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NIWA
Private Bag 14901
Wellington

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EXECUTIVE SUMMARY

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This report addresses the one objective of Ministry of Fisheries project CRA2002/01:

To estimate monthly and annual indices of puerulus settlement at key sites over the main area of the fishery (Gisborne, Napier, Castlepoint, Wellington, Kaikoura, Moeraki, Halfmoon Bay, Chalky Inlet, and Jackson Head).

We update and extend the information on spatial and temporal patterns of settlement of the red rock lobster, *Jasus edwardsii*, on crevice collectors around New Zealand. Both raw and standardised indices are presented. Levels of settlement in 2002 on the east coast of the country, at least from Gisborne to Kaikoura, were generally about average compared with the time series of previously estimated settlement levels. At most sites, settlement in 2002 was higher than in 2001, in turn greater than the particularly low settlement of 1999. Although still low along the southeast coast of the South Island compared with the average seen further north, the significantly higher settlement levels of 2000, the highest since the early 1980s, continued into 2001 and 2002. Settlement in 2002 was moderate in the southwest of the South Island.

Based on the standardised settlement data and estimates of juvenile male growth, recruitment of males to the CRA 3 fishery (and possibly fishery CPUE) is likely to remain low in 2003–04 but improve from 2005. In CRA 4, where males have a larger minimum legal size (MLS), recruitment to the fishery of males is likely to remain low, or even further reduce, until at least 2005. In CRA 5, where males have the same MLS as in CRA 4, the settlement data suggest that male recruitment to the fishery will decline until about 2007 before any improvement begins. In CRA 7, with its lower MLS for much of the fishing year for both males and females, the much improved settlement from 2000 may mean improved recruitment to the fishery for both sexes from about 2005–06. As always, however, such predictions can be confounded by variable growth and survival between years, predation, migration, and high levels of illegal fishing.

1. INTRODUCTION

1.1 Background

Rock lobsters support one of New Zealand's most valuable fisheries. Understanding larval recruitment processes will greatly assist management of this fishery because it may explain changes in levels of recruitment to the fishery and enable prediction of trends in catch levels at least 4 years in advance, allowing management and commercial strategies to be implemented. This report updates and extends the patterns of spatial and temporal settlement of *Jasus edwardsii* on crevice collectors in New Zealand previously reported (Booth et al. 2003b). In so doing, we address the objective of Ministry of Fisheries project CRA2002/02.

> To estimate monthly and annual indices of puerulus settlement at key sites over the main area of the fishery (Gisborne, Napier, Castlepoint, Wellington, Kaikoura, Moeraki, Halfmoon Bay, Chalky Inlet, and Jackson Head).

The estimates of settlement have been made available to the National Rock Lobster Management Group (NRLMG) and the Rock Lobster Working Group (RLWG) during 2003: they were presented to the Rock Lobster Research Planning Group Meeting (at which most of the NRLMG was present) on 25 September 2003, and to the RLWG on 22 October 2003.

Rock lobsters spend several months as phyllosoma larvae in waters tens to hundreds of kilometres offshore. They return to the shore as postlarval pueruli after metamorphosing near the shelf break. The puerulus stage is the settling stage: it resembles the juvenile in shape and is 9–13 mm in carapace length (CL), 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 into collectors after first settling elsewhere. Post-settlement migration such as this is common in invertebrates and in our studies we cannot distinguish it from puerulus settlement except where collectors are cleared after short intervals (e.g., daily). We use the term settlement to encompass both initial puerulus settlement and the capture of animals after post-settlement migration (see Booth & Stewart (1993) and Booth & Forman (1995)). The puerulus moults into the first juvenile instar (sometimes referred to as the first moult postpuerulus) a few days to 3 weeks after settlement, according to water temperature. Depending on sex and locality, the rock lobster then takes several years to reach minimum legal size.

Monthly occurrence of pueruli and young juveniles on crevice collectors (Booth & Tarring 1986) has been followed at eight or nine key sites within the main rock lobster fishery since the early 1980s. Results from this and other monitoring show that settlement is not uniform in time or space. Settlement is mainly at night and at any lunar phase, is usually seasonal, and levels of settlement can vary by an order of magnitude or more from year to year. Since the early 1980s, highest settlement has been along the east coast of the North Island south of East Cape (= southeast North Island or SENI), in the general region of highest offshore abundance of phyllosoma larvae.

1.2 Literature

The following are publications on early life history and larval recruitment in *J. edwardsii* appearing since those referred to by Booth et al. (2003b). Chiswell & Booth (2003) and Chiswell et al. (2003) provided evidence that phyllosomas can reach New Zealand from hatchings in southeast Australia. Cox & Bruce (2003) reported the feeding behaviour of Stages 1–3 phyllosomas, which included characteristic tumbling behaviour before contacting prey and use of the terminal dactyl of the first two pereopods to spear prey. Booth et al. (2003a) reviewed the joint endeavour with Australia to define diel vertical movements of *J. edwardsii* phyllosomas. Enzyme activities in the late-stage phyllosoma and puerulus provided information concerning the fuelling of swimming, their changes mirroring the shift in activity from pelagic ocean swimming to a benthic existence (Wells et al. 2001). Nishida (2002) discussed the sensory, feeding, and digestive systems of the phyllosoma and puerulus of spiny lobsters, with *J. edwardsii* the primary example. Hayakawa & Nishida (2002) described the diel behaviour of captive pueruli and first instar juveniles. Booth (2002) reviewed recent world-wide information on early life history, recruitment processes, and settlement in spiny lobsters, including *J. edwardsii*. Booth et al. (2002) summarised the cooperative work between New Zealand and Japan on *J. edwardsii* that led to advances in understanding of larval recruitment processes.

1.3 Why estimate relative abundance of early life history stages?

Knowing the relative abundance of the early life history stages (phyllosomas, pueruli, and young juveniles) will enhance understanding of the factors that drive fishery recruitment. It may be possible to relate changes in levels of settlement to changes in breeding stock abundance, abundance of advanced stage larvae, and to changes in the ocean climate. In particular, a knowledge of seasonal, annual, and geographic variation in settlement will help us to better understand larval recruitment processes. For example, geographically different settlement patterns may be due to the different water masses from which the postlarvae come. Information on year to year settlement levels may be used to predict trends in recruitment, provide early warning of overfishing, and indicate the extent to which recruitment varies from year to year. Such information can improve the usefulness of fishery assessment models, particularly their predictive capability.

The benefits of accurate prediction of recruitment trends are well demonstrated in Western Australia, where there are more than 30 years of settlement data (Phillips et al. 2000). Accurate forecasts allow improved financial planning and investment by fishers and processors, and proactive rather than reactive fisheries management. Using collectors set in sufficient numbers to deal with spatial variability in settlement is the most cost-effective means of measuring puerulus settlement. Almost every major rock lobster fishery in the world now has in place or is developing such a programme.

