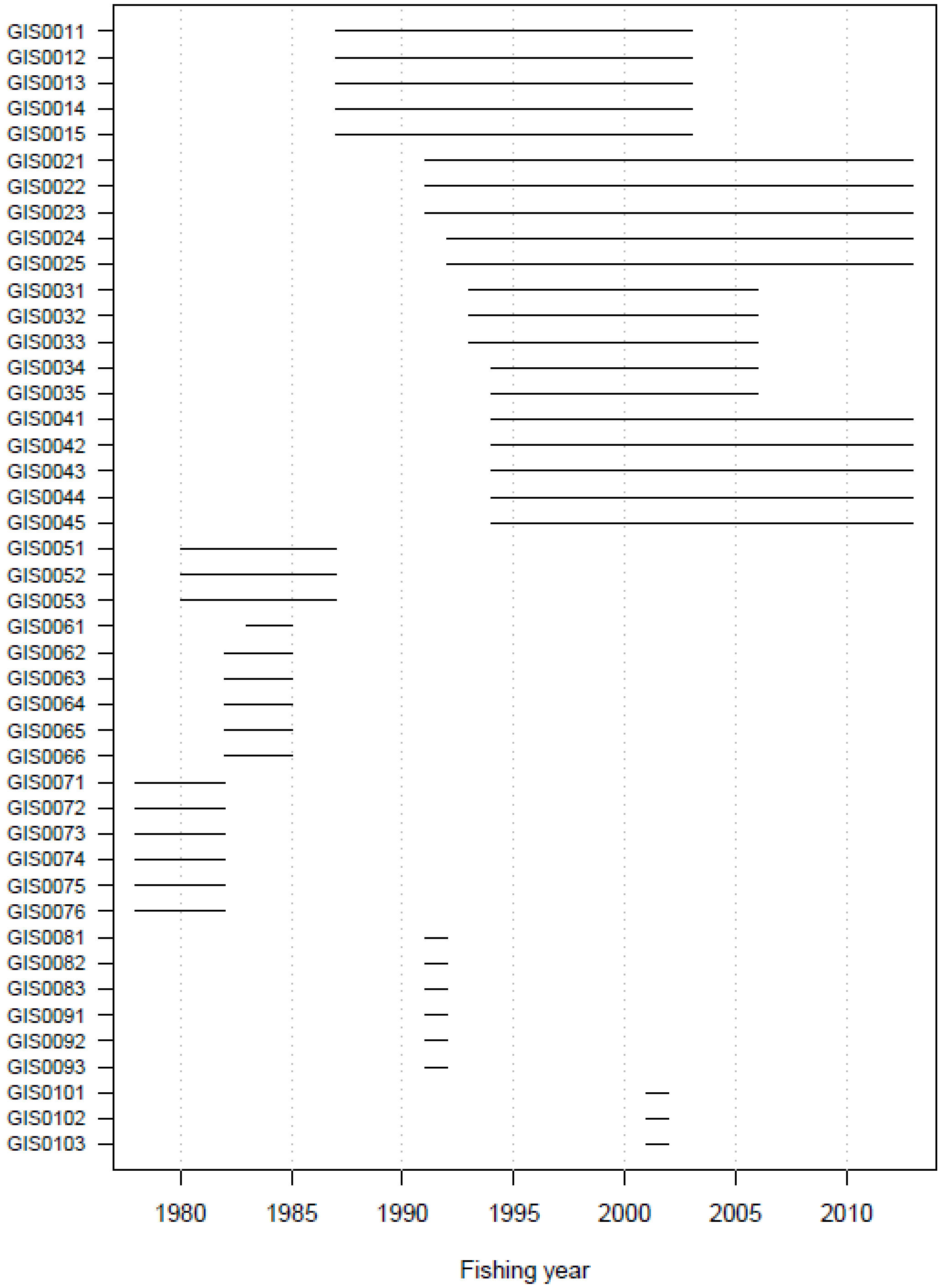

Figure 2: The fishing years over which the collectors in Gisborne have been in operation.

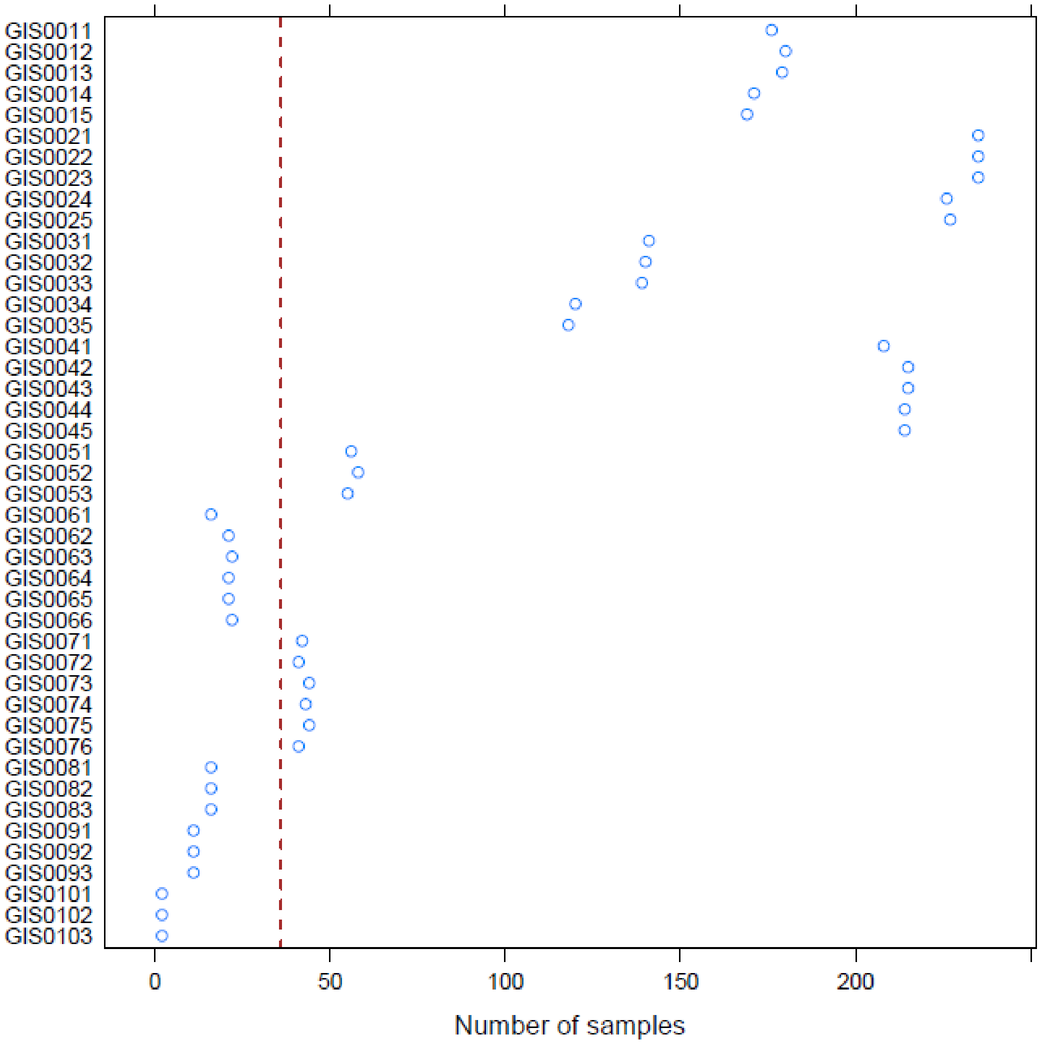

Figure 3: The total number of samples taken from each collector in Gisborne.

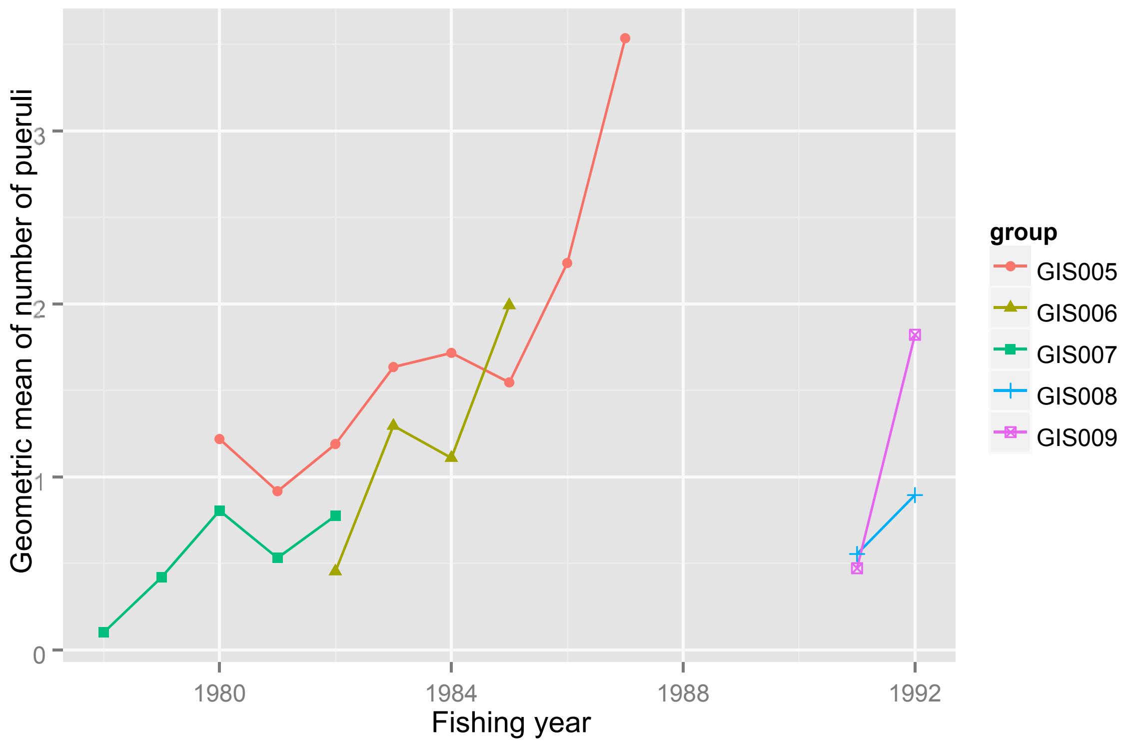

Figure 4: Geometric mean of the number of sampled pueruli for collector groups GIS005 to GIS009.

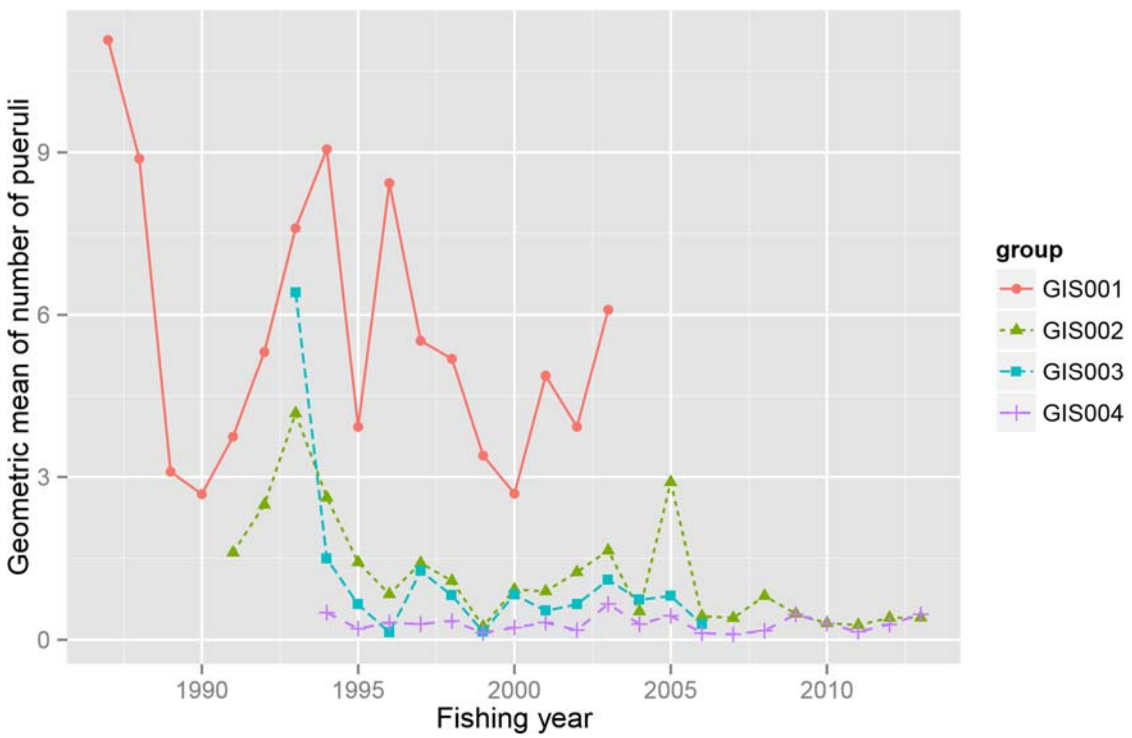

Figure 5: Geometric mean of the number of sampled pueruli for collector groups GIS001 to GIS004.

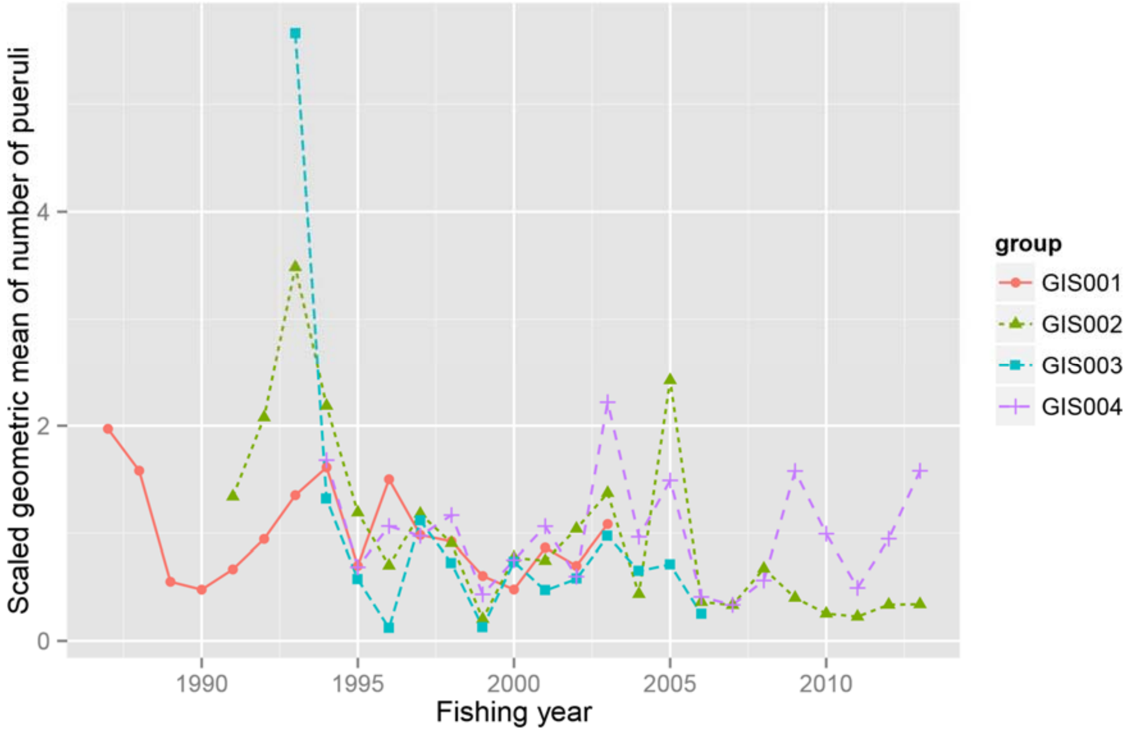

Figure 6: Geometric mean of the number of sampled pueruli for collector groups GIS001 to GIS004, scaled to have a mean value of 1.0 over the years for a group.

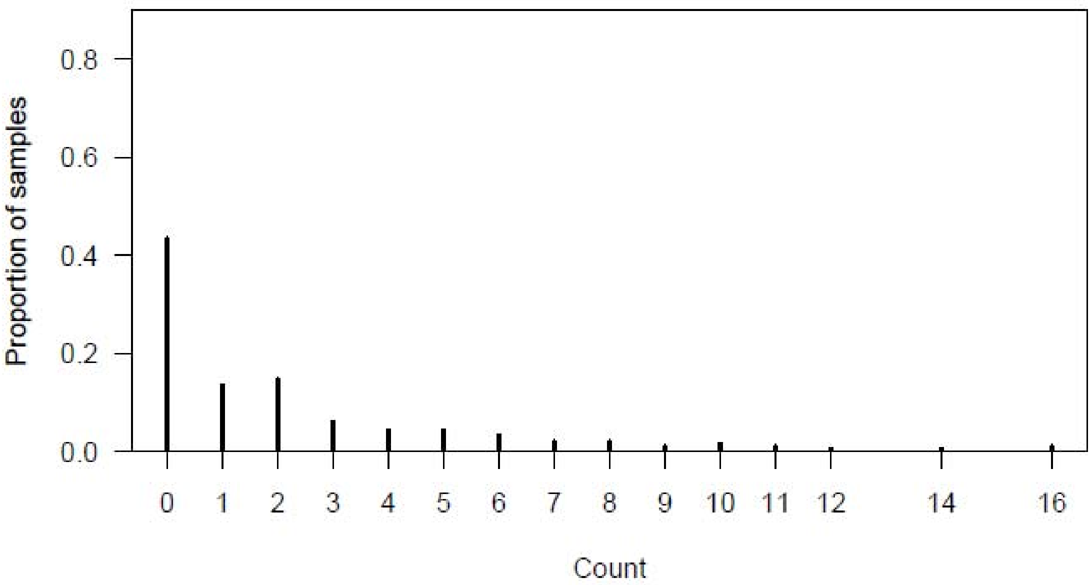

Figure 7: Distribution of counts for collector groups GIS002, GIS003, and GIS004 in 1998.

