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Settlement indices for 2011 for the red rock lobster (*Jasus edwardsii*)

New Zealand Fisheries Assessment Report 2013/32

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Forman, J.S.; McKenzie, A.; Stotter, D.R. (2013). Settlement indices for 2011 for the red rock lobster (*Jasus edwardsii*).

***New Zealand Fisheries Assessment Report 2013/32.* 32 p.**

This report addresses objective one of the Ministry of Fisheries project CRA201202A.

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 2011, 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 five 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.

Puerulus settlement in 2011 was well below the long-term mean in Gisborne, Napier, Kaikoura, and Halfmoon Bay. Castlepoint was just below the long-term mean, and Moeraki was close to it. Jackson Bay, the only site that had above average settlement, recorded its highest levels of settlement since their inception in 1999. At Gisborne and Napier, settlement was the second and third lowest on record respectively and continues a series of poor annual settlement at those sites over recent years.

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 palinurid (e.g., Phillips et al. 2000, Gardner et al. 2001) and homarid (e.g., Wahle et al. 2004) research, with, according to project, encouraging or well-demonstrated success. 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 monitored 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). Since monitoring began, the highest mean annual settlement has been along the east coast of the North Island south of East Cape (i.e. the southeast North Island or SENI), adjacent to the general region of highest abundance of phyllosoma larvae in 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 collectors were developed in New Zealand to catch *J. edwardsii* pueruli and are 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.

There are 5 core, and 1 additional group of 5 collectors, at Gisborne; 5 core, and 1 additional group of 5 collectors, at Napier; 9 core, and 1 additional group of 5 collectors, at Castlepoint; 5 core, and 1 additional group of five collectors, at Kaikoura; 1 core group of 15 collectors (crevice and mesh), at Moeraki; 8 core collectors at Halfmoon Bay; and 5 core collectors at Jackson Bay wharf. Further alterations to the collector network may be made to improve the reliability of estimates. 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. Where 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, 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.

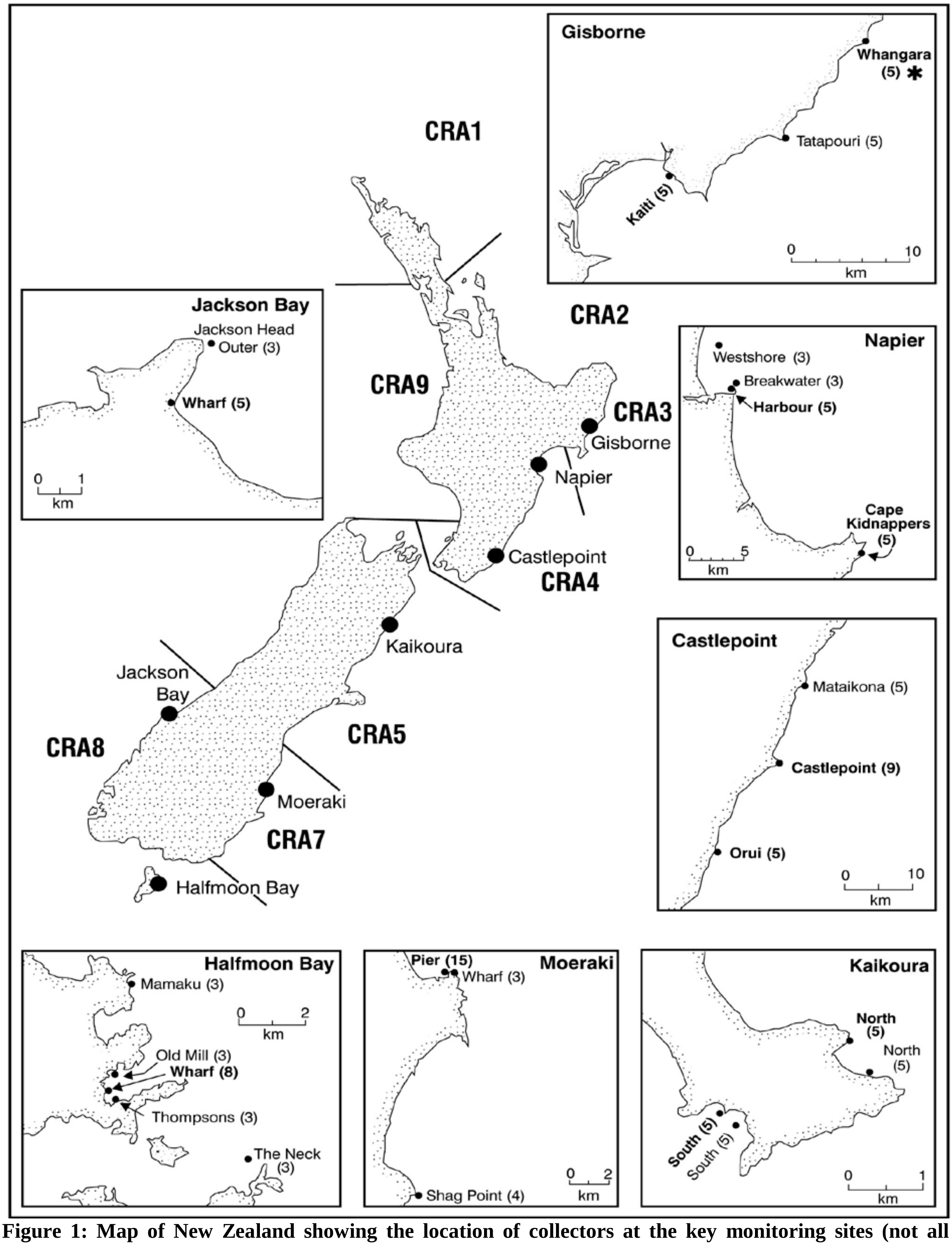

Figure 1: Map of New Zealand showing the location of collectors at the key monitoring sites (not all groups are now checked). The sites that are checked are in bold and the number of collectors in that set is in brackets. Also shown are the CRA areas; CRA 6 is the Chatham Islands and CRA 10 is the Kermadec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

Table 1: Method of collector deployment and number of collectors at each site. Groups no longer monitored from 1 October 2002 (or earlier in a few instances) are given in italics; changes after 1 October 2002 to monitored groups are denoted with strikethrough and underline. For definitions of collector type, see Booth & Tarring (1986) and Phillips & Booth (1994).

Site	No. collectors	Core group	Additional groups	Location	Method of deployment
Gisborne	5	GIS002		Whangara	Shore
	5		*GIS001*	*Harbour*	*Shore*
	5		GIS003	*Tatapouri*	Shore
	5		GIS004	Kaiti	Shore
Napier	5	NAP001		Harbour	Suspended
	3		*NAP002*	*Westshore*	*Closing*
	5		NAP003	C. Kidnappers	Shore
	3		*NAP004*	*Breakwater*	*Shore*
Castlepoint	9	CPT001		Castlepoint	Shore
	5		CPT002	Orui	Shore
	5		*CPT003*	*Mataikona*	Shore
Kaikoura	~~3~~ 5	KAI001		South 13–15	Shore
	3		*KAI002*	*South 31–33*	*Shore*
	~~3~~ 5		KAI003	North 10–12	Shore
	3		*KAI004*	*North 34–36*	*Shore*
Moeraki	*4*	*MOE001*		*Shag Point*	*Shore*
	3		MOE002	*Wharf*	Closing
	3		*MOE004*	*Millers Beach*	*Shore*
	3		*MOE005*	*The Kaik*	*Shore*
	3		*MOE006*	*Kakanui*	*Shore*
	15		MOE007	Pier	Suspended
Halfmoon Bay	~~3~~ 8	HMB001		Wharf	Suspended
	3		*HMB002*	*Thompsons*	*Closing*
	3		*HMB003*	*Old Mill*	*Closing*
	3		*HMB004*	*The Neck*	*Closing*
	3		*HMB005*	*Mamaku Point*	*Closing*
Jackson Bay	~~3~~5	JAC001		Jackson Bay Wharf	Suspended
	3		JAC002	*Jackson Head Inner*	Closing

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: (i) assignment of the month for settlement, and (ii) the groups of collectors used. The term ‘settlement’ refers to the presence of pueruli and juveniles up to 14.5 mm carapace length (CL, the maximum size for a first-instar juvenile observed in laboratory studies).

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

Because a collector check on any one day is thought to be a snapshot of what has been going on for about the last 14 days, it was not considered reasonable to allocate the month of settlement to the nominal month. Instead, if the check took place up to the 7th 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 groups of collectors were dropped. At Gisborne the group of harbour collectors GIS001 were dropped because of the peculiar nature of settlement there, in particular, extraordinarily large catches. For Jackson Bay and Moeraki some pilot study groups of collectors were dropped as they did not catch pueruli very well, and even the best groups of collectors at these two sites often recorded very low counts (Appendix 1). For a summary of the groups of collectors used at sites see Table 2.

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 by the Aikake Information Criterion (AIC) criterion 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, and it is anticipated that these will be investigated in the next set of standardisations (under a different project from this update).

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

In the initial data set there were 508 collectors over all sites. Applying the requirement that a collector must have been sampled at least 36 times left 172 collectors (Figure 2). The annual number of samples for the final groups of collectors used in the standardisation are given in Appendix 2. For four sites (Gisborne, Kaikoura, Moeraki and Halfmoon Bay) there are fewer than 10 samples in the first year and it may be appropriate to remove the first year in future standardisations. 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 3).

Month was selected by the AIC criterion for all standardisations, and for most sites collector was selected instead of group (Table 2). 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 2011 are shown in Table 3. In the following sections site-by-site descriptions of puerulus settlement for 2011 are given, as well as standardised annual graphs from each key site and the monthly mean catch graphs for 2011 from each group.