The settlement indices remain the only widespread fishery-independent data collected in the New Zealand rock lobster fishery. Continuation of the settlement time series will allow the usefulness of the settlement data in predicting changes in trend in recruitment to the fishery to be tested.

2. SPATIAL AND TEMPORAL PATTERNS OF SETTLEMENT

2.1 Introduction

Key sites are sampled to follow levels of settlement on crevice collectors along the main rock lobster fishing coasts of New Zealand (Figure 1), these sites having been finalised after trials over many years. Each key site is separated from its neighbour by 150–400 km, its location chosen based on the distance from the neighbouring site, accessibility, and level of puerulus catch. Other details were given by Booth & Stewart (1993).

At the key sites, crevice collectors are set in groups of 3–9, with a minimum spacing of 2 m between individual collectors. There is usually a core group at each key site; additional groups of collectors are set in both directions along the coast, as conditions allow, 0.1–25 km from the core collectors.

The crevice collectors are either shore, closing, or suspended (see Booth & Tarring 1986 and Phillips & Booth 1994 for collector design) (Table 1). Collectors are checked approximately monthly, at least over the main settlement season, and all lobsters removed (details of methods were given by Booth & Stewart 1993).

Crevice collectors on the sea floor (shore and closing crevice collectors) provide a combined index of (a) the number of pueruli in the water column which are settling, and (b) the result of post-settlement migration, the net number of older animals (older pueruli, and less often, young juveniles) moving onto the collector after having lived on the surrounding sea floor, and animals of similar age moving from the collector to the surrounding sea floor (Booth & Stewart 1993). Most of the animals on the collectors are from the first group and we assume that, for each collector, the proportion of each of these groups that make up the index is more or less constant among years. In contrast, crevice collectors suspended above the sea floor or at the surface (suspended crevice collectors) provide an index to the number of pueruli in the water column minus the number of older animals that settled on the collector and then emigrated from it. Immigration from the sea floor into suspended crevice collectors is much less likely to take place (although it can take place over a scale of metres — Booth & Forman (1995)). In this document the presence in a collector of a puerulus at any stage of development, or a first instar juvenile, is taken to mean that there has been settlement. But for both bottom and suspended collectors, migration means that the numbers of lobsters on a collector at each monthly check is less than the number of lobsters that have been present on the collector at some time during that month. Booth & Forman (1995) estimated that, on average, lobsters remain in a collector for about two weeks after settlement.

There is variation in levels of settlement within and among sites. Monthly catches of adjacent collectors within groups at any particular check are often very different, but the average catches of these individual collectors measured over several months or years are usually similar. These results are consistent with spatially uniform settlement over the scale of metres to tens of metres over time intervals of months to years.

Levels of settlement among areas can be compared when the same collection techniques have been used at several sites over a number of years: settlement over the past almost two decades has generally been several times higher in SENI than in most other parts of the country. Year-to-year settlement is correlated between several widespread sites. Changes in the large-scale ocean climate can contribute to changes in the patterns of puerulus recruitment: for example, there is significant positive correlation between El Niño–Southern Oscillation (ENSO) events and levels of settlement off Western Australia (Pearce & Phillips 1988).

2.2 Seasonality in settlement

The main settlement season varies according to location, but with large stretches of coast (regions) having the same general settlement seasons. These were reported by Booth (1994) for observations to the end of 1992 and are updated to 2002 in Figure 2. The seasonality has remained essentially the same. Adjacent sites have similar seasons, except for those pairs of sites that straddle regional boundaries. Winter is the most widespread main settlement season, but on the east coast of central New Zealand (Castlepoint to Kaikoura) there is usually also high settlement in summer and autumn. The reasons for these seasonalities, and their variation between areas, remain unclear.

2.3 Calculating indices

Until now the interannual index produced each year has been a raw index based only on the main settlement season (eg., Booth et al. 2003b). This *settlement season index* of annual settlement is the mean catch per collector of pueruli, plus juveniles up to and including 14.5 mm CL (the maximum size for a first instar juvenile observed from laboratory studies), of the core collectors over the main settlement season ± 1 s.e. of that mean. The main settlement season varies between 6 and 10 months according to site (Table 1), so the nominal values of the annual index are not always directly comparable between sites.

For the first time in this series of annual reports on settlement levels, standardised indices are also provided. The approach to the standardisation taken was based on that of Bentley et al. (in press). The *standardised index* differs most from the settlement season index in that it incorporates all settlement, irrespective of month. Furthermore, the standardised index takes into account changes in collector location and when sampling took place. In brief, a Generalised Linear Model framework was used, in which the response (dependent) variable was the log of numbers of settlers per collector sample. 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 was included. Each set of indices is presented as the annual value divided by the geometric mean of all annual values, allowing indices to be interpreted as deviations from the overall mean in log space. Thus a value for the index above one represents above average settlement for that year, and a value below one less than average settlement. For comparison, a raw form of this index is also given.

There were, however, small differences in approach to the standardisation compared with that taken by Bentley et al. (in press). First, early 'pilot' settlement results were not included because they usually involved checks of small numbers of collectors over short periods, often with little temporal overlap with previous and/or subsequent collector checks. As outlined above, it often took years of trials to arrive at what was considered to be a reasonable measure of levels of settlement for any particular site and these early results were not necessarily intended to be part of an index. Second, 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 10th of the month its catch was attributed to the previous month. This avoided the situation of, for example, a collector during approximately monthly checks being checked on the first and last days of a month having two entries for that month and none for the previous or subsequent one. Third, most of the outliers removed by Bentley et al. (in press) were incorporated. The exception were those associated with the Harbour collectors at Gisborne (GIS001). Results from these collectors were not included because of the peculiar nature of settlement there, in particular some extraordinarily large catches. These changes in procedure did not greatly affect the outcome.

2.4 Collector catches, 2002

Changes were made to the collector network in 2002 as a result of changes to the contract. From 1 October 2002, sites in CRA 1 and CRA 2 were discontinued, and some groups of collectors at other sites were no longer checked whereas others had their numbers of collectors increased. These changes are summarised in Table 1.

Settlement season annual indices for key sites by group are given in Table 2; these and the standardised and raw annual data are given in Figures 3–17.

2.4.1 Gisborne

Settlement in 2002 was about the same as in 2001, and well up on the record low of 1999 (Figures 3 and 4). As in previous years, settlement on all collectors peaked in winter, but there was also significant late spring/early summer settlement at Whangara. Whangara had highest settlement season index, with the values for Tatapouri and Kaiti lower and about the same (Table 2; the Harbour collectors are no longer checked).

