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Tini a Tangaroa

Red rock lobster (*Jasus edwardsii*) settlement indices for the 2022–23 fishing year

New Zealand Fisheries Assessment Report 2024/04

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Plain language summary

The rock lobster fishery is one of New Zealand's most valuable fisheries.

Understanding larval settlement processes can greatly assist the management of this fishery because they may explain changes in recruitment to the fishery (i.e., reaching legal size), which takes between four and eleven years. This report aims to determine trends in puerulus settlement at selected key sites around New Zealand.

Annual patterns of red rock lobster settlement are described for North Island and South Island coastal areas, based on monthly monitoring of puerulus (the post-larval stage of red rock lobster) settlement collectors.

The monitoring data for 2022–23 are described in this report and used to provide indices of puerulus settlement for 2022–23, and thus extend the time series used to identify annual trends of settlement (since 1979).

Puerulus settlement during the 2022–23 fishing year was above the long-term mean at Gisborne, Castlepoint, and Halfmoon Bay and below the long-term mean at Napier, Kaikōura, Moeraki, and Jackson Bay.

In New Zealand there are significant correlations between the level of settlement and fishery catch per unit effort for most fishery areas.

EXECUTIVE SUMMARY

Forman, J.S.[1]; McKenzie, A.; Stotter, D.R. (2024). Red rock lobster (*Jasus edwardsii*) settlement indices for the 2022–23 fishing year.

***New Zealand Fisheries Assessment Report 2024/04*. 42 p.**

Information on annual patterns of settlement for the red rock lobster (CRA, *Jasus edwardsii*) on crevice collectors at key sites in Quota Management Areas (QMA) CRA 3 (Gisborne), CRA 4 (Napier and Castlepoint), CRA 5 (Kaikōura), CRA 7 (Moeraki), and CRA 8 (Halfmoon Bay and Jackson Bay) were updated for the 2022–23 fishing year (1 April 2022–31 March 2023).

Puerulus collectors were monitored for: one collector group in Gisborne, Moeraki, Halfmoon Bay, and Jackson Bay; two groups at Napier and Castlepoint; and five groups at Kaikōura. No data were received for a monitoring site at Chalky Inlet. Monitoring at this site has been discontinued by NIWA but the collectors there have been opportunistically monitored by lobster fishers whenever they were in the area. Each group has at least three collectors that are checked monthly, from which a monthly mean catch per group of collectors is calculated. Raw and standardised indices of puerulus settlement are produced from the groups of collectors at each key site based on the rock lobster fishing year.

Puerulus settlement during the 2022–23 fishing year was above the long-term mean at Gisborne, Castlepoint, and Halfmoon Bay, and below the long-term mean at Napier, Kaikōura, Moeraki, and Jackson Bay. At Gisborne, settlement has gradually increased every year since the record low in 2017, with the last three years above average. At Napier settlement has been below the long-term mean for the last five years. Castlepoint continues a good run of settlement with seven of the last eight years above the long-term mean including record settlement in 2021. At Kaikōura, settlement has been below or close to the long-term mean in five of the last six years. Settlement at Moeraki, although low this year, has recorded settlement well above the long-term mean in the previous seven years. Halfmoon Bay, although above the long-term mean this year, has seen low to average settlement over the last four years. At Jackson Bay, this is the fourth consecutive year of average or below average settlement.

[1] All authors: National Institute of Water & Atmospheric Research Ltd (NIWA), New Zealand.

1. INTRODUCTION

The rock lobster fishery is one of New Zealand's most valuable fisheries. Understanding larval settlement processes can greatly assist the management of this fishery because they may explain changes in recruitment to the fishery (i.e., reaching legal size), which takes at least four years (Booth & McKenzie 2008). This allows better management and commercial fishing strategies to be implemented. This report updates the patterns of spatial and temporal settlement of rock lobster (CRA, *Jasus edwardsii*) on crevice collectors in New Zealand for the 2022–23 fishing year (hereafter the 2022 fishing year).

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 and resembles a transparent juvenile of 9–13 mm carapace length. Pueruli settle when they cease extensive forward swimming and take up residence on the substrate, although some older pueruli and young juveniles undertake post-settlement migration (secondary dispersal) after first settling (Booth & Phillips 1994). Post-settlement migration is not uncommon among invertebrates and is thought to be a strategy to reduce density-dependent mortality in juveniles (Reyns & Eggleston 2004). Pueruli moult into a 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 (Booth & Tarring 1986). Depending on sex and locality, the rock lobster then takes about 4–11 years to reach minimum legal size (Booth & McKenzie 2008).

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 (spiny lobsters) (e.g., Phillips et al. 2000, Gardner et al. 2001) and homarids (clawed lobsters) (e.g., Wahle et al. 2004), with encouraging or well-demonstrated success for some fisheries. In New Zealand there are significant correlations between the level of settlement and fishery catch per unit effort (CPUE) for most fishery areas. The best correlations occur in fisheries with shorter intervals between larval settlement and recruitment to the fishery, and for those stocks where puerulus settlement is highly variable (Booth & McKenzie 2008).

Environmental drivers of recruitment are likely complex and operate at different scales, but southerly storminess is associated with higher settlement levels along the southeast coast of the North Island (Booth et al. 2000) and La Niña conditions with higher settlement for southern regions of New Zealand (Hinojosa et al. 2017).

Crevice collectors were developed in New Zealand to catch *J. edwardsii* pueruli and are currently used to monitor settlement rates between Gisborne and the south of the South Island. They are inexpensive, easily set and checked, and provide a standard settlement surface for between-month and between-site comparisons (Booth & Tarring 1986). Monthly occurrence of pueruli and young juveniles on these crevice collectors has been monitored at up to eight 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, is independent of lunar phase, has been shown to be seasonal, and can vary by an order of magnitude or more from year to year (Booth & Stewart 1993, Forman et al. 2014). For further background information on the puerulus sampling programme in New Zealand see Booth et al. (2006, 2007).

This report addresses objective one of the Fisheries New Zealand project CRA2021-02.

Objective

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 (Gisborne), CRA 4 (Napier and Castlepoint), CRA 5 (Kaikōura), CRA 7 (Moeraki), and CRA 8 (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, Phillips & Booth 1994) at seven key sites that encompass much of the main rock lobster fishing coast of New Zealand (as well as opportunistically at Chalky Inlet in Fiordland). 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 expected level of puerulus catch.

At each key site, collectors are set in groups of between 3 and 20 units, 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 minimal impact on the overall monthly and annual index. At each site there is a core group of at least three (usually five) collectors. At most sites there have been up to three additional groups of three or more collectors, set along the coast as conditions allow. Since 2002, however, fewer of these additional groups of collectors have been monitored; the focus is now on a core group of collectors at each site (usually the one first established and, therefore, with the longest record of settlement). Where feasible, another group of collectors is also monitored at some sites. Table 1 gives a summary of the collector sites, the number of collectors by site, the method of collector deployment, and the years of operation. 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 collectors are maintained at each site or nearby as replacements. If possible, collector replacement is made outside the main settlement season.

At Gisborne, Napier, Kaikōura, Stewart Island, and Jackson Bay, local people are employed to check the collectors, as directed by the National Institute of Water and Atmospheric Research (NIWA). At Castlepoint and Moeraki, NIWA staff check the collectors. Quality control of checks and equipment is maintained with direct contact once or twice per year. A standard result form is completed and sent to NIWA after each check. Monthly checks, especially during the main winter settlement season (June to August), are not always possible for all groups of collectors because of logistical issues (e.g., weather and access to collectors). Three groups of collectors in Kaikōura (KAI005, KAI006, and KAI010) are fully managed by Cray Management Area Council (CRAMAC) 5, and one other group of collectors in Kaikōura (KAI003) is funded by CRAMAC 5 but is maintained by NIWA.

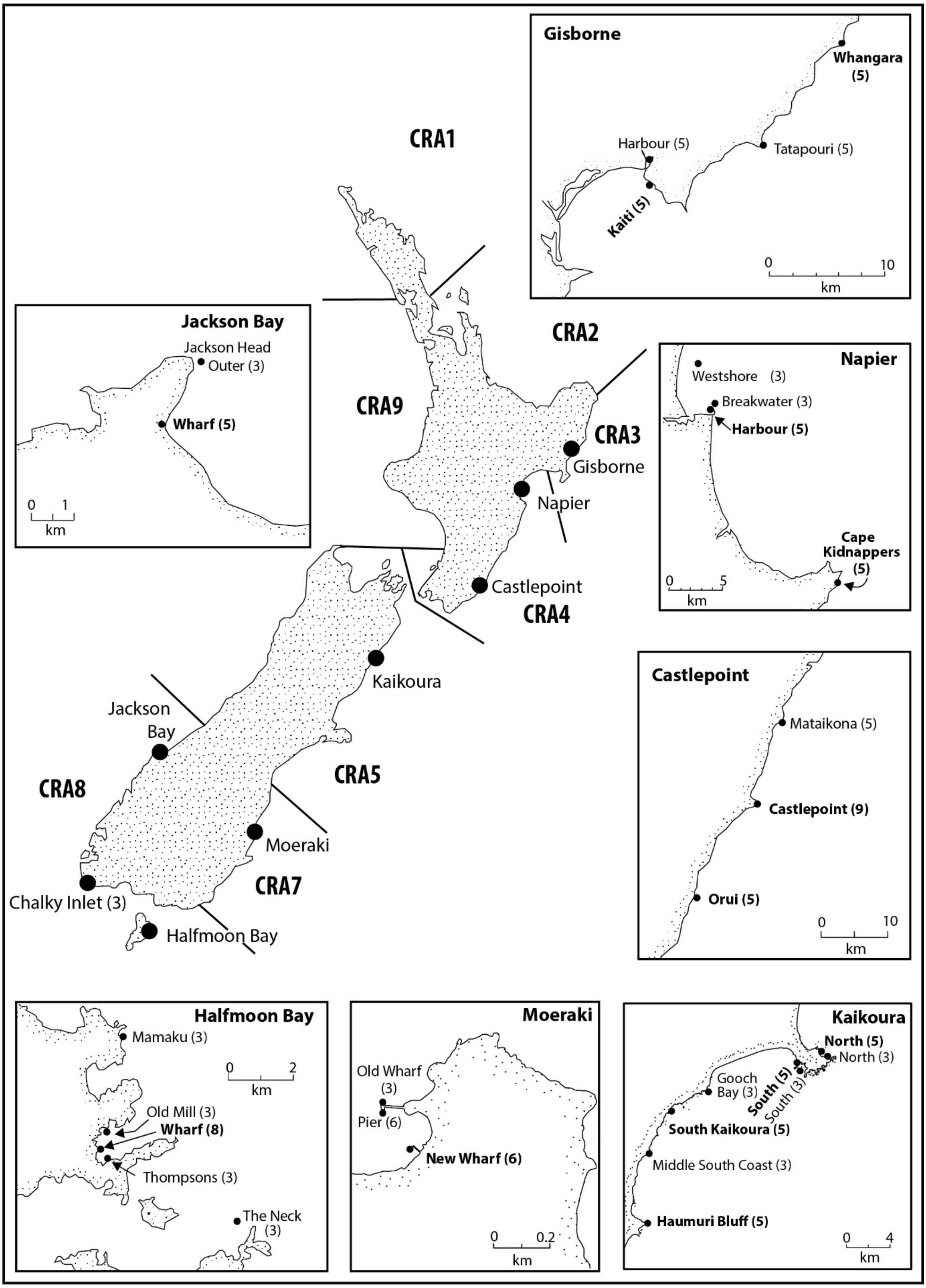

Figure 1: Map of New Zealand showing the location of collectors at the key monitoring sites (although not all groups are now checked). The sites that are checked are in bold and the number of collectors in each set is given in brackets. Also shown are the CRA areas; CRA 6 the Chatham Islands and CRA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

Table 1: Site, number of collectors per group, group location (with shorthand label in brackets), method of collector deployment, and years of operation of all collectors used in the settlement index.

Site	Number of collectors	Group 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
Kaikōura	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
	5	South Kaikōura (KAI005)	Shore	2008–Present
	5	Haumuri Bluff (KAI006)	Shore	2008–Present
	3	Gooch Bay (KAI008)	Shore	1980–1983
	3	Middle South Coast (KAI009)	Shore	1981–1988
	5	North Coast (KAI010)	Shore	2021–Present
Moeraki	3	Old wharf (MOE002)	Closing	1990–2006
	6	Pier (MOE007)	Suspended	1998–2017
	6	New wharf (MOE008)	Suspended	2017–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 (JKB001)	Suspended	1999–Present
	3	Jackson Head (JKB002)	Closing	1999–2006
Chalky Inlet	3	Chalky Inlet (CHI001)	Closing	1986–2018

2.2 Calculating indices of settlement

All standardised settlement indices calculated before 2014 were by calendar year. In contrast, all subsequent standardisations, including those presented in this report, 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, and 11 Feb 2004 is in the 2003 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 indices have been made available as potential recruitment indices. Biologically, the settlement year starts between October and December at all sites, except for Jackson Bay, where settlement does not appear to follow a seasonal pattern (see Figure 2).

The standardised index of annual settlement incorporated all settlement data for the year for each site, except when the months used were restricted to reduce the number of zero counts (see below). This approach to standardisation is based on the methods developed by Bentley et al. (2004). The term 'settlement' refers to the presence of pueruli and juveniles up to 14.5 mm carapace length (the maximum size for a first-instar juvenile observed in laboratory studies).

Following Bentley et al. (2004), the standardisation process employed in the present report only utilised collectors that have been sampled at least 36 times (equivalent to three years of monthly sampling). In the Bentley et al. (2004) study, data outliers were removed after the standardisation procedure and the standardisation was then repeated, but the effect on the standardised indices was minor. In this study, no outliers were removed.

Because a collector check on any one day is assumed to be a snapshot of what has been going on for about the last 14 days, the appropriate month to label as settlement may not be the nominal month. In standardisations prior to 2014, if the check took place up to the seventh day of the month, its catch was attributed to the previous month. This also avoided the situation where a collector was checked on the first and last day of a month, which would generate 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 after 2014.

At three sites (Gisborne, Jackson Bay, and Moeraki), some early pilot groups of collectors were dropped because of logistical reasons, or because they did not capture pueruli very well (Forman et al. 2015, Forman et al. 2016). At Gisborne, three early pilot groups of collectors were dropped from 1982 to 1986 (inclusive), as were three pilot groups of collectors that operated for only a few years (early 1990s and early 2000s). For Jackson Bay and Moeraki, counts of pueruli at even the best remaining groups of collectors were very low throughout their operation (except for Jackson Bay wharf after 2010). For example, for the JKB001 group of collectors, zero counts were recorded about 60% of the time, and, for the MOE002 and MOE007 group of collectors, zero counts were recorded about 80% of the time (appendix 1 of Forman et al. 2014). To reduce the proportion of zero counts at some sites, the months used for the standardisation were restricted to those months where the proportion of non-zero counts were highest (Table 2). The choice of months to use was conducted in consultation with the RLWG, with months chosen to capture the peak of settlement. If the number of sampling events in a fishing year was low (fewer than 10) at any given site, that year was excluded from the standardisation.

The annual settlement 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 was the log of numbers of settlers per collector sample and a negative binomial distribution was assumed. For Kaikōura and Moeraki alternative distributions were investigated (quasi-Poisson, zero-inflated Poisson, zero-inflated negative binomial) but the negative binomial was still preferred (Forman et al. 2016). In a previous standardisation for Gisborne, alternative distributions were investigated and the negative binomial was again chosen (Forman et al. 2015). For the other sites the RLWG decided that the negative binomial distribution should also be used.

The predictor variables available to the standardisation models 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).

Table 2: Months for which data were used in standardisation.

Site	Months	For further detail on months used
Gisborne	May–September	Forman et al. (2015)
Napier	All	Forman et al. (2017)
Castlepoint	All	Forman et al. (2017)
Kaikōura	January–September	Forman et al. (2016)
Moeraki	May–October	Forman et al. (2014)
Halfmoon Bay	May–December	Forman et al. (2014)
Jackson Bay	All	Forman et al. (2014)

In summary, the standardisation method common to all sites (but modified for Moeraki as explained below) was to:

1. use the fishing year from 1 April to 31 March
2. use the actual month in which a sample was taken (instead of samples taken up to the 7th of the month being assigned to the previous month)
3. exclude collectors with fewer than 36 samples
4. restrict (where necessary) the months used (to reduce the proportion of zero counts in the data)
5. exclude fishing years with fewer than 10 samples (this occurred after the restriction of months)
6. fit a negative binomial model to 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. For either method, a value for the index above 1 indicates 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), scaled to have an average value of 1 across all years.

The data set used for all sites is an extract from the *rocklob* database and is complete for the 2022 fishing year (i.e., data are complete up to 31 March 2023).

3. RESULTS

3.1 Standardised indices for sites

New standardised indices were produced for the following sites: Gisborne (CRA 3), Napier (CRA 4), Castlepoint (CRA 4), Kaikōura (CRA 5), Moeraki (CRA 7), Halfmoon Bay (CRA 8), and Jackson Bay (CRA 8). To reduce the number of zero observations, a subset of months was selected for many of the standardisations (see Table 2). Group and month factors were selected as predictor variables for each analysis, so the final predictor variables were year, group, and month.

For each site, plots are given in the following sections for puerulus data characteristics, standardised indices, and standardisation diagnostics. Diagnostics (quantile-quantile, deviance residuals versus predicted values, predicted puerulus numbers counts versus observed puerulus numbers) appeared to be reasonable for all sites, which indicates an acceptable model fit (Appendix 1). The standardised indices for all sites are summarised in Table 3.

Table 3: Standardised annual indices for each site. Year is fishing year (1 April–31 March), where the 2022–23 fishing year is labelled as 2022. '–': no usable sampling was conducted; 0.00: no observed settlement.