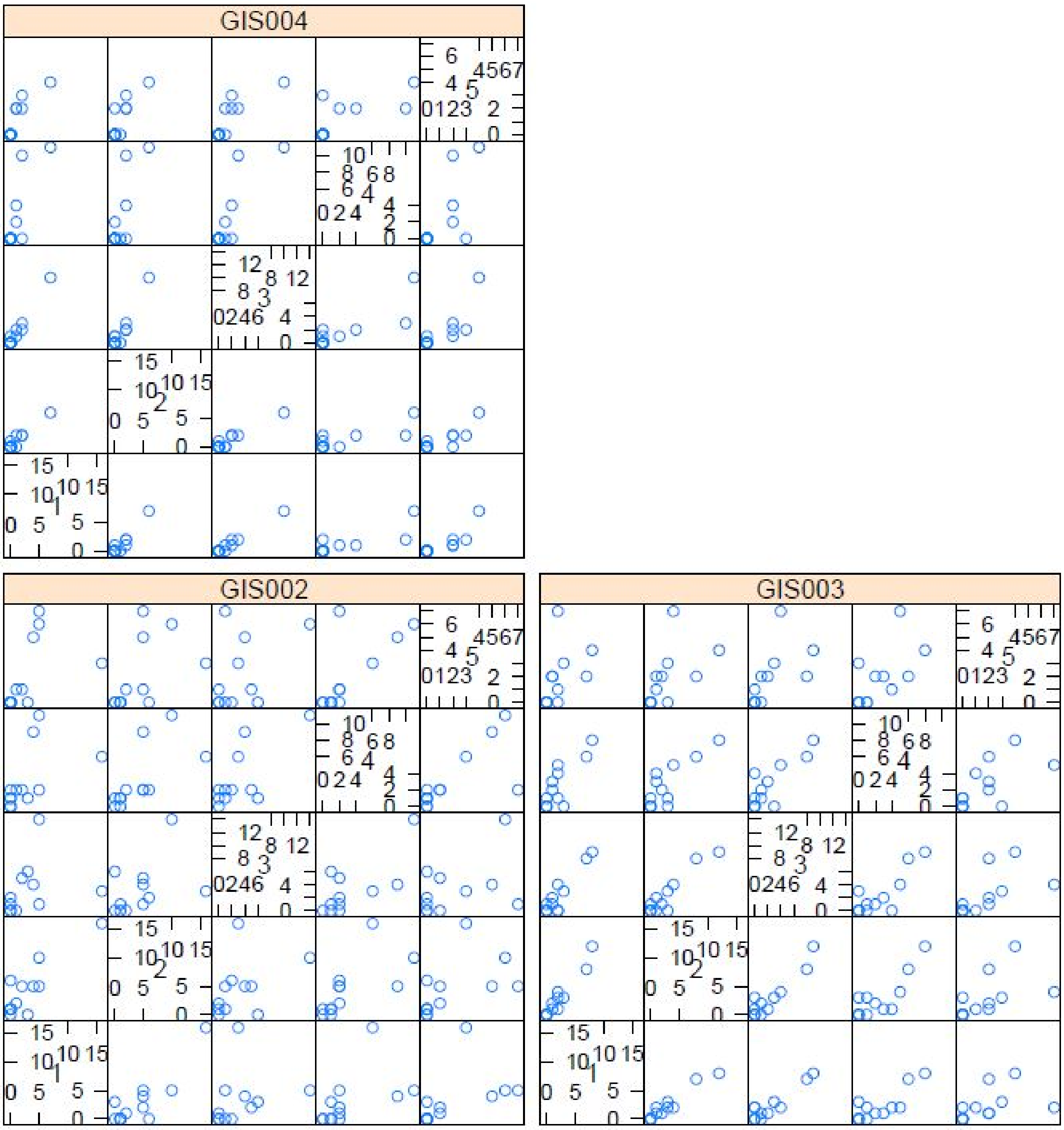

Figure 8: Scatterplot of puerulus counts for the five collectors associated with the Gisborne collector groups GIS002, GIS003, and GIS004.

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

	GIS002	GIS003	GIS004	Total
1991	13	0	0	13
1992	41	0	0	41
1993	54	3	0	57
1994	55	50	52	157
1995	44	60	60	164
1996	40	35	55	130
1997	50	58	60	168
1998	59	60	65	184
1999	59	55	48	162
2000	58	60	60	178
2001	60	60	60	180
2002	60	42	55	157
2003	53	46	65	164
2004	50	47	57	154
2005	45	39	55	139
2006	58	43	50	151
2007	53	0	20	73
2008	54	0	55	109
2009	53	0	55	108
2010	50	0	50	100
2011	44	0	64	108
2012	50	0	50	100
2013	55	0	30	85

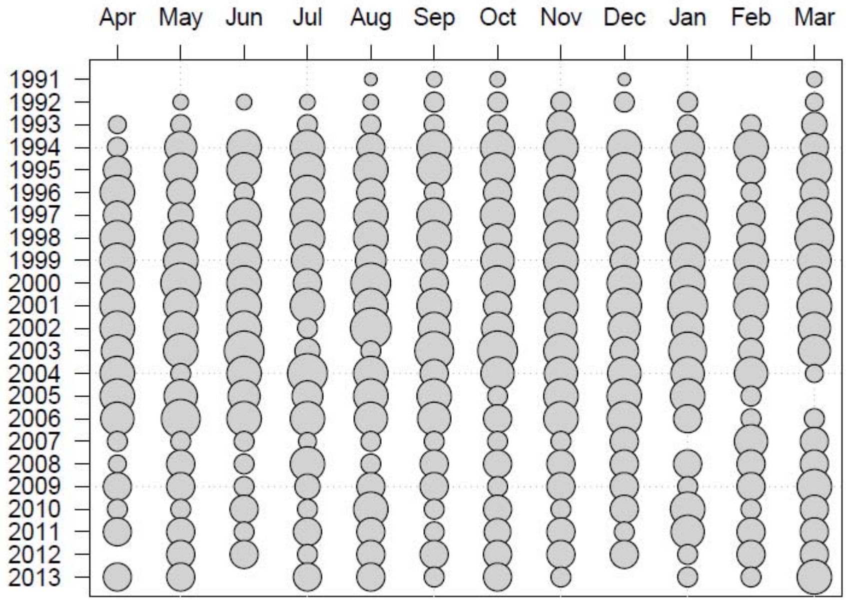

Figure 9: Number of samples by month and fishing year in the Gisborne dataset. The area of a circle is proportional to the number of samples, with a maximum value of 20.

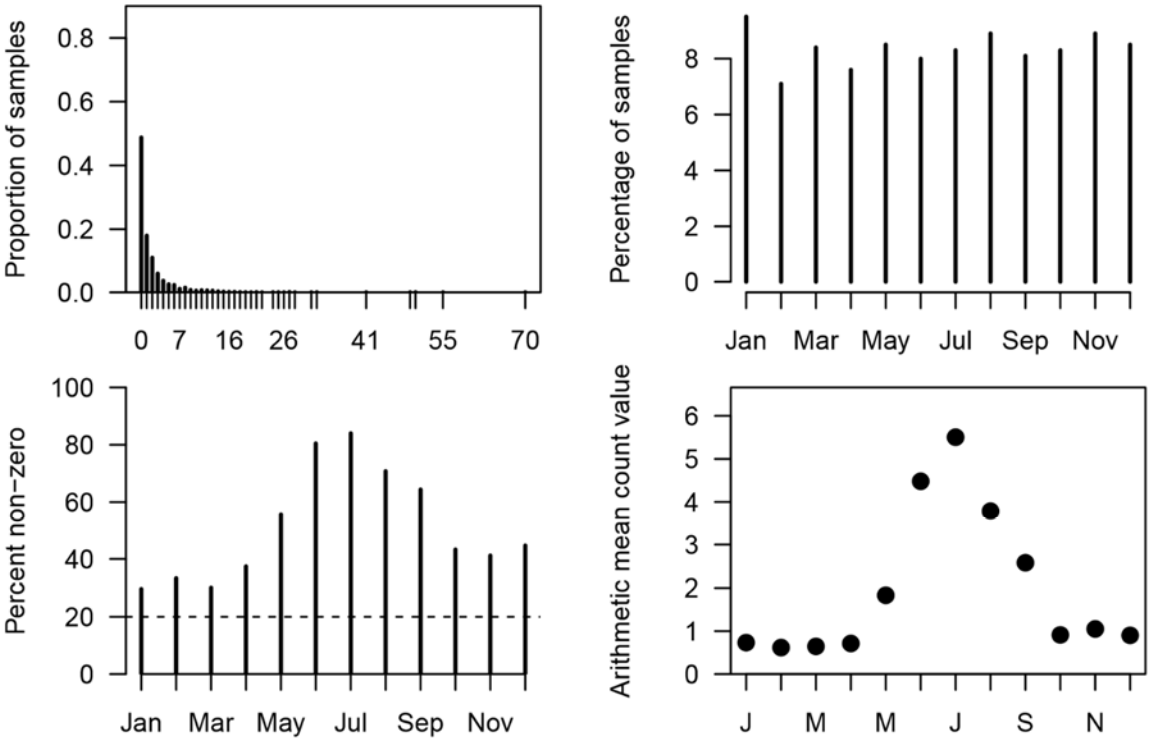

Figure 10: Characteristics of the Gisborne puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

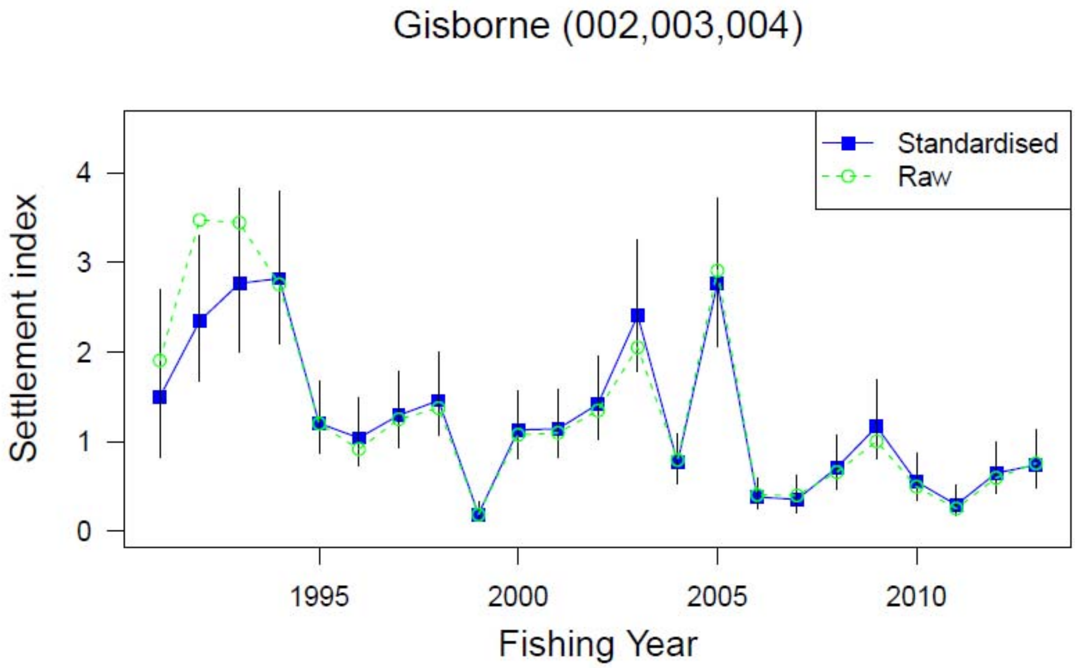

Figure 11: Standardised and raw indices of settlement with 95% confidence intervals. Indices are scaled to have a geometric mean of one.

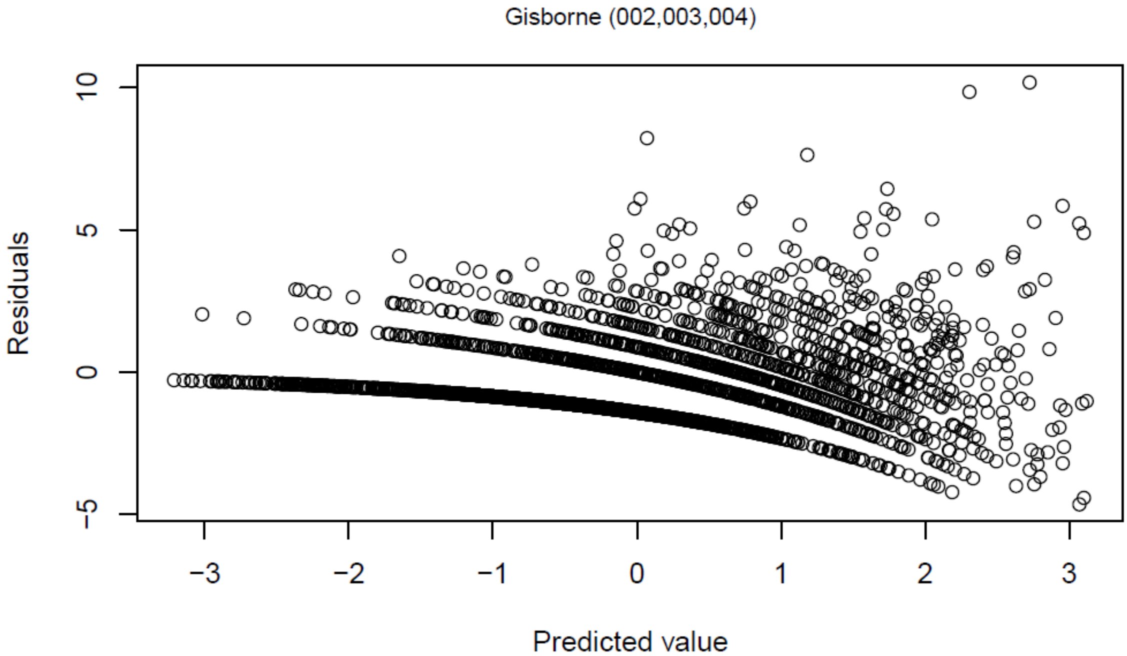

Figure 12: Residuals for standardisation model. The predicted values are in log space.

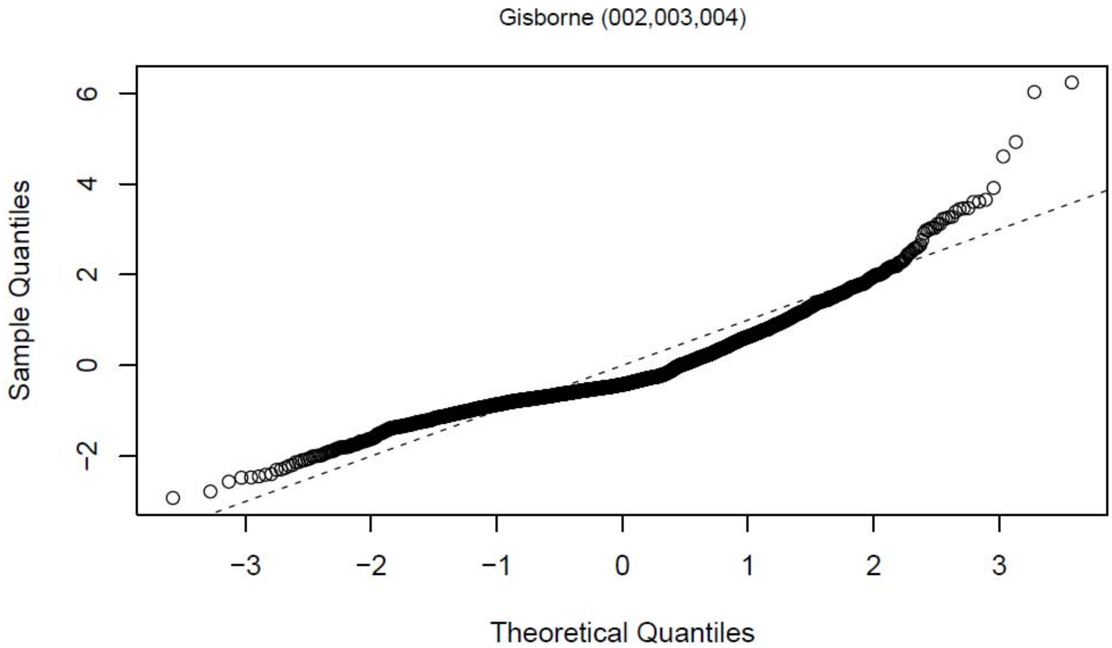

Figure 13: Quantile-quantile plot from the standardisation model.

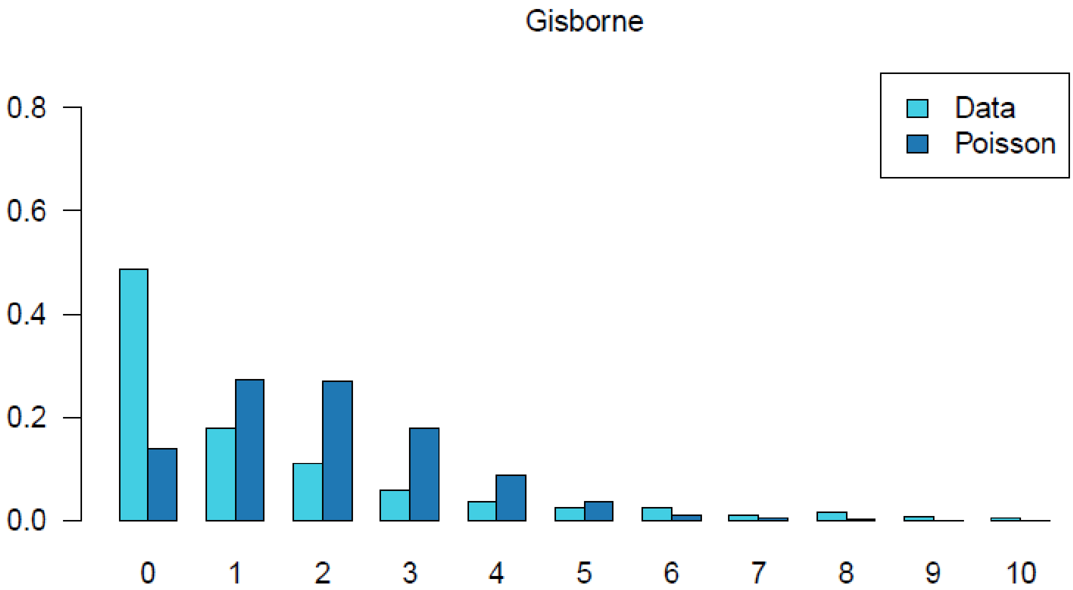

Figure 14: Data distribution and the Poisson distribution with the same mean. The plot is truncated at 10.

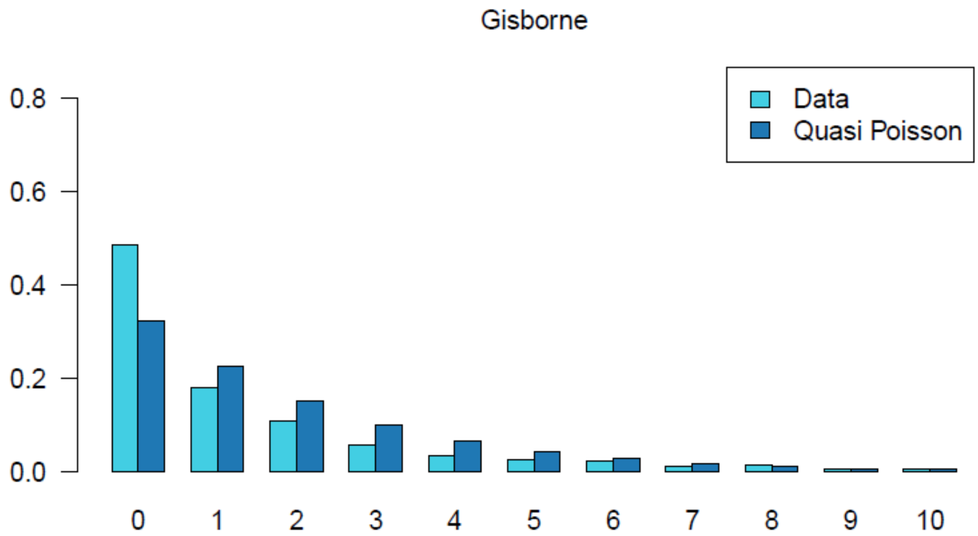

Figure 15: Data distribution and that from a negative binomial approximation to the quasi Poission. The plot is truncated at 10.