2.4.2 Napier

There was lower settlement on the core (Harbour) collectors in 2002 than in 2001, but for the other sets (and when the data were standardised) it was about the same as in 2001 and well up on 1999 (the record recent low year) and 2000 (Figures 5 and 6, Table 2). Settlement peaked during winter.

2.4.3 Castlepoint

Settlement in 2002 remained below the observed long-term average, at levels similar to 2000 but up on the record low year of 1999 (Figures 7 and 8, Table 2). On all groups of collectors, there were both summer and winter peaks. The Castlepoint collectors had the highest settlement levels, those at Mataikona the lowest.

2.4.4 Wellington

Settlement on all collectors peaked in autumn and winter (Figure 9). Settlement levels during 2002 were moderate and well up on the record low year of 1999 (Figures 9 and 10). Highest settlement was again recorded at Island Bay (Table 2).

2.4.5 Kaikoura

Catch rates in 2002 were low across all collector groups, and similar to those in 2001 (Figures 11 and 12, Table 2). Unusually, settlement was highest in late spring.

2.4.6 Moeraki

Settlement in 2002, although down on 2000 and 2001, was much higher than seen during the 1990s (Figures 13 and 14, Table 2). Most settlement was in late winter and early spring. Collectors installed in Moeraki Bay continued to be the most effective. Several sites were discontinued. The poor precision of the standardised index was due to collector catch variability and the data not fitting the model well because of the large number of zero catches.

2.4.7 Halfmoon Bay

Settlement in 2002, although down a little on 2001, was among the highest for 15 years (Figures 15 and 16, Table 2), most taking place during late winter and early spring. Again, the poor precision of the standardised index was due to collector catch variability and the data not fitting the model well because of the large number of zeros.

2.4.8 Chalky Inlet

The remoteness of this site meant that several of the monthly checks were missed and it was not possible to produce a settlement season index (Figure 17, Table 2). However, the standardised index based on the three monthly checks made are given in Figure 18. Like 2001, 2002 appears to have been a moderate settlement year. The poor precision of the standardised index was due mainly to collector catch variability and missed checks.

2.4.9 Jackson Bay

Settlement levels in 2002 began at about the same (low) level seen in 2000-01, the most successful collectors being the wharf ones, but then improved markedly in late 2002 (Table 2). This is a relatively new site, for which the logistics of monthly checks of all groups of collectors are still being determined.

2.4.10 Summary

For the east coast of New Zealand, at least from Gisborne to Kaikoura, 2002 was an average settlement year compared with the time series of estimated settlement levels for each site, with settlement significantly higher than in the record low year of 1999. The dramatic increase in recent settlement levels in the southeast of New Zealand (southeast South Island and east coast Stewart Island, SENZ), particularly Moeraki, persisted into 2002. For the southwest of the South Island, 2002 was an average settlement year.

The within-site patterns reported by Booth et al. (2003b) persisted: there were often significant differences in the levels of settlement between groups of collectors within sites and sometimes this difference was large. The standardisation addressed this concern. Seasonality among groups at particular sites was, however, generally consistent.

2.5 Variability among sites over the long term

The geographic pattern in settlement on the collectors in 1994–98 and 2000–02 was similar to that seen through the 1980s, in that settlement on the east coast was generally high as far south as about Cook Strait. In contrast, during 1991–93 the area of high settlement extended further south, to at least Kaikoura — but not as far south as the south side of Banks Peninsula. In 1999, settlement along the east coast of the North Island was exceptionally low, about the same as that seen on the east coast of the South Island, improving slightly in 2000, and still further in 2001–02. These features can be seen in the standardised settlement for CRA 3 (see Gisborne — see Figure 4), CRA 4 (Figure 19), and CRA 5 (see Figure 12). However, in 2000–02 there was a marked increase in settlement levels in SENZ, particularly at Moeraki, to a level similar to that of the early 1980s (see Figures 13, 14, and 16). In the southwest of the South Island, at Chalky Inlet (see Figure 18), the levels of settlement on the collectors for most years have been moderate to high compared with those in SENZ.

2.6 Reasons for spatial variation in settlement

The much higher levels of settlement usually seen on collectors along SENI compared with those along SENZ is consistent with the pattern of phyllosoma abundance found in all widespread sampling (Booth 1994) and with the later plankton surveys in April 1994, March 1995, and February 1998. Advanced phyllosomas (those at and beyond Stage 5) were widespread and abundant off SENI, catches being orders of magnitude greater than off SENZ. It was concluded that regional differences in phyllosoma abundance were likely to be a major determinant of the differences in levels of settlement seen between SENI and SENZ. This in turn seemed to be closely related to the abundance of breeders, the oceanography, and certain environmental factors such as the persistence of southerly storms (see Booth et al. 2000). Unfortunately, there are no recent data on phyllosoma distribution or abundance, but we contend that the low-to-moderate levels of settlement along SENI in 1999–2001 were probably due more to the La Niña conditions than to any reduced abundance offshore of phyllosomas. The increased settlement off SENZ in 2000–02 (and into 2003 — not shown) could have been a result of increased numbers of advanced phyllosomas there.

2.7 Year to year variation in settlement over the long term

Indices of year-to-year settlement on the core collectors at the key sites given above and in Table 2 update those given by Booth et al. (2003b). Levels of annual settlement remained significantly correlated among sites along the east coast from Gisborne south (Gisborne-Napier-Castlepoint; Moeraki-Halfmoon Bay) (Table 3). Interannual levels of settlement between groups of collectors within the key sites with sufficient data are usually highly correlated (not shown).

Because of these correlations, and because, for example, 1991 and 1992 were very high settlement years, and 1998 a very low settlement year, along much of the east coast of northern and central New Zealand, factors that drive larval recruitment appear to affect wide areas.

Settlement in SENZ has been low, except in the early 1980s, and in 2000–02 when it increased markedly, at Moeraki in particular.

Settlement was moderate to high in the southwest of the South Island during 1987–91, in 1994, during 1996–97, and in 2000–01; it was low in 1985–86, 1992–93, and 1998.

3. MANAGEMENT IMPLICATIONS

Although the 1999 settlement level for nearly all SENI sites was very low in relation to the time series of settlement estimates — about 30% or less of those of the recent peak years 1991–92 — settlement in 2002 was closer to the average. In most areas the fishery is still largely dependent on just a few newly recruited year classes (Ministry of Fisheries and SeaFIC data). Nowhere else are the implications of the recent settlement estimates likely to be more marked than at Gisborne, where the fishery is mainly directed at very small, young, newly recruited males (Sullivan & O'Brien 2002). The record low settlement observed in CRA 3 in 1999 is likely to contribute to further low recruitment to the fishery (and perhaps fishery CPUE) in 2003–04 (based on an average 4–5 years for males to recruit; McKoy & Esterman (1981)). The much improved settlement in 2001–02 over that in 1999 should mean, however, improving recruitment to the fishery from about 2005. In CRA 4, where males have a larger minimum legal size (MLS), male recruitment to the fishery is likely to remain low, or even further reduce, until at least 2005. In CRA 5, where males have the same MLS as in CRA 4, the Kaikoura settlement data suggest that male recruitment to the fishery will decline until about 2007 before any improvement begins. In CRA 7, with its lower MLS for much of the fishing year for both males and females, the much improved settlement from 2000 may mean improved recruitment to the fishery of both sexes from about 2005–06, based on the growth estimates of Street & Booth (1985) and Annala & Bycroft (1985). As always, however, the validity of such predictions can be confounded by variable growth and survival (including density-dependence which can smooth peaks and troughs in recruitment), predation, migration, and high levels of illegal fishing.