Fishing year	Gisborne CRA 3	Napier CRA 4	Castlepoint CRA 4	Kaikōura CRA 5	Moeraki CRA 7	Halfmoon Bay CRA 8	Chalky Inlet CRA 8	Jackson Bay CRA 8
1979	–	0.86	–	–	–	–	–	–
1980	–	1.37	–	–	–	–	–	–
1981	–	2.23	–	0.57	–	7.93	–	–
1982	–	1.26	2.22	0.73	–	0.38	–	–
1983	–	1.45	1.06	0.17	–	3.89	–	–
1984	–	0.46	0.66	0.41	–	0.30	–	–
1985	–	0.24	0.54	0.25	–	0.00	0.34	–
1986	–	–	0.76	0.09	–	0.11	0.20	–
1987	3.56	–	1.52	1.13	–	1.56	1.28	–
1988	2.98	1.52	0.88	0.41	–	0.22	1.20	–
1989	1.06	1.30	1.07	0.86	–	0.59	1.57	–
1990	0.47	1.15	1.01	1.61	–	0.41	1.72	–
1991	1.15	2.66	1.96	7.09	0.00	0.93	0.99	–
1992	3.13	2.26	2.04	5.60	0.05	0.53	0.49	–
1993	1.93	2.36	1.02	2.23	0.00	0.00	0.14	–
1994	3.27	1.64	0.83	1.10	0.00	1.17	1.54	–
1995	1.17	1.12	0.87	0.62	0.04	0.39	0.38	–
1996	1.76	1.64	1.23	0.65	0.35	0.32	1.67	–
1997	1.07	1.13	1.60	2.17	0.16	0.55	1.33	–
1998	1.95	1.03	1.04	2.17	0.20	0.29	0.46	–
1999	0.31	0.45	0.32	1.36	0.04	0.23	1.61	0.25
2000	0.98	0.78	0.49	1.38	1.58	1.20	1.20	0.57
2001	1.21	1.30	0.69	0.56	0.67	1.72	0.58	0.21
2002	1.02	1.50	0.74	3.28	0.34	1.43	1.33	1.27
2003	2.94	1.37	0.86	3.52	2.83	4.07	1.49	0.47
2004	0.76	1.10	0.46	1.08	0.13	0.15	0.29	0.38
2005	2.67	1.35	1.19	2.37	0.03	0.00	–	1.04
2006	0.30	0.68	0.46	1.18	0.02	0.13	–	0.24
2007	0.40	0.97	0.98	1.66	0.02	0.48	–	0.22
2008	0.69	0.67	0.97	1.65	0.04	0.10	–	0.07
2009	1.79	0.92	1.00	0.50	0.25	1.00	–	0.14
2010	0.64	0.98	1.13	1.32	0.54	1.63	6.68	1.75
2011	0.20	0.51	0.85	0.54	0.42	0.14	1.38	2.12
2012	0.72	0.73	0.56	1.17	0.58	0.18	4.18	6.92
2013	0.98	1.00	1.62	0.79	0.65	0.74	–	11.77
2014	0.42	1.05	0.65	1.28	0.21	0.84	–	20.09
2015	1.57	1.09	1.57	0.85	4.51	0.55	–	4.41
2016	1.25	0.70	1.77	2.64	1.63	1.36	–	12.25
2017	0.18	1.03	0.98	0.98	4.22	2.00	–	1.03
2018	0.35	0.39	1.01	0.38	2.93	0.60	3.71	2.33
2019	0.70	0.63	1.09	0.38	1.86	0.42	–	0.50
2020	1.08	0.60	1.68	0.65	5.18	0.98	–	1.20
2021	1.16	0.85	2.58	1.77	1.72	1.03	–	0.89
2022	1.42	0.77	1.48	0.84	0.80	1.43	–	0.64

3.2 Summary and discussion of trends for each site

Long-term average monthly trends in settlement for all key sites are shown in Figure 2. Peak puerulus settlement occurred during winter months at Gisborne, Napier, Moeraki, Halfmoon Bay, and Chalky Inlet. For Castlepoint and Kaikōura, the highest levels of puerulus settlement were during January–July. Jackson Bay had similar puerulus settlement throughout the year. Trends in the annual settlement indices over time for each site and monthly settlement for 2022 at each site are discussed below (Figures 3–17).

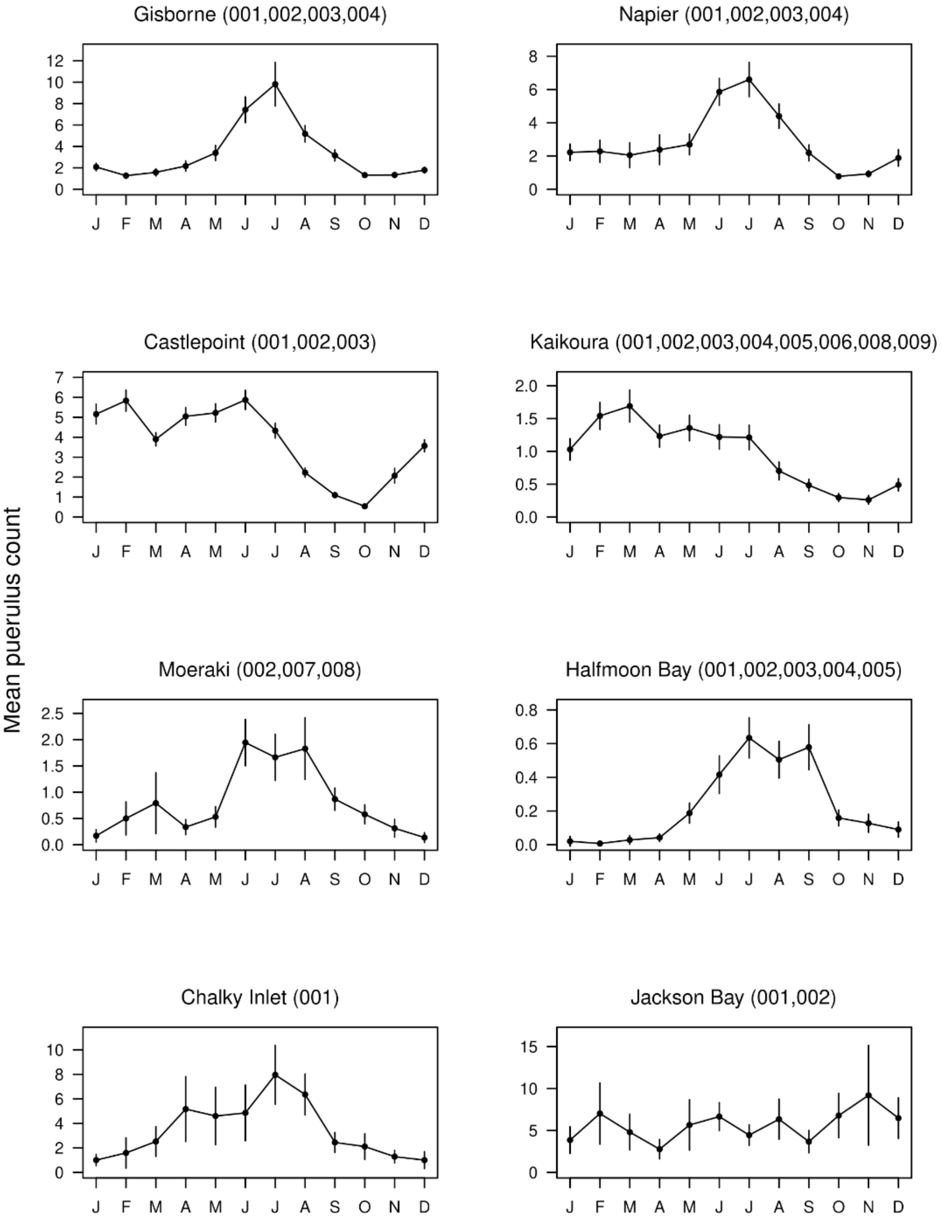

Figure 2: The mean puerulus count by month across all years of sampling for a site, for each key collector site. Vertical lines show 95% confidence intervals for the mean value (for some months this interval is very tight and will not be apparent on the figure). The numbers in brackets identify groups of collectors from which the data are summarised in this figure. See Table 1 for collector group descriptors.

Gisborne

Settlement at Gisborne in the 2022 fishing year was above the long-term mean (Figure 3). There has been a gradual increase in settlement since the record low in 2017 with the last three years above the long-term mean. Kaiti (GIS004), the only site presently operating in Gisborne since Whangara was stopped in 2021, recorded high settlement between June and August, but relatively low or zero settlement in the other months that were sampled (Figure 4).

Napier

Settlement at Napier was below the long-term mean (Figure 5). At Port of Napier (NAP001), settlement was low in all of months sampled. At Cape Kidnappers (NAP003), settlement was higher than Port of Napier in all but one month. Settlement peaked in June with moderate settlement from July to January

(Figure 6). The last five years have been below average and over the last 17 years, settlement has only been close to or below the long-term mean.

Castlepoint
At Castlepoint, settlement was above the long-term mean (Figure 7). Except for September, the levels and pattern of settlement were very similar at Castlepoint (CPT001) and Orui (CPT002) with both sites peaking in June (Figure 8). This is the third consecutive year of above average settlement in this area and five of the last eight years have been above average.

Kaikōura
Settlement at Kaikōura was just below the long-term mean (Figure 9). South Bay (KAI001) had low levels of settlement in all months (Figure 10). North Bay (KAI002) was very low in all months except February and March. South Kaikōura (KAI003) recorded the best settlement of all Kaikōura sites with high levels of settlement in May and June but had similar levels of settlement to other sites in the other months. Haumuri Bluffs (KAI006) had moderate settlement in May, July, August, and March, but all other months that were sampled were low. A new group of collectors, North Coast (KAI010), had moderate settlement in April, July, and March but low settlement in all other months.

Moeraki
For the first time in eight years, settlement at Moeraki was just below the long-term mean (Figure 11). Settlement at New wharf (MOE008) peaked in May, and, although generally low, some level of settlement occurred in all other months (except for March) which is unusual for this site (Figure 12).

Halfmoon Bay
Above average levels of settlement were recorded in Halfmoon Bay (Figure 13). Settlement was relatively high in July and September but relatively low or zero for all other months that were sampled (Figure 14).

Jackson Bay
Settlement was below the long-term mean at Jackson Bay (Figure 15). This is the fourth consecutive year of average to below average settlement. There were two peaks in settlement recorded, one in June and the other in October to December (Figure 16).

Chalky Inlet
No new data were received in the 2022 fishing year. Historical data are shown in Figure 17.

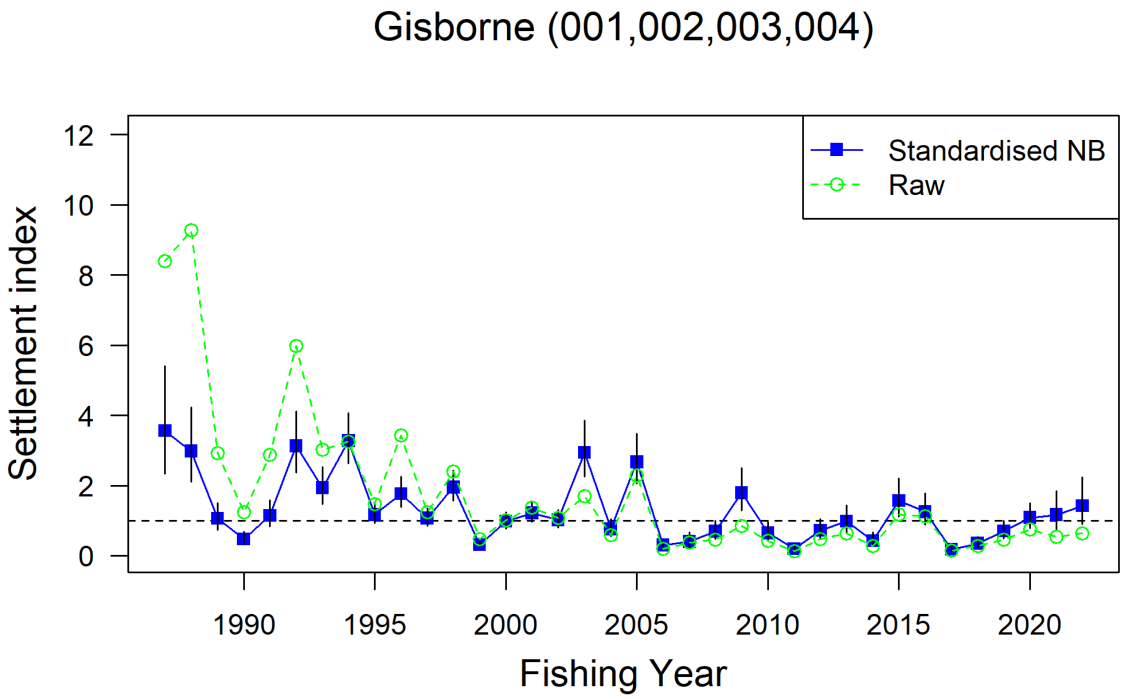

Figure 3: Standardised negative binomial (NB) and raw indices of annual settlement for Gisborne, with 95% confidence intervals, for the 1987–2022 fishing years. The figure title indicates the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

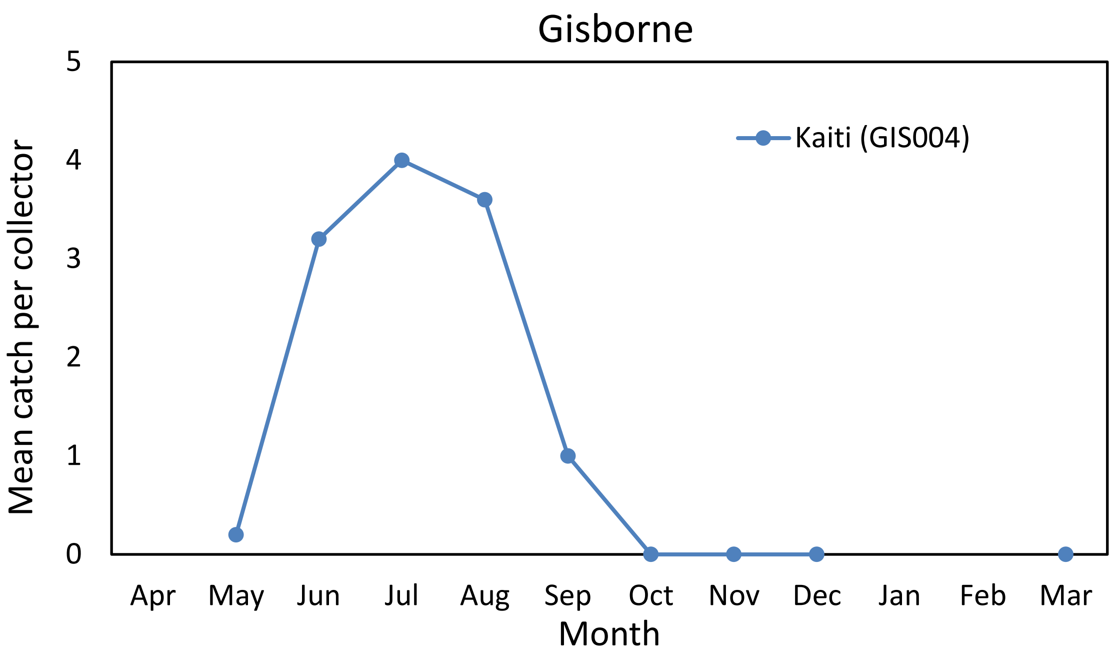

Figure 4: Monthly settlement in the 2022 fishing year for the Gisborne site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector. Where the monthly plot icon (blue circle) is absent, no sampling occurred.