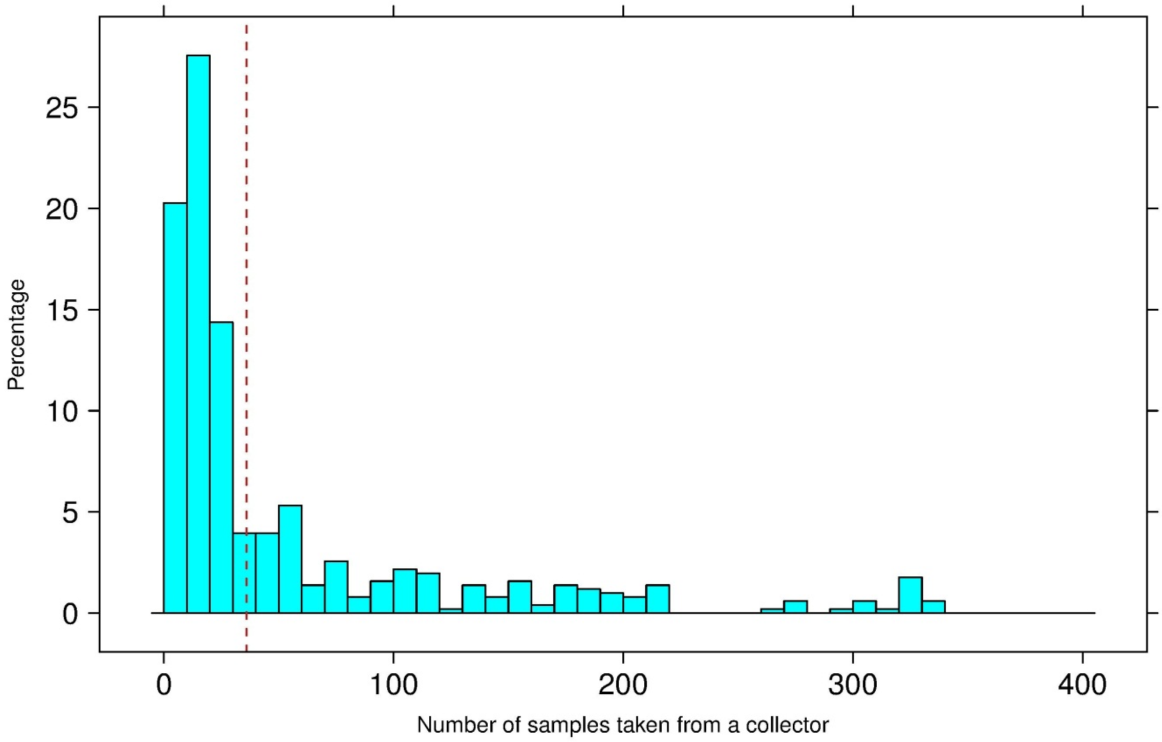

Figure 2: Distribution for the number of collectors, by number of samples taken from a collector. The vertical dashed line is at 36 samples.

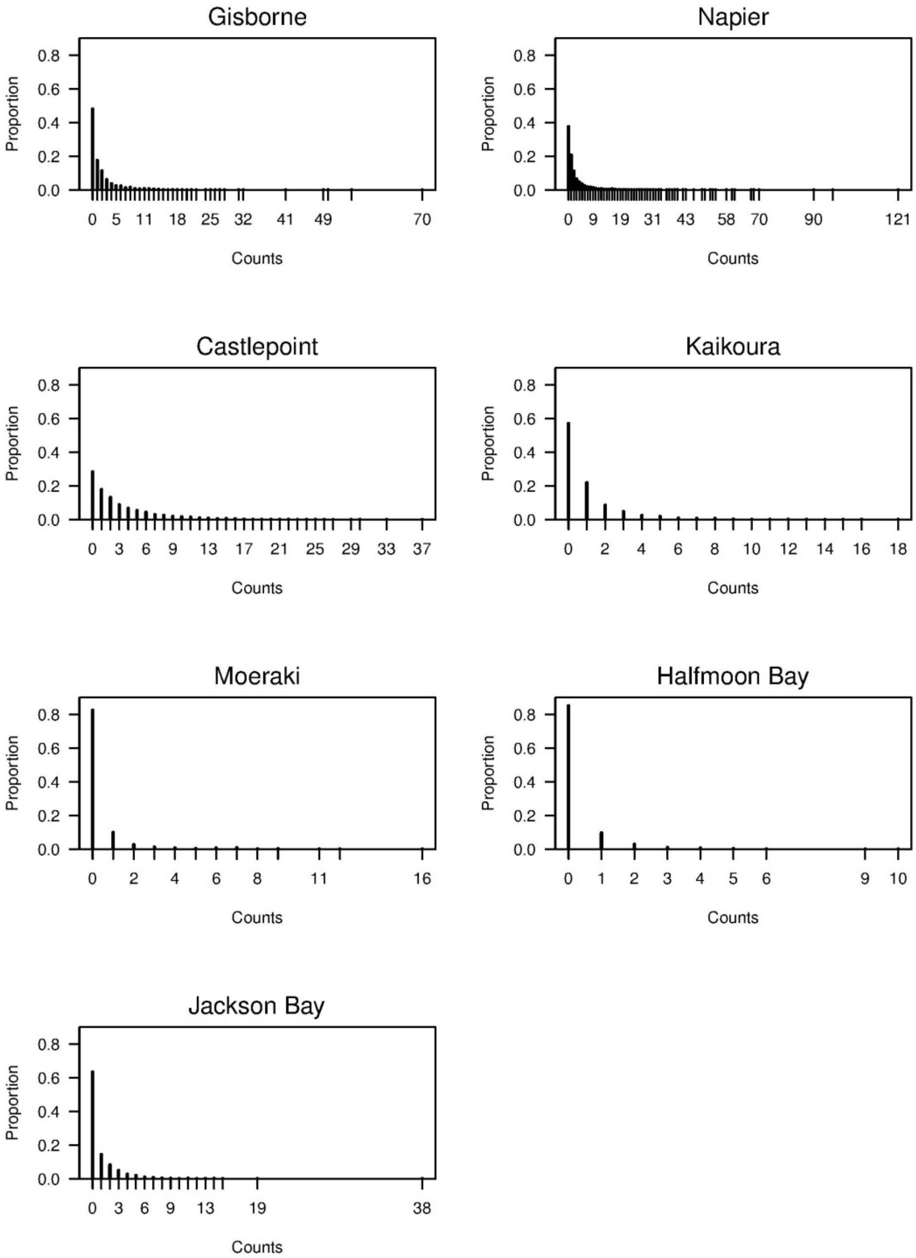

Figure 3: Distribution of number of puerulus collected at monthly samples by site.

Table 2: Group of collectors used in standardisations, additional factors (all included year and month), and estimated dispersion.

Site	Groups	Additional factors	Estimated dispersion
Gisborne	002, 003, 004	Collector	2.86
Napier	001, 002, 003, 004	Collector	3.65
Castlepoint	001, 002, 003	Collector	2.68
Kaikoura	001, 002, 003, 004	Collector	1.64
Moeraki	002, 007	-	1.54
Halfmoon Bay	001, 002, 003, 004, 005	Group	1.10
Jackson Bay	001, 002	Collector	2.94

Table 3: Standardised annual indices for each site. Year is calendar year (January–December).

	Gisborne	Napier	Castlepoint	Kaikoura	Moeraki	Halfmoon Bay	Jackson Bay
1979	-	0.84	-	-	-	-	-
1980	-	1.51	-	0.00	-	1.77	-
1981	-	2.04	-	1.48	-	7.66	-
1982	-	0.99	-	0.04	-	0.36	-
1983	-	1.23	1.42	1.19	-	4.28	-
1984	-	0.41	1.35	0.35	-	0.36	-
1985	-	0.19	0.87	0.49	-	0.00	-
1986	-	-	0.50	0.15	-	0.10	-
1987	-	-	1.70	1.70	-	1.53	-
1988	-	1.49	0.98	0.75	-	0.20	-
1989	-	1.07	1.52	1.25	-	0.51	-
1990	-	1.13	0.93	0.42	0.77	0.42	-
1991	1.63	2.26	1.95	8.26	0.00	0.80	-
1992	2.36	2.39	2.41	9.57	0.15	0.59	-
1993	2.01	1.90	1.47	4.84	0.00	0.00	-
1994	3.07	1.42	0.93	1.29	0.00	1.06	-
1995	1.20	1.05	0.88	1.52	0.12	0.30	-
1996	1.11	1.67	1.31	1.14	1.14	0.30	-
1997	1.15	1.28	1.14	2.41	0.68	0.51	-
1998	1.60	1.09	1.67	3.19	0.66	0.25	-
1999	0.11	0.29	0.34	2.13	0.14	0.23	0.74
2000	1.04	0.66	0.56	1.86	3.93	1.14	0.75
2001	1.25	1.38	0.76	0.69	2.44	1.63	0.81
2002	1.22	1.11	0.68	1.82	0.95	1.25	3.07
2003	2.45	1.28	0.75	7.72	7.46	3.34	1.53
2004	0.84	1.08	0.65	2.66	0.43	0.12	0.32
2005	2.71	1.25	1.16	3.46	0.11	0.00	3.58
2006	0.41	0.59	0.64	2.89	0.06	0.13	0.41
2007	0.34	1.04	0.88	1.94	0.04	0.44	0.50
2008	0.77	0.59	0.88	3.65	0.10	0.08	0.34
2009	1.13	0.76	0.92	0.77	0.46	0.91	0.29
2010	0.62	1.30	1.60	2.87	1.40	1.60	4.50
2011	0.24	0.36	0.89	0.63	0.97	0.13	4.62

Gisborne
Settlement in Gisborne in 2011 was the second lowest on record. This continues a series of well below average settlement, with five of the six lowest settlement years occurring within the last six years (Figure 4). Settlement at Whangara and Kaiti was both low and sporadic with little consistency in monthly settlement between sites. July was the peak month for Whangara and November was the peak month for Kaiti (Figure 5).

Napier
Settlement in Napier was the third lowest since records began in 1979. In four of the last six years, settlement has been below the long-term mean (Figure 6). Like Gisborne, settlement at both the harbour site and at Cape Kidnappers was low and sporadic. Settlement in Napier harbour peaked in July while the peak at Cape Kidnappers was in April (Figure 7).

Castlepoint
At Castlepoint, settlement was just below the long-term mean. Below average settlement has occurred in 11 of the last 13 years (Figure 8). Settlement between the Castlepoint and Orui sites was generally consistent, with average settlement occurring throughout summer and autumn, but dropping off during winter, a period when settlement is usually high (Figure 9).