The above discussion relates changes in trends in settlement with possible subsequent changes in trends in recruitment to the fishery. A change in trend is where a consistent settlement trend (e.g., decline) over a period of years has changed to another consistent trend (e.g., increase) over a period of years, rather than year-to-year changes. The relationships between settlement and recruit abundance have been previously investigated, with some promising early indications of significant correlation (Booth et al. 2000). However, the settlement data were found to be unhelpful in explaining changes in the fishery in the later investigation of Bentley et al. (in press), who compared standardised indices of settlement with the estimates of recruitment obtained from the recent stock assessments, and also used a simple length-based model of the rock lobster fishery to examine the correspondence between settlement indices and catch-sampled males.

However, it is only since the early to mid 1990s that several fisheries have become largely male fisheries, together with there being marked changes in trends in settlement. For the east coast (at least from Gisborne to Kaikoura), among the highest-ever settlements occurred in the early 1990s, declining to among the lowest-ever settlements in the late 1990s, followed by a recovery in settlement levels beginning in the early 2000s. Consistent with this, a) commercial CPUE on the east coast of central New Zealand increased to high levels in the late 1990s with a subsequent steep decline, and b) the stock assessment models suggest that a large recruitment pulse occurred in NSN (the northern substock, comprising CRA 1 and CRA 2) and NSC (the central substock, comprising CRA 3, CRA 4, and CRA 5) in the early to mid 1990s, followed by much lower recruitment in subsequent years. A different pattern of settlement pertains to CRA 7 (Otago). Settlement was very low during the 1990s but it has improved markedly since 2000, and by 2003 had reached levels in the low range of what is normally seen on the east coast North Island. A similar, though somewhat muted, trend has become apparent further south, at Halfmoon Bay.

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Table 1: Collector type and number by site, and main settlement season. 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). Not all sites have a designated core set.

Site	No. collectors	Core group	Additional groups	Location	Type	Main settlement season
Houhora	*5*		*HOU001*	*Heads*	*Suspended*	*?*
	5		*HOU002*	*Henderson*	*Shore*	*?*
Bowentown	*5*		*BOW001*	*Papatu*	*Shore*	*?*
	5		*BOW002*	*Yellow*	*Shore*	*?*
Gisborne	5	GIS002		Whangara	Shore	Apr–Oct
	5		*GIS001*	*Harbour*	*Shore*	*Apr–Oct*
	5		GIS003	Tatapouri	Shore	Apr–Oct
	5		GIS004	Kaiti	Shore	Apr–Oct
Napier	6	NAP001		Harbour	Suspended	Apr–Sep
	3		*NAP002*	*Westshore*	*Closing*	*Apr–Sep*
	5		NAP003	C. Kidnappers	Shore	Apr–Sep
	3		*NAP004*	*Breakwater*	*Shore*	*Apr–Sep*
Castlepoint	9	CPT001		Castlepoint	Shore	Dec–Sep
	5		CPT002	Orui	Shore	Dec–Sep
	5		CPT003	Mataikona	Shore	Dec–Sep
Wellington	3		WGT001	Island Bay	Shore	Jan–May
	3		*WGT002*	*Lyall Bay*	*Shore*	*Jan–May*
	3		WGT003	Breaker Bay	Shore	Jan–May
	3		WGT004	Palmer Head	Shore	Jan–May
Kaikoura	~~3~~ 5	KAI001		South 13–15	Shore	Jan–Sep
	3		*KAI002*	*South 31–33*	*Shore*	*Jan–Sep*
	~~3~~ 5		KAI003	North 10–12	Shore	Jan–Sep
	3		*KAI004*	*North 34–36*	*Shore*	*Jan–Sep*
Moeraki	*4*	*MOE001*		*Shag Point*	*Shore*	*Mar–Oct*
	3		MOE002	Wharf	Closing	Mar–Oct
	3		*MOE004*	*Millers Beach*	*Shore*	*Mar–Oct*
	3		*MOE005*	*The Kaik*	*Shore*	*Mar–Oct*
	3		*MOE006*	*Kakanui*	*Shore*	*Mar–Oct*
	15		MOE007	Pier	Suspended	Mar–Oct
Halfmoon Bay	~~3~~ 15	HMB001		Wharf	Suspended	May–Oct
	3		*HMB002*	*Thompsons*	*Closing*	*May–Oct*
	3		*HMB003*	*Old Mill*	*Closing*	*May–Oct*
	3		*HMB004*	*The Neck*	*Closing*	*May–Oct*
	3		*HMB005*	*Mamaku Point*	*Closing*	*May–Oct*
Chalky Inlet	6	CHA001		Shallow Passage	Closing	Mar–Oct
Jackson Head	~~3~~5		JAC001	Jackson Bay Wharf	Suspended	Mar–Oct
	3		JAC002	Jackson Head Inner	Closing	Mar–Oct
	3		*JAC003*	*Jackson Head Outer*	*Closing*	*Mar–Oct*
	3		*JAC004*	*Smoothwater Bay*	*Closing*	*Mar–Oct*

Table 2: Annual settlement season indices (mean number of pueruli + juveniles at least 14.5 mm carapace length per collector during the main settlement season — see Table 2) on core (usually, but not always, 001) and additional groups of collectors at the key sites to 2002. Collectors are all crevice collectors. GIS001 is Harbour 1–5 at Gisborne, GIS002 is Whangara 1–5, GIS003 is Tatapouri 1–5, and GIS004 is Kaiti 1–5; NAP001 is Harbour 1–6 at Napier, NAP002 is Westshore 1–3, NAP003 is Cape Kidnappers 1–5, and NAP004 is Breakwater 1–3; CPT001 is Castlepoint 1–9 at Castlepoint, CPT002 is Orui 1–5, and CPT003 is Mataikona 1–5; WGT001 is Island Bay 1–3, WGT002 is Lyall Bay 1–3, WGT003 is Breaker Bay 1–3, and WGT004 is Palmer Head 1–3; KAI001 is South 13–15 on the Kaikoura Peninsula, KAI002 is South 31–33, KAI003 is North 10–12, and KAI004 is North 34–36; MOE001 is Shag Point 1-4 near Moeraki, MOE002 is Wharf 1–3, MOE004 is Millers Beach 1–3, MOE005 is The Kaik 1–3, MOE006 is Kakanui 1–3, Overall is an index based on at least nine collectors each month, but the collectors checked were not always the same; HMB001 is Wharf 1–3 in Halfmoon Bay, Stewart Island, HMB002 is Thompsons 1–3, HMB003 is Old Mill 1–3, HMB004 is The Neck 1–3, and HMB005 is Mamaku Point 1–3; CHA is Chalky Inlet 1-6. Settlement (Overall) at Houhora (HOU), Bowentown (BOW), and Jackson Head (JAC) was usually based on at least nine collectors checked each month but more rigorous treatment of these results was not appropriate. Columns give mean catch across the collectors ± 1 s.e. of that mean; –, no data.