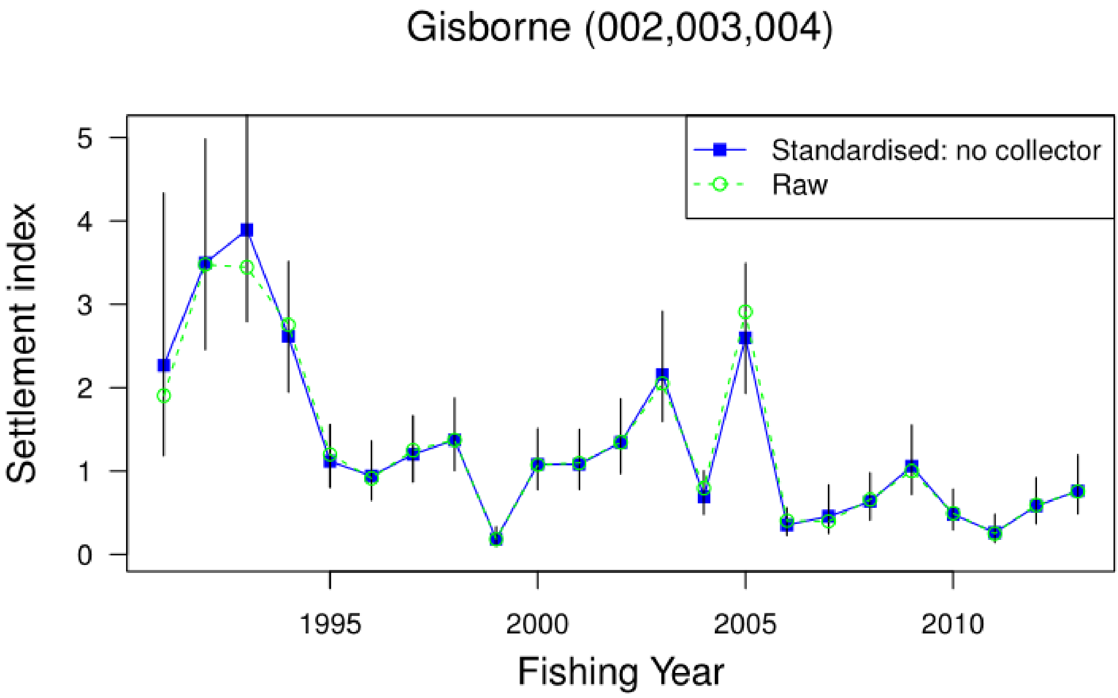

Figure 16: Effect on the standardised indices of dropping the collector variable from the standardisation (thus using only year and month). The indices are scaled to be 1.0 in the first year.

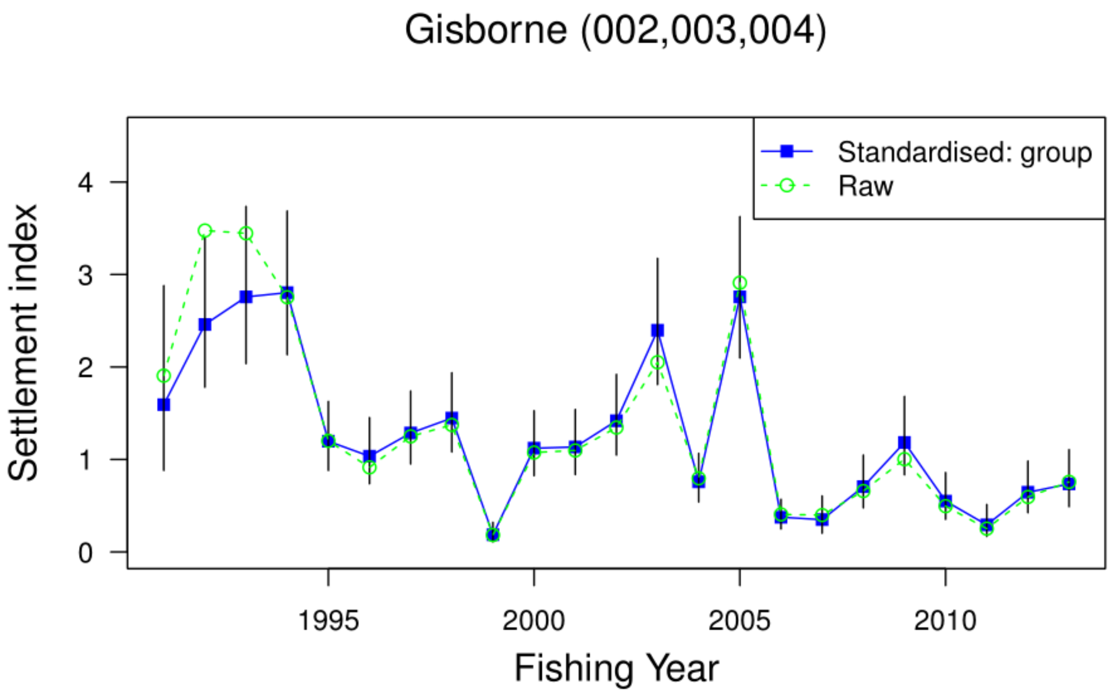

Figure 17: Effect on the standardised indices of using group instead of collector in the standardisation. Standardised and raw indices of settlement with 95% confidence intervals. Indices are scaled to have a geometric mean of 1.0.

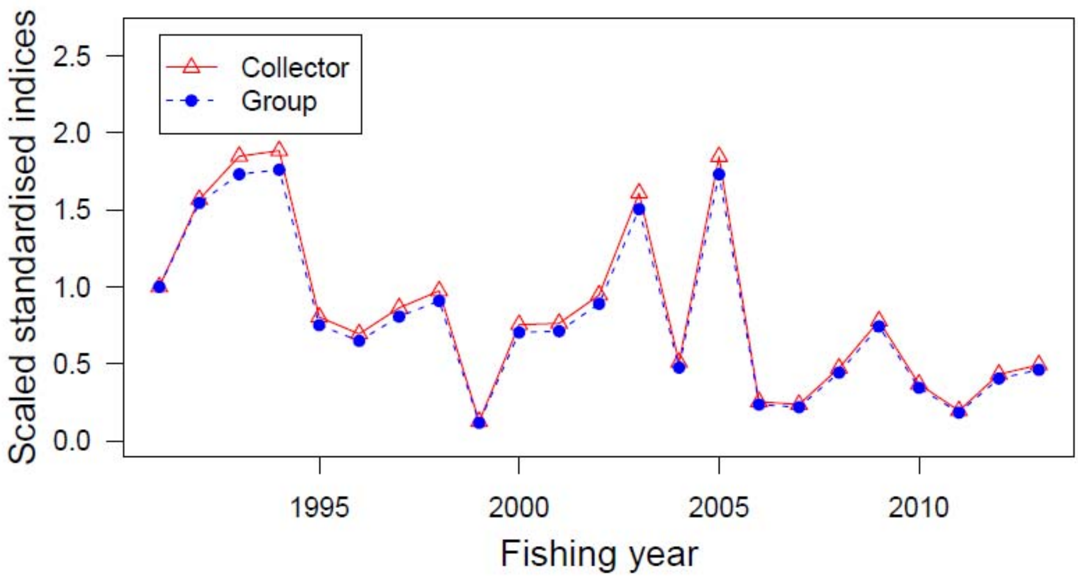

Figure 18: Effect on the standardised indices of using group instead of collector in the standardisation for the Gisborne data. The indices are scaled to have the value 1.0 in the first year.

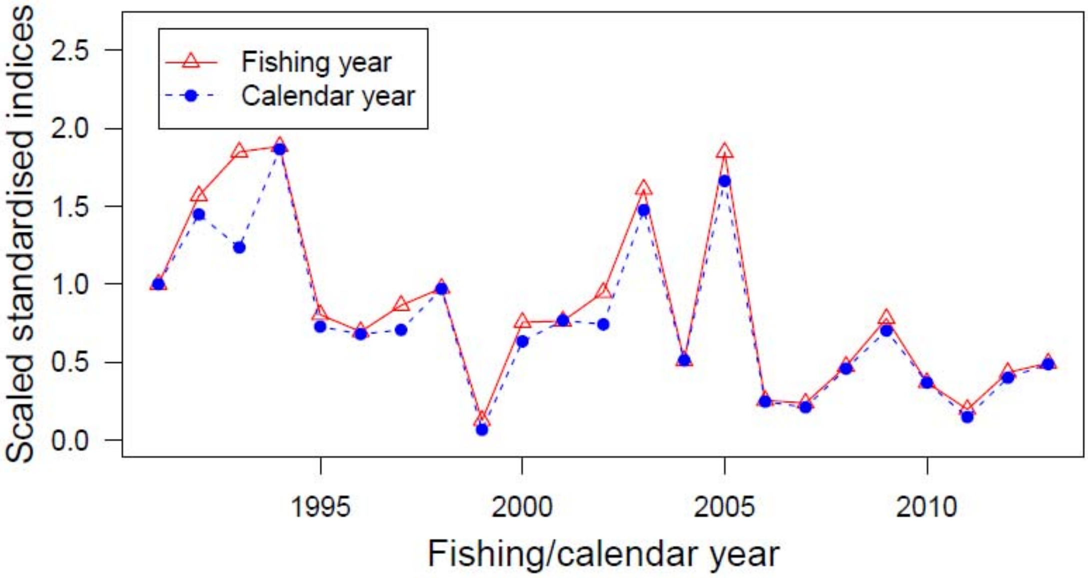

Figure 19: Effect of using fishing year instead of calendar year in the standardisation for the Gisborne data. The indices are scaled to have value 1.0 in the first year.

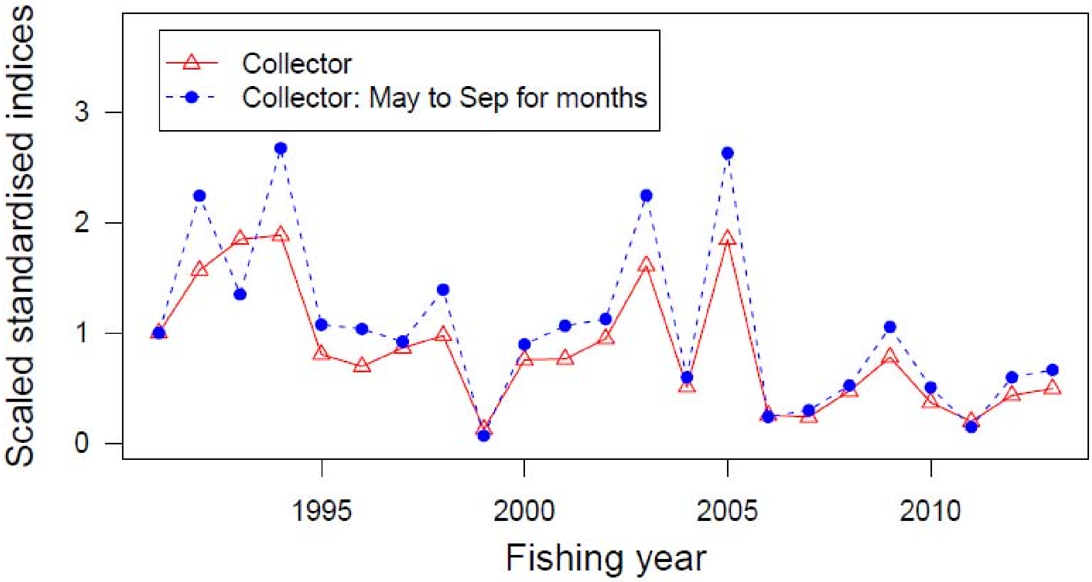

Figure 20: The effect of using a subset of the data from May to September in the standardisation for the Gisborne data. The standardised indices are scaled to have the value 1.0 in the first year.

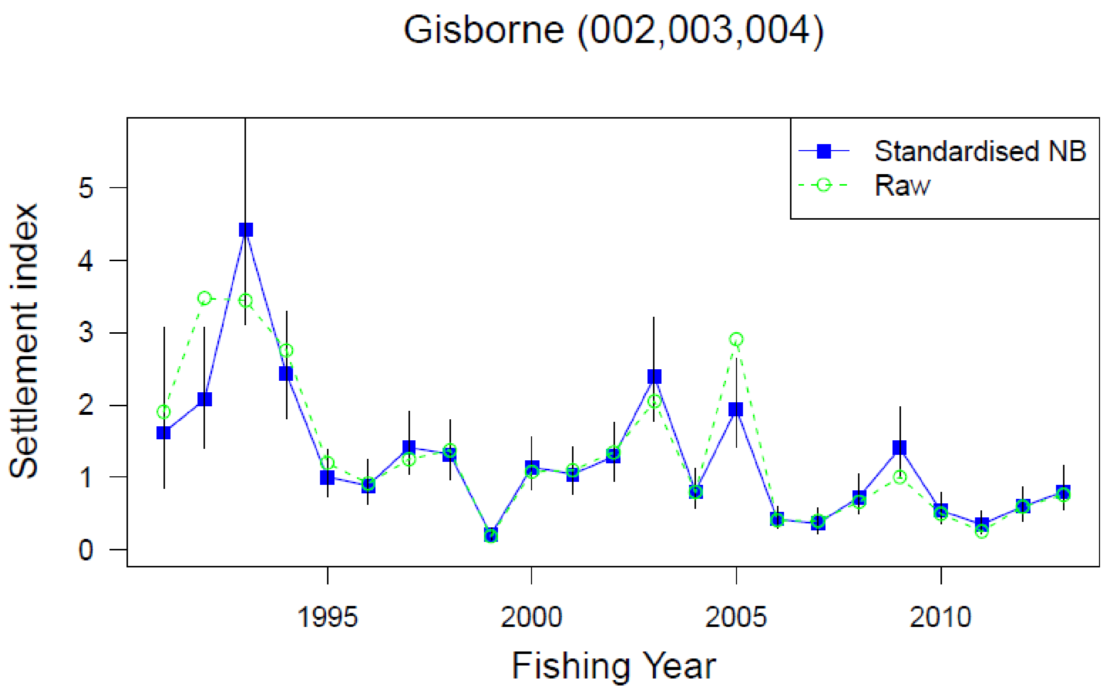

Figure 21: Standardised index using a negative binomial model. Standardised and raw indices with 95% confidence intervals.

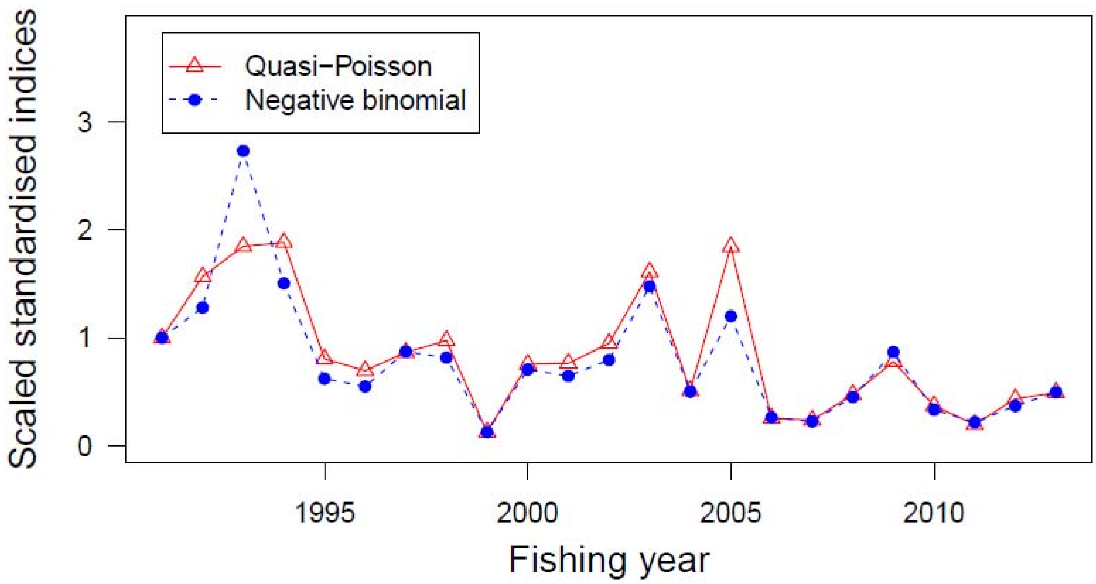

Figure 22: Using a negative binomial model instead of quasi-Poisson in the standardisation for the Gisborne dataset. The standardised indices are scaled to value 1.0 in the first year.

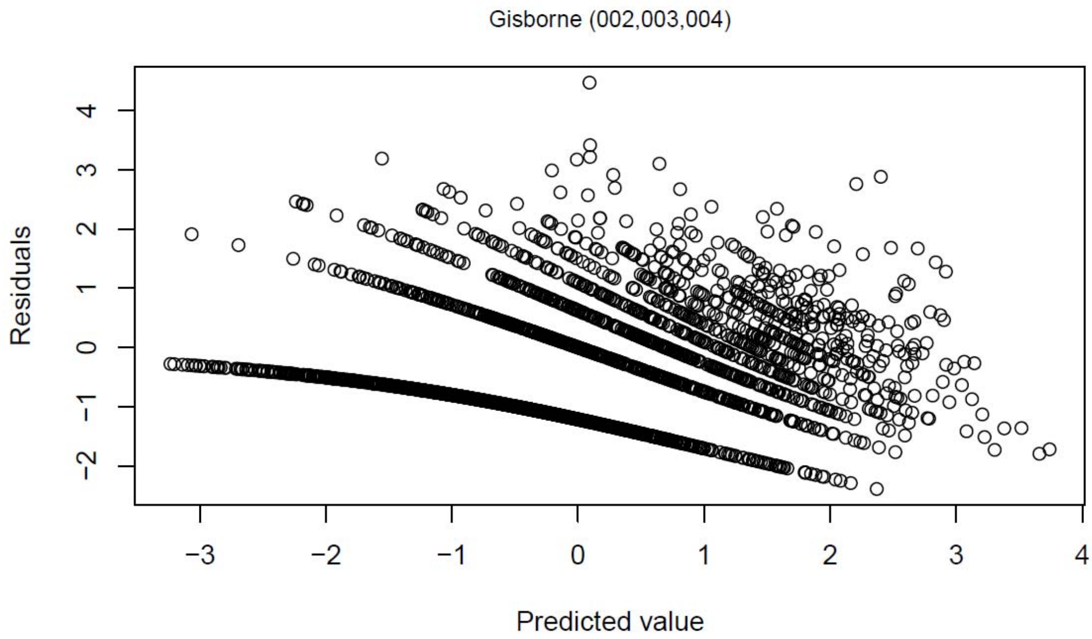

Figure 23: Residuals for negative binomial standardisation model. The predicted values are in log space.