Kaikoura
Settlement in 2011 was well below average in Kaikoura (Figure 10). A similar monthly pattern of settlement was recorded at both sites with settlement mainly occurring in autumn with a sharp increase in December (Figure 11).

Moeraki
Average settlement was recorded in Moeraki in 2011 (Figure 12). Settlement peaked in August (Figure 13).

Halfmoon Bay
Settlement was well below average in Halfmoon Bay (Figure 14). April, August and September were the only months where settlement occurred (Figure 15).

Jackson Bay
For the second year in a row, record levels of settlement were recorded in Jackson Bay (Figure 16). Settlement was highest in May (Figure 17).

Mean settlement by month over all years is shown in Figure 18. With the exception of Jackson Bay, where settlement is irregular, highest settlement generally occurs in winter and the lowest settlement is in spring.

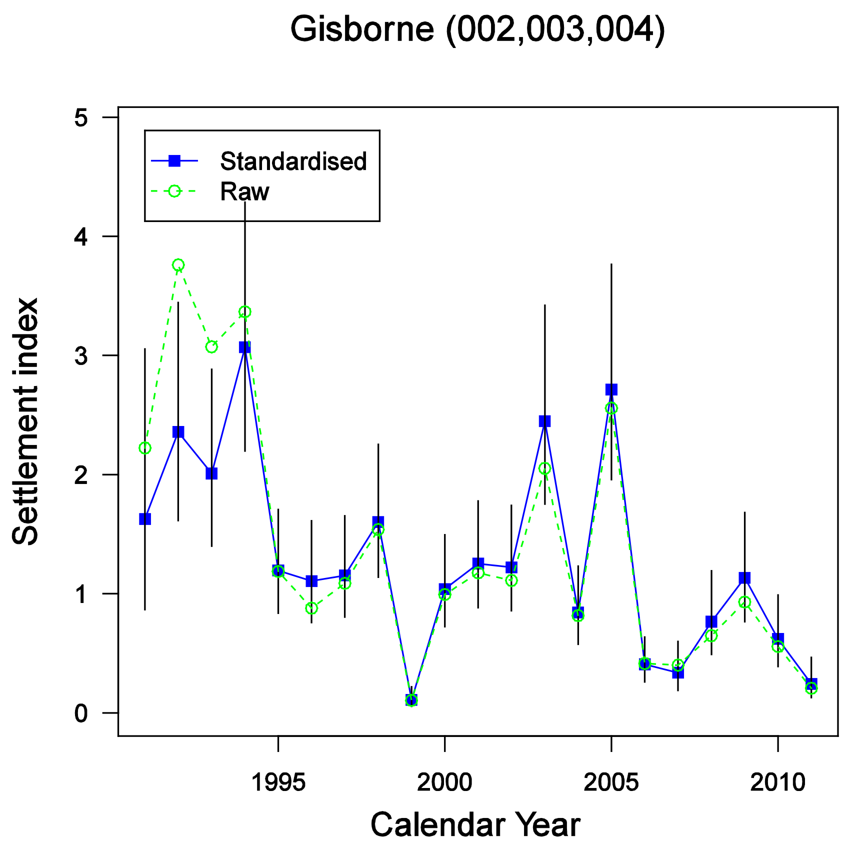

Figure 4: Gisborne–standardised and raw indices of annual settlement with 95% confidence intervals.

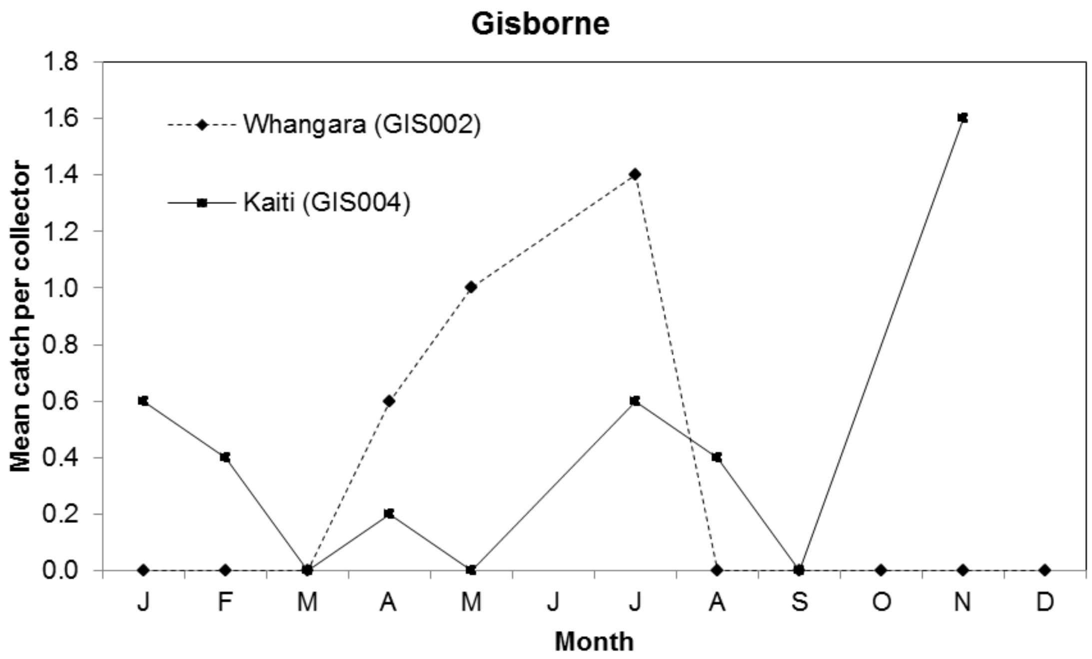

Figure 5: Whangara and Kaiti monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

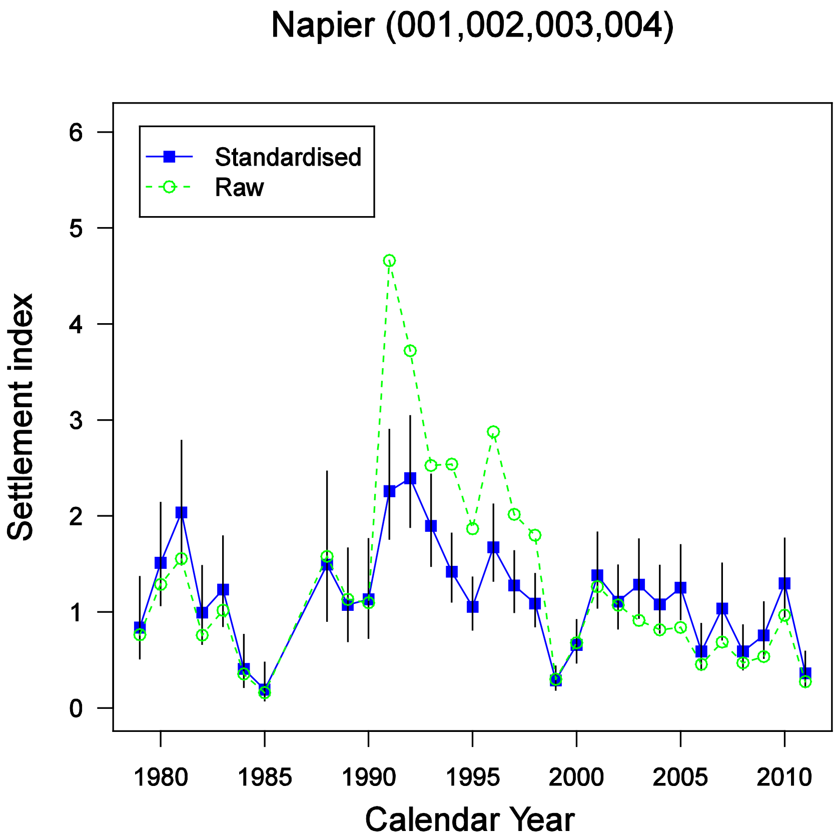

Figure 6: Napier—standardised and raw indices of annual settlement with 95% confidence intervals. Note that there were no checks in 1986–87.

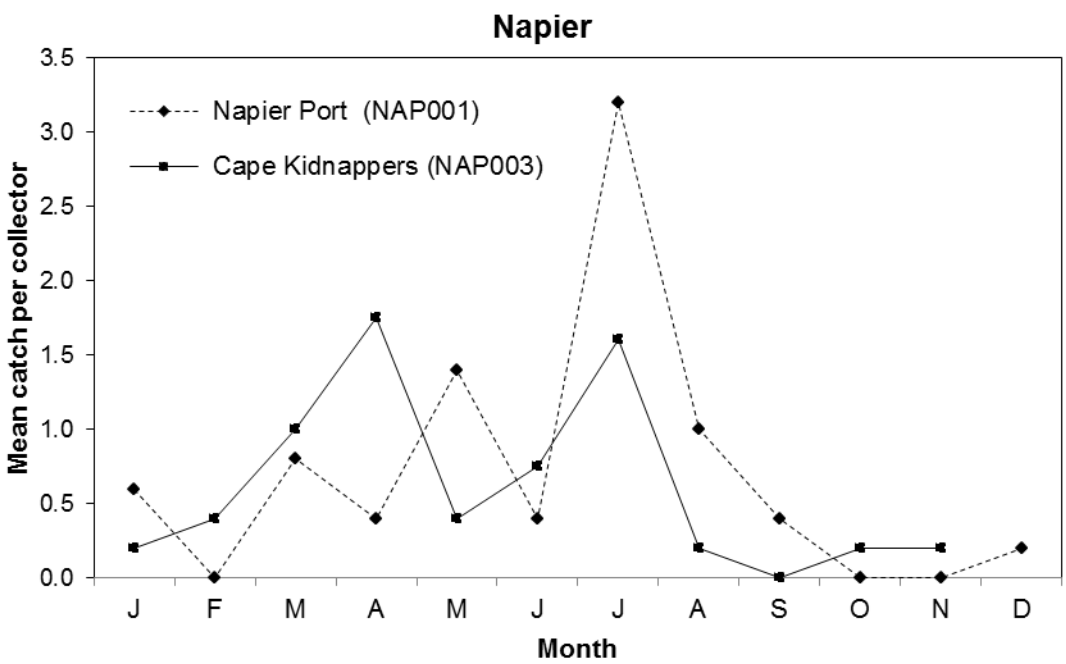

Figure 7: Napier harbour and Cape Kidnappers monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