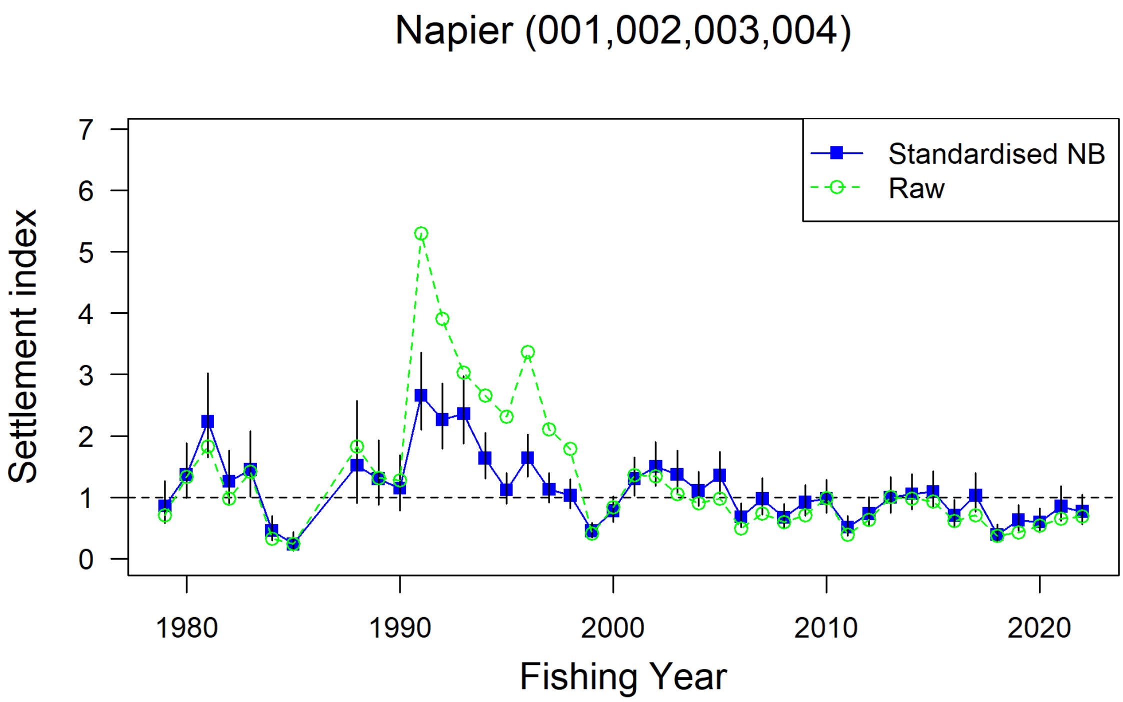

Figure 5: Standardised negative binomial (NB) and raw indices of annual settlement for Napier, with 95% confidence intervals, for fishing years between 1979 and 2022. Note that there were no sampling events in 1986 or 1987. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

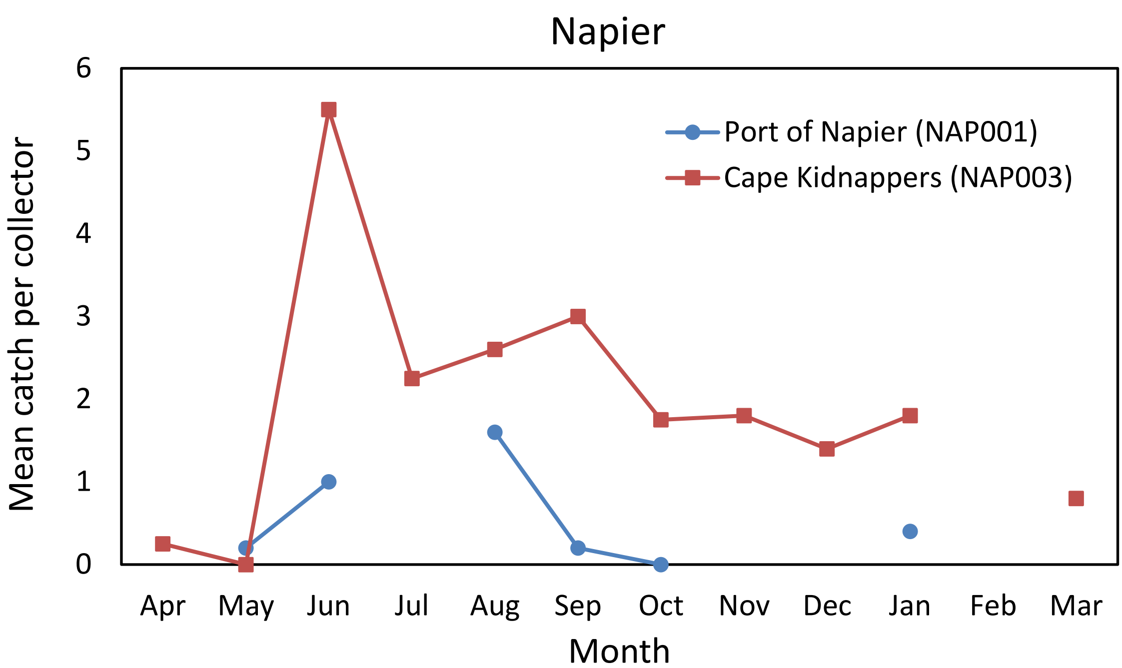

Figure 6: Monthly settlement in the 2022 fishing year for the Napier site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector for each group of collectors (Port of Napier and Cape Kidnappers) within the Napier site. Where the monthly plot icon (square or circle) is absent, no sampling occurred.

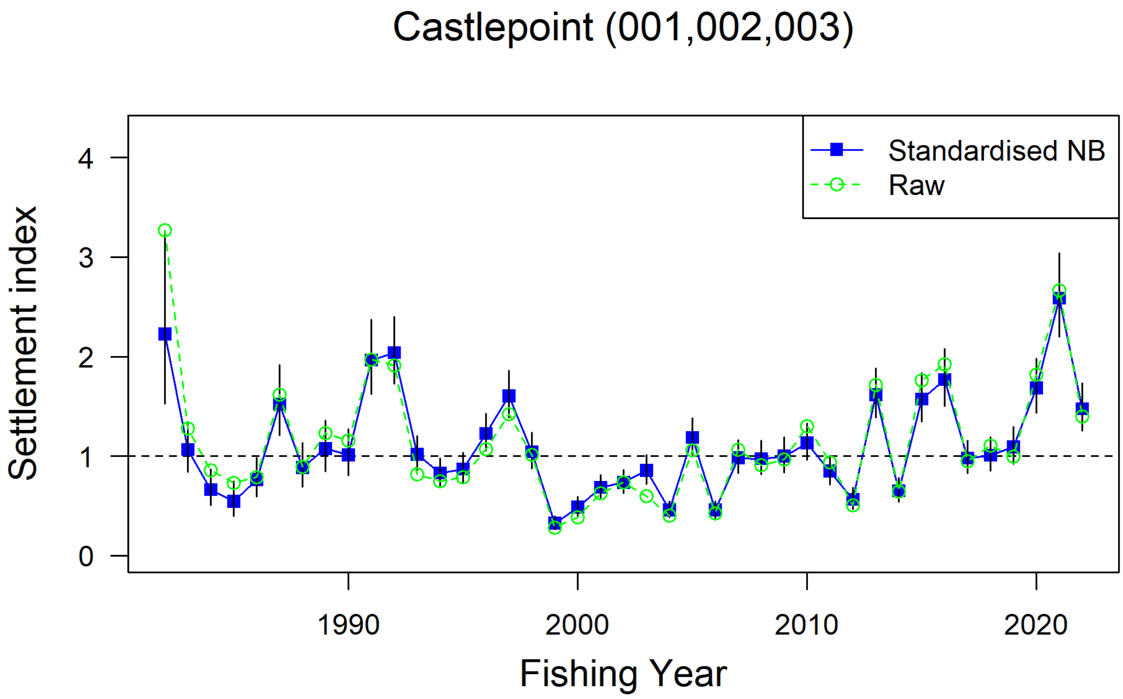

Figure 7: Standardised negative binomial (NB) and raw indices of annual settlement for Castlepoint, with 95% confidence intervals, for the 1982–2022 fishing years. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

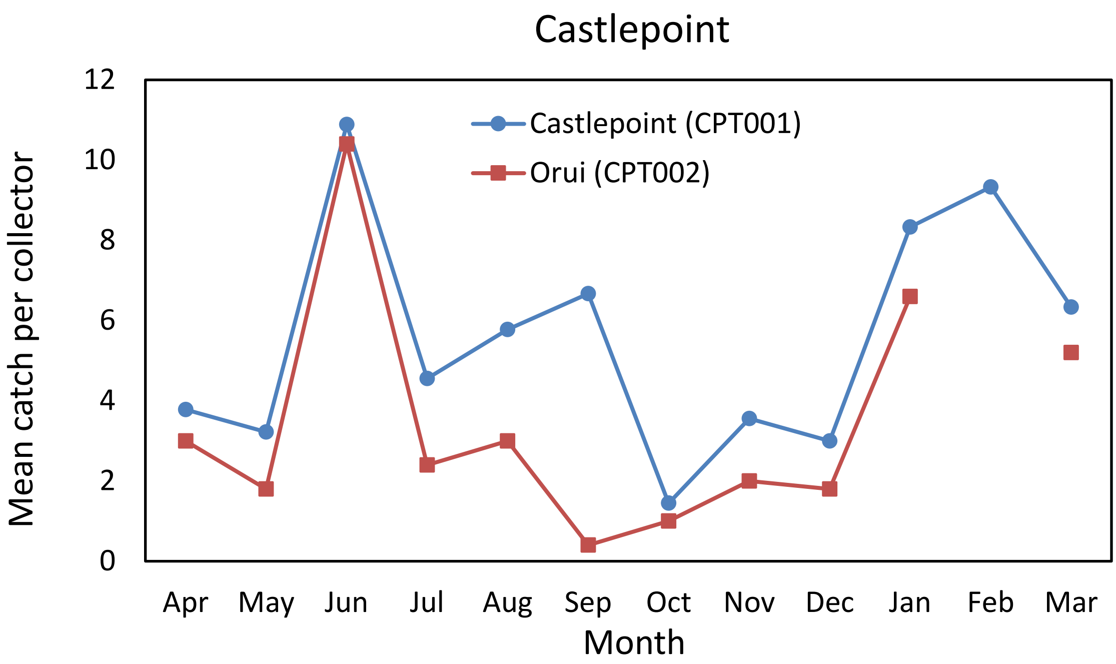

Figure 8: Monthly settlement in the 2022 fishing year for the Castlepoint site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector for each group of collectors (Castlepoint and Orui) within the Castlepoint site. Where the monthly plot icon (square or circle) is absent, no sampling occurred.

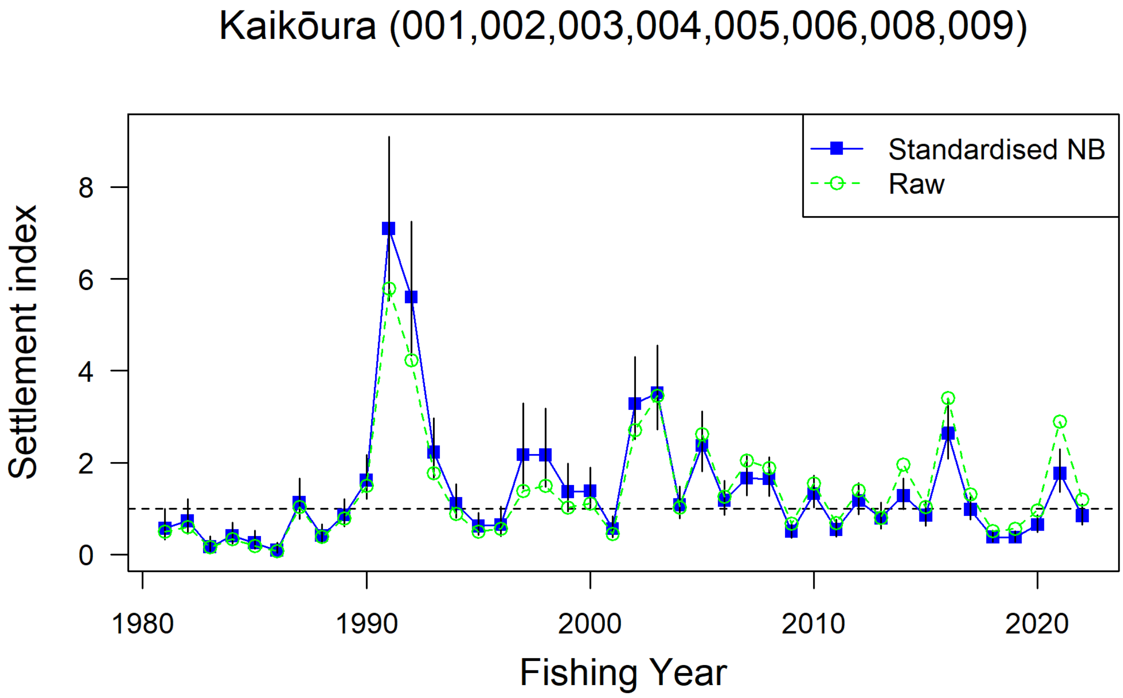

Figure 9: Standardised negative binomial (NB) and raw indices of annual settlement for Kaikōura, with 95% confidence intervals, for the 1981–2022 fishing years. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

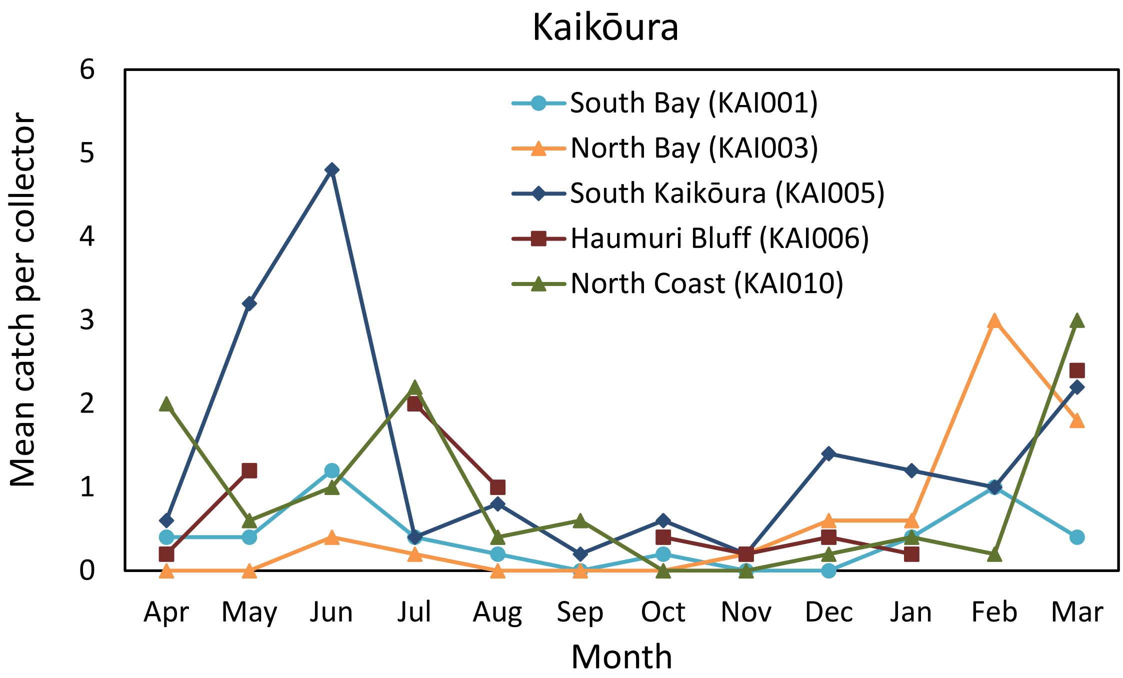

Figure 10: Monthly settlement in the 2022 fishing year for the Kaikōura site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector for each group of collectors (South Bay, North Bay, South Kaikōura, Haumuri Bluff, and North Coast) within the Kaikōura site. Where the monthly plot icon (e.g., square or circle) is absent, no sampling occurred.

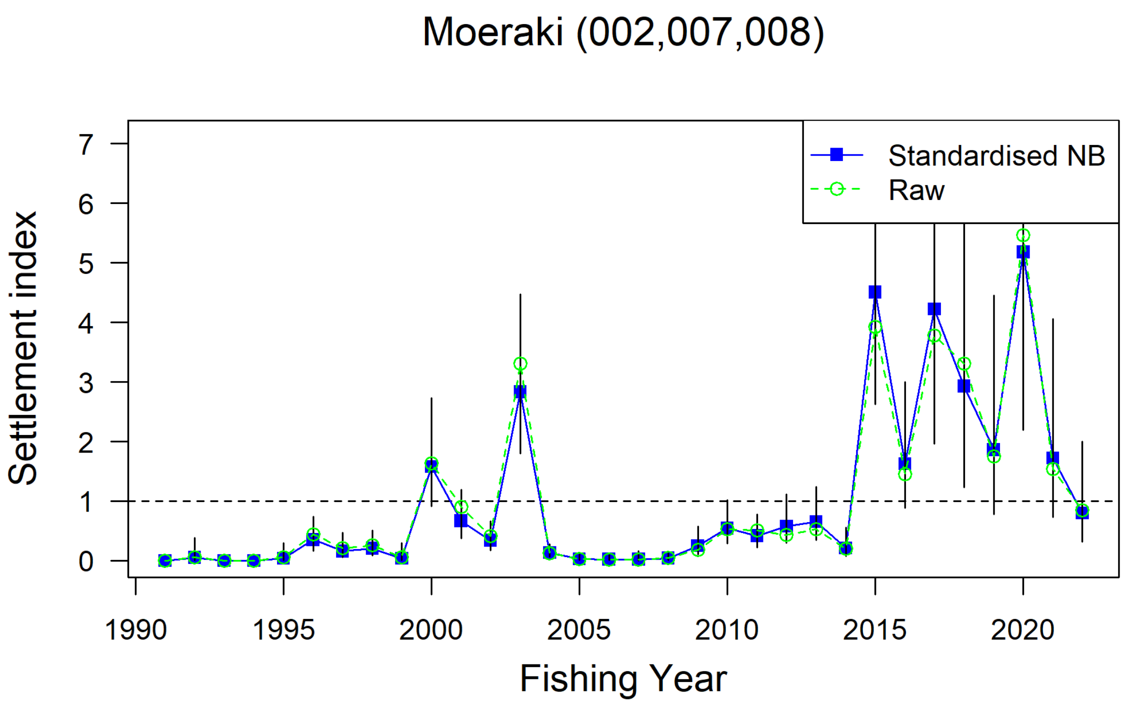

Figure 11: Standardised negative binomial (NB) and raw indices of annual settlement for Moeraki, with 95% confidence intervals (where collectors with less than 36 samples were used), for the 1991–2022 fishing years. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

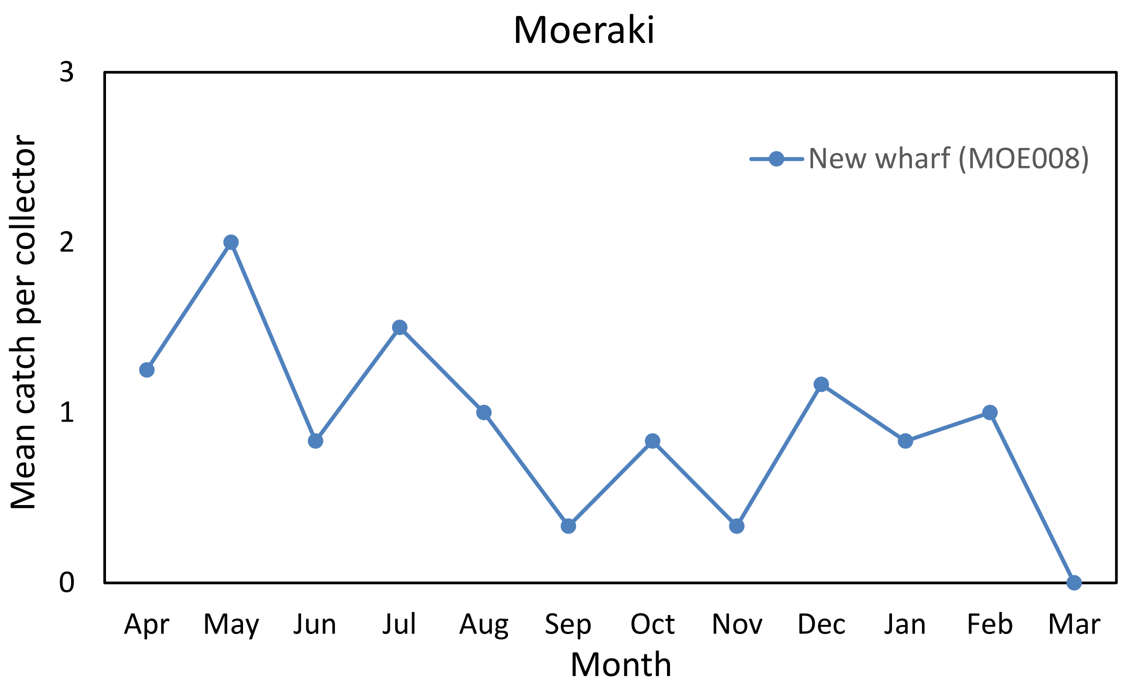

Figure 12: Monthly settlement in the 2022 fishing year for the Moeraki site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