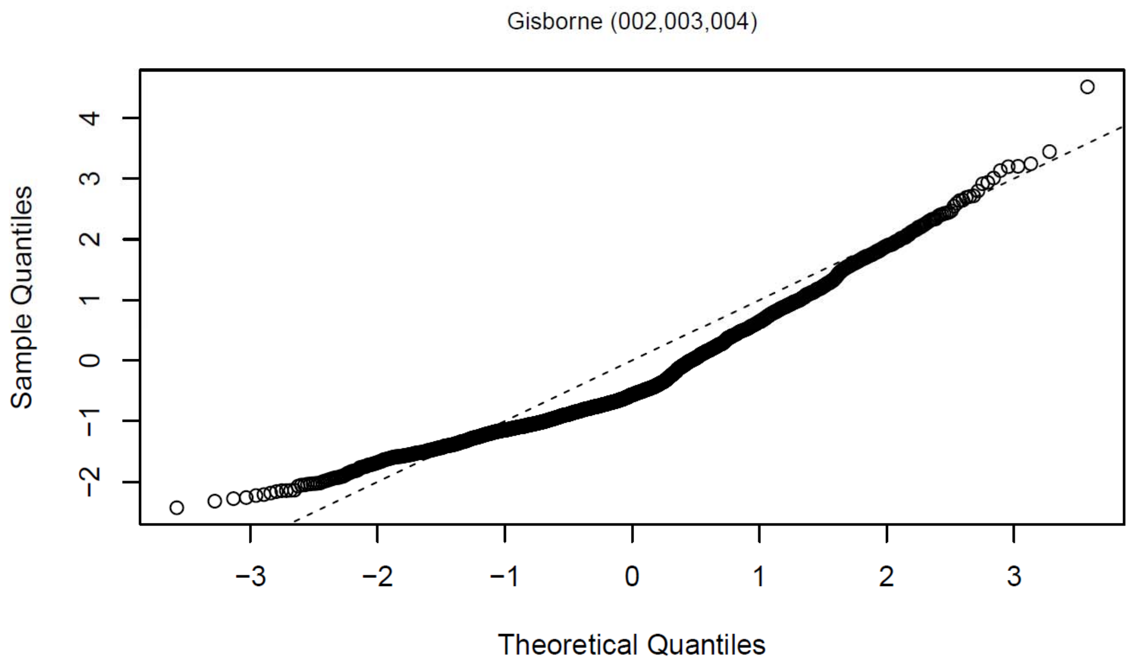

Figure 24: Quantile-quantile plot for the negative binomial standardisation model.

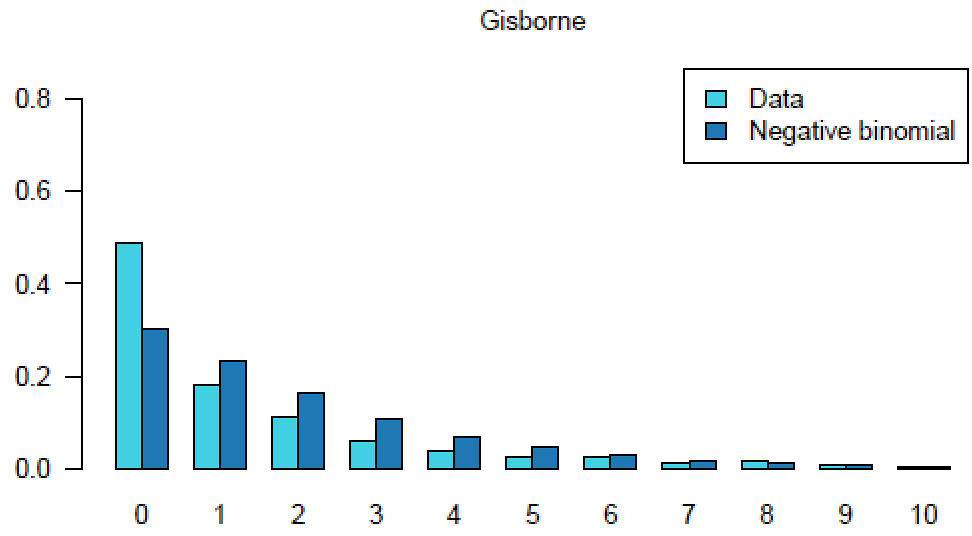

Figure 25: Data distribution and that from the fitted negative binomial.

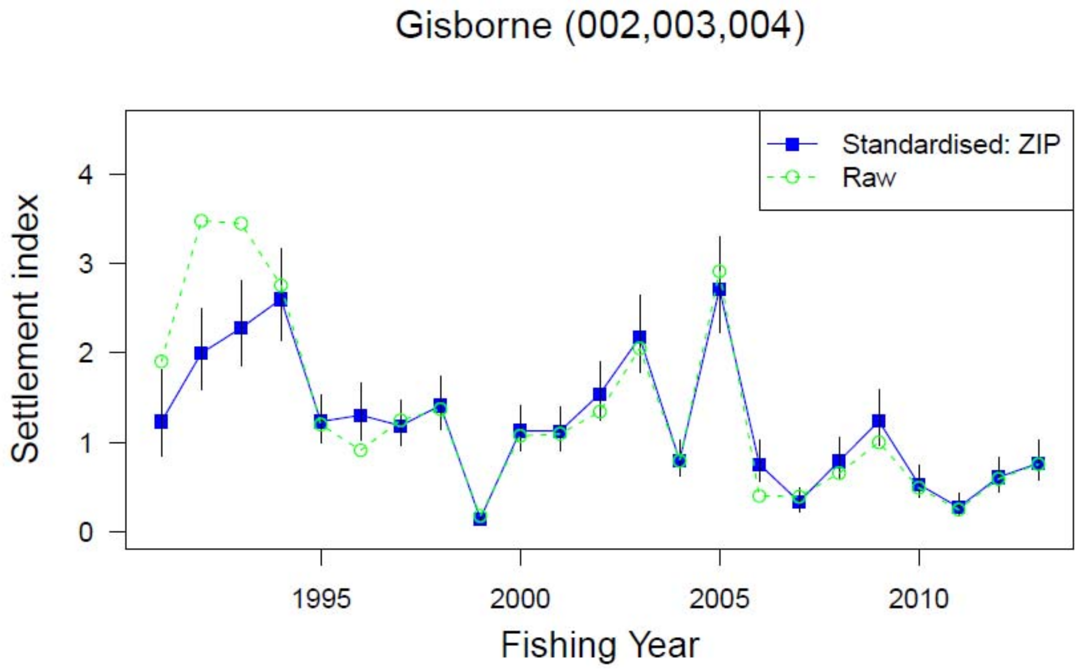

Figure 26: ZIP model. Standardised and raw indices with 95% confidence intervals.

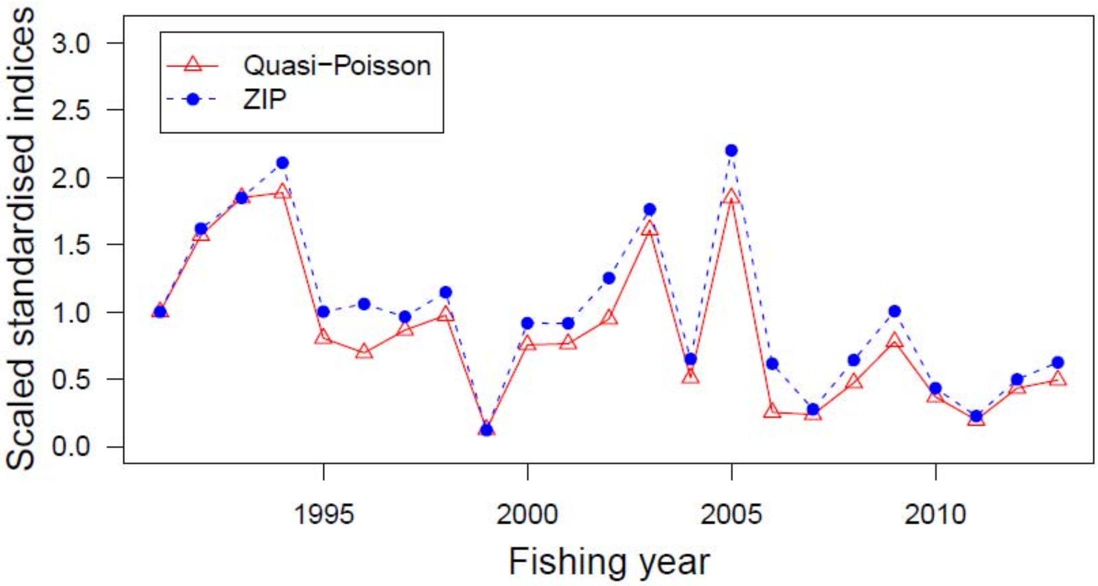

Figure 27: Using zero inflated Poisson (ZIP) instead of quasi-Poisson in the standardisation. The standardised indices are scaled to value 1.0 in the first year.

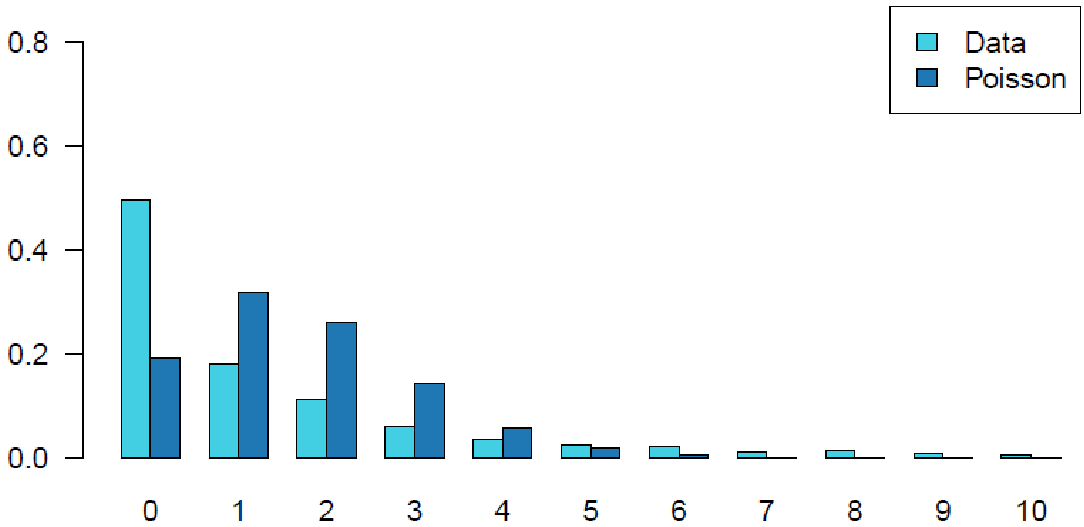

Figure 28: Truncated data distribution using values of 15 or less and the Poisson distribution with the same mean. The plot is truncated at 10.

Table 4: Final Gisborne standardisation dataset. Number of puerulus samples by group and fishing year.

	GIS001	GIS002	GIS003	GIS004
1987	15	0	0	0
1988	23	0	0	0
1989	25	0	0	0
1990	25	0	0	0
1991	25	5	0	0
1992	24	17	0	0
1993	25	20	0	0
1994	25	20	25	23
1995	25	24	25	25
1996	25	20	0	25
1997	25	20	23	25
1998	25	25	25	25
1999	20	25	21	18
2000	23	25	25	25
2001	24	25	25	25
2002	20	25	19	25
2003	0	18	19	30
2004	0	20	20	25
2005	0	25	19	25
2006	0	23	24	30
2007	0	24	0	0
2008	0	20	0	25
2009	0	18	0	25
2010	0	15	0	25
2011	0	20	0	20
2012	0	20	0	25
2013	0	20	0	15

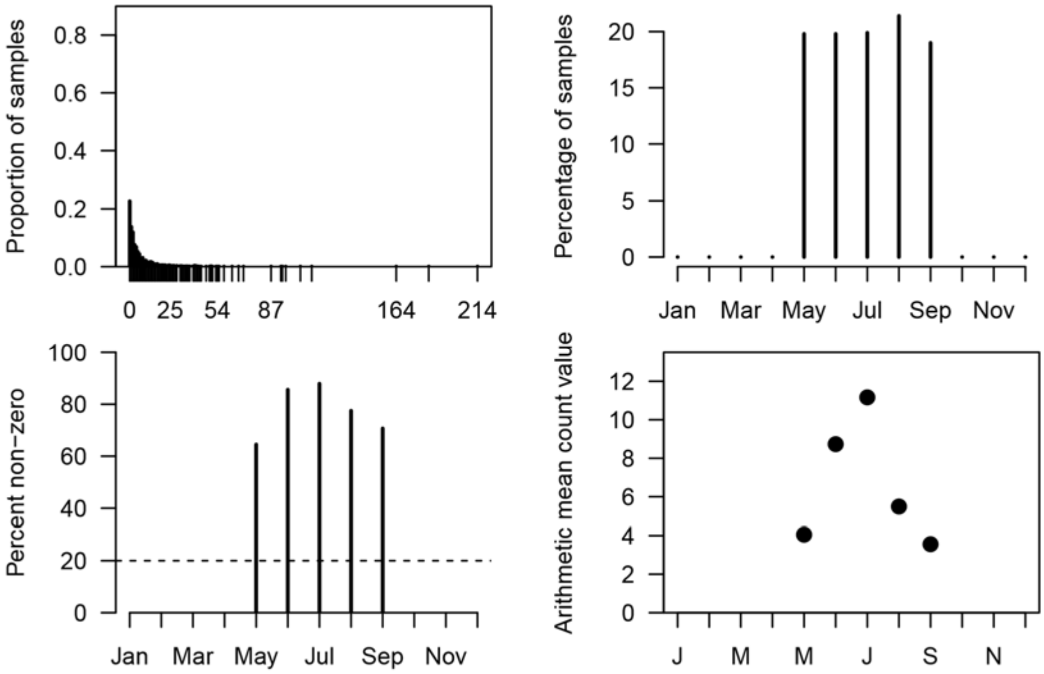

Figure 29: Final standardisation. Characteristics of the Gisborne puerulus standardisation data. The top-left figure shows the distribution of puerulus counts, and the bottom-left the proportion of these that are non-zero. Count refers to the number of pueruli measured in a sample.

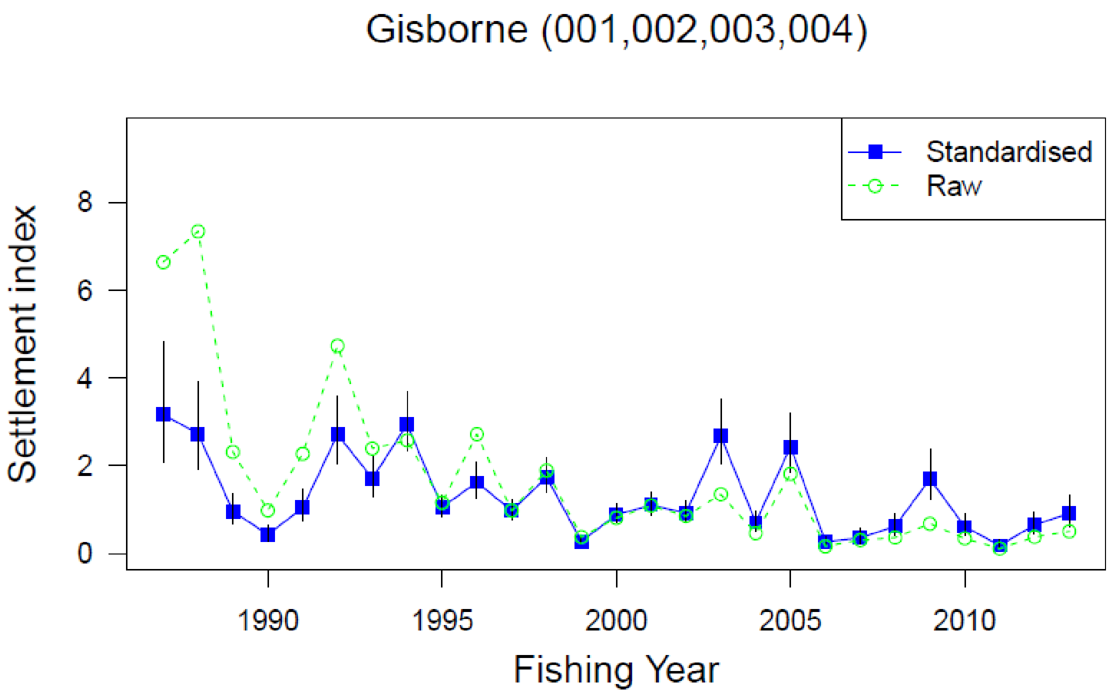

Figure 30: Final standardisation of the Gisborne dataset. Standardised and raw indices of settlement with 95% confidence intervals. Indices are scaled to have a geometric mean of 1.0.

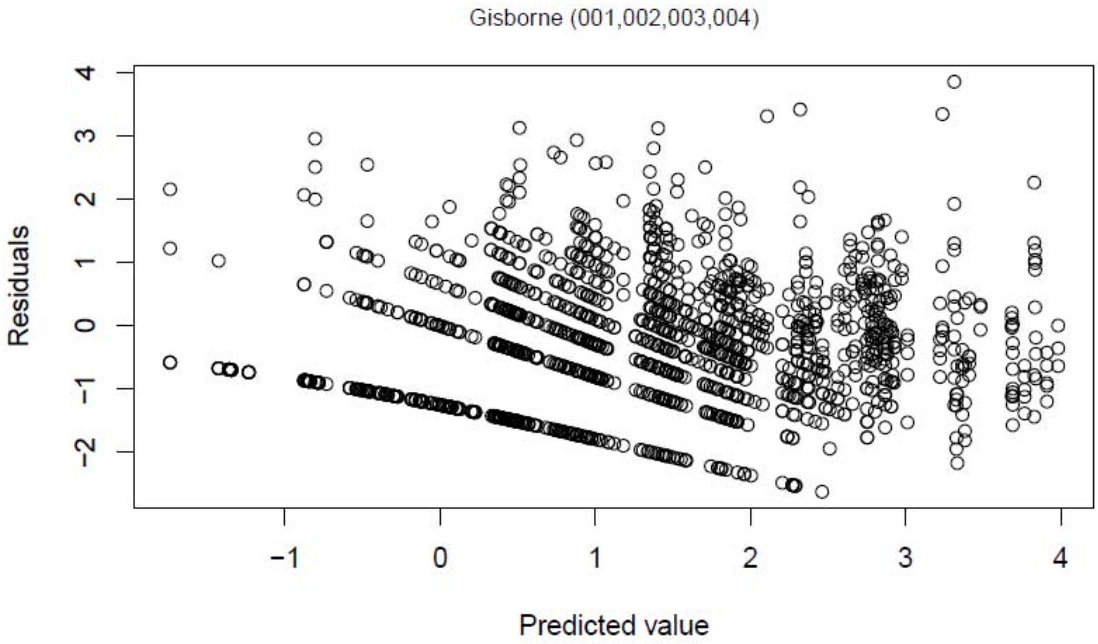

Figure 31: Final standardisation of the Gisborne dataset. Residuals for the standardisation model. The predicted values are in log space.