Houhora	Overall
2001	0.5

Bowentown	Overall
2001	3.2

Gisborne	GIS001	GIS002	GIS003	GIS004
1987	170 ± 8.9	–	–	–
1988	177.7 ± 15.4	–	–	–
1989	58.4 ± 4.5	–	–	–
1990	29.4 ± 3.5	–	–	–
1991	64.4 ± 5.9	–	–	–
1992	171.2 ± 27.7	70.3 ± 7.6	–	–
1993	107.8 ± 11.3	33.7 ±2.6	–	–
1994	131.2 ± 10.7	48.6 ± 10.4	77.4 ± 11.4	23.8 ± 1.9
1995	66.4 ± 6.4	40.8 ± 6.2	16.4 ± 2.2	5.0 ± 1.73
1996	165.8 ± 38.9	30.3 ± 1.5	–	13.4 ± 3.1
1997	53.8 ± 9.1	19.6 ± 3.2	25.2 ± 2.0	7.6 ± 1.3
1998	114.4 ± 45.3	33.1 ± 3.4	24.4 ± 1.9	16.6 ± 2.8
1999	31.2 ± 3.7	2.4 ± 0.8	0	1.00 ± 0.5
2000	40.8 ± 8.8	16.6 ± 3.6	23.2 ± 3.1	4.6 ± 1.4
2001	61 ± 11.3	35.0 ± 7.2	15.6 ± 3.0	14.6 ± 5.6
2002	–	37.0 ± 7.7	8.4 ± 1.4	5.2 ± 2.2

Table 2 -continued

Napier	NAP001	NAP002	NAP003	NAP004
1979	10.7 ± 1.5	–	–	–
1980	26.5 ± 6.4	–	–	–
1981	39.2 ± 2.9	–	–	–
1982	18.8 ± 2.3	–	–	–
1983	22.8 ± 4.7	–	–	–
1984	6.5 ± 1.2	–	–	–
1985	4.4 ± 0.6	–	–	–
1986	–	–	–	–
1987	–	–	–	–
1988	22.0 ± 1.2	–	–	–
1989	16.0 ± 2.5	–	–	–
1990	15.8 ± 1.9	–	–	–
1991	48.7 ± 6.7	173.3 ± 9.5	–	–
1992	29.0 ± 2.7	224.3 ± 4.4	–	97.2 ± 5.9
1993	23.3 ± 4.8	–	–	55.7 ± 4.9
1994	32.8 ± 1.8	115.0 ± 19.6	–	25.5 ± 3.4
1995	20.2 ± 1.5	103.3 ± 7.2	13.0 ± 1.9	23.2 ± 5.3
1996	26.0 ± 3.4	173.3 ± 51.4	11.6 ± 1.4	82.5 ± 15.0
1997	12.2 ± 0.8	137.7 ± 3.3	15.4 ± 2.4	54.7 ± 8.0
1998	19.1 ± 1.5	88.0 ± 11.3	30.8 ± 5.7	43.0 ± 8.7
1999	6.0 ± 1.4	–	2.4 ± 0.7	6.3 ± 0.3
2000	13.0 ± 1.7	–	7.8 ± 1.2	18.7 ± 1.5
2001	37.2 ± 3.8	–	18.2 ± 4.7	20.17 ± 3.4
2002	15.2 ± 3.3	–	21.8 ± 3.2	15.3 ± 0.3

Castlepoint	CPT001	CPT002	CPT003
1983	70.2 ± 7.5	–	–
1984	54.8 ± 3.1	–	–
1985	35.0 ± 7.1	–	–
1986	15.9 ± 2.0	–	–
1987	62.4 ± 5.1	–	–
1988	42.3 ± 3.0	–	–
1989	51.4 ± 3.4	–	–
1990	31.4 ± 8.6	–	–
1991	81.6 ± 6.0	–	–
1992	93.7 ± 5.8	118.0 ± 8.6	30.0 ± 3.8
1993	50.6 ± 7.2	65.8 ± 5.9	20.2 ± 2.5
1994	40.2 ± 1.9	22.8 ± 3.8	6.8 ± 1.0
1995	47.7 ± 5.2	22.9 ± 3.5	8.8 ± 1.2
1996	51.6 ± 6.1	42.6 ± 5.6	25.8 ± 2.9
1997	43.1 ± 3.8	54.6 ± 2.1	37.2 ± 3.4
1998	64.2 ± 4.0	65.2 ± 6.5	28.5 ± 2.4
1999	11.9 ± 1.5	Sanded	5.2 ± 0.7
2000	18.8 ± 2.2	Sanded	15.4 ± 1.5
2001	22.2 ± 2.7	Sanded	12.8 ± 2.3
2002	28.6 ± 3.1	23.9 ± 1.5	8.4 ± 2.2

Table 2 -continued

Wellington	Overall	WGT001	WGT002	WGT003	WGT004
1981	6.3	6.3	–	–	–
1982	0.2	0.2	–	–	–
1983	3.7	3.7	–	–	–
1984	0.4	0.4	–	–	–
1985	–	–	–	–	–
1986	–	–	–	–	–
1987	–	–	–	–	–
1988	–	–	–	–	–
1989	–	–	–	–	–
1990	–	–	–	–	–
1991	–	–	–	–	–
1992	–	–	–	–	–
1993	–	–	–	–	–
1994	6.6	11.7 ± 2.0	2.3 ± 0.3	–	5.7 ± 0.9
1995	4.9	4.7 ± 1.8	3.0 ± 1.5	–	7.0 ± 1.5
1996	4.2	7.3 ± 1.2	0.7 ± 0.7	4.7 ± 1.5	–
1997	22.8	57.0 ± 5.6	2.7 ± 0.7	8.7 ± 2.3	–
1998	5.3	10.0 ± 1.0	0.7 ± 0.7	5.3 ± 0.9	–
1999	3.0	7.0 ± 2.3	0	2.0 ± 0.6	–
2000	14.2	19.7 ± 1.2	–	6.3 ± 0.9	16.7 ± 1.9
2001	12.3	21.3 ± 4.9	–	4.3 ± 0.3	11.3 ± 1.5
2002	16.2	24.7 ± 4.2	–	15.3 ± 3.4	8.7 ± 3.1