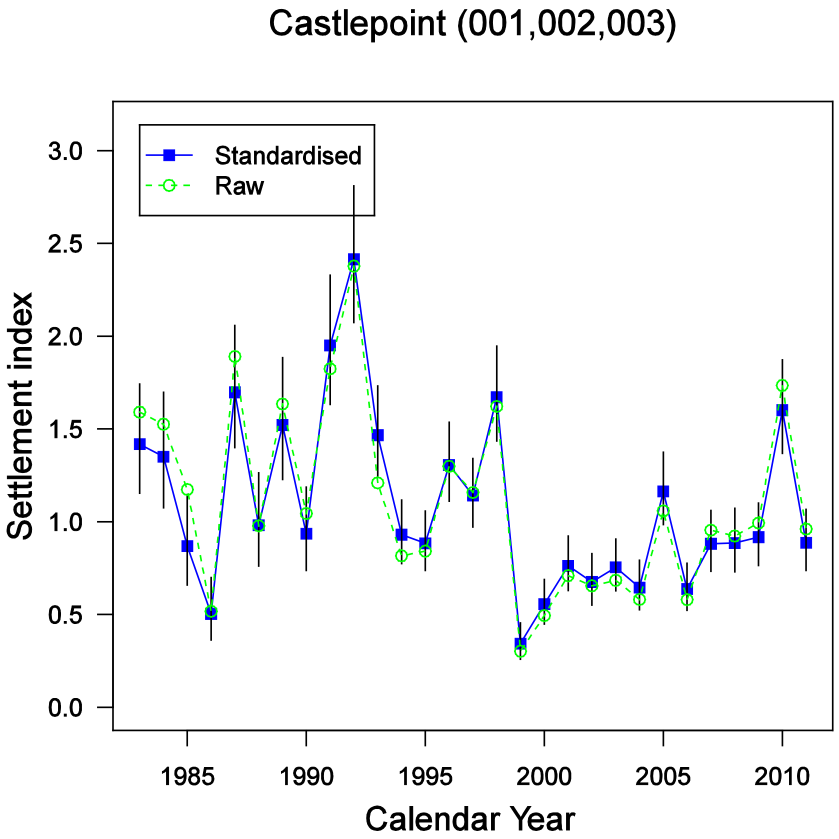

Figure 8: Castlepoint—standardised and raw indices of annual settlement with 95% confidence intervals.

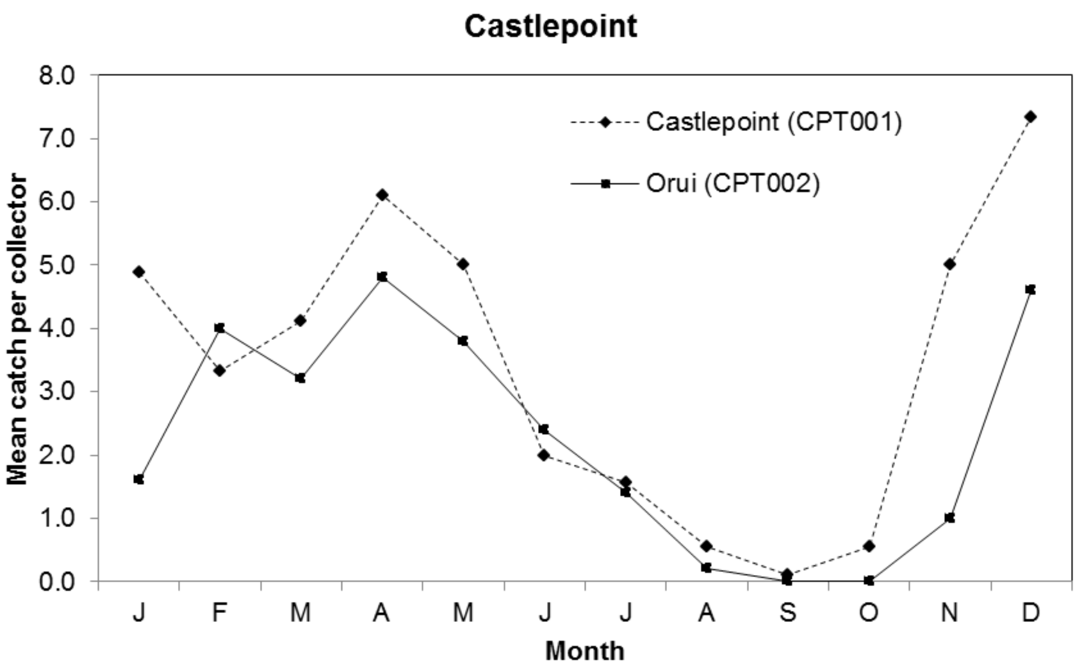

Figure 9: Castlepoint and Orui monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

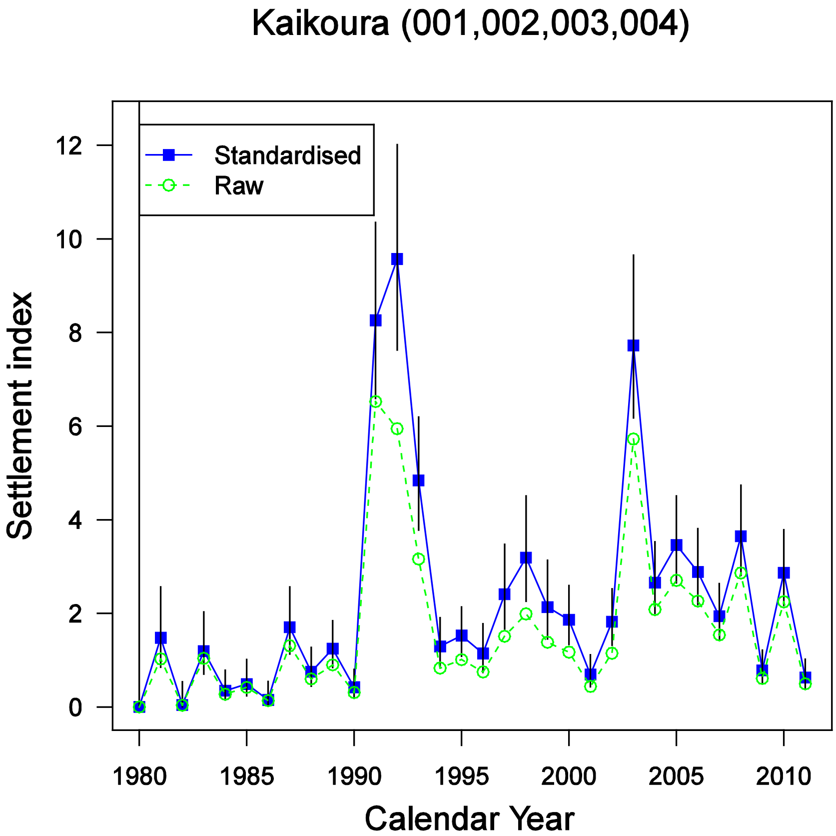

Figure 10: Kaikoura—standardised and raw indices of annual settlement with 95% confidence intervals.

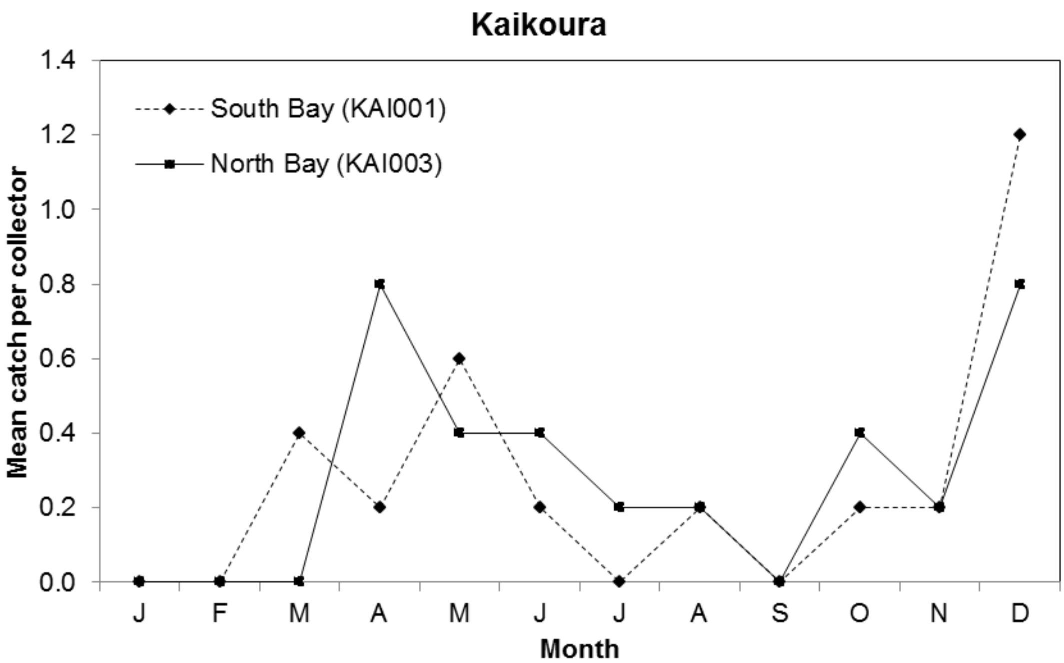

Figure 11: South Bay and North Bay monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