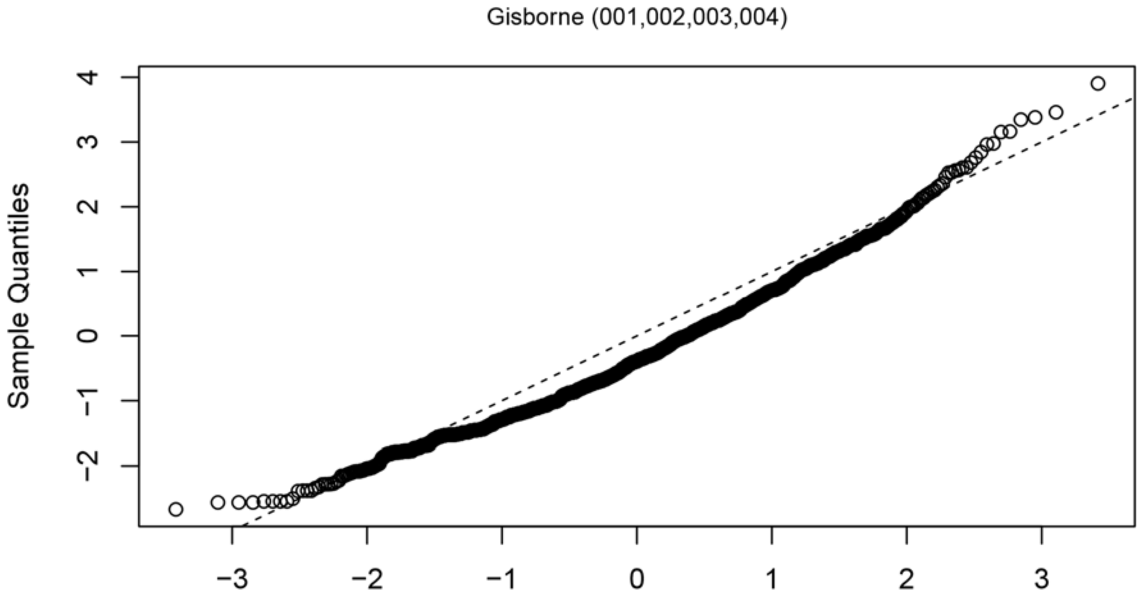

Figure 32: Final standardisation of the Gisborne dataset. Quantile-quantile plot for the standardisation model.

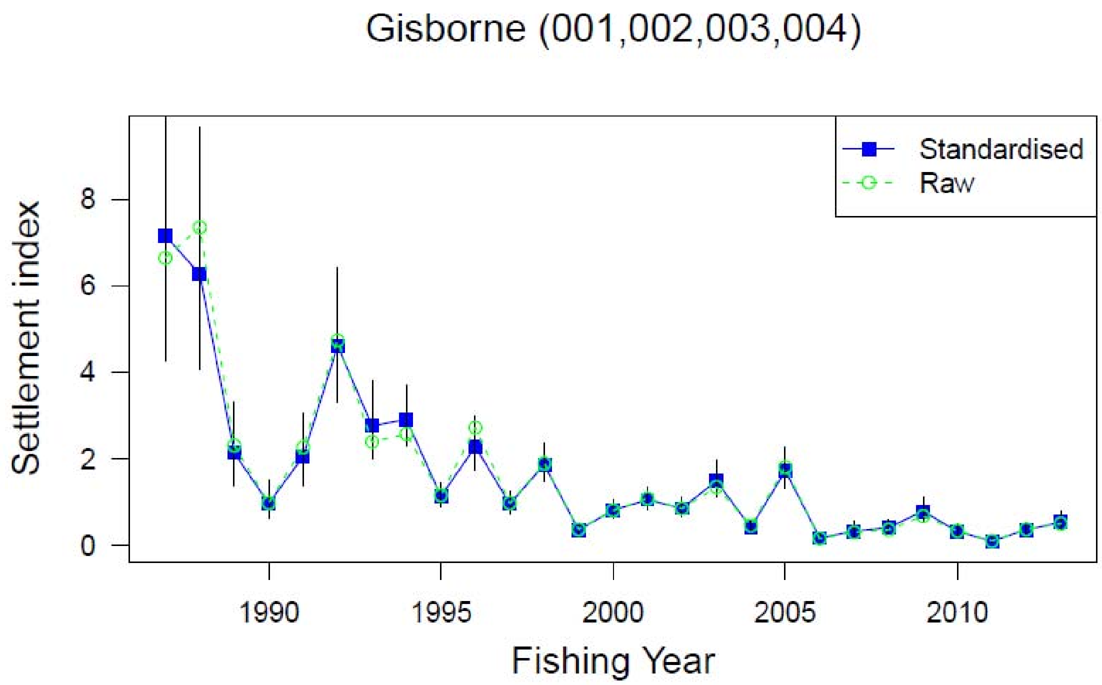

Figure 33: Final standardisation of the Gisborne dataset without group as a predictor variable. Standardised and raw indices of settlement with 95% confidence intervals. Indices are scaled to have a geometric mean of 1.0.

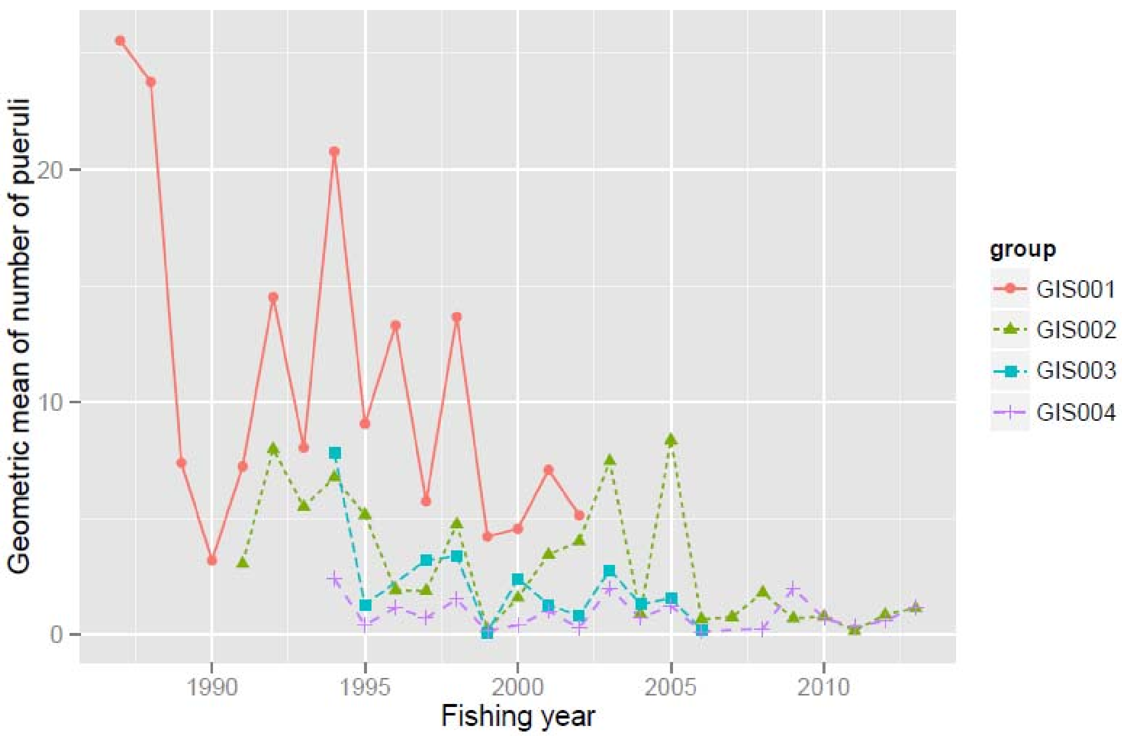

Figure 34: Final standardisation of the Gisborne dataset showing the geometric mean of the number of sampled pueruli. Note that a sub-sample of data from May–September (inclusive) is used for the final standardisation, so this figure differs from Figure 5.

3.4 Standardised indices for sites other than Gisborne

Standardisations are presented here for sites other than Gisborne, using the methods outlined in Section 2.2. For completeness, summary results and discussion for Gisborne are also included in this section.

In the initial data set, including Gisborne, there were 499 collectors over all sites. Applying the requirement that a collector must have been sampled at least 36 times left 179 collectors (Figure 35). The annual numbers of samples for the final groups of collectors used in the standardisation are given in Appendix 2. Any year for a site where there were fewer than 10 samples was removed from the standardisation. This occurred for the first year from four sites (Kaikoura, Moeraki, Halfmoon Bay, and Chalky Inlet). For the final data set used in the standardisation there are still many monthly samples for Moeraki and Halfmoon Bay where no puerulus were recorded (Figure 36).

Month was selected by the AIC criterion for all standardisations, and for most sites collector was selected instead of group (Table 5). Regression diagnostics are given in Appendix 3, and these indicate that for Moeraki, Halfmoon Bay, and Jackson Bay there is an excess of zeros relative to the assumed Poisson distribution.

The standardised annual collector indices up to 2013 are shown in Table 6. In the following sections site-by-site descriptions of puerulus settlement for 2013 are given, as well as standardised annual graphs from each key site and the monthly mean catch graphs for 2013 from each group.

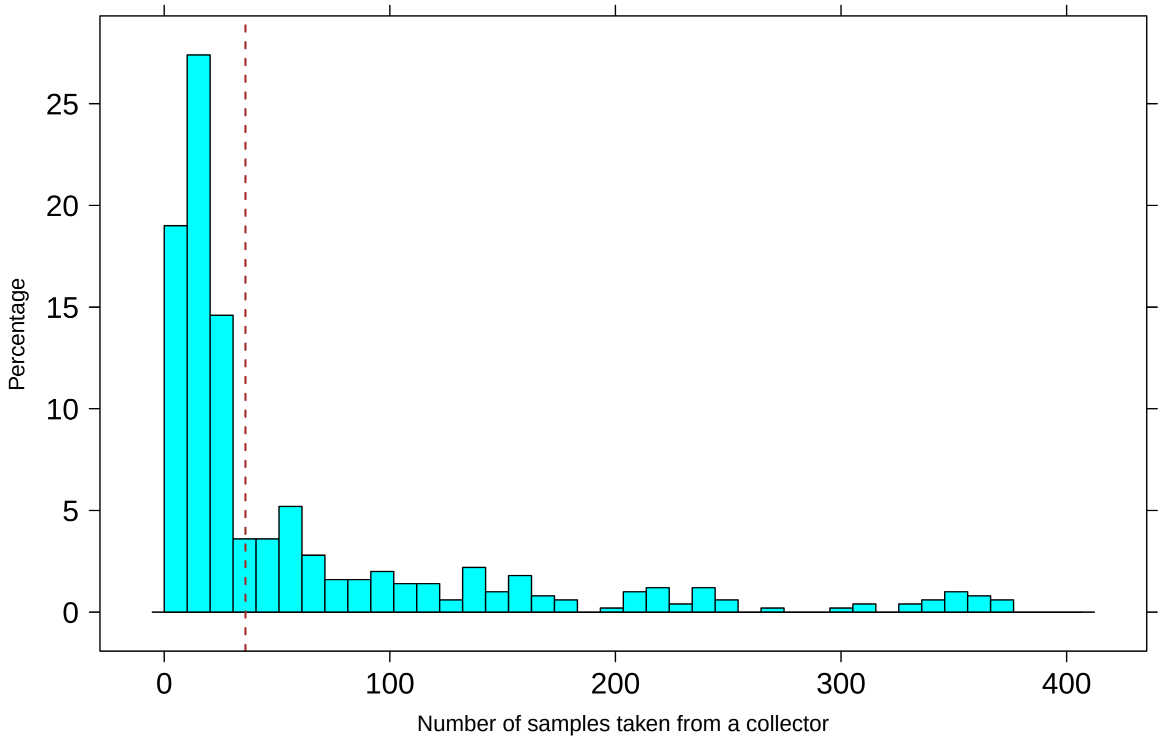

Figure 35: Distribution for the number of samples taken from a collector. The vertical dashed line is at 36 samples.

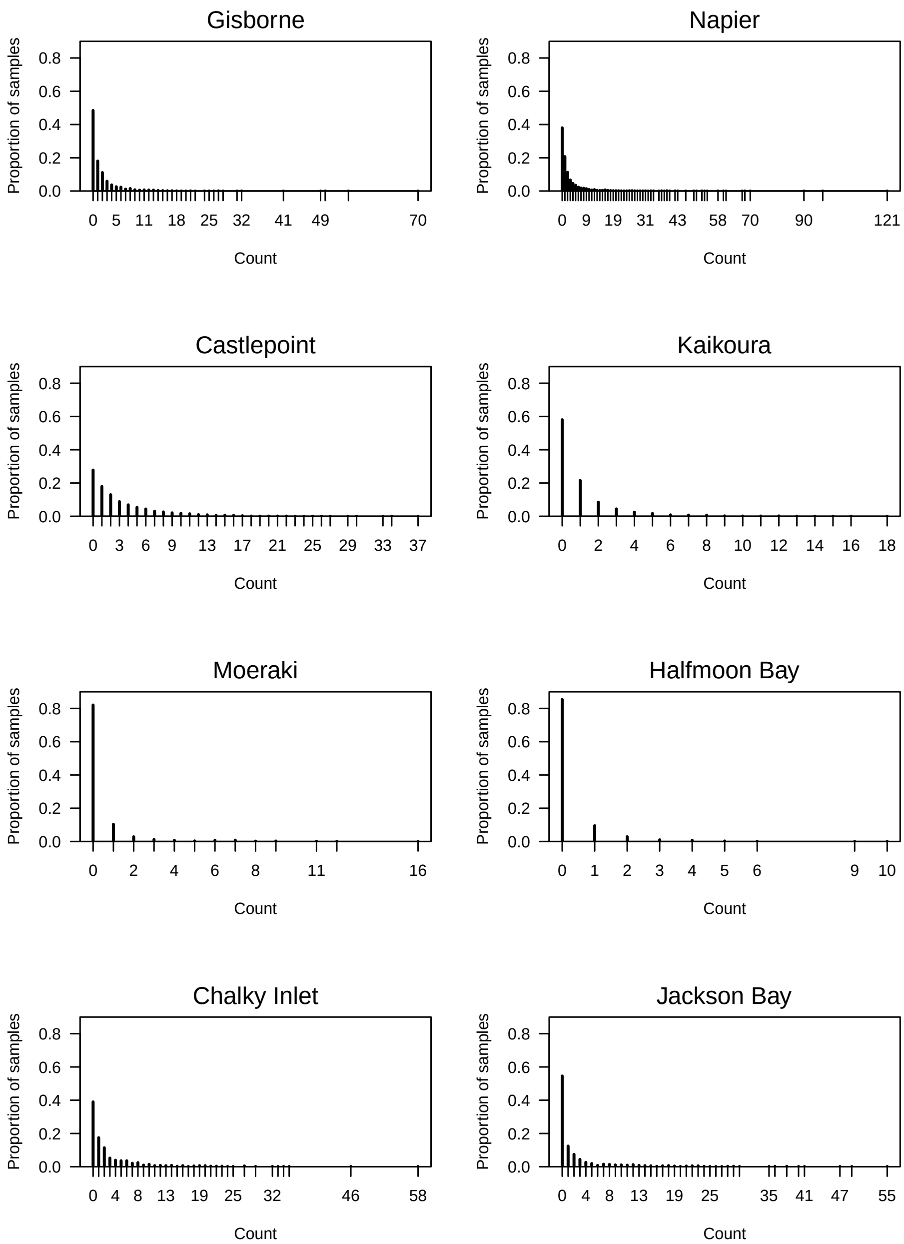

Figure 36: Distribution of number of puerulus collected at monthly samples by site.

Table 5: Groups of collectors used in standardisations, additional factors (all included year and month), and estimated dispersion. * Estimated using negative binomial instead of the quasi–Poisson, with group forced into standardisation instead of collector (see Section 3.3.1).

Site	Groups	Additional factors	Estimated dispersion
Gisborne*	001, 002, 003, 004	Group	-
Napier	001, 002, 003, 004	Collector	3.56
Castlepoint	001, 002, 003	Collector	2.69
Kaikoura	001, 002, 003, 004, 005, 006	Group	1.70
Moeraki	002, 007	-	1.61
Halfmoon Bay	001, 002, 003, 004, 005	Group	1.07
Chalky Inlet	001	Collector	1.07
Jackson Bay	001, 002	Collector	3.73

Table 6: Standardised annual indices for each site. Year is calendar year (January–December), and for Gisborne a subset of the data from May–September (inclusive) is used (see Section 3.3.1).

	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	-	0.84	-	-	-	-	-	-
1980	-	1.52	-	-	-	-	-	-
1981	-	2.06	-	1.19	-	8.09	-	-
1982	-	1.00	-	0.02	-	0.38	-	-
1983	-	1.24	1.41	0.76	-	4.58	-	-
1984	-	0.41	1.34	0.25	-	0.38	-	-
1985	-	0.19	0.86	0.35	-	0.00	-	-
1986	-	-	0.50	0.11	-	0.11	0.07	-
1987	3.16	-	1.69	1.22	-	1.60	1.95	-
1988	2.73	1.51	0.97	0.54	-	0.20	1.61	-
1989	0.96	1.08	1.51	0.89	-	0.54	2.19	-
1990	0.43	1.14	0.93	0.29	-	0.44	1.92	-
1991	1.03	2.26	1.94	5.91	0.00	0.84	1.06	-
1992	2.71	2.40	2.41	6.80	0.15	0.62	0.39	-
1993	1.71	1.91	1.46	3.41	0.00	0.00	0.13	-
1994	2.94	1.42	0.93	0.92	0.00	1.11	2.33	-
1995	1.05	1.06	0.88	1.08	0.11	0.32	0.56	-
1996	1.62	1.68	1.31	0.82	1.11	0.31	2.26	-
1997	0.97	1.29	1.15	1.68	0.66	0.53	1.52	-
1998	1.73	1.09	1.67	2.27	0.65	0.26	0.43	-
1999	0.27	0.29	0.34	1.53	0.14	0.24	1.04	0.56
2000	0.88	0.66	0.49	1.34	3.85	1.21	1.26	0.54
2001	1.10	1.32	0.76	0.49	2.36	1.71	0.99	0.66
2002	0.92	1.17	0.72	1.30	0.93	1.31	0.69	1.96
2003	2.67	1.32	0.76	5.21	7.21	3.45	1.59	1.01
2004	0.71	1.05	0.65	1.75	0.44	0.14	0.21	0.21
2005	2.43	1.28	1.17	2.30	0.10	0.00	-	1.96
2006	0.27	0.58	0.64	1.91	0.06	0.13	-	0.55
2007	0.35	1.03	0.88	1.26	0.03	0.46	-	0.25
2008	0.62	0.59	0.89	2.45	0.09	0.09	-	0.19
2009	1.70	0.75	0.92	0.49	0.52	0.96	-	0.18
2010	0.61	1.30	1.60	1.98	1.39	1.69	5.50	2.50
2011	0.18	0.36	0.89	0.46	0.91	0.13	1.49	3.07
2012	0.65	0.78	0.65	1.61	0.84	0.21	4.25	8.86
2013	0.91	1.16	1.65	0.69	1.46	0.98	-	18.71

Gisborne

Settlement at Gisborne in 2013 was just below the long-term mean. This is a continuation of a series of below average settlement for the region. With the exception of 2009, seven of the last eight years have been below average (Figure 37). Unusually, settlement was lower at Whangara, peaking in July. Kaiti's peak settlement was in June (Figure 38).

Napier

Settlement at Napier was only just above the long-term mean. In five of the last eight years, settlement has been below the long-term mean, and no significantly high settlement has occurred since the 1990s (Figure 39). Settlement at Napier Port peaked in June and Cape Kidnappers peaked in July (Figure 40).

Castlepoint

Settlement at Castlepoint in 2013 was above the long-term mean and similar to levels recorded in 2010. Other than in these two years and 2005, settlement has been below average since 1998 (Figure 41). Levels of settlement between Castlepoint and Orui was generally consistent. Orui peaked in April and Castlepoint peaked in May (Figure 42).