Kaikoura	KAI001	KAI002	KAI003	KAI004
1981	–	–	8.4 ± 1.2	–
1982	0	–	0	–
1983	7.2 ± 1.2	–	4.2 ± 1.2	–
1984	1.7 ± 0.3	–	2.3 ± 1.0	–
1985	2.0 ± 0.6	–	3.7 ± 0.4	–
1986	0.3 ± 0.3	–	1.2 ± 0	–
1987	15.2 ± 0.6	–	2.0 ± 0.3	–
1988	6.7 ± 0.9	–	1.3 ± 0.3	–
1989	9.7 ± 1.5	4.0 ± 1.5	4.0 ± 1.5	–
1990	2.3 ± 1.5	1.7 ± 0.9	0.7 ± 0.7	–
1991	60.7 ± 2.2	35.3 ± 1.2	24.0 ± 2.1	–
1992	68.5 ± 5.7	34.3 ± 2.7	22.7 ± 0.3	–
1993	35.7 ± 1.2	12.3 ± 0.9	14.7 ± 0.9	10.7 ± 0.9
1994	7.8 ± 2.1	1.8 ± 0.3	1.3 ± 0.9	1.0 ± 1.0
1995	12.0 ± 1.2	4.3 ± 0.9	4.0 ± 0.6	3.3 ± 2.0
1996	8.0 ± 1.3	4.5 ± 1.2	2.9 ± 0.6	1.3 ± 1.0
1997	16.3 ± 2.7	5.8 ± 0.9	5.0 ± 0.3	7.0 ± 1.5
1998	24.5 ± 1.2	11.0 ± 2.5	4.2 ± 1.2	11.8 ± 1.5
1999	12.5 ± 0.7	6.7 ± 0.6	5.5 ± 1.2	5.2 ± 1.9
2000	13.5 ± 2.4	3.0 ± 0.9	10.7 ± 2.2	3.2 ± 1.5
2001	5.0 ± 2.1	0	6.3 ± 2.7	0.3 ± 0.3
2002	8.3 ± 2.0	0.7 ± 0.3	7.0 ± 0.6	1.3 ± 0.9

Table 2 -continued

Moeraki	Overall	MOE001	MOE002	MOE004	MOE005	MOE006
1981	6.6	–	–	–	–	–
1982	0.2	–	–	–	–	–
1983	3.8	4.3 ± 1.9	–	–	–	–
1984	0.3	0.7 ± 0.3	–	–	–	–
1985	0	0	–	–	–	–
1986	0	0	–	–	–	–
1987	2.5	3.3 ± 1.0	3.7 ± 1.0	–	–	–
1988	0.1	0	0	–	–	–
1989	2.8	4.7 ± 1.2	2.0 ± 0.6	–	–	–
1990	2.2	0.8 ± 0.7	–	–	–	–
1991	0.4	0	0	–	–	–
1992	0.3	0.5 ± 0.3	0.5 ± 0.3	0	–	–
1993	0.3	0	0	0	–	–
1994	0.3	0.5 ± 0.3	0	0	–	–
1995	0.3	0	0.3 ± 0.6	0	–	–
1996	1.1	0.4 ± 0.3	3.3 ± 2.3	0	–	–
1997	0.4	0	1.7 ± 0.3	0	–	–
1998	1.0	–	2.0 ± 0	0	–	–
1999	0.3	–	0.3 ± 0.3	0	0	0
2000	6.1	–	11.7 ± 0.3	0	1.3 ± 1.0	0
2001	6.4	–	8.7 ± 4.1	–	0.7 ± 0.3	–
2002	3.4	–	4.7 ± 1.5	–	–	–

Halfmoon Bay	HMB001	HMB002	HMB003	HMB004	HMB005
1981	29.9 ± 3.5	–	–	–	–
1982	1.8 ± 0.7	–	–	–	–
1983	14.3 ± 1.8	–	–	–	–
1984	0.7 ± 0.3	–	–	–	–
1985	0	–	–	–	–
1986	0.5 ± 0.3	–	–	–	–
1987	5.0 ± 1.0	–	–	–	–
1988	0.7 ± 0.3	0.7 ± 0.7	–	–	–
1989	2.0 ± 1.0	1.3 ± 0.7	–	–	–
1990	2.8 ± 0.2	0.5 ± 0.3	1.2 ± 0.6	–	–
1991	1.0 ± 0	5.2 ± 0.9	1.7 ± 0.7	–	–
1992	4.0 ± 0.3	2.0 ± 0.6	0.3 ± 0.3	0.3 ± 0.3	0.7 ± 0.3
1993	0	0	0	0	0
1994	2.2 ± 0.6	5.0 ± 0.6	2.0 ± 1.5	1.3 ± 1.3	3.3 ± 2.0
1995	2.3 ± 0.7	1.0 ± 1.0	0.3 ± 0.3	0.3 ± 0.3	0
1996	1.5 ± 0	1.0 ± 0.6	0	0.3 ± 0.3	0.7 ± 0.7
1997	2.0 ± 0.9	1.7 ± 0.9	0	0.3 ± 0.3	2.7 ± 1.2
1998	0.7 ± 0.3	1.0 ± 1.0	0.7 ± 0.3	0.7 ± 0.3	0.3 ± 0.3
1999	0.3 ± 0.3	1.5 ± 0.7	0.3 ± 0.3	0	0.5 ± 0.3
2000	4.0 ± 1.5	5.0 ± 0.3	2.2 ± 0.6	0.7 ± 0.3	1.8 ± 0.3
2001	7.0 ± 1.5	3.3 ± 0.7	2.3 ± 1.2	2.0 ± 1.0	3.7 ± 1.2
2002	2.3 ± 0.9	3.3 ± 1.5	6.7 ± 2.0	3.0 ± 0.6	1.7 ± 0.3

Table 2 -continued

Chalky Inlet	CHA001		CHA001		CHA001
1987	53.3 ± 5.3	1993	5.3 ± 0.7	1999	12.3 ± 1.7
1988	49.1 ± 5.2	1994	90.5 ± 21.3	2000	33.7 ± 2.9
1989	67.0 ± 9.0	1995	19.0 ± 2.9	2001	29.6 ± 4.8
1990	35.5 ± 4.2	1996	37.6 ± 4.7	2002	–
1991	37.9 ± 6.1	1997	47.3 ± 9.5		
1992	13.5 ± 1.7	1998	5.0 ± 1.1		

Jackson Head	Overall
2000	5.9
2001	6.3
2002	22.8

Table 3: Pearson correlation coefficients for the pattern of year-to-year settlement (mean number of pueruli + juveniles at least 14.5 mm carapace length per collector during the main settlement season) on core collectors among some key sites (insufficient data for Jackson Bay). GIS, Gisborne (1992–2002); NAP, Napier (1979–85, 1988–2002); CPT, Castlepoint (1983–2002); KAI, Kaikoura (1982–2002); MOE, Moeraki overall (1981–2002); HMB, Halfmoon Bay (1981–2002); CHA, Chalky Inlet (1987–2002); degrees of freedom are given in parentheses; * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$; other correlations not significant.