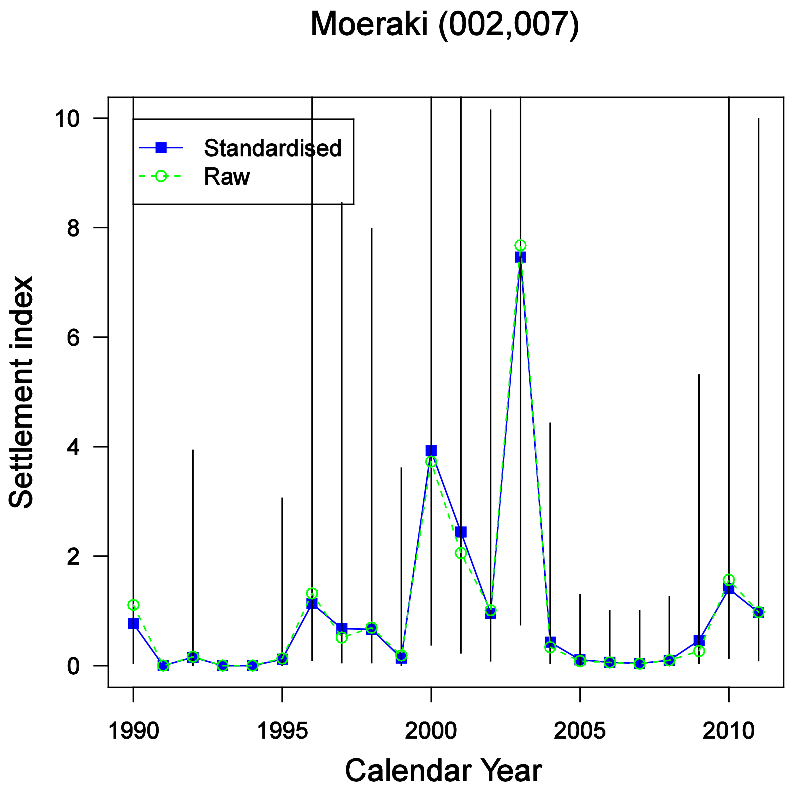

Figure 12: Moeraki—standardised and raw indices of annual settlement with 95% confidence intervals.

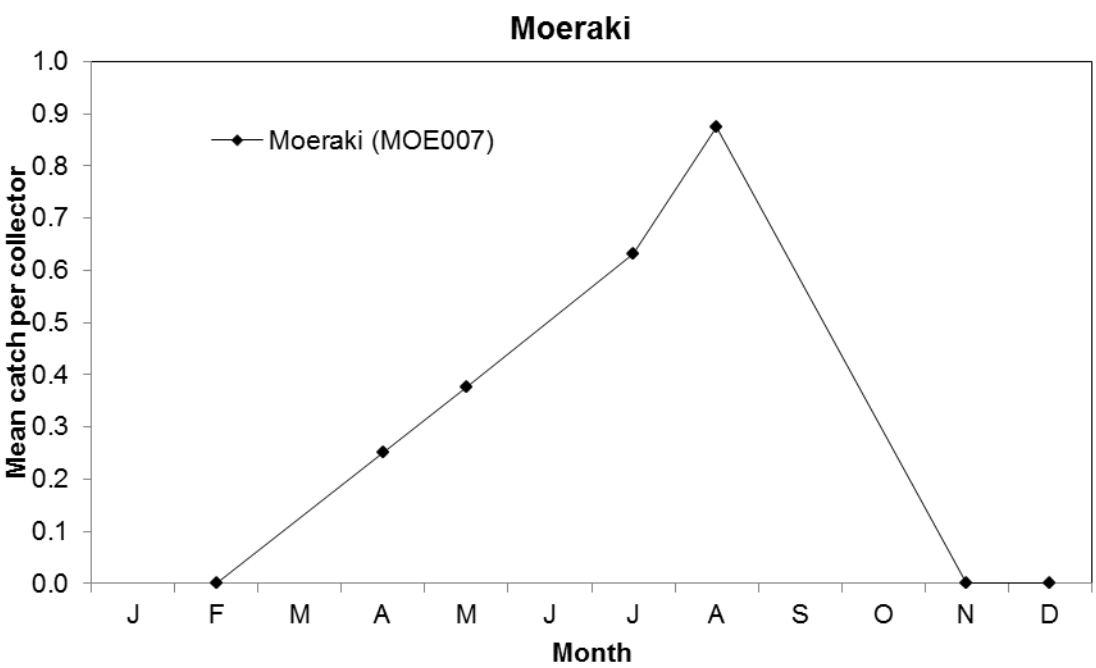

Figure 13: Moeraki monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

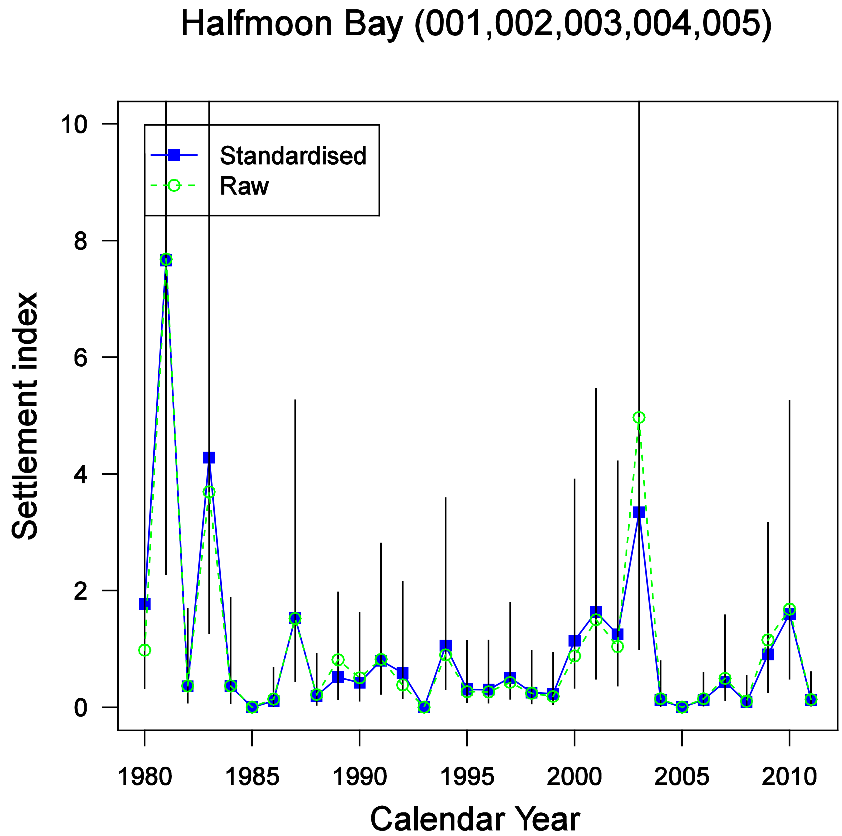

Figure 14: Halfmoon Bay—standardised and raw indices of annual settlement with 95% confidence intervals. The 95% confidence bounds were large because of high collector catch variability and the data not fitting the standardisation model well because of the large number of zero catches.

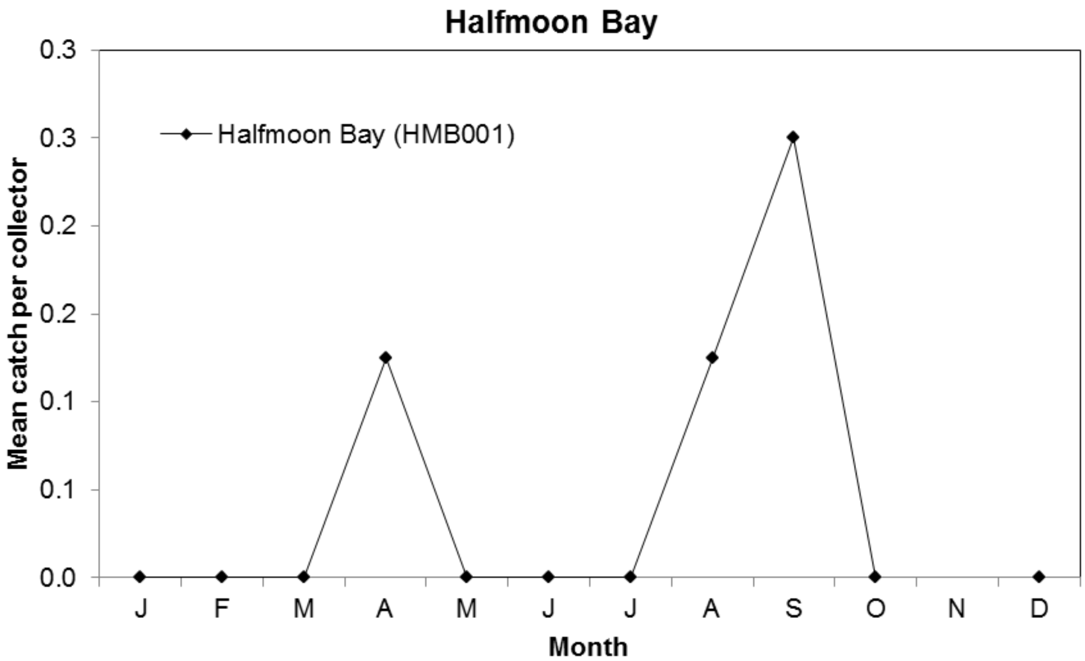

Figure 15: Halfmoon Bay monthly settlement, 2011. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

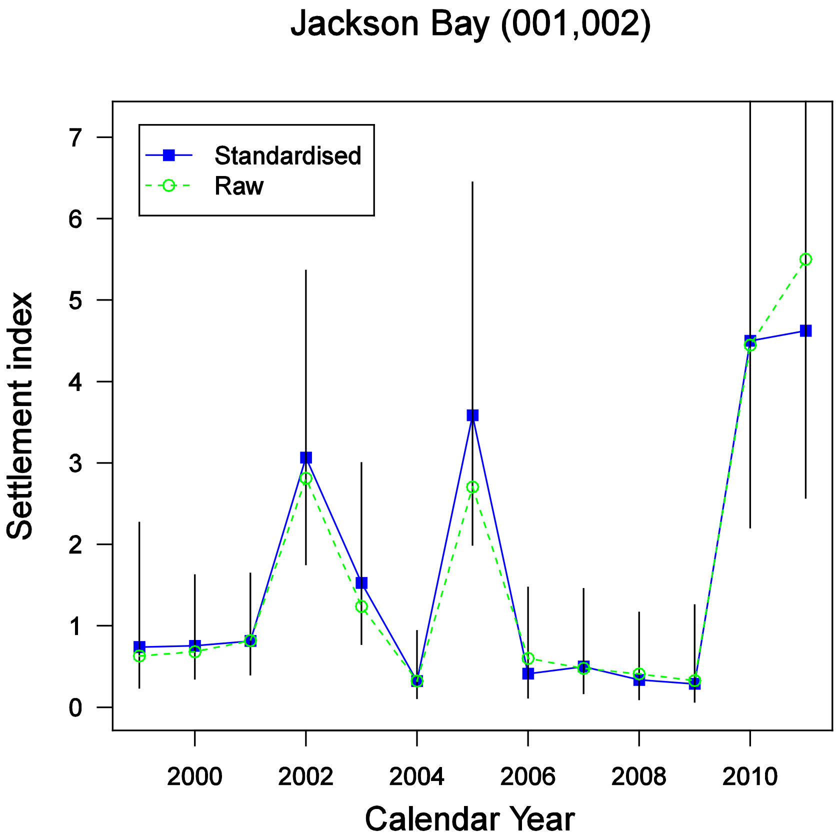

Figure 16: Jackson Bay—standardised and raw indices of annual settlement with 95% confidence intervals.