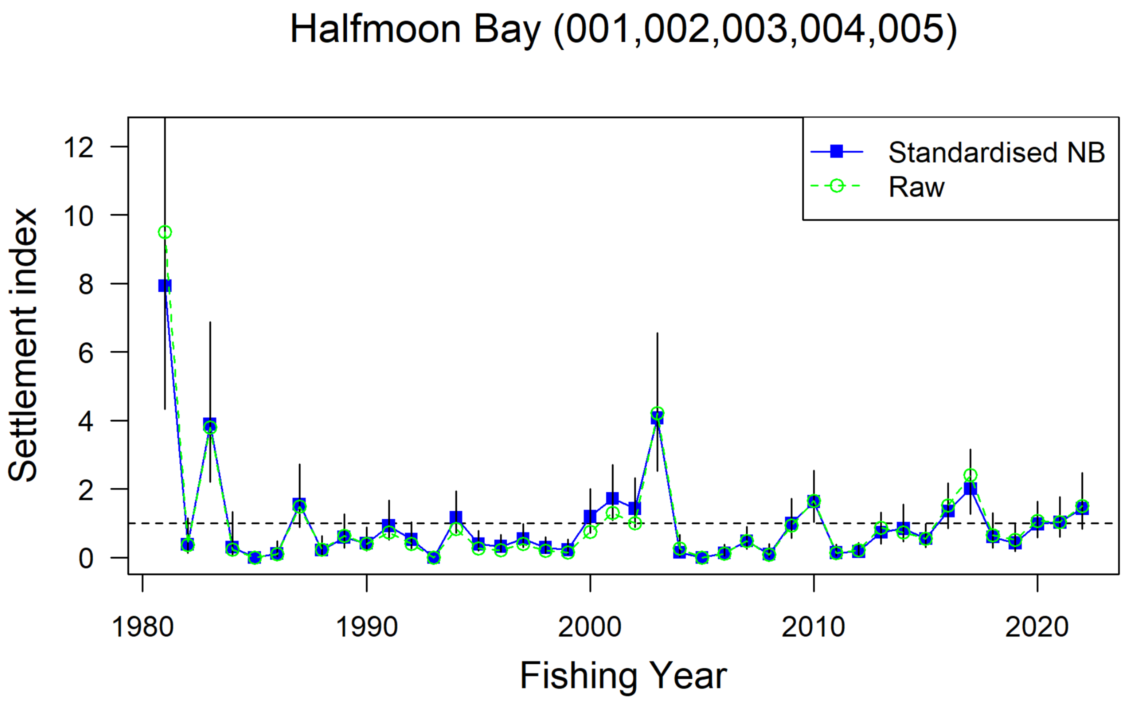

Figure 13: Standardised negative binomial (NB) and raw indices of annual settlement for Halfmoon Bay, with 95% confidence intervals, for the 1981–2022 fishing years. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

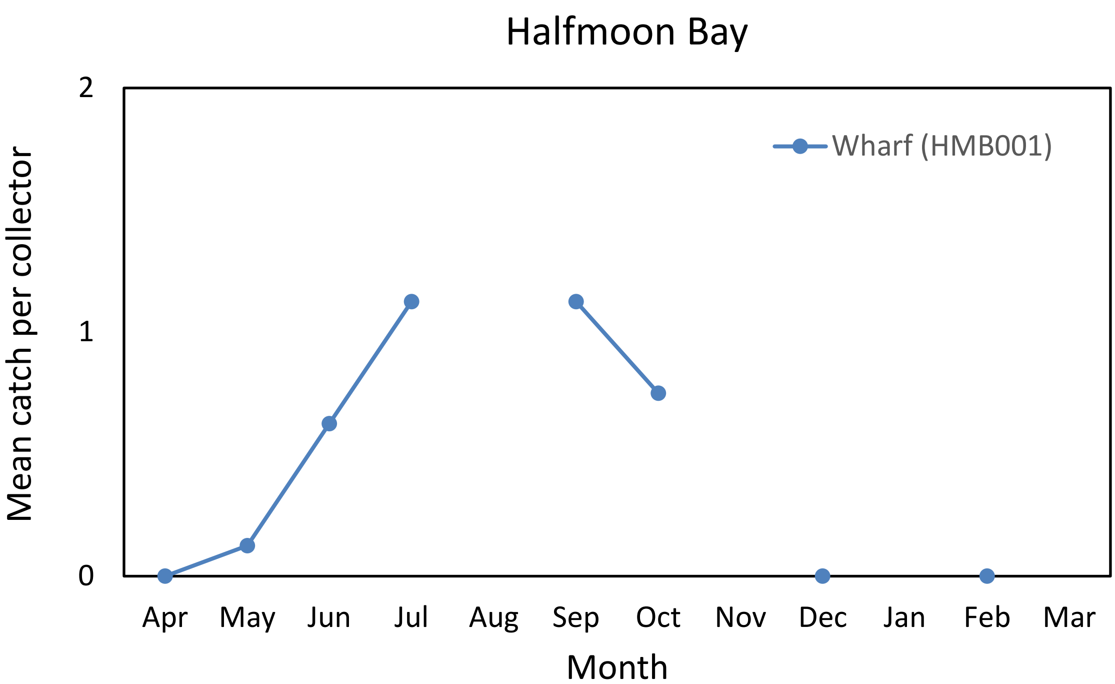

Figure 14: Monthly settlement in the 2022 fishing year for the Halfmoon Bay site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector. Where the monthly plot icon (blue circle) is absent, no sampling occurred.

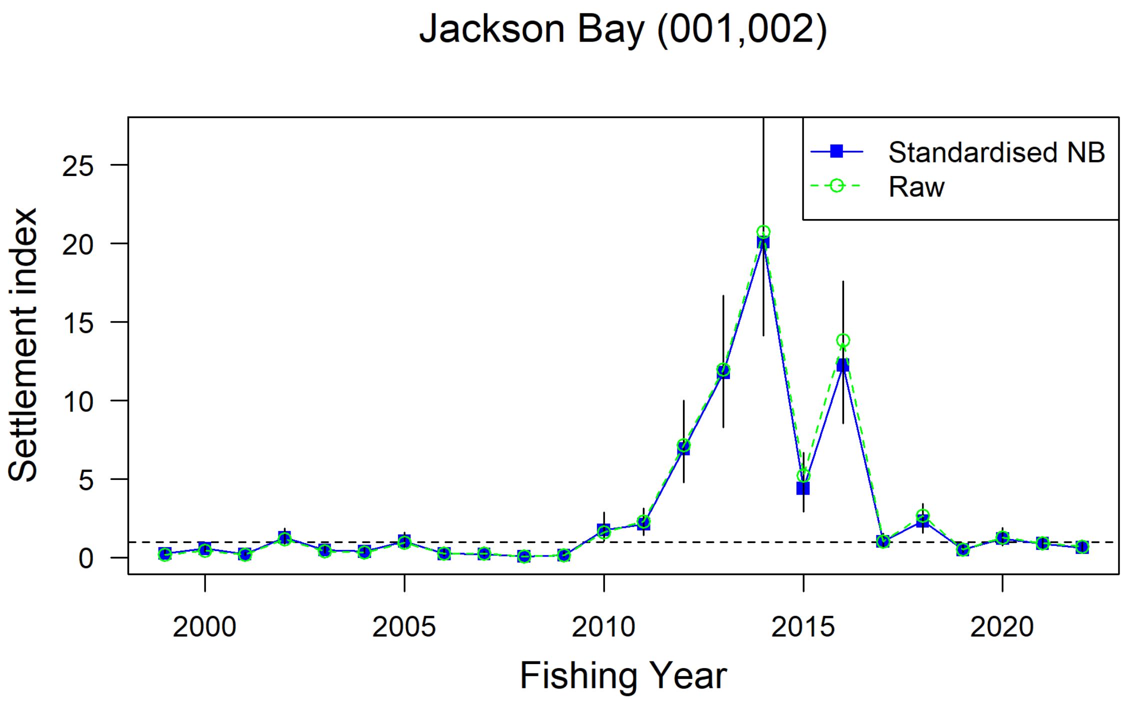

Figure 15: Standardised negative binomial (NB) and raw indices of annual settlement for Jackson Bay, with 95% confidence intervals, for the 1999–2022 fishing years. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

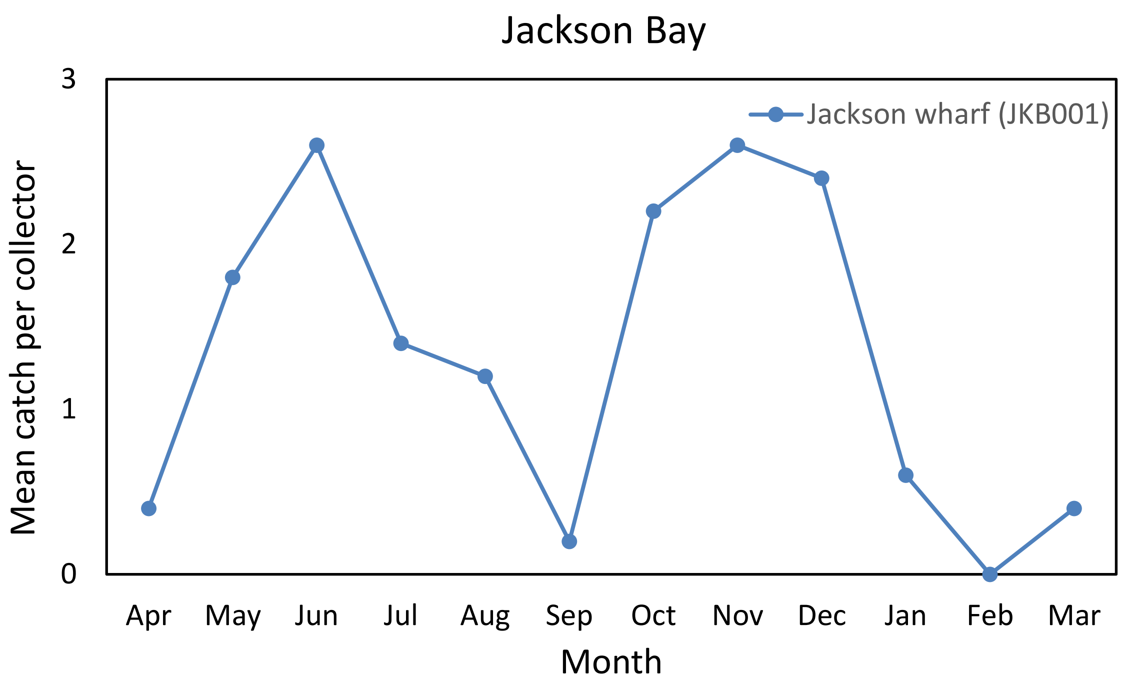

Figure 16: Monthly settlement in the 2022 fishing year for the Jackson Bay site. Values plotted are the monthly mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

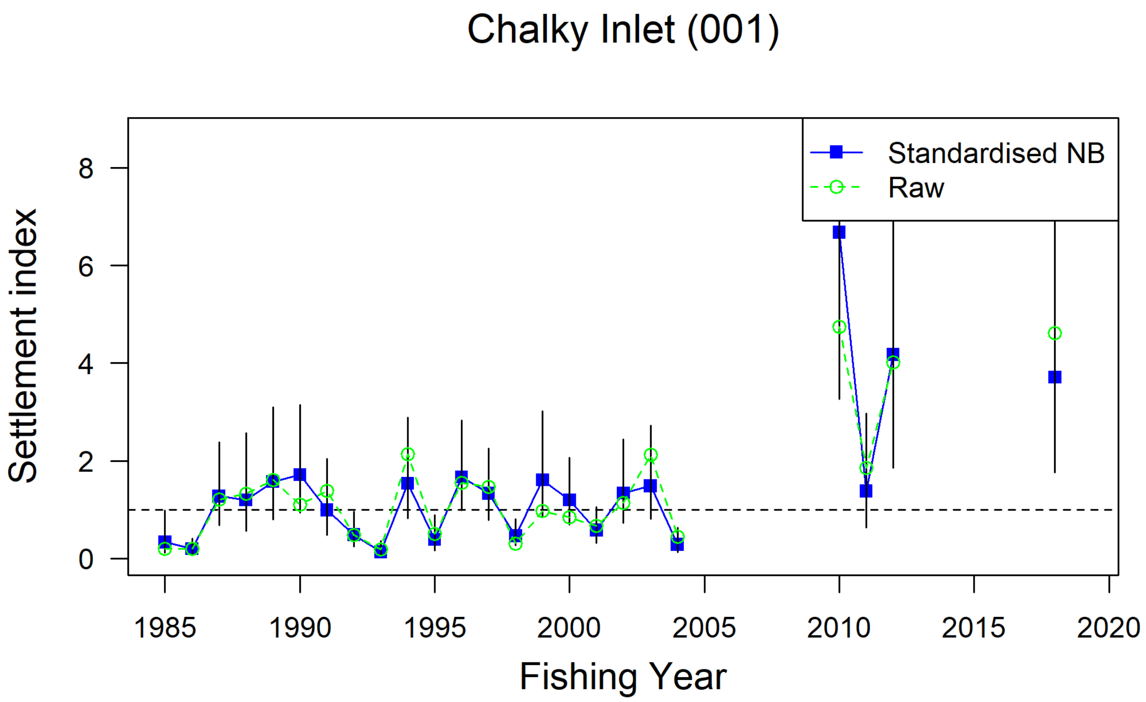

Figure 17: Standardised negative binomial (NB) and raw indices of annual settlement for Chalky Inlet, with 95% confidence intervals, for fishing years between 1985 and 2018. Note that there were no sampling events from 2005 to 2009 and from 2013 to 2017. The figure title shows the groups of collectors used in the standardisation, and the horizontal dashed line at one is the average value of a series over all years.

4. CONCLUSIONS

Settlement in 2022 was above average at Gisborne (CRA 3), Castlepoint (CRA 4) and Halfmoon Bay (CRA 8), and below average at Napier (CRA 4), Kaikōura (CRA 5), and Moeraki (CRA 7), but there was no exceptionally high or low settlement at any of the monitored sites in the 2022 fishing year.

At Gisborne, there has been a gradual increase in settlement since the record low in 2017, with the last three years above the long-term mean. At Napier, settlement continues to be low with the last five years below the long-term mean. Castlepoint continues a good run of settlement with seven of the last eight years above the long-term mean, including record settlement in 2021. At Kaikōura, settlement has been below or close to the long-term mean in five of the last six years. Settlement at Moeraki, although low this year, has recorded settlement well above the long-term mean in the previous seven years. Halfmoon Bay, although above the long-term mean this year, has seen low to average settlement over the last four years. At Jackson Bay, this is the fourth consecutive year of average or below average settlement and there has been a steady decline in settlement since the very high settlement period between 2012 and 2015.

For Gisborne, Napier, and Castlepoint, the puerulus index is potentially a signal for recruited abundance 4–6 years into the future; for Moeraki, the estimated interval is 4–5 years; and for Halfmoon Bay it is 6–8 years (Booth & McKenzie 2008).

5. ACKNOWLEDGEMENTS

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APPENDIX 1: DATA CHARACTERISTICS AND DIAGNOSTICS

For each site, plots are given for puerulus data characteristics and standardisation diagnostics (Figures 18–45). To reduce the number of zeros, a subset of months was used for many of the standardisations (see Table 2). The number of puerulus samples by group and fishing year at each site are given in Tables 4–10.

The diagnostics show that the negative binomial distribution is a good fit for the distribution of puerulus counts, although for Jackson Bay this model is not as good when compared with the other sites. The deviance residuals tend to be less for higher predicted count values, but the difference is not of a size that would lead to biased parameter estimates in the standardisations (more than two-fold difference).