Kaikoura

Kaikoura was below the long term mean (Figure 43). Both groups had very similar levels of settlement with peak settlement occurring in April (Figure 44).

Moeraki

Moeraki was above the long term mean in 2013 (Figure 45). Most of the settlement occurred in July, August, and September (Figure 46).

Halfmoon Bay

Settlement was very close to the long-term mean in Halfmoon Bay (Figure 47), peaking in August (Figure 48).

Chalky Inlet

No data were received in 2013.

Jackson Bay

Extraordinarily high levels of settlement were recorded at Jackson Bay in 2013. This follows on from, and dramatically surpasses, the record settlement from last year (Figure 49). Settlement was lowest in February with about 10 puerulus per collector (just lower than the highest month from Castlepoint or Napier). Settlement peaked in April with an incredible average of about 45 puerulus per collector and remaining consistently high throughout the rest of the year (Figure 50).

Mean settlement by month over all years is shown in Figure 51. With the exception of Jackson Bay, where settlement is irregular, highest settlement generally occurs in winter and the lowest settlement is in spring.

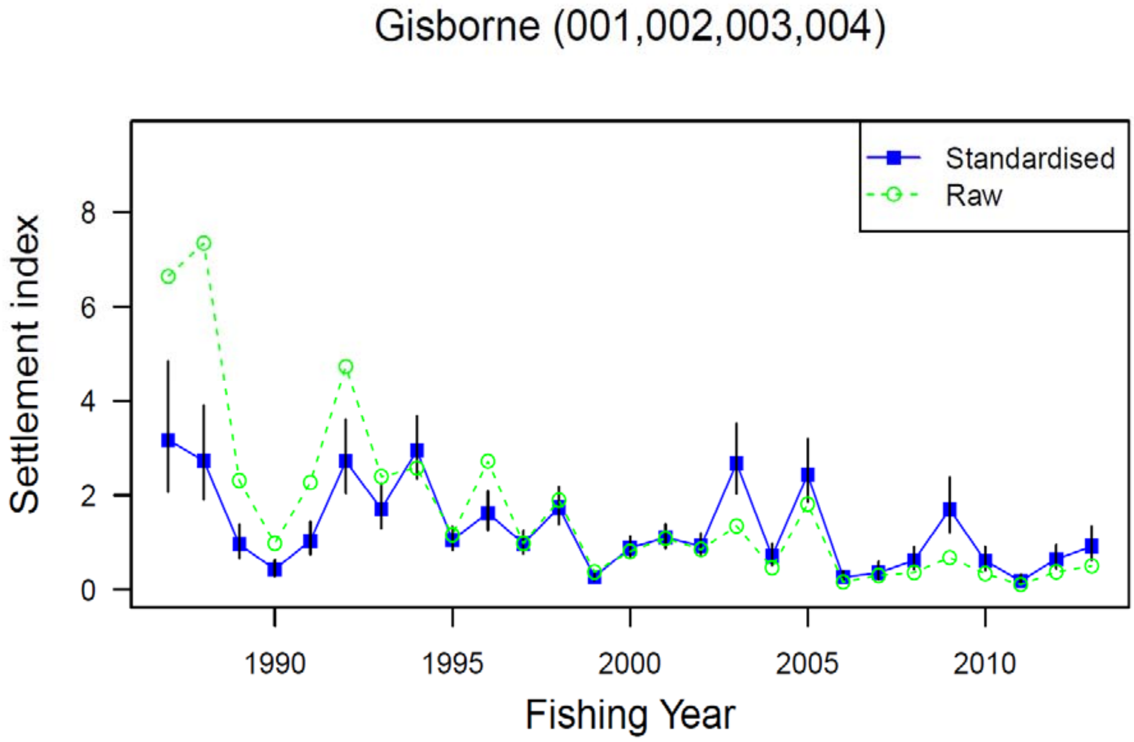

Figure 37: Gisborne–standardised and raw indices of annual settlement with 95% confidence intervals.

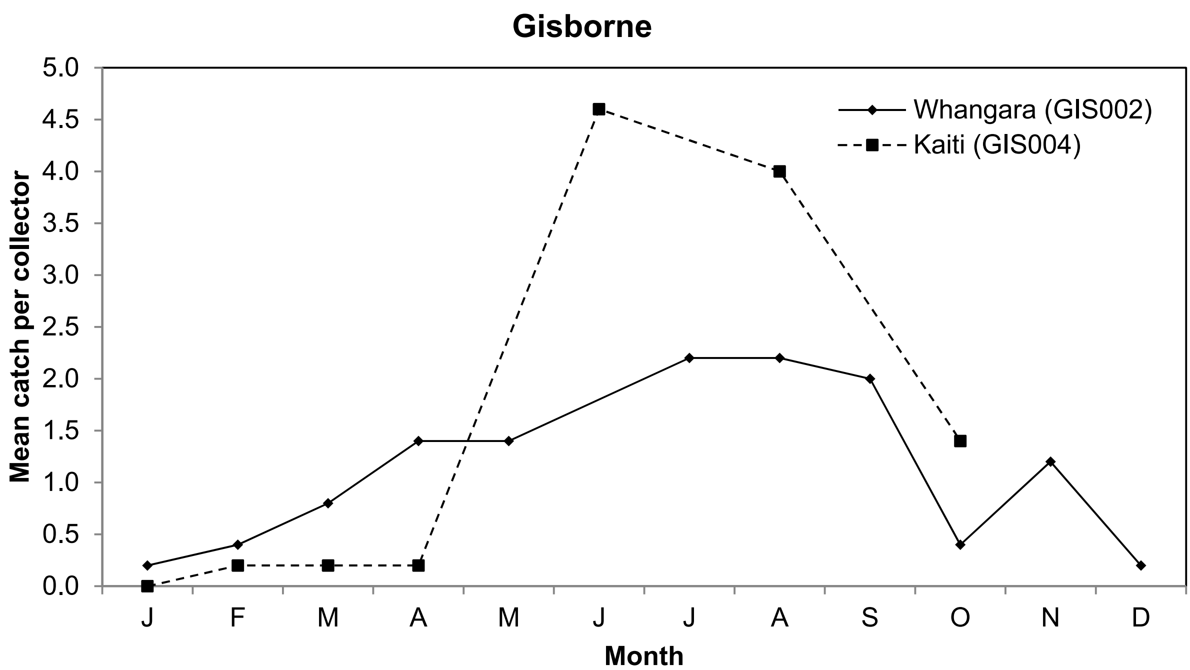

Figure 38: Whangara and Kaiti monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

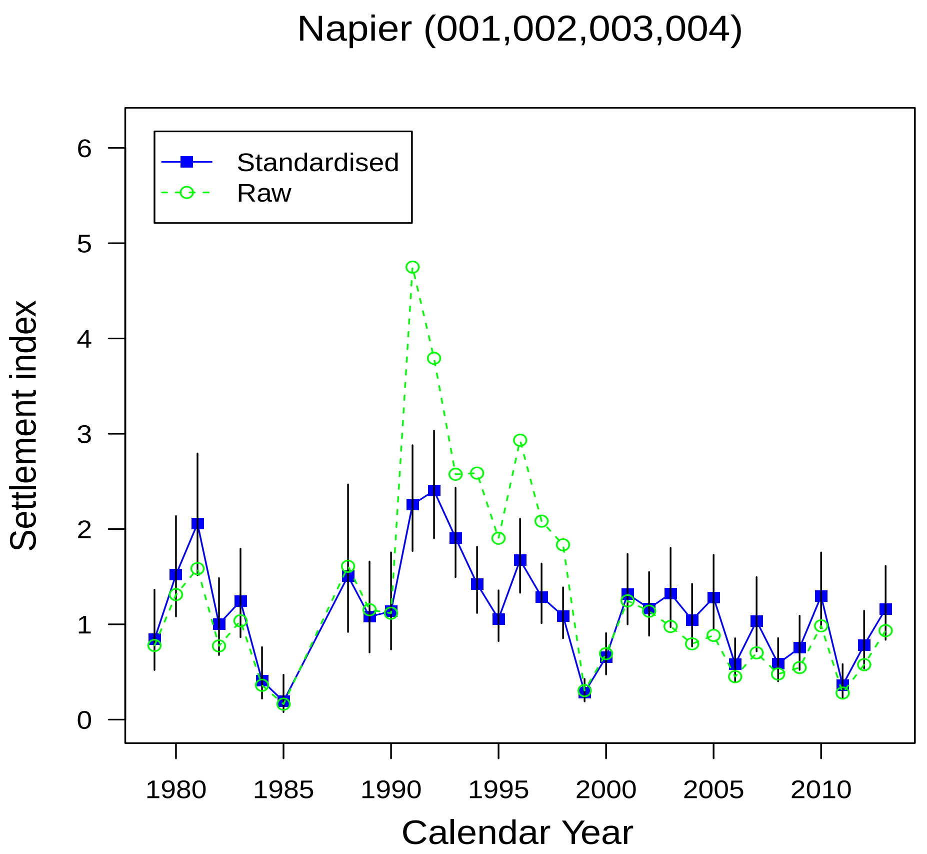

Figure 39: Napier—standardised and raw indices of annual settlement with 95% confidence intervals. Note that there were no checks in 1986–87.

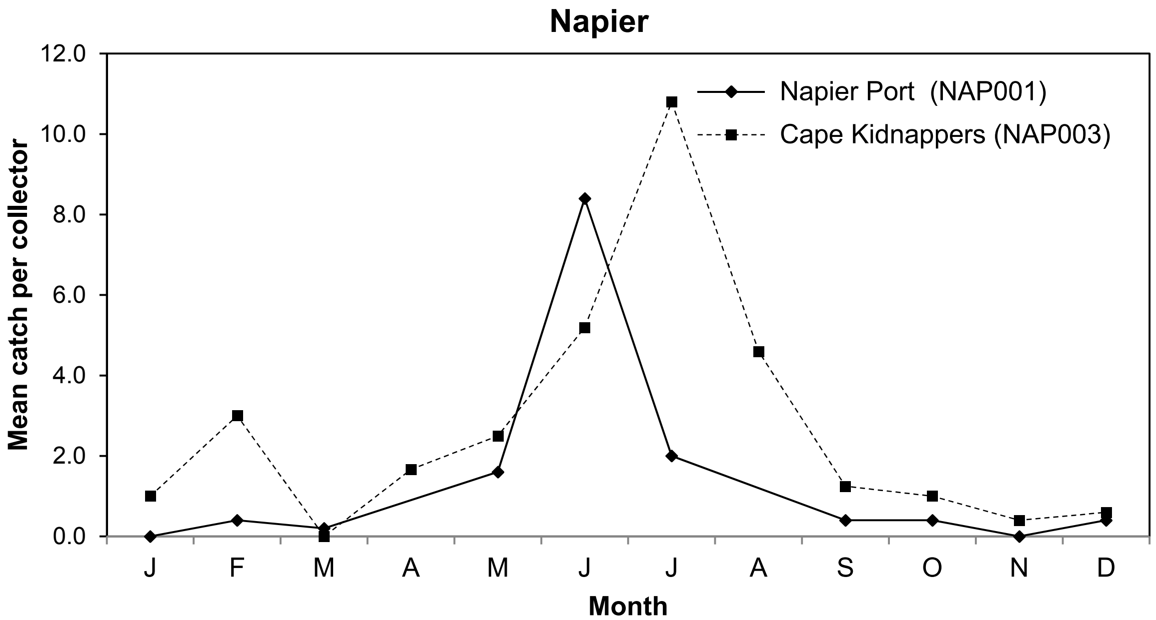

Figure 40: Napier harbour and Cape Kidnappers monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

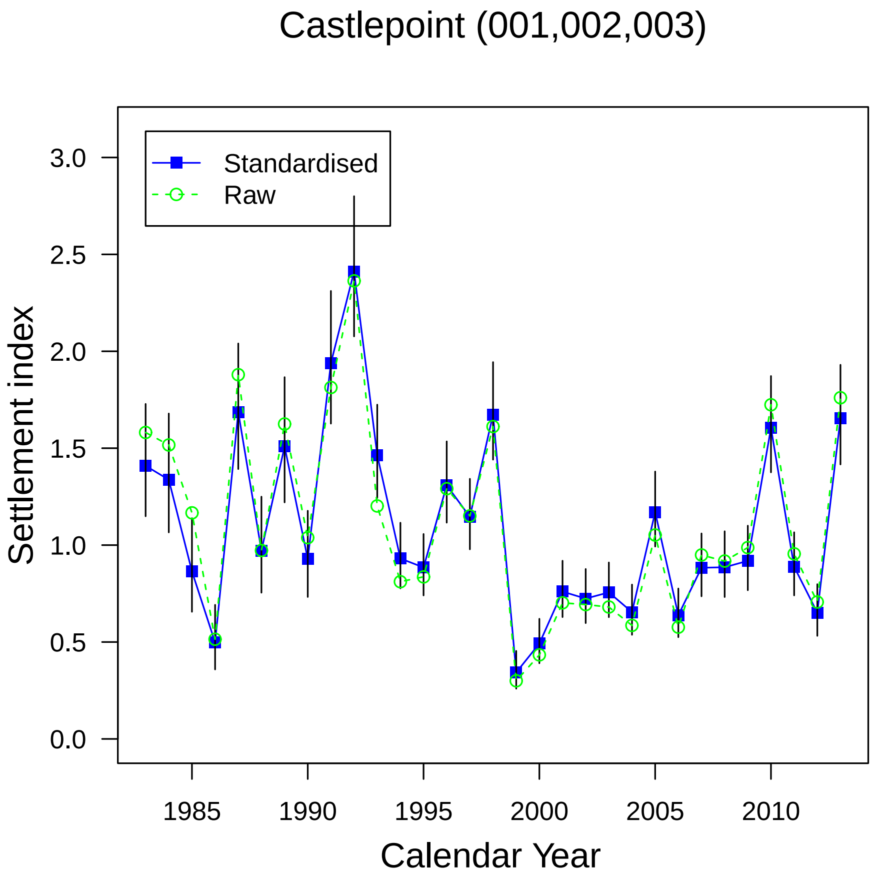

Figure 41: Castlepoint—standardised and raw indices of annual settlement with 95% confidence intervals.

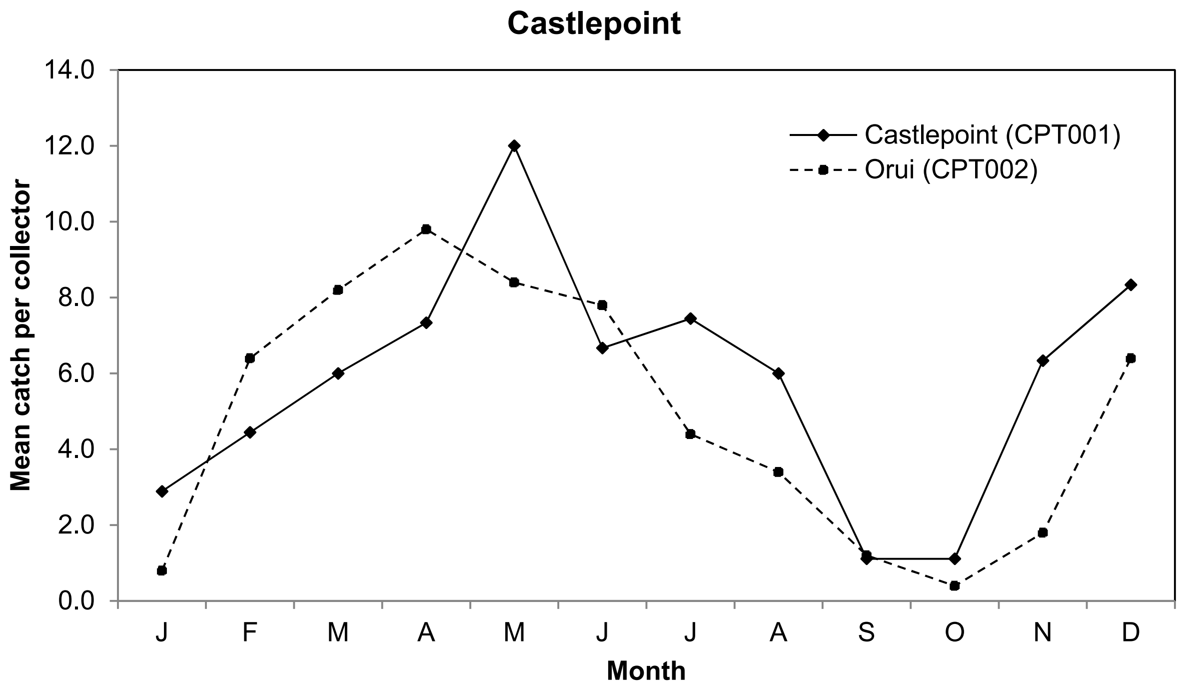

Figure 42: Castlepoint and Orui monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

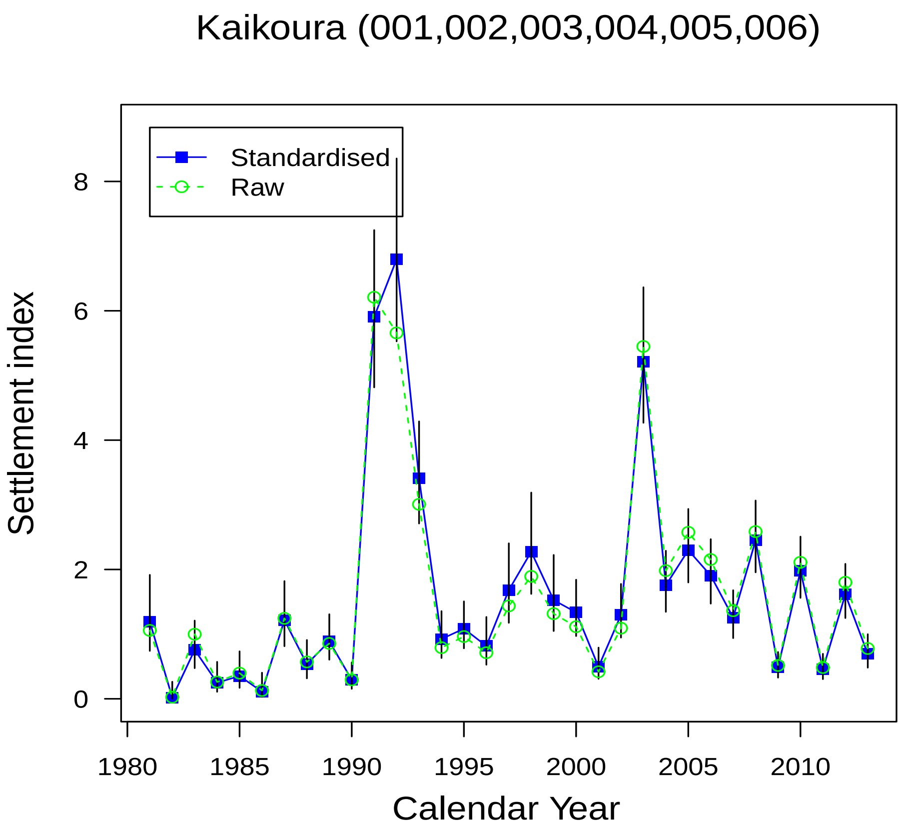

Figure 43: Kaikoura—standardised and raw indices of annual settlement with 95% confidence intervals.