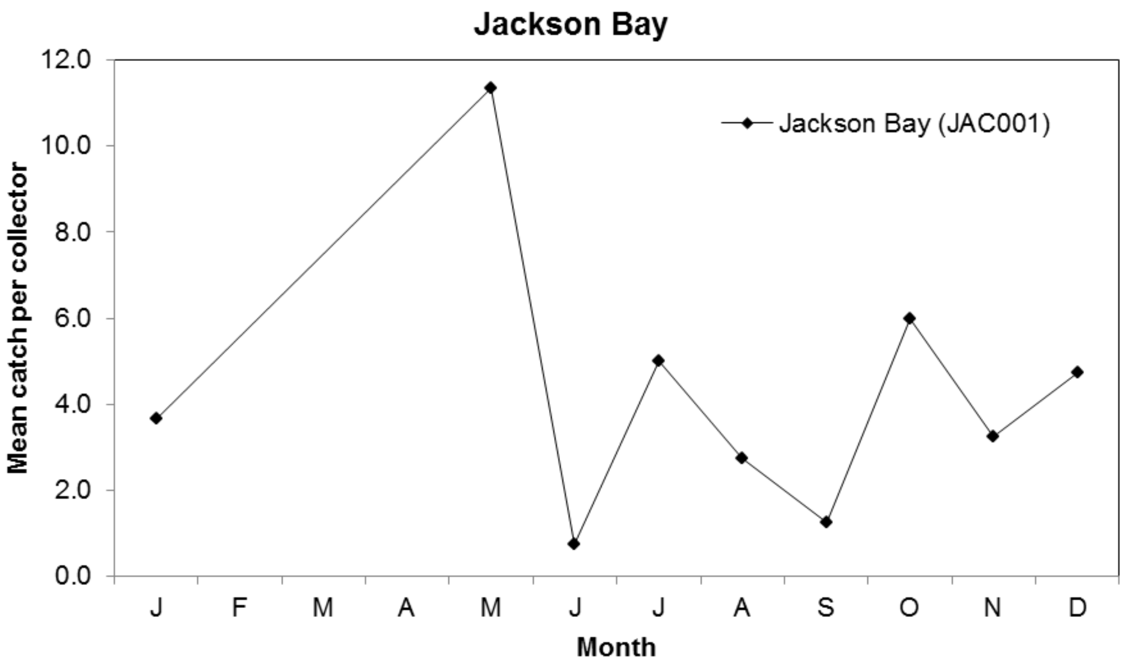

Figure 17: Raw monthly settlement, 2010. Mean number of *Jasus edwardsii* pueruli plus juveniles less than 14.5 mm carapace length per collector.

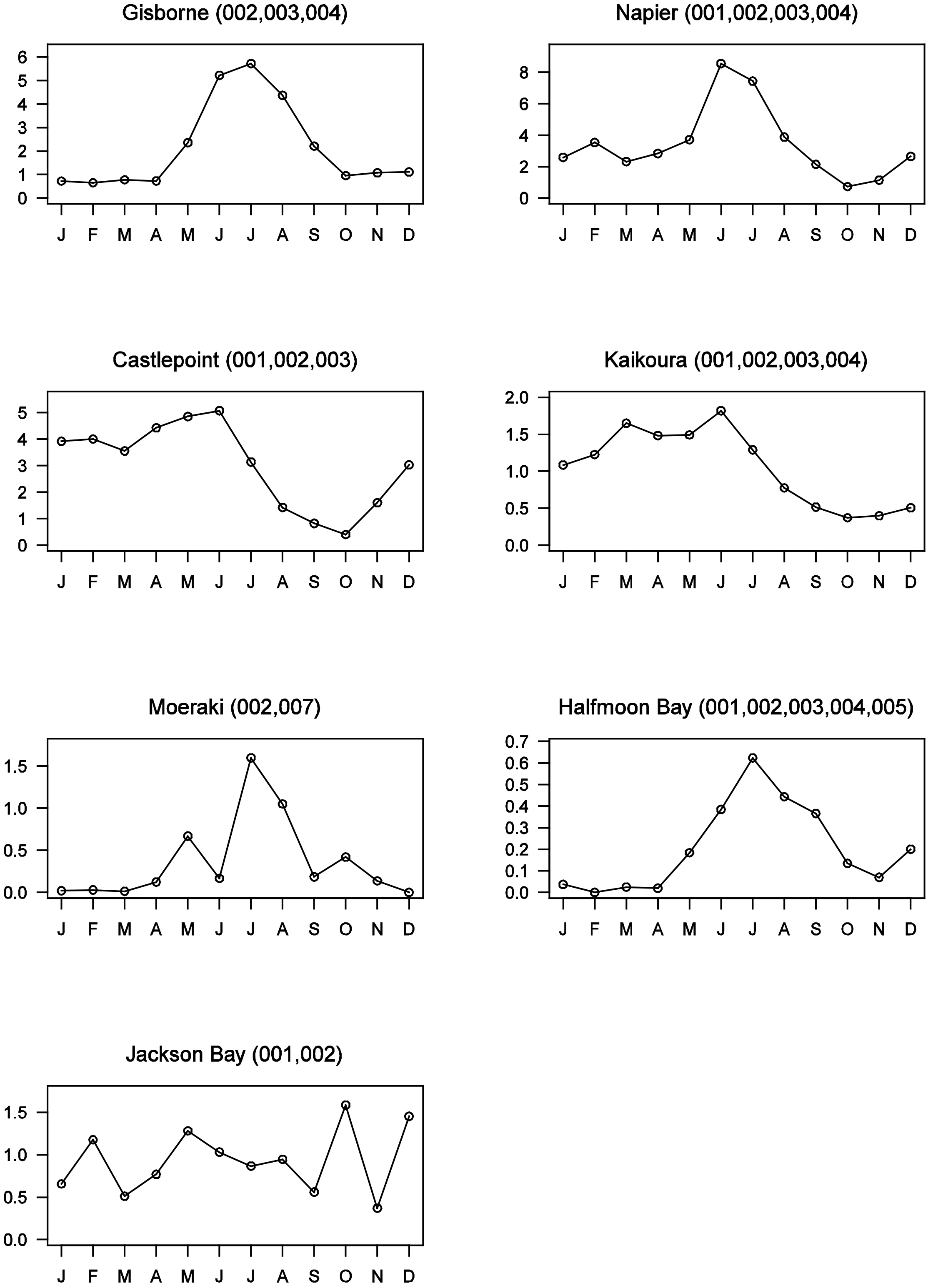

Figure 18: The mean settlement by month, over all years, for each key collector site. See Table 1 for the collector groups.

4. CONCLUSIONS

In 2011, Gisborne, Napier, Kaikoura, and Halfmoon Bay recorded levels of puerulus settlement that were well below their long-term means. Castlepoint was just below, and Moeraki was close to the long-term mean. Jackson Bay was the only site to have above average settlement.

The low levels of settlement that were recorded in Gisborne (CRA 3) in 2011 are a continuation of below average settlement that has occurred over the last six years. With the exception of 1999, the next five lowest settlement years have occurred in the last six years.

In CRA 4, Napier and Castlepoint were both below the long-term mean. This continues a series of mostly average to below average settlement since the record low of 1999. In Napier, four of the last six years have been below average and at Castlepoint, settlement has been above average only twice in the last 13 years.

Settlement at Kaikoura (CRA 5) was well below the long-term mean in 2011 and in 2009. Apart from these two years, Kaikoura has generally recorded above average settlement over the last 10 years.

Moeraki (CRA 7) settlement, like last year, was close to its long-term mean; however, this was preceded by six years of very low settlement.

In CRA 8, Halfmoon Bay recorded low levels of settlement, similar to the low levels recorded between 2004 and 2008. Since 2004 it has only recorded above average settlement once, in 2010. Jackson Bay, after four years of very low settlement between 2006 and 2009, has now recorded two consecutive years of very high settlement.

5. MANAGEMENT IMPLICATIONS

For Gisborne, Napier, and Castlepoint the puerulus index is plausibly 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).

For Gisborne the puerulus indices for five out of the last six years are significantly below the long-term average, indicating a reduced abundance in the near future. Napier shows a similar pattern with four of the last six years having below average puerulus indices, and an irregular decline since 2001. At Castlepoint five out the last six years are near or above the long-term average, with an upward trend since 2000.

For Kaikoura the puerulus index shows a decline since 2003, though levels are still above or near the long-term average. For Moeraki levels of puerulus settlement have been low since 2004, although they show a substantial increase in the last two years. At Halfmoon Bay settlement has been low since 2004, then picked up substantially for 2009 and 2010, but then dropped back to low levels in 2011. At Jackson Bay there was a period of low settlement from 2006 to 2009; subsequent to this period of low settlement there were two years of approximately 15 times higher settlement.