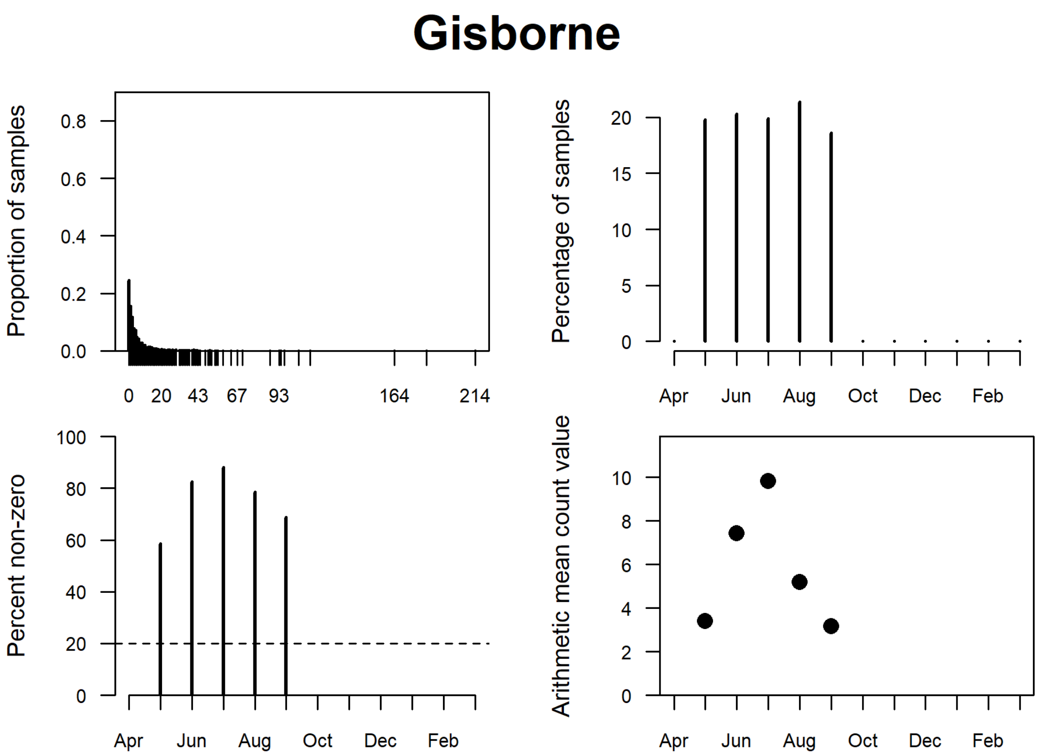

Figure 18: Characteristics of the Gisborne puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with that count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

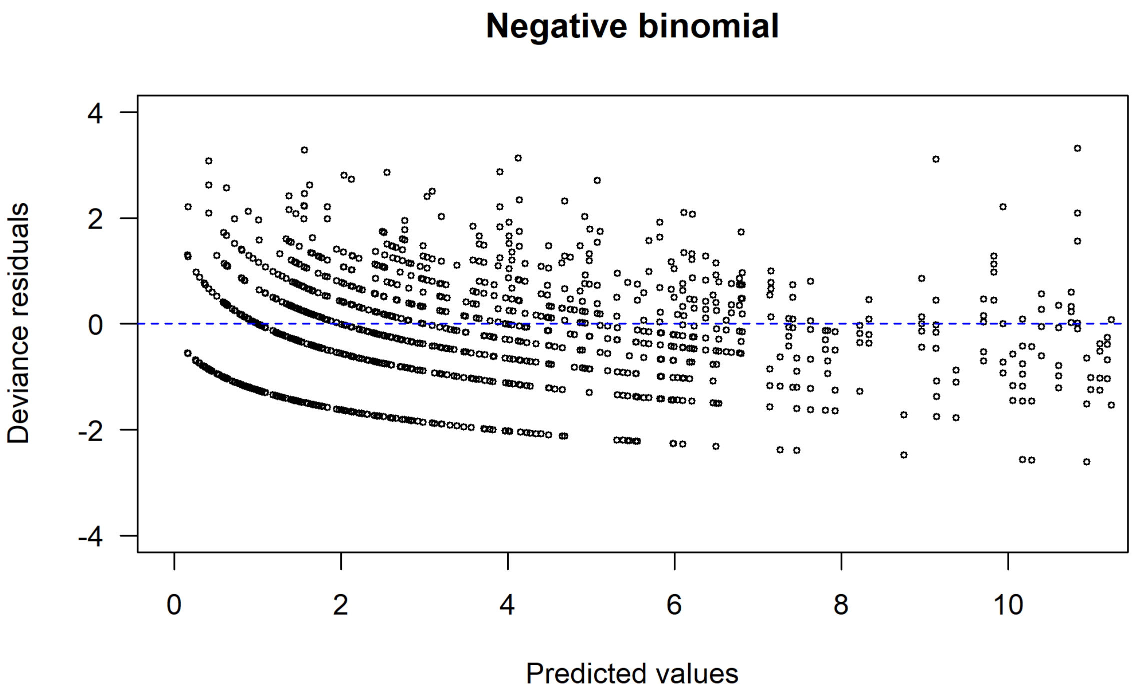

Figure 19: Deviance residuals for the negative binomial model for Gisborne. Predicted values are in natural space.

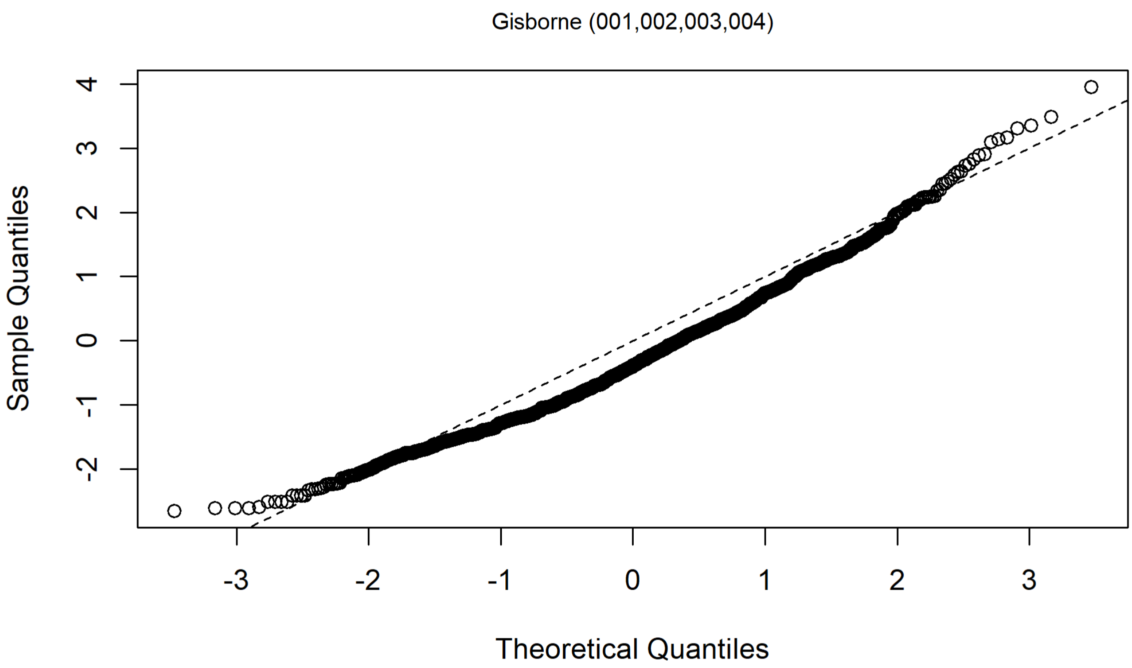

Figure 20: Quantile-quantile plot for the negative binomial standardisation model for Gisborne.

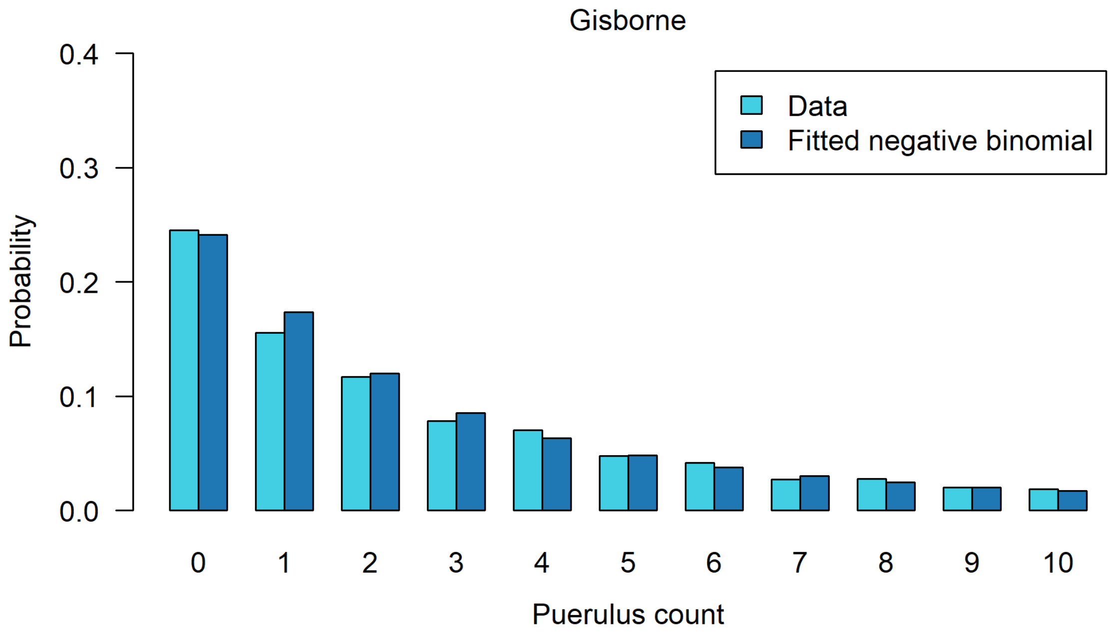

Figure 21: Distribution of data and of fitted data from the negative binomial model for Gisborne.

Table 4: Gisborne standardisation data set. Number of puerulus sampling events by group and fishing year.

Fishing year	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
2016	0	20	0	19	39
2017	0	20	0	18	38
2018	0	25	0	19	44
2019	0	24	0	24	48
2020	0	25	0	25	50
2021	0	5	0	20	25
2022	0	0	0	25	25

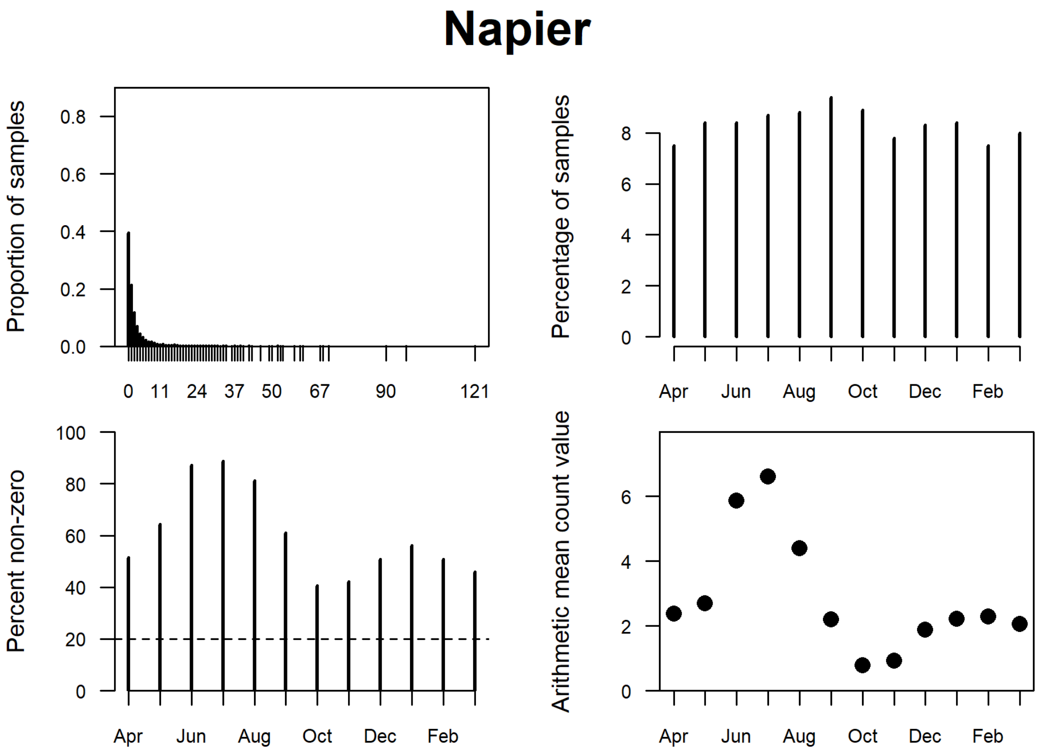

Figure 22: **Characteristics of the Napier puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.**

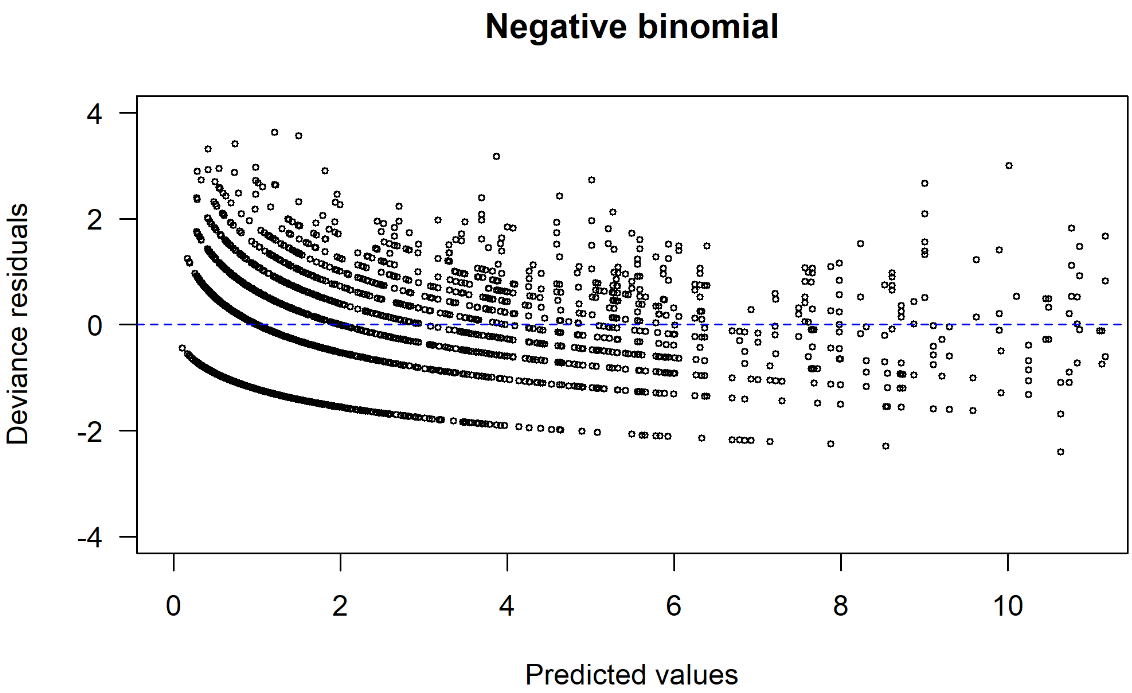

Figure 23: Deviance residuals for the negative binomial model for Napier. Predicted values are in natural space.

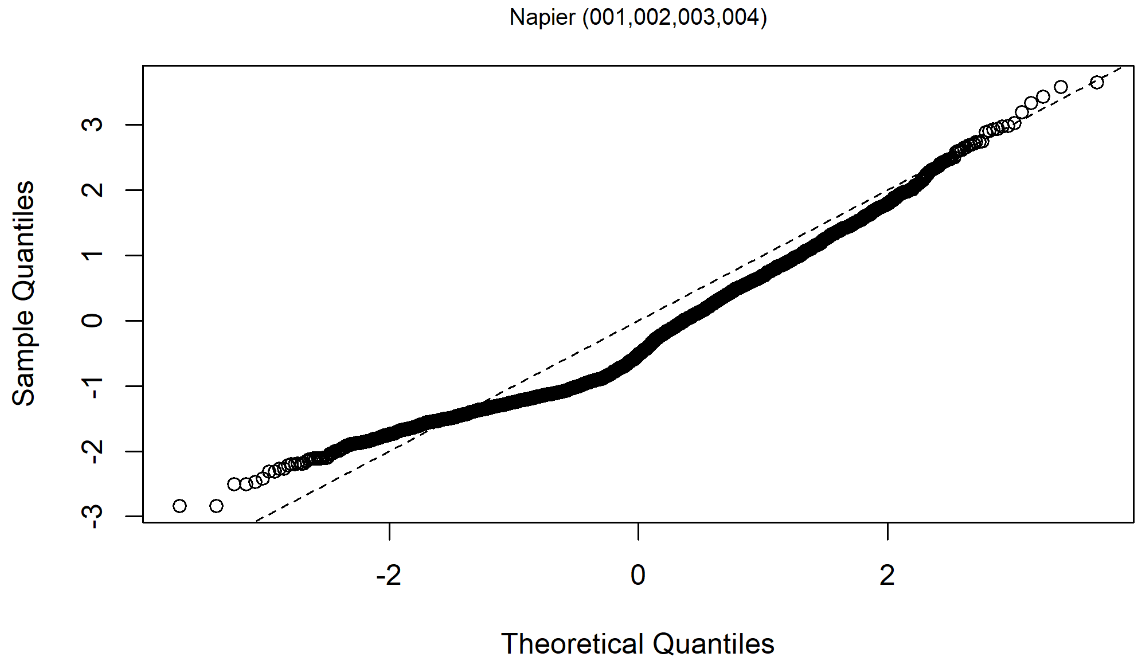

Figure 24: Quantile-quantile plot for the negative binomial standardisation model for Napier.

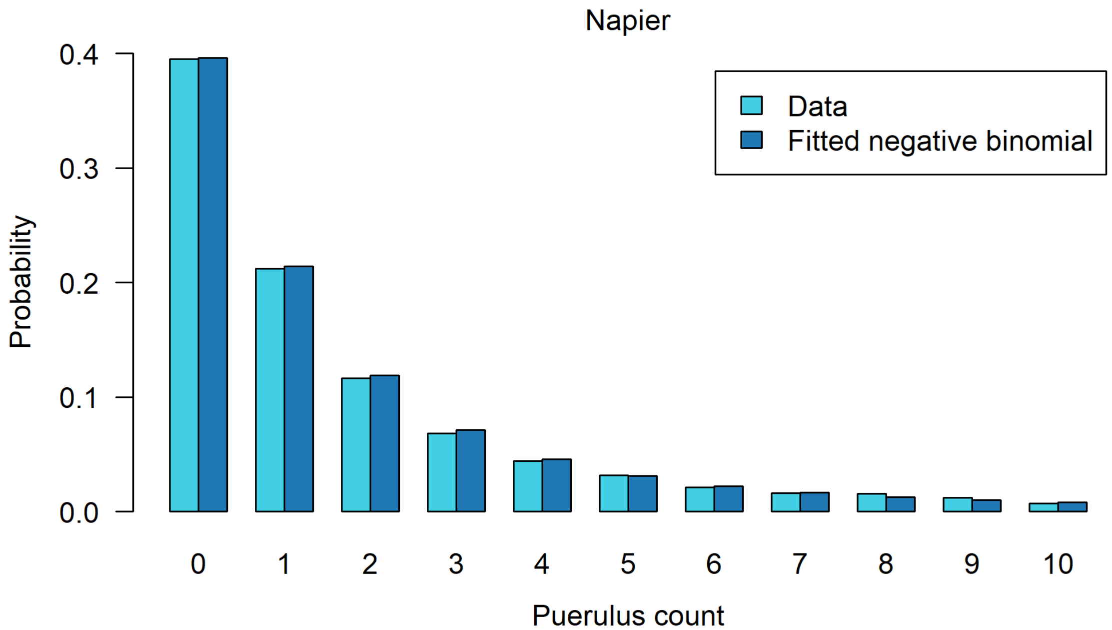

Figure 25: Distribution of data and of fitted data from the negative binomial model for Napier.