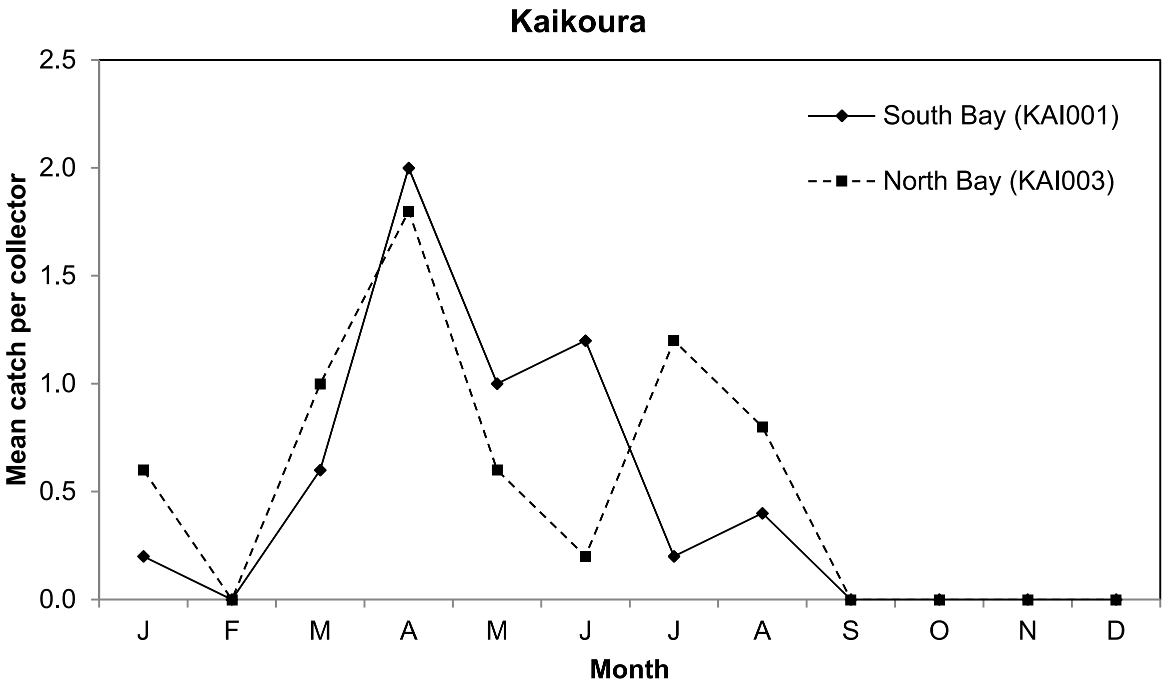

Figure 44: South Bay and North Bay monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

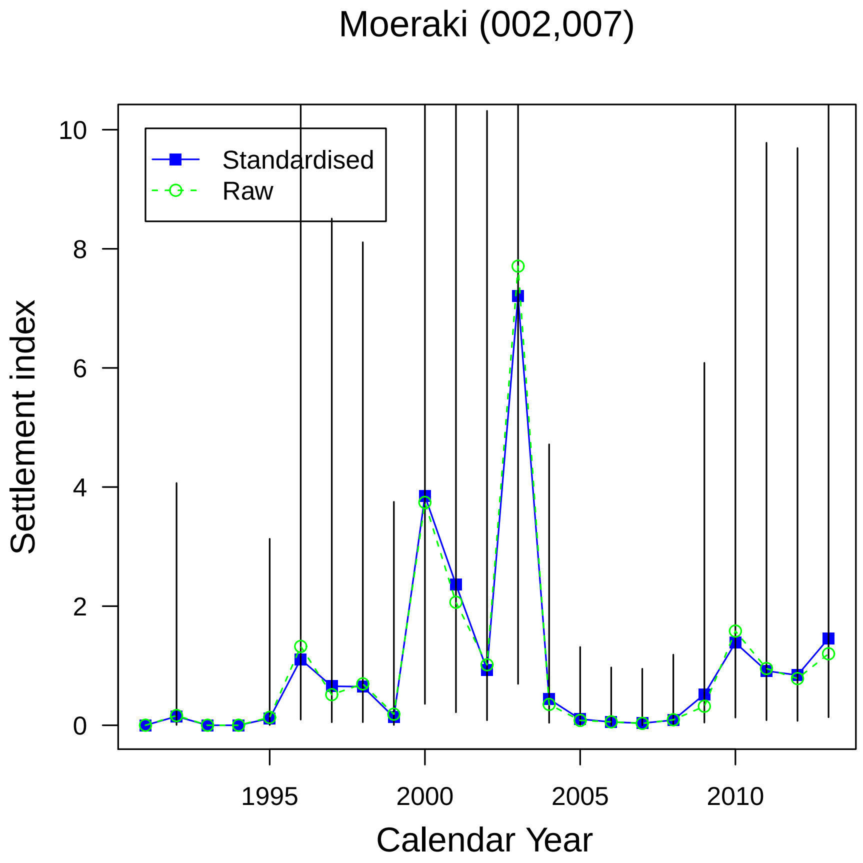

Figure 45: Moeraki—standardised and raw indices of annual settlement with 95% confidence intervals.

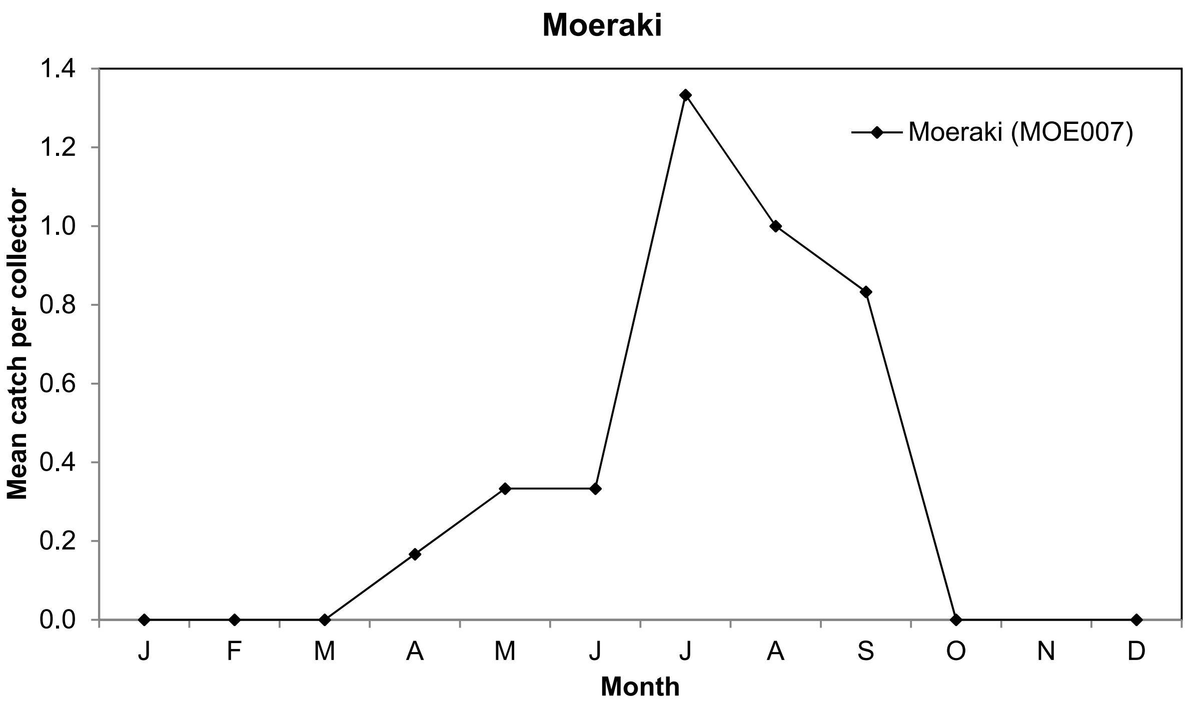

Figure 46: Moeraki monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

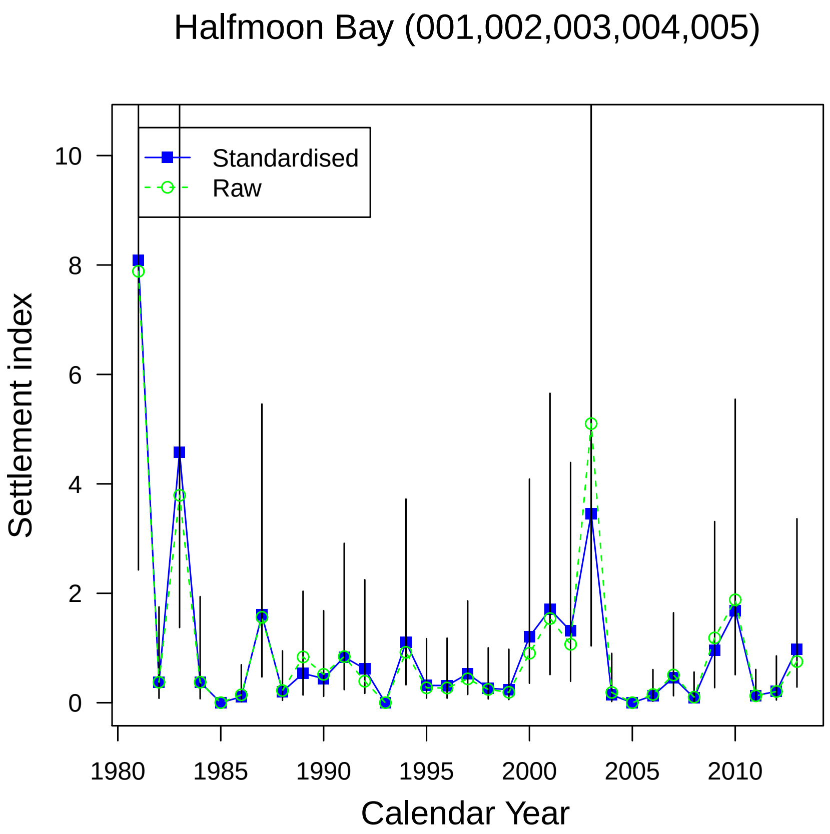

Figure 47: Halfmoon Bay—standardised and raw indices of annual settlement with 95% confidence intervals. The 95% confidence bounds were large because of high collector catch variability and the data not fitting the standardisation model well because of the large number of zero catches.

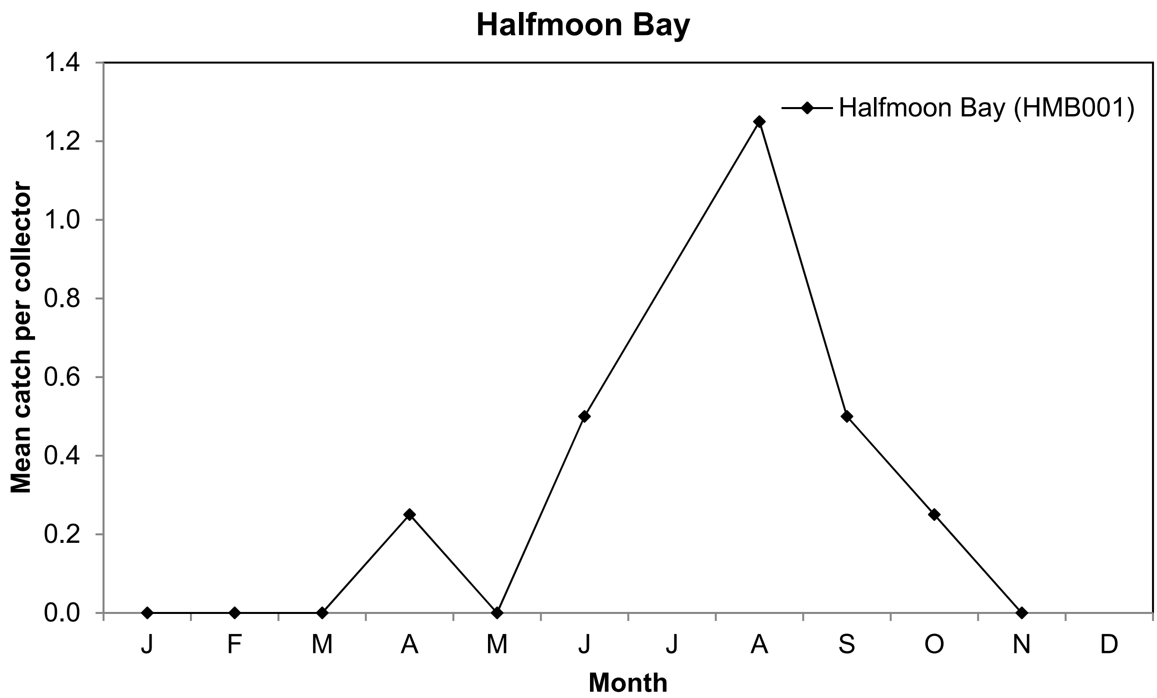

Figure 48: Halfmoon Bay monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

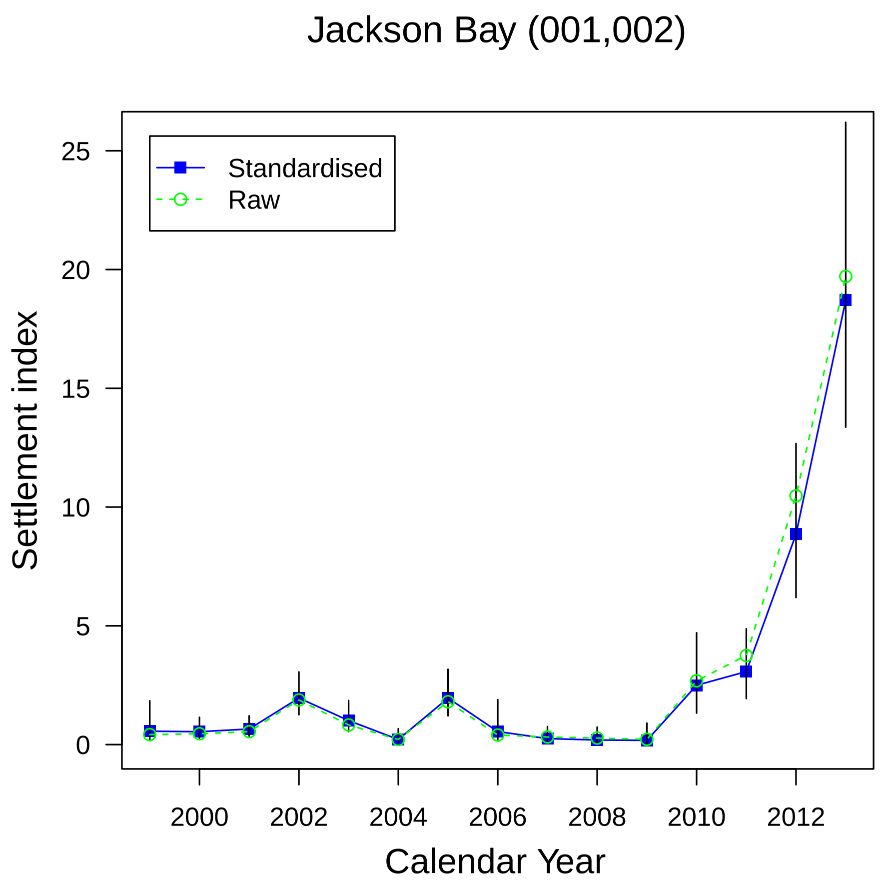

Figure 49: Jackson Bay—standardised and raw indices of annual settlement with 95% confidence intervals.

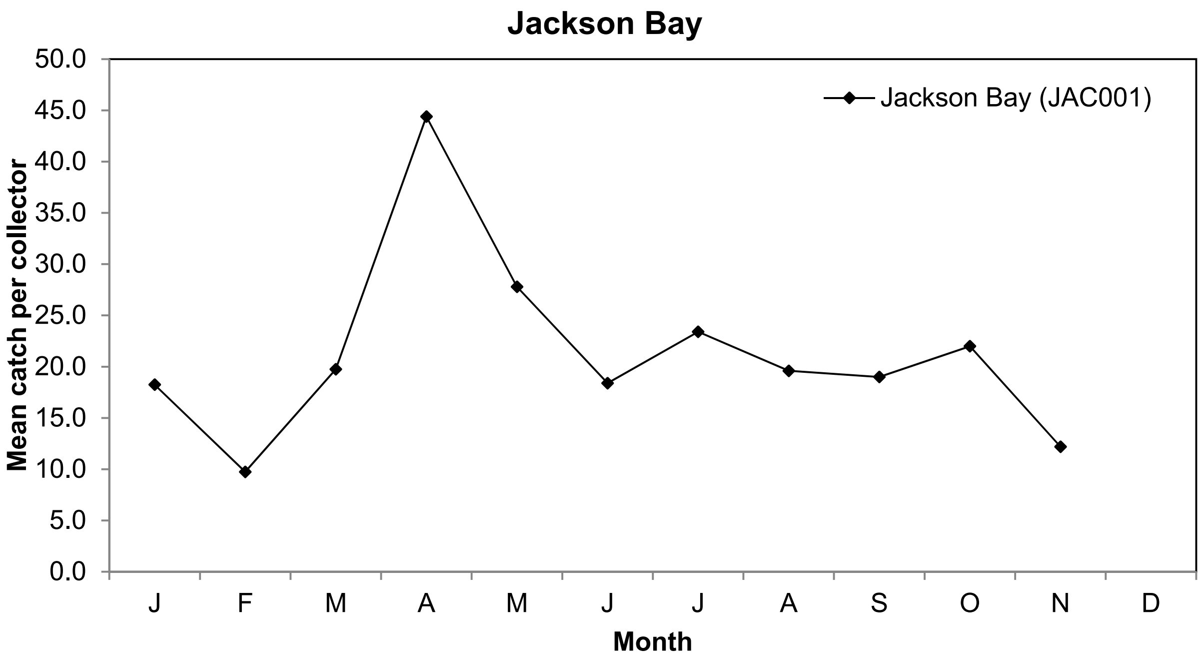

Figure 50: Raw monthly settlement, 2013. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

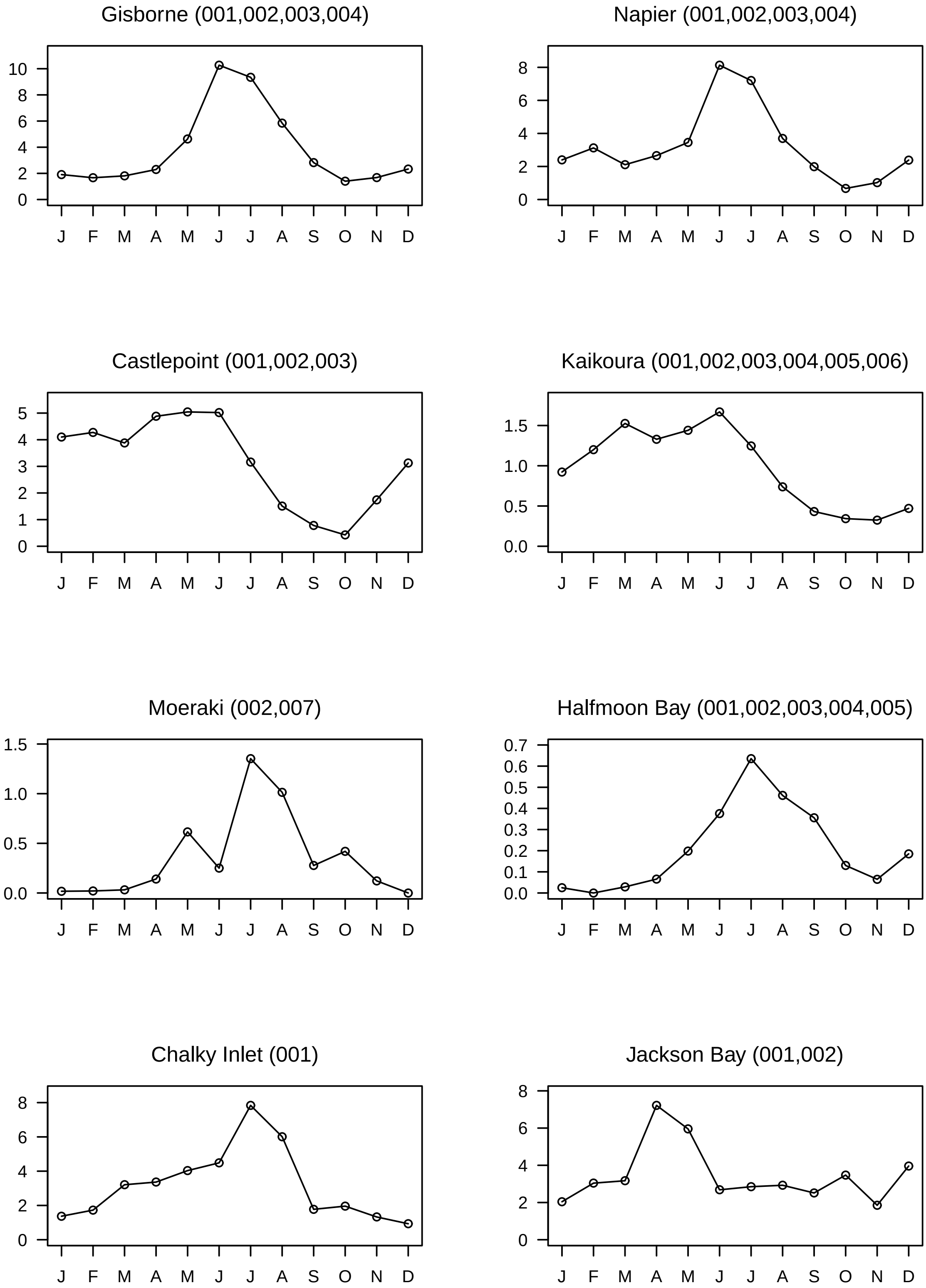

Figure 51: The mean settlement by month, over all years, for each key collector site. See Table 1 for the collector groups.