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Appendix 1: Proportion Of Zero Counts For Jackson Bay and Moeraki

Jackson Bay

The number of puerulus samples taken by groups of collectors is shown in Table A1. Note that there is a large gap from 1986 to 1998 inclusive. The group of collectors JKB003 and JKB004 were dropped from the sampling programme as they did not catch pueruli very well (John Booth, pers. comm., e-mail 2009). This leaves the group of collectors JKB001 and JKB002 from 1999 onwards, as appears in the current update to 2011.

To more directly evaluate the effectiveness of the group of collectors at catching pueruli, plots are shown of the distributions for the number of pueruli counted from monthly sampling (Figure A1). The groups JKB003 and JKB004 have recorded zero counts about 70% of the time, and no counts over 8. The core group JKB001 is better at catching pueruli, with zero counts recorded about 60% of the time, and some counts over 8. The group JKB002 is similar to the two groups JKB003 and JKB004, and arguably could be dropped like them from the analysis (sampling from it stopped in 2007 in a reduction of the sampling program).

Moeraki

The number of puerulus samples taken by groups of collectors is shown in Table A2. MOE002 and MOE007 were chosen for the standardisation as they were the best at collecting pueruli (John Booth, pers. comm., e-mail 2009), this giving an index that goes from 1990 onwards.

Plotting the distribution of pueruli counts from samples, it does appear that MOE002 and MOE007 are the best of a poor selection at catching pueruli (Figure A2). The group MOE004 was described as “hopeless” for collecting pueruli; the group MOE001 did catch some pueruli but was discontinued for safety reasons as a large bull sea lion would harangue the divers.

Table A1: Number of times a group was sampled by calendar year for Jackson Bay. This table only includes collectors that have been sampled at least 36 times.

	JKB001	JKB002	JKB003	JKB004
1981	0	0	0	6
1982	0	0	0	22
1983	0	0	0	23
1984	0	0	0	20
1985	0	0	0	5
1999	15	11	9	15
2000	38	32	32	26
2001	54	41	41	30
2002	51	30	30	24
2003	41	24	24	0
2004	34	21	0	0
2005	39	20	0	0
2006	19	6	0	0
2007	40	0	0	0
2008	30	0	0	0
2009	25	0	0	0

2010	23	0	0	0
2011	30	0	0	0

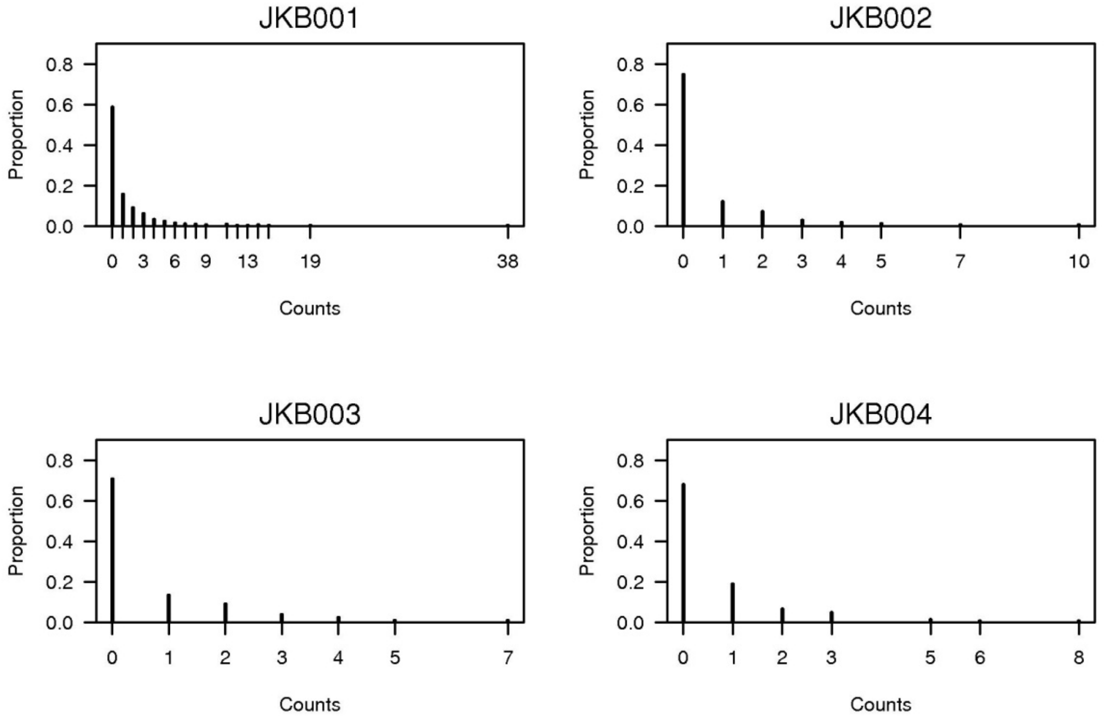

Figure A1: Number of pueruli counted in samples from Jackson Bay. This figure only includes collectors that have been sampled at least 36 times.

Table A2: Number of times a group is sampled by calendar year for Moeraki. This table only includes collectors that have been sampled at least 36 times.

	MOE001	MOE002	MOE003	MOE004	MOE007
1982	8	0	0	0	0
1983	10	0	0	0	0
1984	14	0	0	0	0
1985	9	0	0	0	0
1986	12	0	11	0	0
1987	12	0	20	0	0
1988	20	0	12	0	0
1989	14	0	15	0	0
1990	28	5	0	0	0
1991	17	21	18	0	0
1992	19	17	9	12	0
1993	16	18	27	30	0
1994	23	18	14	19	0
1995	26	21	27	27	0
1996	18	21	21	21	0
1997	21	27	21	24	0
1998	15	24	0	24	0
1999	3	15	0	21	0
2000	0	26	0	27	0
2001	0	28	0	6	7
2002	0	23	0	0	18
2003	0	30	0	0	98
2004	0	12	0	0	136
2005	0	24	0	0	143
2006	0	9	0	0	86
2007	0	0	0	0	82
2008	0	0	0	0	114
2009	0	0	0	0	83
2010	0	0	0	0	53
2011	0	0	0	0	102

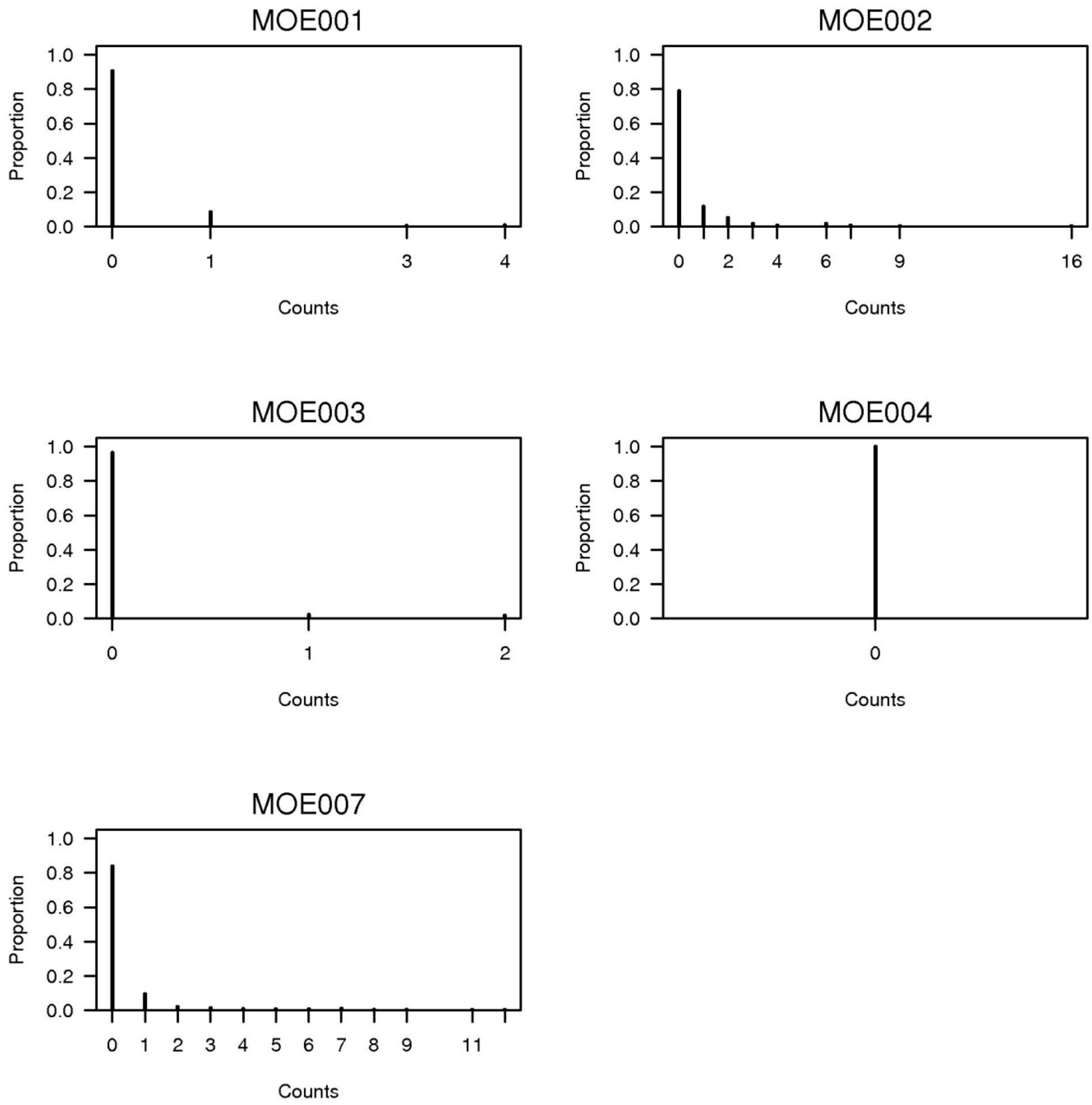

Figure A2: Number of pueruli counted in samples from Moeraki. This figure only includes collectors that have been sampled at least 36 times.

Appendix 2: Number Of Samples Taken By Calendar Year and Group Of Collectors

Table A3: Gisborne.