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

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
2016	40	0	53	0	93
2017	40	0	41	0	81
2018	35	0	57	0	92
2019	45	0	46	0	91
2020	40	0	48	0	88
2021	25	0	53	0	78
2022	30	0	51	0	81

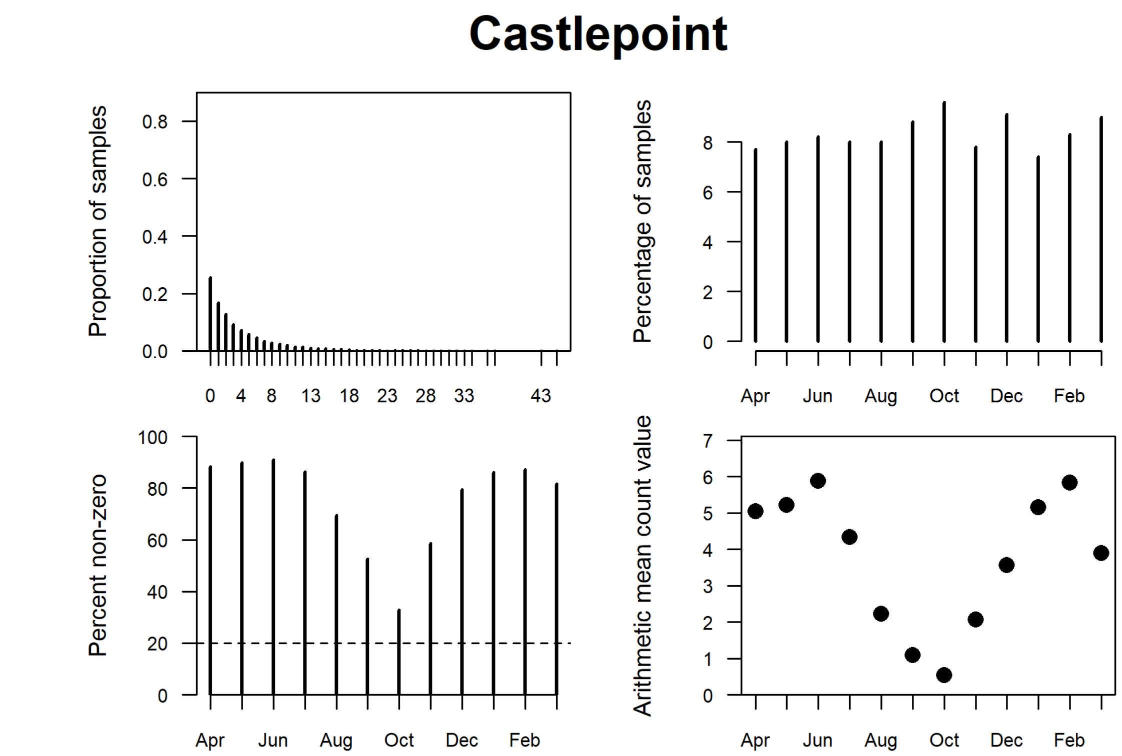

Figure 26: Characteristics of the Castlepoint puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

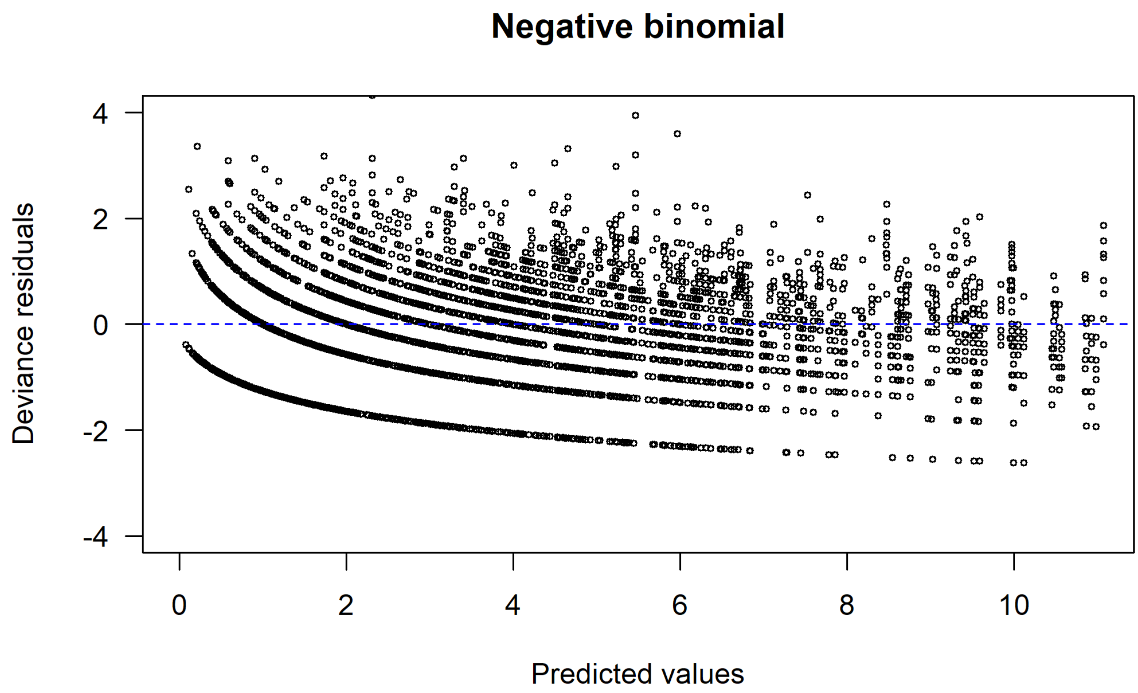

Figure 27: Deviance residuals for the negative binomial model for Castlepoint. Predicted values are in natural space.

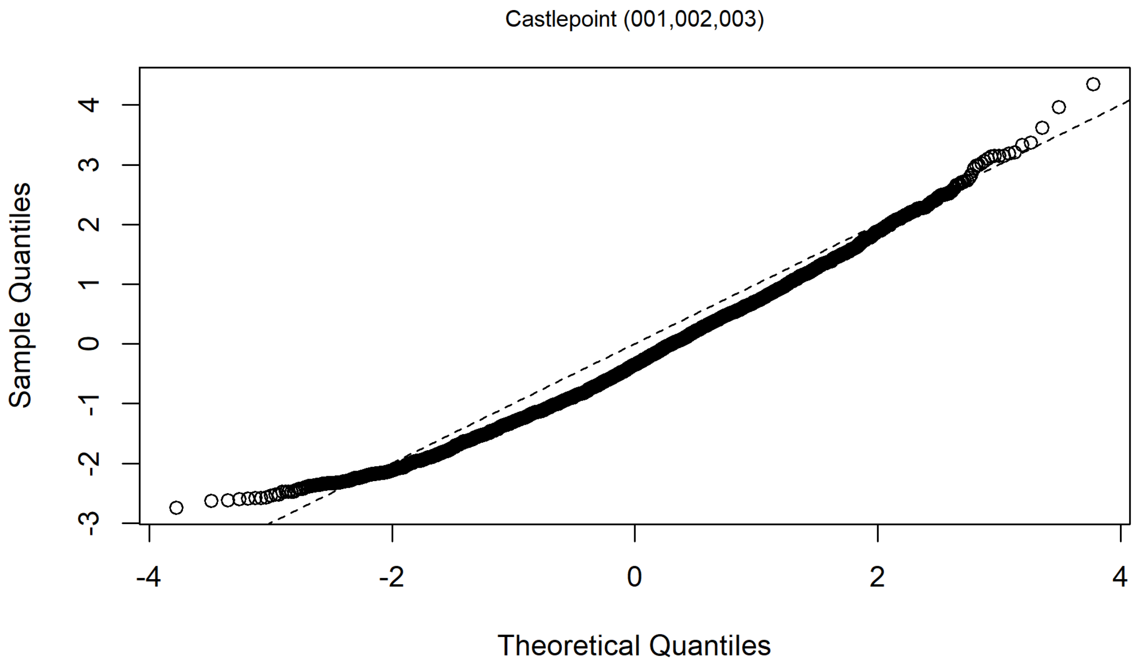

Figure 28: Quantile-quantile plot for the negative binomial standardisation model for Castlepoint.

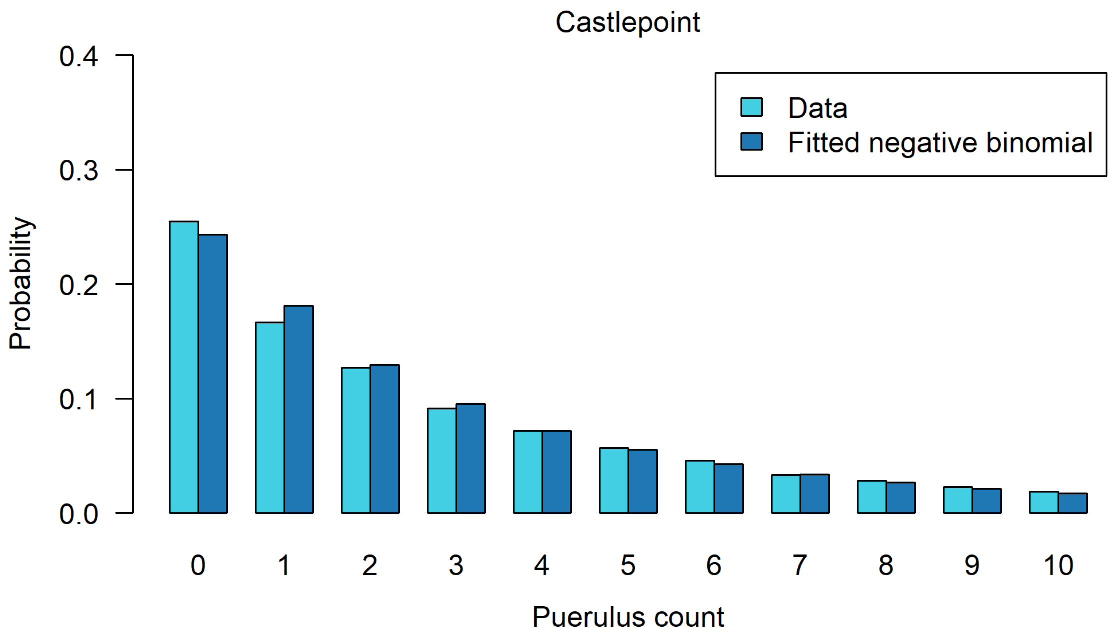

Figure 29: Distribution of data and of fitted data from the negative binomial model for Castlepoint.

Table 6: Castlepoint standardisation data set. Number of puerulus samples by group and fishing year.

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	64	0	169
2016	103	52	0	155
2017	107	58	0	165
2018	107	55	0	162
2019	106	40	0	146
2020	105	46	0	151
2021	107	30	0	137
2022	106	55	0	161

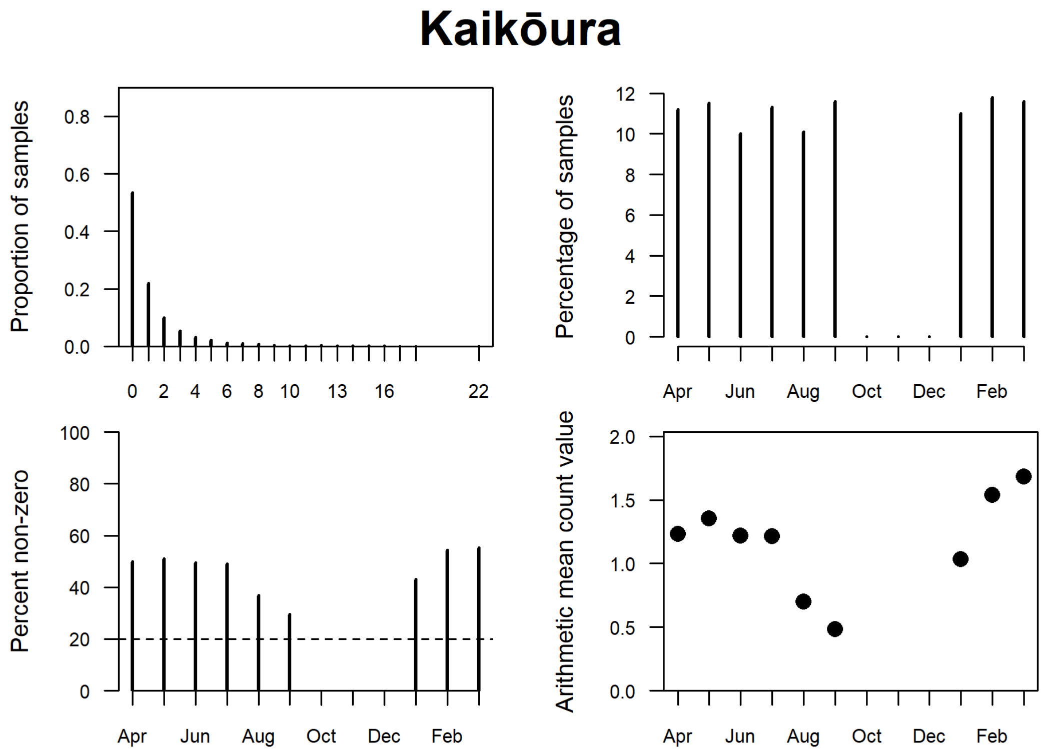

Figure 30: Characteristics of the Kaikōura puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

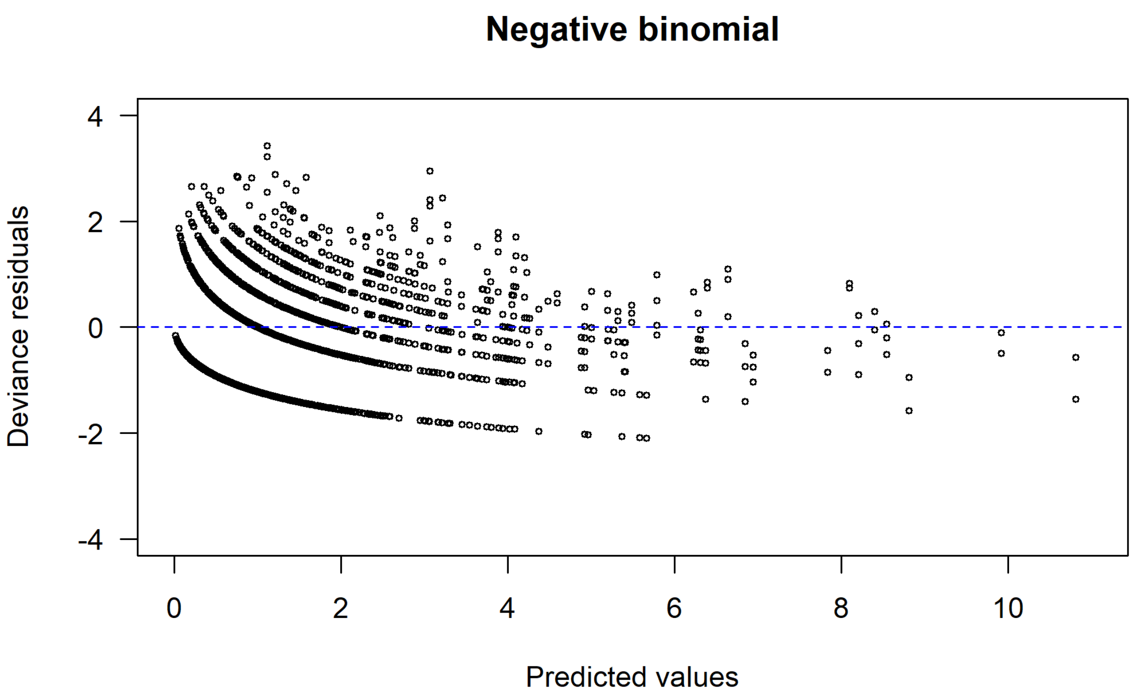

Figure 31: Deviance residuals for the negative binomial model for Kaikōura. Predicted values are in natural space.