	GIS	NAP	CPT	KAI	MOE	HMB
NAP	0.71(9)*					
CPT	0.76(9)**	0.46(16)*				
KAI	0.58(9)	0.53(17)*	0.70(18)***			
MOE	–0.19(9)	0.26(18)	–0.27(18)	–0.20(19)		
HMB	0.30(9)	0.42(18)	0.22(18)	–0.06(19)	0.69(20) ***	
CHA	0.10(9)	0.17(13)	–0.09(14)	–0.38(14)	0.07(14)	0.15(14)

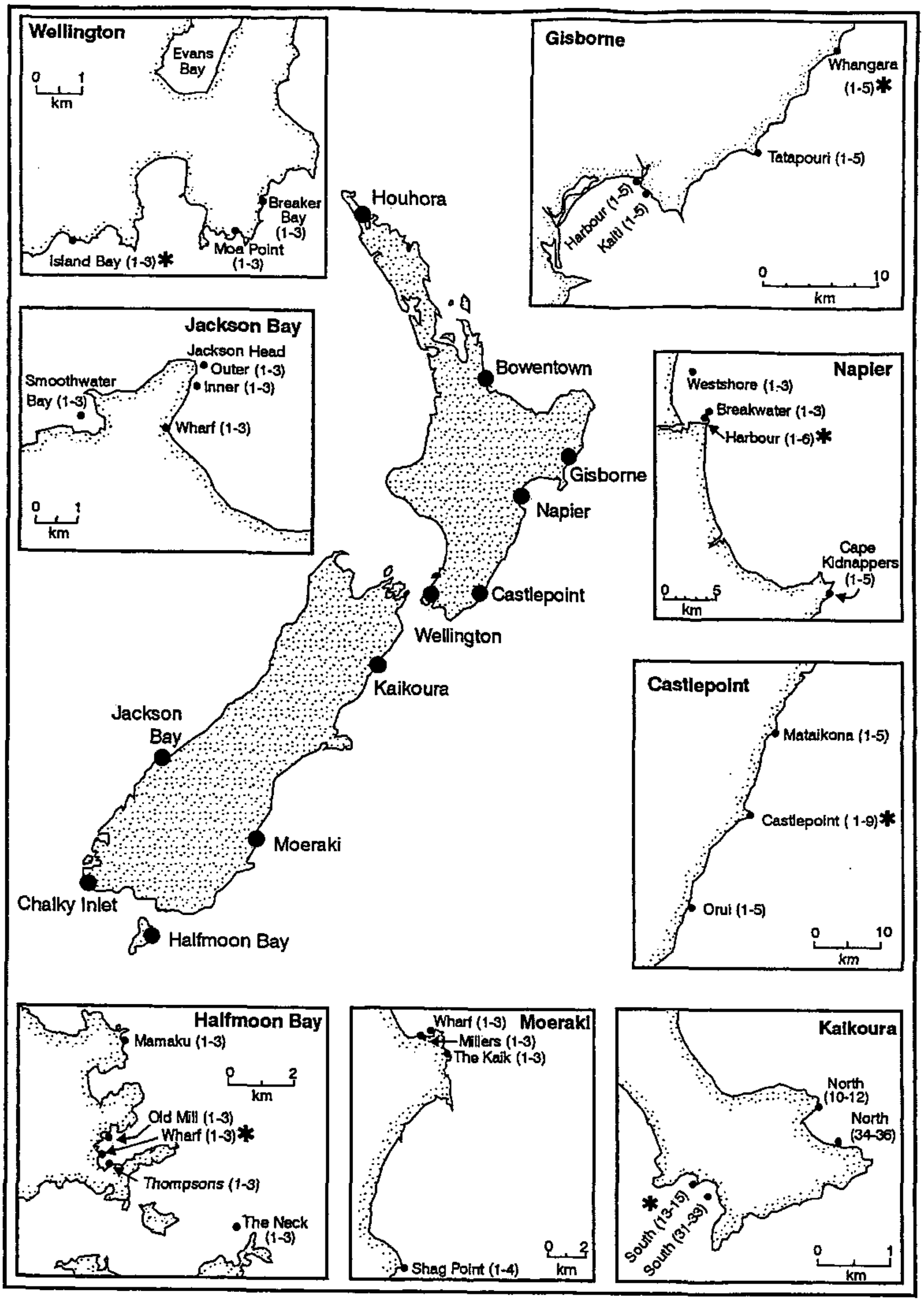

Figure 1: Map of New Zealand showing location of collectors at the key monitoring sites, although not all groups are now checked (see Table 1). The insets show the numbers and arrangement of collectors at sites with more than one group of collectors. *, core group of collectors where one has been nominated.