Year	GIS002	GIS003	GIS004
1991	10	0	0
1992	35	0	0
1993	53	0	0
1994	50	43	38
1995	49	55	59
1996	45	35	65
1997	40	58	65
1998	60	60	55
1999	59	55	48
2000	58	60	55
2001	59	60	60
2002	60	48	65
2003	53	46	60
2004	55	46	55
2005	50	44	62
2006	48	48	55
2007	59	0	10
2008	48	0	55
2009	58	0	55
2010	45	0	50
2011	45	0	54

Table A4: Napier.

Year	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	39
1998	66	27	63	33
1999	72	6	54	24
2000	59	0	47	27
2001	59	0	63	21
2002	57	0	54	24
2003	66	0	47	0
2004	65	0	60	0
2005	78	0	59	0
2006	66	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

Table A5: Castlepoint.

Year	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	115	27	65
2001	107	35	60
2002	86	43	50
2003	116	60	65
2004	99	46	55
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

Table A6: Kaikoura.

Fishing year	KAI001	KAI002	KAI003	KAI004
1980	0	0	6	0
1981	18	0	24	0
1982	24	0	24	0
1983	24	0	21	0
1984	33	0	33	0
1985	30	0	26	0
1986	27	0	26	0
1987	33	0	33	0
1988	36	6	36	0
1989	36	36	36	0
1990	33	33	33	0
1991	36	33	36	0
1992	30	30	30	21
1993	33	33	33	33
1994	29	30	30	30
1995	36	36	36	36
1996	24	24	24	24
1997	21	21	21	18
1998	18	18	15	15
1999	18	18	21	21
2000	33	33	33	33
2001	35	32	36	36
2002	36	33	36	36
2003	54	9	54	8
2004	60	0	60	0
2005	59	0	60	0
2006	60	0	60	0
2007	60	0	65	0
2008	60	0	60	0
2009	59	0	59	0
2010	60	0	60	0
2011	60	0	60	0

Table A7: Moeraki.

Year	MOE002	MOE007
1990	5	0
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	136
2005	24	143
2006	9	86
2007	0	82
2008	0	114
2009	0	83
2010	0	53
2011	0	102

Table A8: Halfmoon Bay.

Year	HMB001	HMB002	HMB003	HMB004	HMB005
1980	9	0	0	0	0
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	40	0	0	0	0
2005	48	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	96	0	0	0	0
2011	88	0	0	0	0

Table A9: Jackson Bay

Fishing year	JKB001	JKB002
1999	15	11
2000	38	32
2001	54	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	23	0
2011	30	0

Appendix 3: Regression Diagnostics

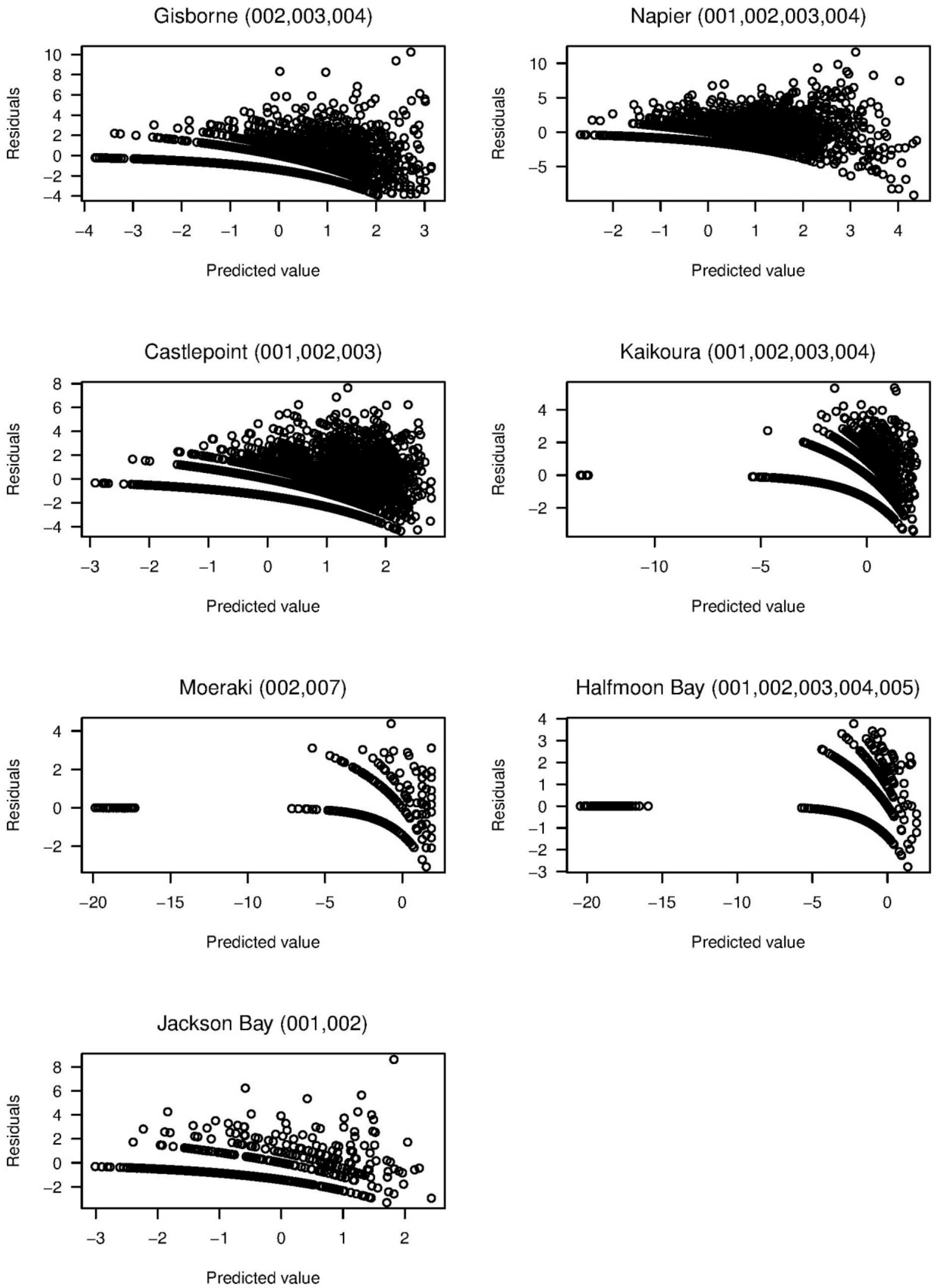

Figure A3: Residual plots from standardisation model for each site. The predicted values are in log space.

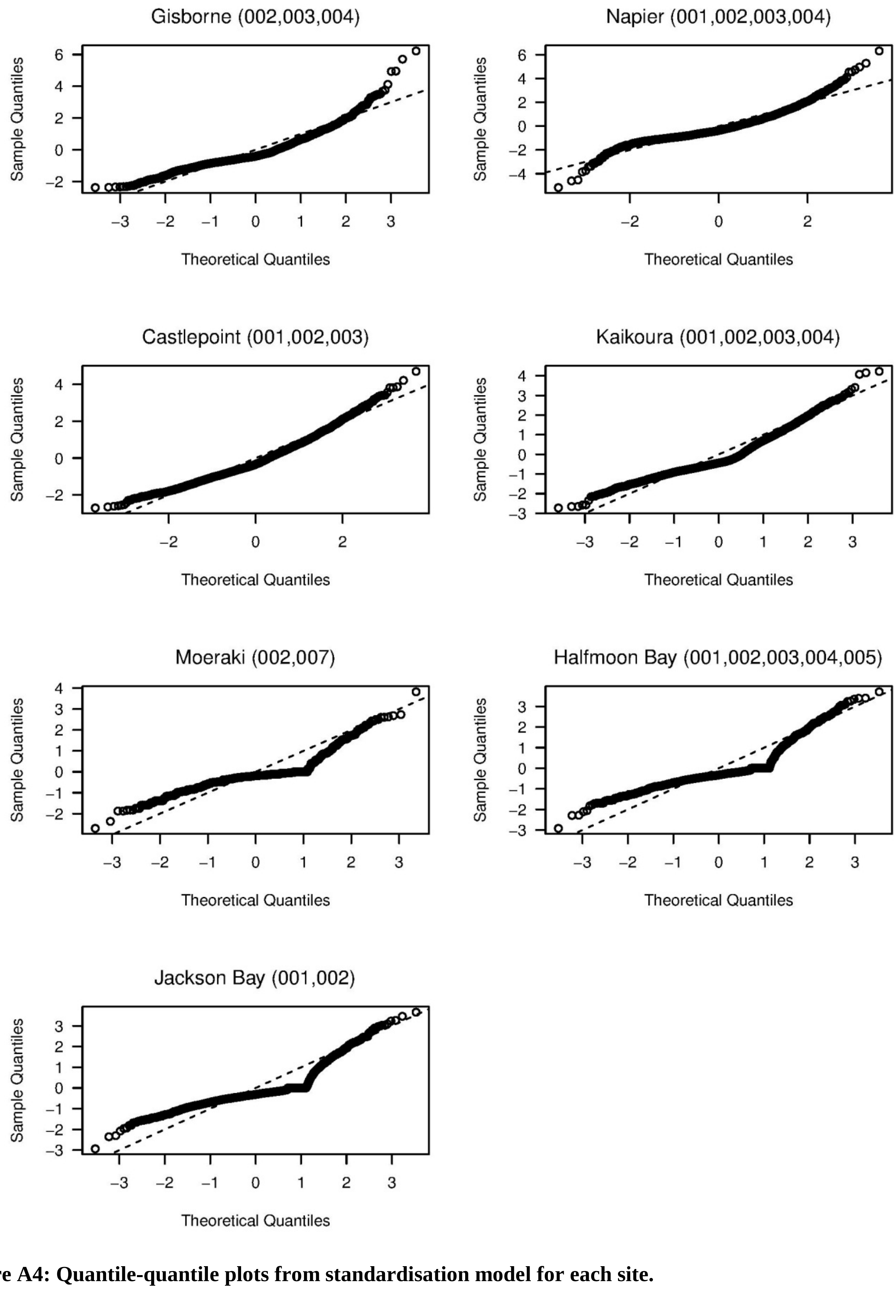

Figure A4: Quantile-quantile plots from standardisation model for each site.