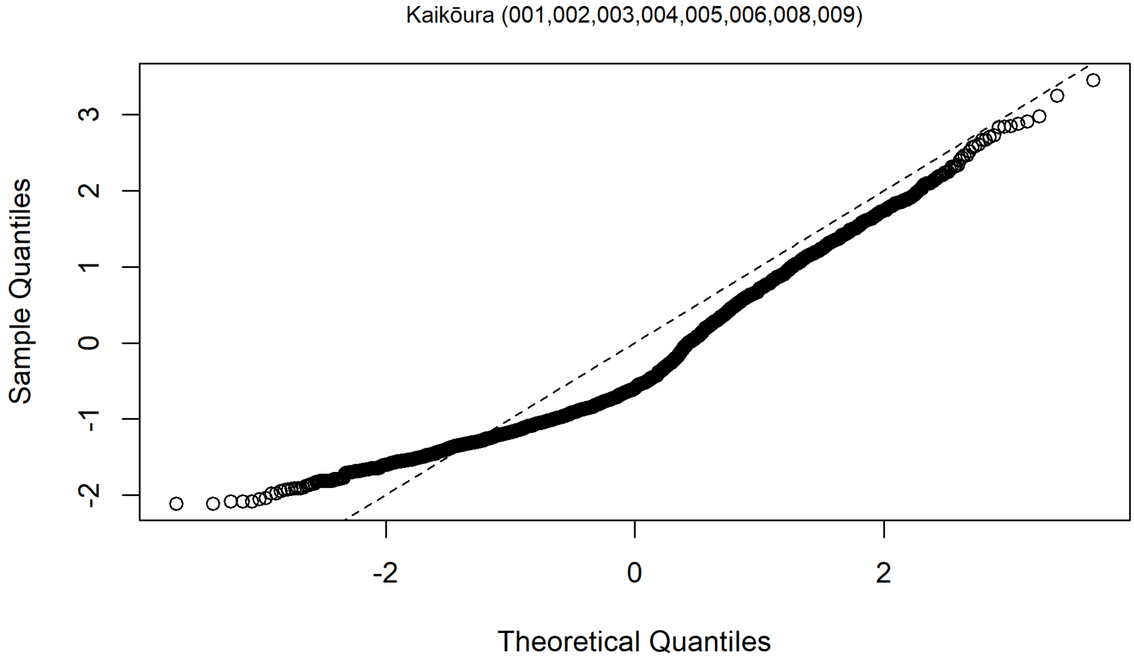

Figure 32: Quantile-quantile plot for the negative binomial standardisation model for Kaikōura.

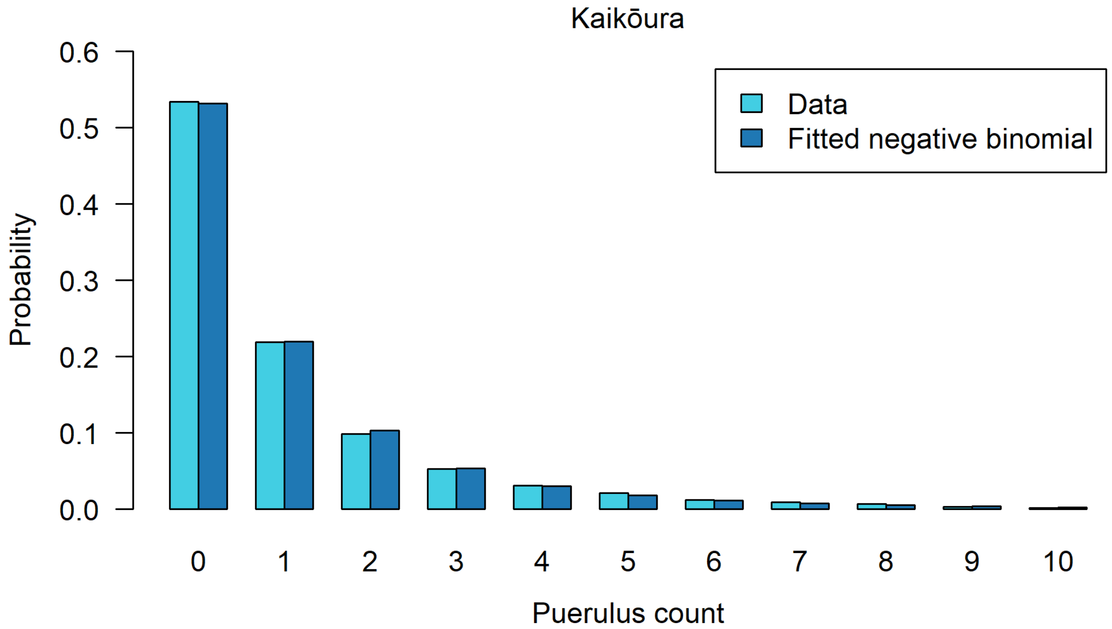

Figure 33: Distribution of data and of fitted data from the negative binomial for Kaikōura.

Table 7: Kaikōura standardisation data set. Number of puerulus samples by group and fishing year.

Fishing year	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	12	6	0	0	103
2013	39	0	40	0	4	3	0	0	86
2014	40	0	40	0	32	24	0	0	136
2015	45	0	45	0	16	9	0	0	115
2016	45	0	45	0	15	15	0	0	120
2017	45	0	45	0	40	40	0	0	170
2018	45	0	45	0	45	40	0	0	175
2019	42	0	45	0	45	25	0	0	157
2020	40	0	40	0	45	33	0	0	158
2021	15	0	15	0	45	38	0	0	113
2022	45	0	45	0	45	30	0	0	165

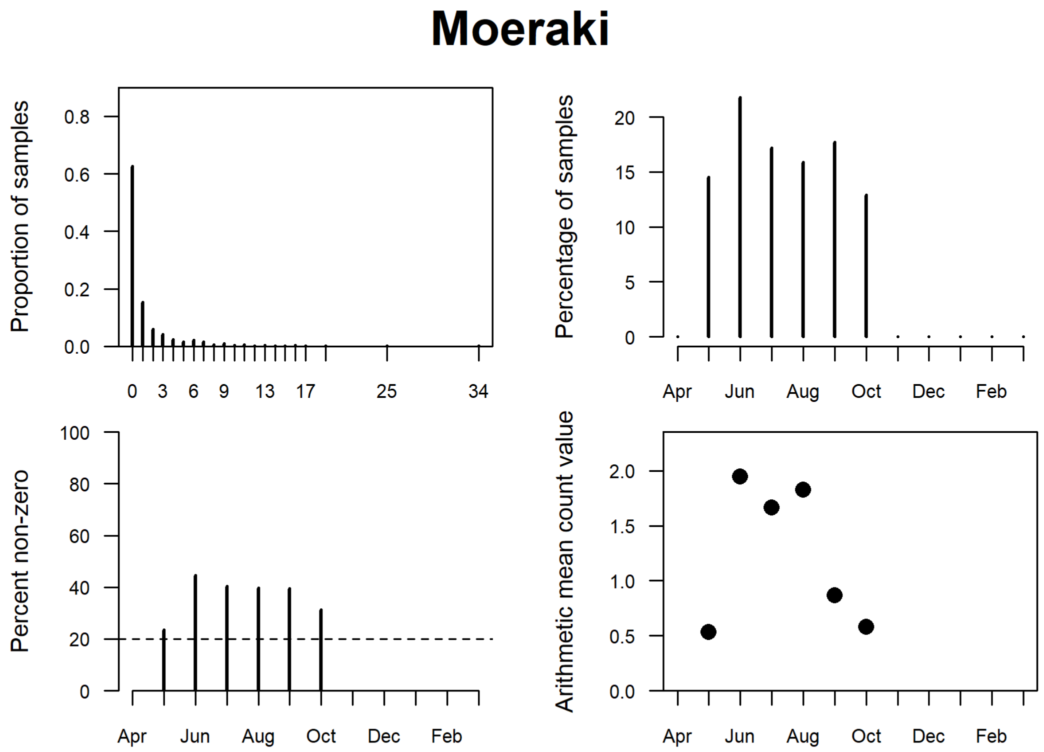

Figure 34: Characteristics of the Moeraki puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

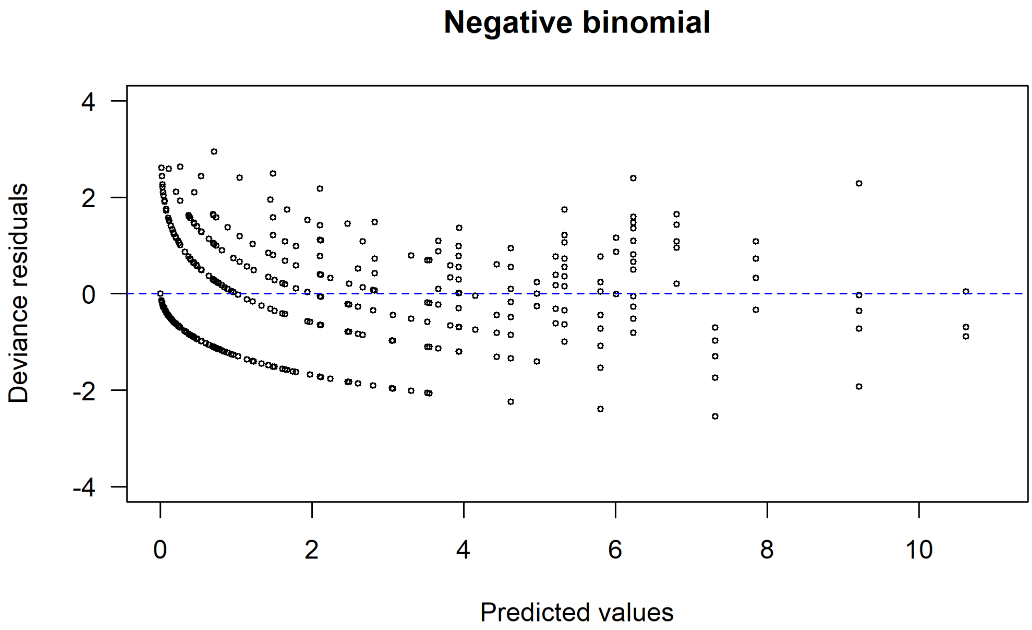

Figure 35: Deviance residuals for the negative binomial model for Moeraki. Predicted values are in natural space.

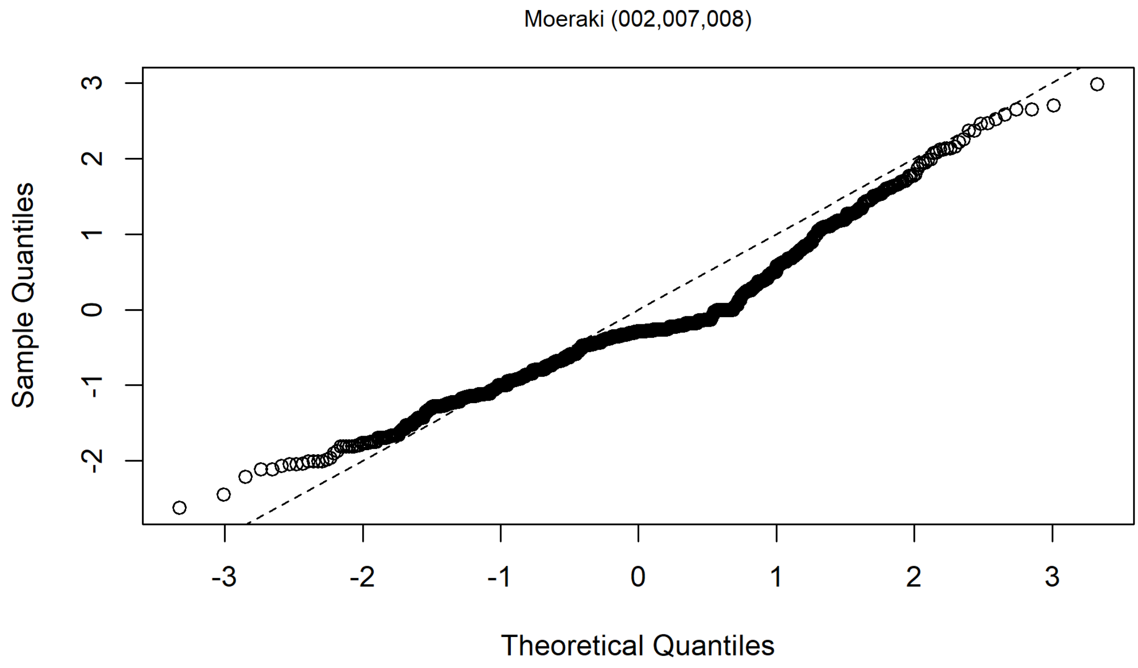

Figure 36: Quantile-quantile plot for the negative binomial standardisation model for Moeraki.

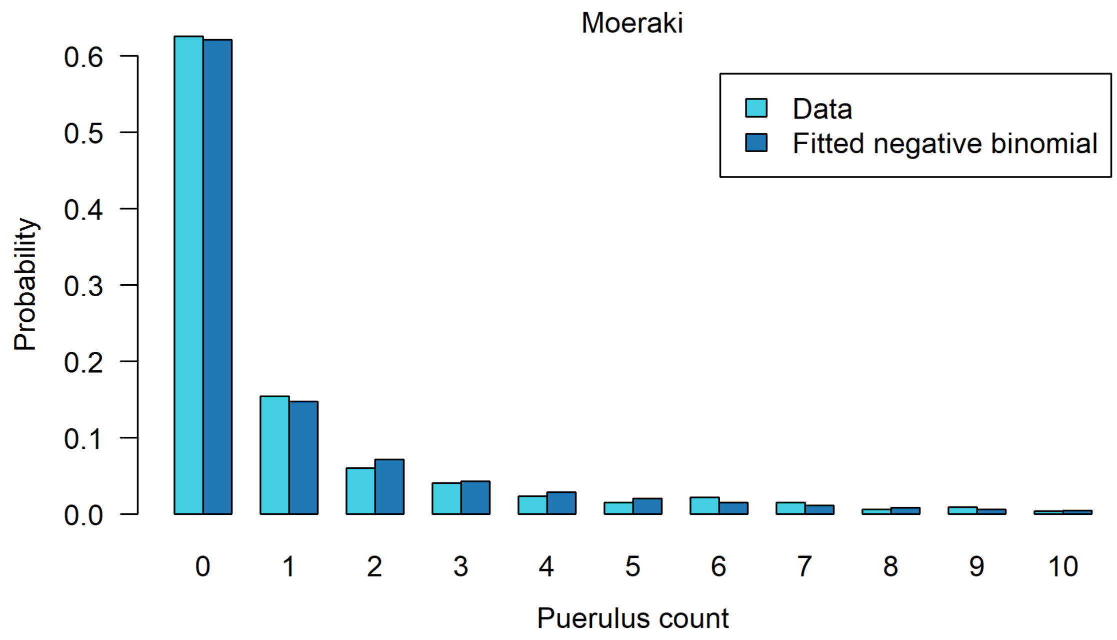

Figure 37: Distribution of data and of fitted data from the negative binomial for Moeraki.

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

Fishing year	MOE002	MOE007	MOE008	Total
1991	16	0	0	16
1992	14	0	0	14
1993	12	0	0	12
1994	15	0	0	15
1995	15	0	0	15
1996	18	0	0	18
1997	15	0	0	15
1998	18	0	0	18
1999	15	0	0	15
2000	15	0	0	15
2001	17	4	0	21
2002	18	9	0	27
2003	15	67	0	82
2004	6	71	0	77
2005	15	71	0	86
2006	6	73	0	79
2007	0	52	0	52
2008	0	73	0	73
2009	0	39	0	39
2010	0	46	0	46
2011	0	50	0	50
2012	0	36	0	36
2013	0	36	0	36
2014	0	24	0	24
2015	0	36	0	36
2016	0	30	0	30
2017	0	6	41	47
2018	0	0	26	26
2019	0	0	28	28
2020	0	0	26	26
2021	0	0	35	35
2022	0	0	26	26

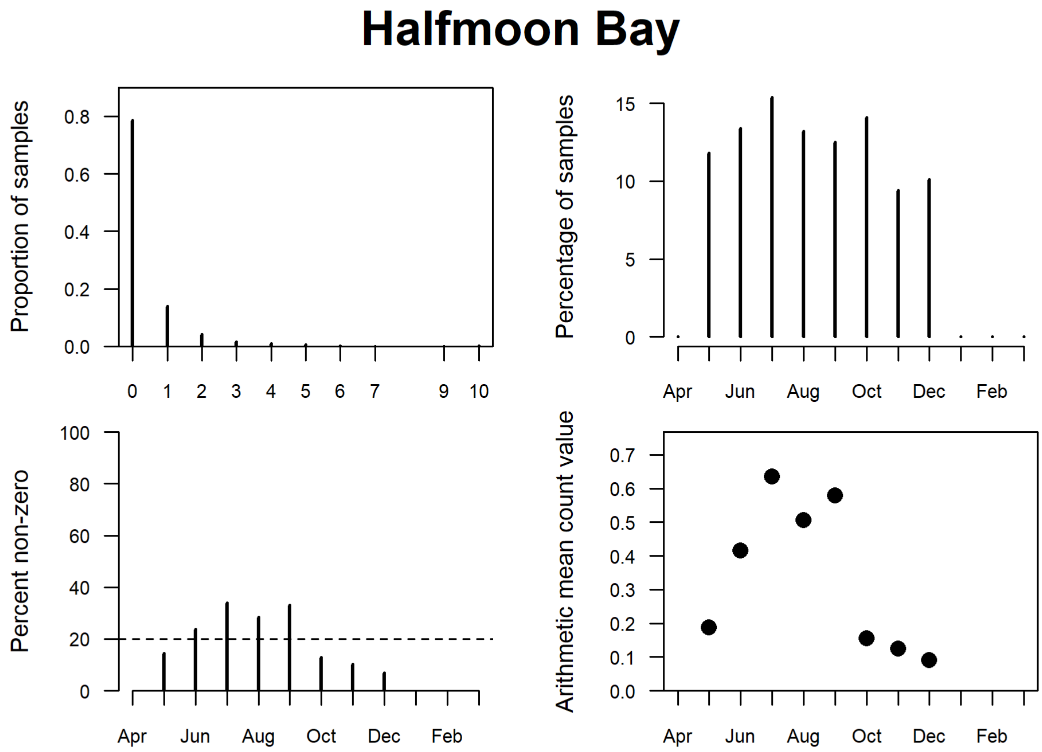

Figure 38: Characteristics of the Halfmoon Bay puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

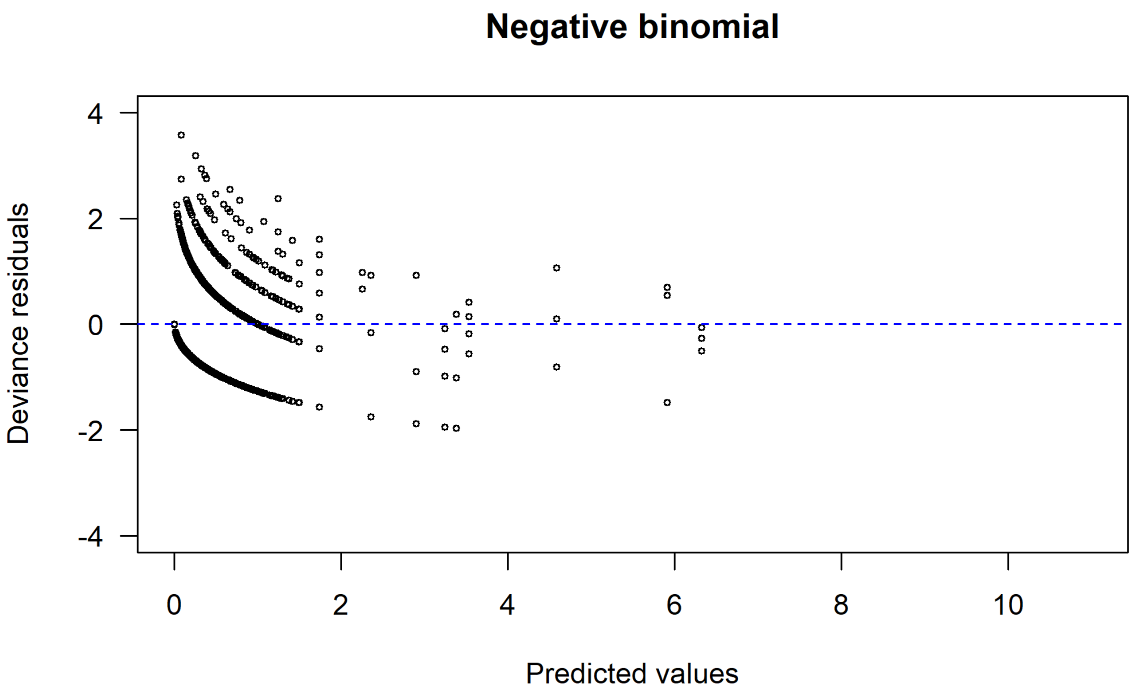

Figure 39: Deviance residuals for the negative binomial model at Halfmoon Bay. Predicted values are in natural space.