4. CONCLUSIONS

In 2013, above average settlement was recorded in Napier, Castlepoint, Moeraki, and in particular, Jackson Bay, where extremely high levels of settlement were recorded. Halfmoon Bay was close to the long term mean and Gisborne and Kaikoura were below their long-term means

The low levels of settlement that were recorded in Gisborne (CRA 3) in 2013 are a continuation of below average settlement that has occurred during seven of the last eight years.

In Napier and more so in Castlepoint (CRA 4), settlement was above the long-term mean and similar to the levels seen in 2010.

Settlement at Kaikoura (CRA 5) was below the long-term mean in 2013 and continues a downward trend from the high settlement in 2003.

Moeraki (CRA 7) was above the long-term mean and similar to the levels seen in 2010.

In Jackson Bay (CRA 8), extremely high levels of settlement were again recorded. This is the fourth consecutive year of very high settlement in this area. In Halfmoon Bay, average settlement was recorded.

5. MANAGEMENT IMPLICATIONS

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).

The exceptionally high levels of settlement recorded in Jackson Bay over recent years suggests that increasing levels of abundance should occur in the near future, at least in the Fiordland area of CRA 8. In contrast, Halfmoon Bay has only been above average once in the last four years (2010), well below average in 2011 and 2012, and average in 2013.

In Gisborne (CRA 3) the puerulus indices have generally been lower than average. Seven out of the last eight years in Gisborne have been significantly below the long-term average, and in Kaikoura the puerulus index shows a gradual decline in settlement since 2003, with three of the last five years well below the long-term average, suggesting declining abundance in both of these areas.

In Napier and Castlepoint (CRA 4), settlement has shown some recent improvement with above average settlement in 2010 and 2013, but this has been interspersed with some very low settlement years at both sites.

For Moeraki (CRA 7) levels of puerulus settlement have been steady around or just above the long term mean for the last four years but are a marked improvement over the six years preceding this.

6. ACKNOWLEDGMENTS

Thank you to Andy and Glenys Bassett, Neil and Murray Burden, Phred Dobbins, Wiremu Kaa, Shane Metcalfe, Craig and Helen Petherick, Port of Napier, Paul Reinke, Neil Rose, CRAMAC 5, and CRAMAC 8 for collector checks and field assistance. Nokome Bentley has kindly made his code available to us to generate the standardised settlement indices. Thank you to the Rock Lobster Working Group for suggestions made regarding the work, Reyn Naylor for reviewing the document, and Marianne Vignaux for editorial polishing up. This project was funded by the Ministry for Primary Industries under project CRA201202C.

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Appendix 1: Request for CRA 3 Puerulus Index

NZ ROCK LOBSTER INDUSTRY COUNCIL

Ka whakapai te kai o te moana

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lobster@seafood.co.nz

April 7th 2014

Dr. Andy McKenzie, fisheries modeller, NIWA
CC: Dr. R.J. Hurst, Chief Scientist, NIWA
CC: Dr. Kevin Sullivan, Assistant Chief Scientist, MPI
CC: ECs

CRA 3 PUERULUS INDEX FOR CRA 3 STOCK ASSESSMENT

Dear Andy:

At a previous meeting it was agreed that the stock assessment team would tell you specifically what we need by way of a puerulus settlement index.

We need an annual standardised index for CRA 3, based on the fishing year, 1 April through 30 September.

We note that NIWA sometimes ascribes puerulus checks made in one month to the preceding month. We would like the standardisation to be done using the date of the actual check.

We also note that a 36-check threshold is used: collectors are not used unless they have been checked at least 36 times. There seems to be potential for much data to be discarded by this rule, and we would like to see some exploration of the effect of this rule.

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). Associated with this, we will need to see a characterisation of the data from CRA 3: how many collectors in what groups in what locations for which periods. It appears that recent work has been done using only two of the groups.

The first RLFAWG meeting is on 26 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

NZ Rock Lobster Industry Council

Daryl R Sykes

Appendix 2: Number Of Samples By Calendar Year and Group

Table A1: Napier.

	NAP001	NAP002	NAP003	NAP004
1979	40	0	0	0
1980	59	0	0	0
1981	66	0	0	0
1982	66	0	0	0
1983	60	0	0	0
1984	48	0	0	0
1985	48	0	0	0
1988	18	0	0	0
1989	36	0	0	0
1990	36	0	0	0
1991	48	17	0	20
1992	64	19	0	32
1993	69	14	0	30
1994	65	27	19	33
1995	58	31	37	33
1996	72	34	50	30
1997	71	21	60	36
1998	66	27	63	33
1999	72	6	54	27
2000	59	0	47	27
2001	59	0	59	21
2002	57	0	58	24
2003	60	0	47	0
2004	71	0	60	0
2005	72	0	59	0
2006	72	0	47	0
2007	53	0	34	0
2008	64	0	58	0
2009	55	0	59	0
2010	60	0	52	0
2011	60	0	53	0
2012	55	0	44	0
2013	50	0	44	0

Table A2: Castlepoint.

	CPT001	CPT002	CPT003
1983	70	0	0
1984	55	0	0
1985	44	0	0
1986	68	0	0
1987	71	0	0
1988	66	0	0
1989	61	0	0
1990	72	0	0
1991	72	11	12
1992	72	37	27
1993	70	63	61
1994	92	60	50
1995	106	54	46
1996	99	54	51
1997	108	60	55
1998	108	51	44
1999	106	8	56
2000	106	22	60
2001	107	35	60
2002	95	48	55
2003	108	55	60
2004	107	51	60
2005	105	57	60
2006	108	58	60
2007	108	60	0
2008	105	45	0
2009	108	60	0
2010	108	60	0
2011	108	60	0
2012	108	56	0
2013	108	60	0

Table A3: Kaikoura.

	KAI001	KAI002	KAI003	KAI004	KAI005	KAI006
1981	18	0	24	0	13	0
1982	24	0	24	0	22	0
1983	24	0	21	0	15	0
1984	33	0	33	0	0	0
1985	30	0	26	0	0	0
1986	27	0	26	0	0	0
1987	33	0	33	0	0	0
1988	36	6	36	0	0	0
1989	36	36	36	0	0	0
1990	33	33	33	0	0	0
1991	36	33	36	0	0	0
1992	30	30	30	21	0	0
1993	33	33	33	33	0	0
1994	29	30	30	30	0	0
1995	36	36	36	36	0	0
1996	24	24	24	24	0	0
1997	21	21	21	18	0	0
1998	18	18	15	15	0	0
1999	18	18	21	21	0	0
2000	33	33	33	33	0	0
2001	35	32	36	36	0	0
2002	36	33	36	36	0	0
2003	54	9	54	8	0	0
2004	60	0	60	0	0	0
2005	59	0	60	0	0	0
2006	60	0	60	0	0	0
2007	60	0	65	0	12	0
2008	60	0	60	0	32	30
2009	59	0	59	0	27	24
2010	60	0	60	0	33	27
2011	60	0	60	0	21	18
2012	60	0	55	0	23	15
2013	60	0	60	0	6	6

Table A4: Moeraki.

	MOE002	MOE007
1991	21	0
1992	17	0
1993	18	0
1994	18	0
1995	21	0
1996	21	0
1997	27	0
1998	24	0
1999	15	0
2000	26	0
2001	28	7
2002	23	18
2003	30	98
2004	12	139
2005	24	145
2006	9	89
2007	0	87
2008	0	121
2009	0	87
2010	0	58
2011	0	105
2012	0	39
2013	0	44

Table A5: Halfmoon Bay.

	HMB001	HMB002	HMB003	HMB004	HMB005
1981	21	0	0	0	0
1982	32	0	0	0	0
1983	27	0	0	0	0
1984	24	0	0	0	0
1985	21	0	0	0	0
1986	21	21	0	0	0
1987	30	24	0	0	0
1988	33	21	0	0	0
1989	18	18	0	0	0
1990	28	15	15	0	0
1991	33	21	21	0	0
1992	27	21	17	21	21
1993	30	24	24	24	20
1994	30	27	27	25	25
1995	33	27	24	24	24
1996	27	24	24	24	24
1997	30	27	27	27	27
1998	24	27	24	24	24
1999	15	24	24	24	24
2000	21	24	24	27	24
2001	33	24	24	24	24
2002	30	27	27	27	27
2003	36	0	0	0	0
2004	32	0	0	0	0
2005	56	0	0	0	0
2006	80	0	0	0	0
2007	83	0	0	0	0
2008	58	0	0	0	0
2009	61	0	0	0	0
2010	88	0	0	0	0
2011	96	0	0	0	0
2012	88	0	0	0	0
2013	88	0	0	0	0

Table A6: Jackson Bay.

	JKB001	JKB002
1999	15	11
2000	36	32
2001	56	41
2002	51	30
2003	41	24
2004	34	21
2005	39	20
2006	19	6
2007	40	0
2008	30	0
2009	25	0
2010	19	0
2011	34	0
2012	48	0
2013	52	0

Appendix 3: Regression Diagnostics

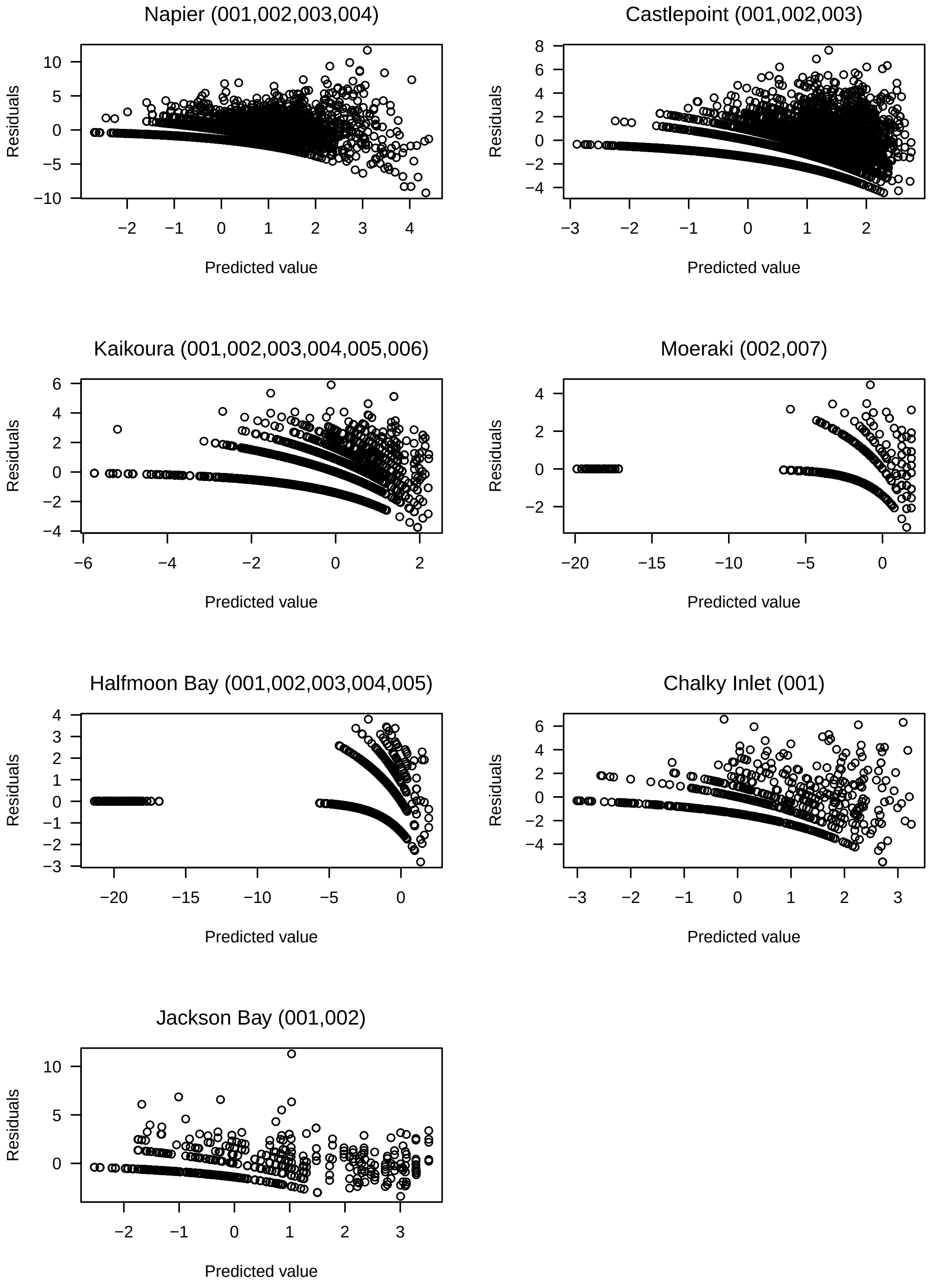

Figure A1: Residual plots from standardisation model for each site. The predicted values are in log space.

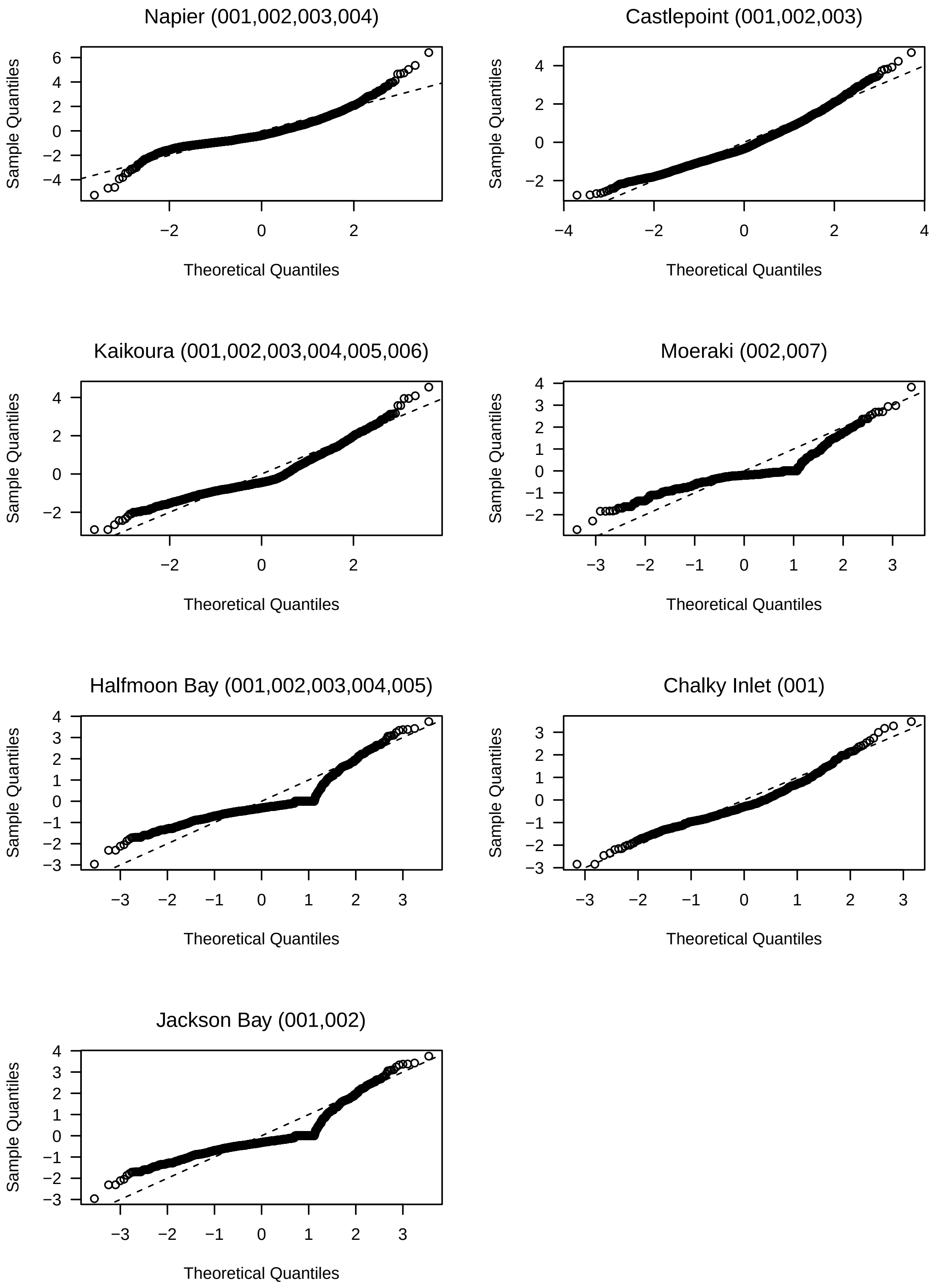

Figure A2: Quantile-quantile plots from standardisation models for each site.