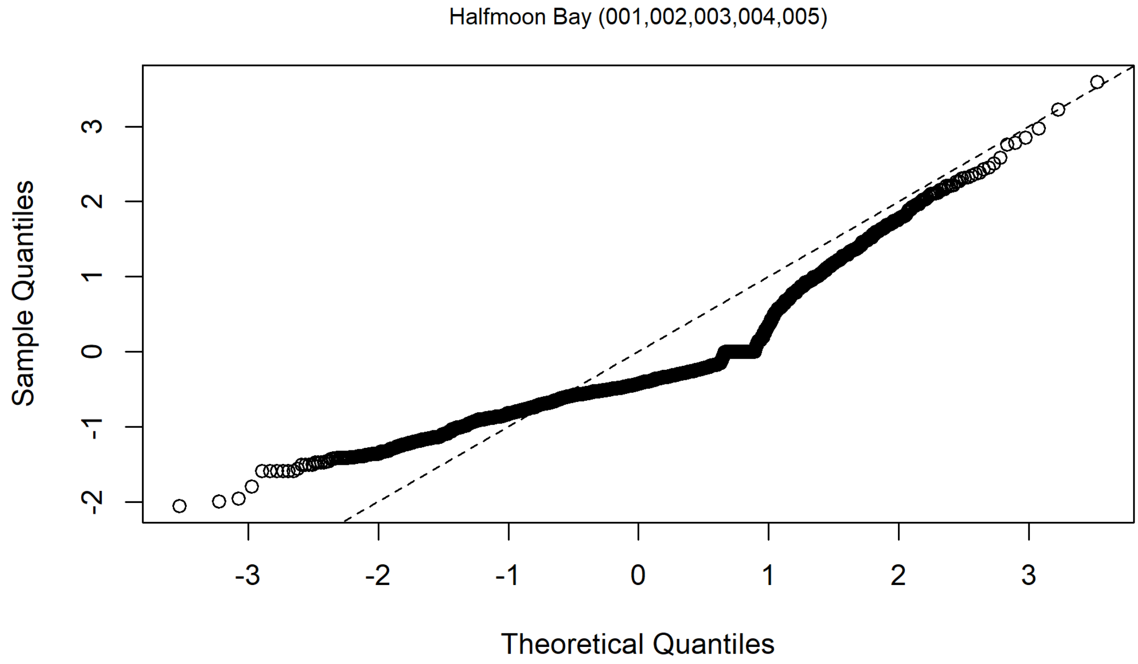

Figure 40: Quantile-quantile plot for the negative binomial standardisation model for Halfmoon Bay.

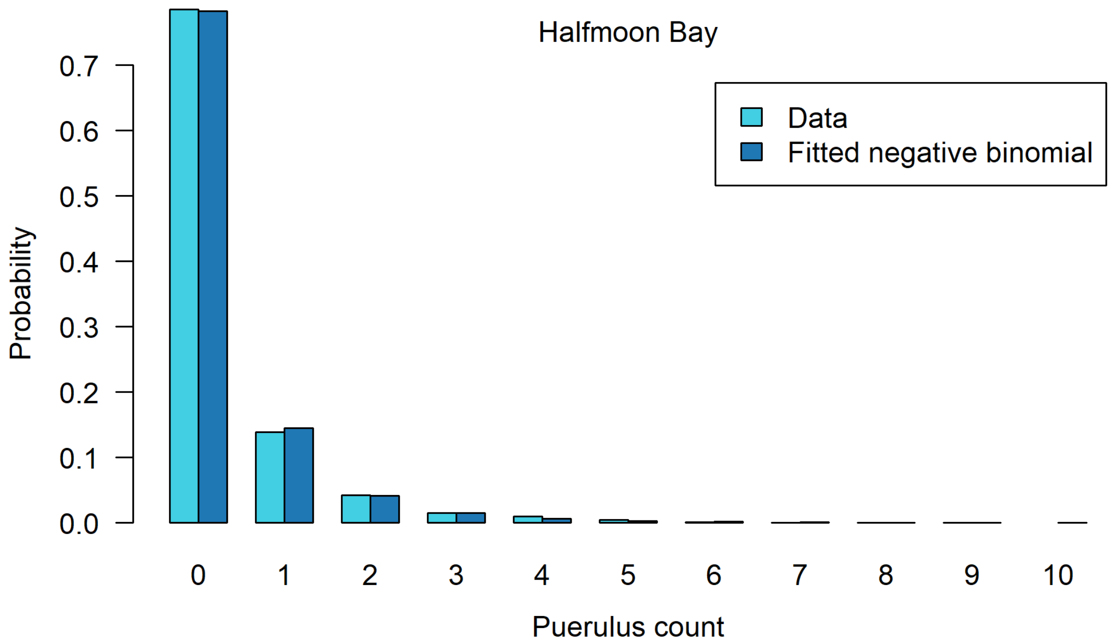

Figure 41: Distribution of data and of fitted data from the negative binomial model for Halfmoon Bay.

Table 9: Halfmoon Bay standardisation data set. Number of puerulus samples by group and fishing year.

Fishing year	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
2016	56	0	0	0	0	56
2017	56	0	0	0	0	56
2018	32	0	0	0	0	32
2019	32	0	0	0	0	32
2020	56	0	0	0	0	56
2021	48	0	0	0	0	48
2022	40	0	0	0	0	40

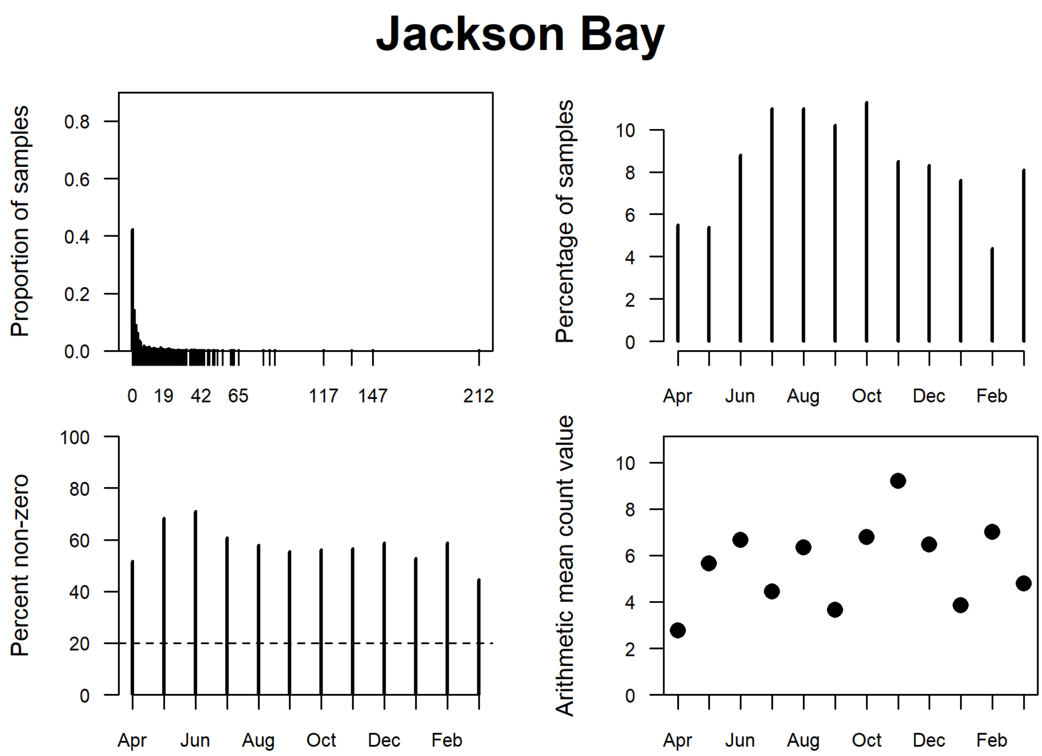

Figure 42: Characteristics of the Jackson Bay puerulus standardisation data. The top-left barplot shows the distribution of puerulus counts, with the x-axis being the count, and the y-axis being the proportion of samples with this count. The bottom-left figure shows the percentage of puerulus samples that have non-zero counts, by month, with a visual reference line at 20%. The top-right plot shows the percentage of samples by month, and the bottom-right figure the arithmetic mean puerulus count by month. Count refers to the number of pueruli measured in a sample.

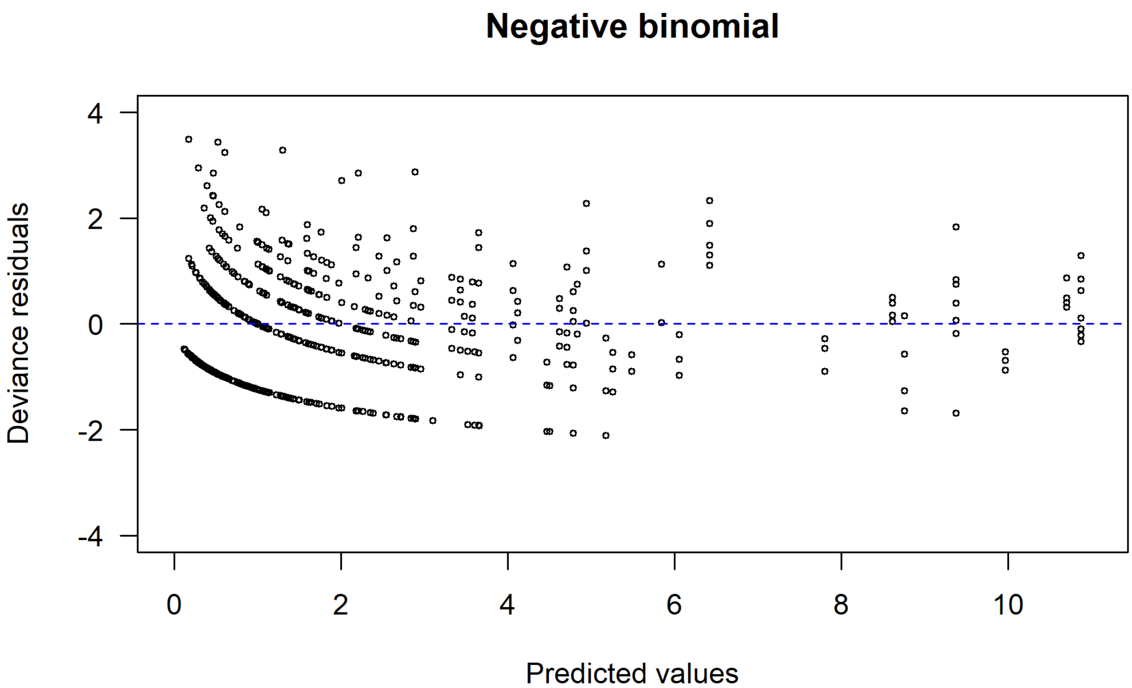

Figure 43: Deviance residuals for the negative binomial model for the Jackson Bay site. Predicted values are in natural space.

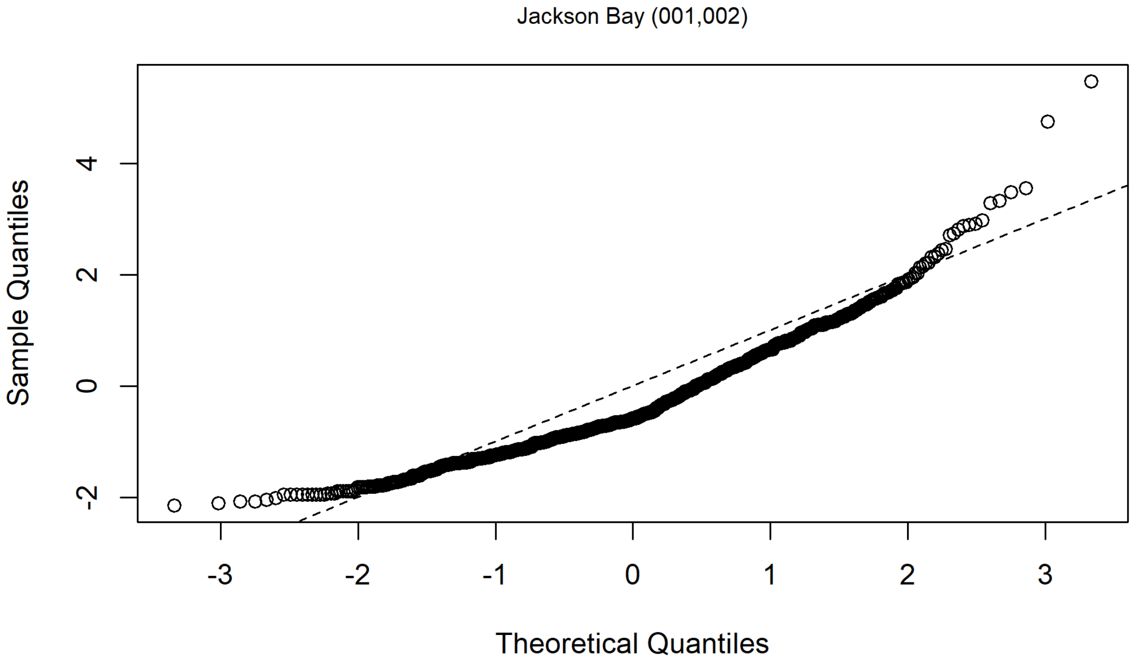

Figure 44: Quantile-quantile plot for the negative binomial standardisation model for Jackson Bay.

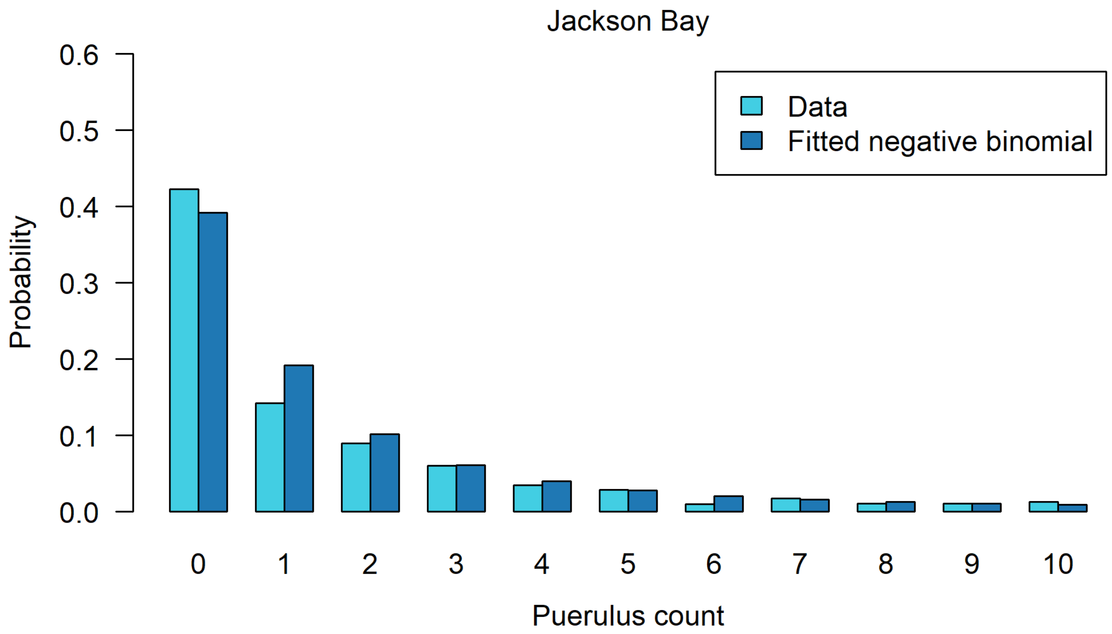

Figure 45: Distribution of data and of fitted data from the negative binomial for Jackson Bay.

Table 10: Jackson Bay standardisation data set. Number of puerulus samples by group and fishing year.

Fishing year	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
2016	46	0	46
2017	45	0	45
2018	47	0	47
2019	59	0	59
2020	35	0	35
2021	60	0	60
2022	60	0	60