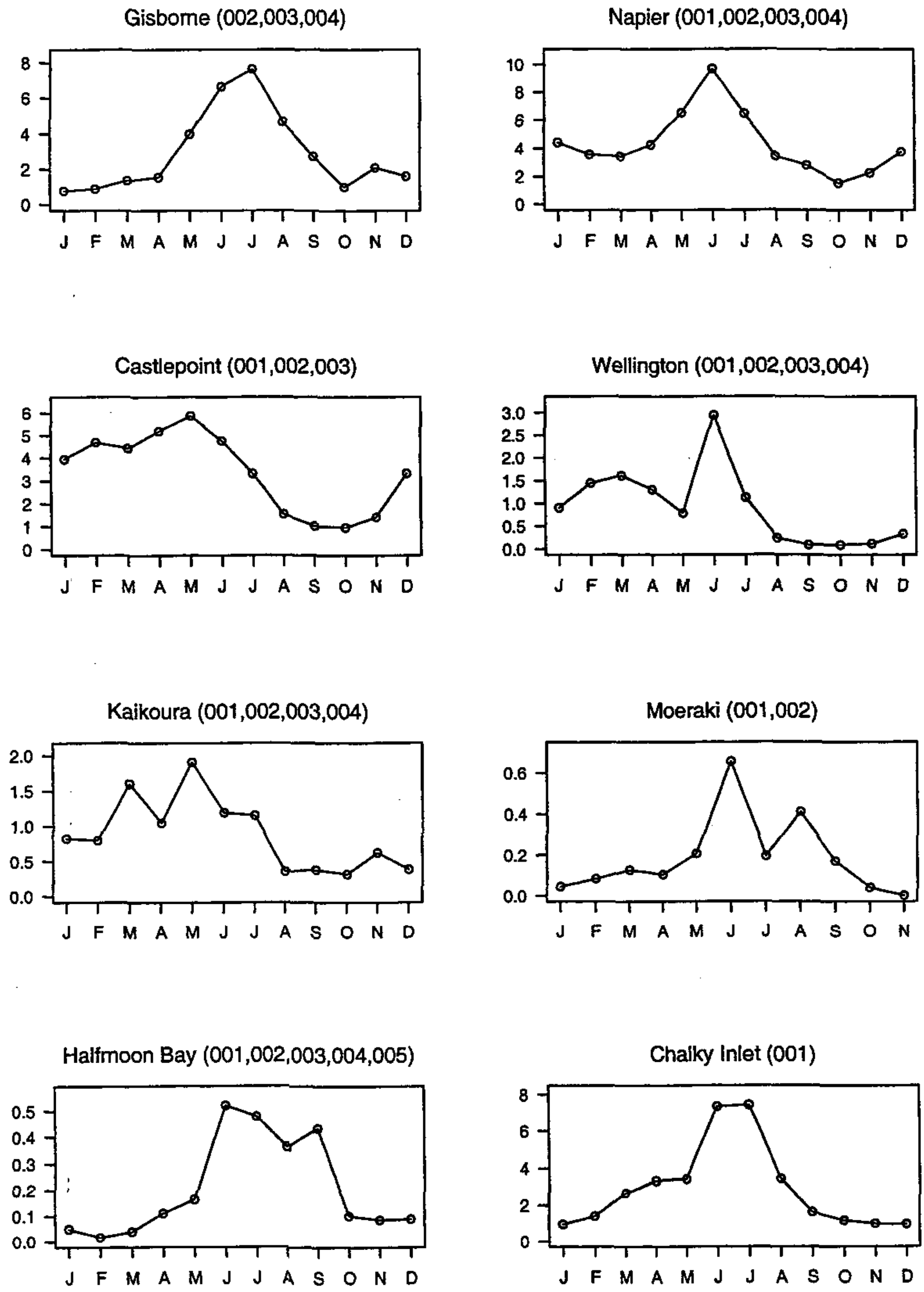

Figure 2: Patterns of monthly mean annual settlement for key collector sites, based on entire record.

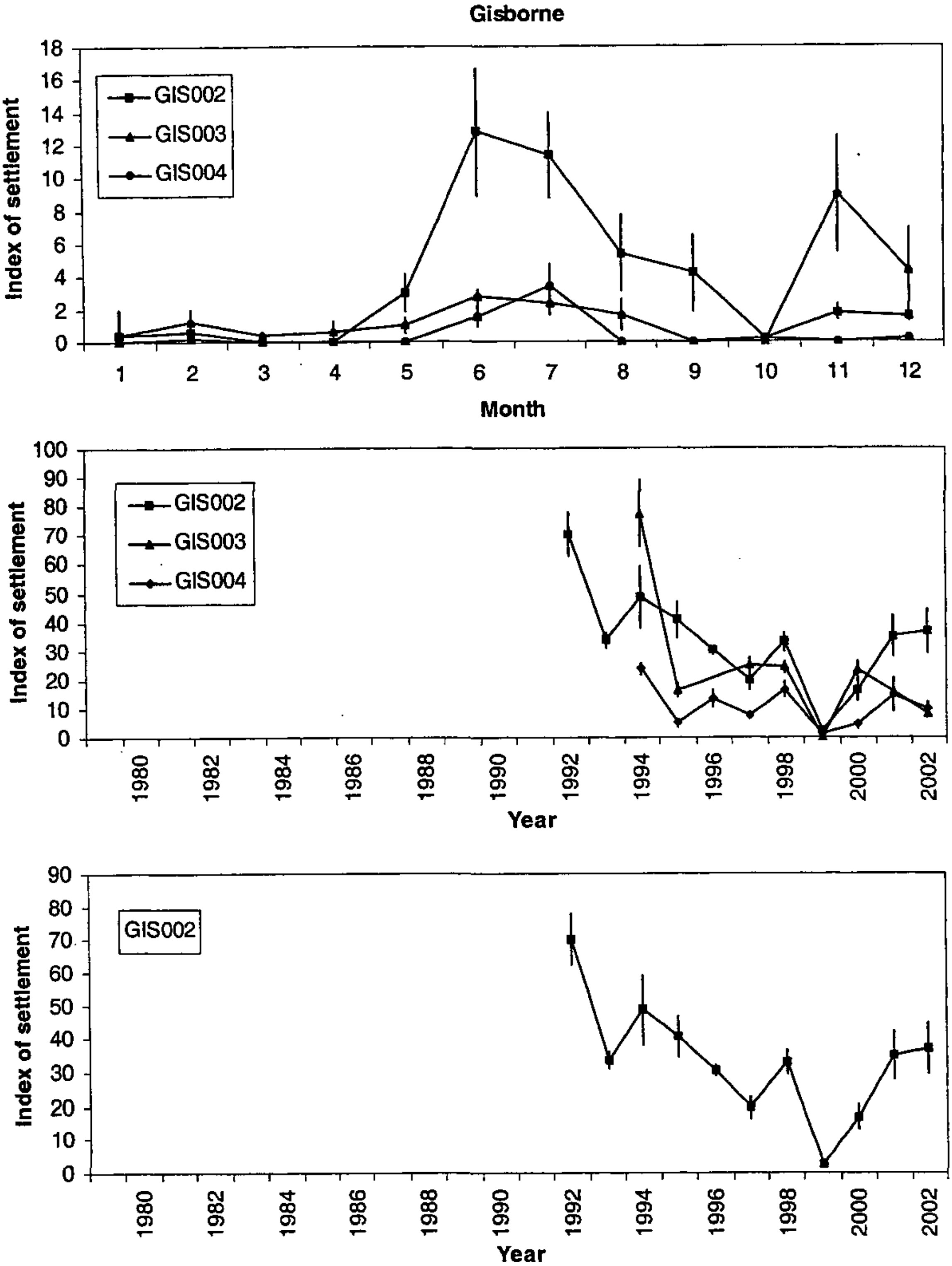

Figure 3: Gisborne – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, April to October) on groups of collectors ± 1 standard error (*middle*) and on the core group (*lower*). GIS002 is Whangara (core); GIS003 is Tatapouri; GIS004 is Kaiti (see Figure 1). GIS001, the harbour group, is not shown on the middle panel because it obscures and confuses the interannual pattern (see Booth et al. 1998).

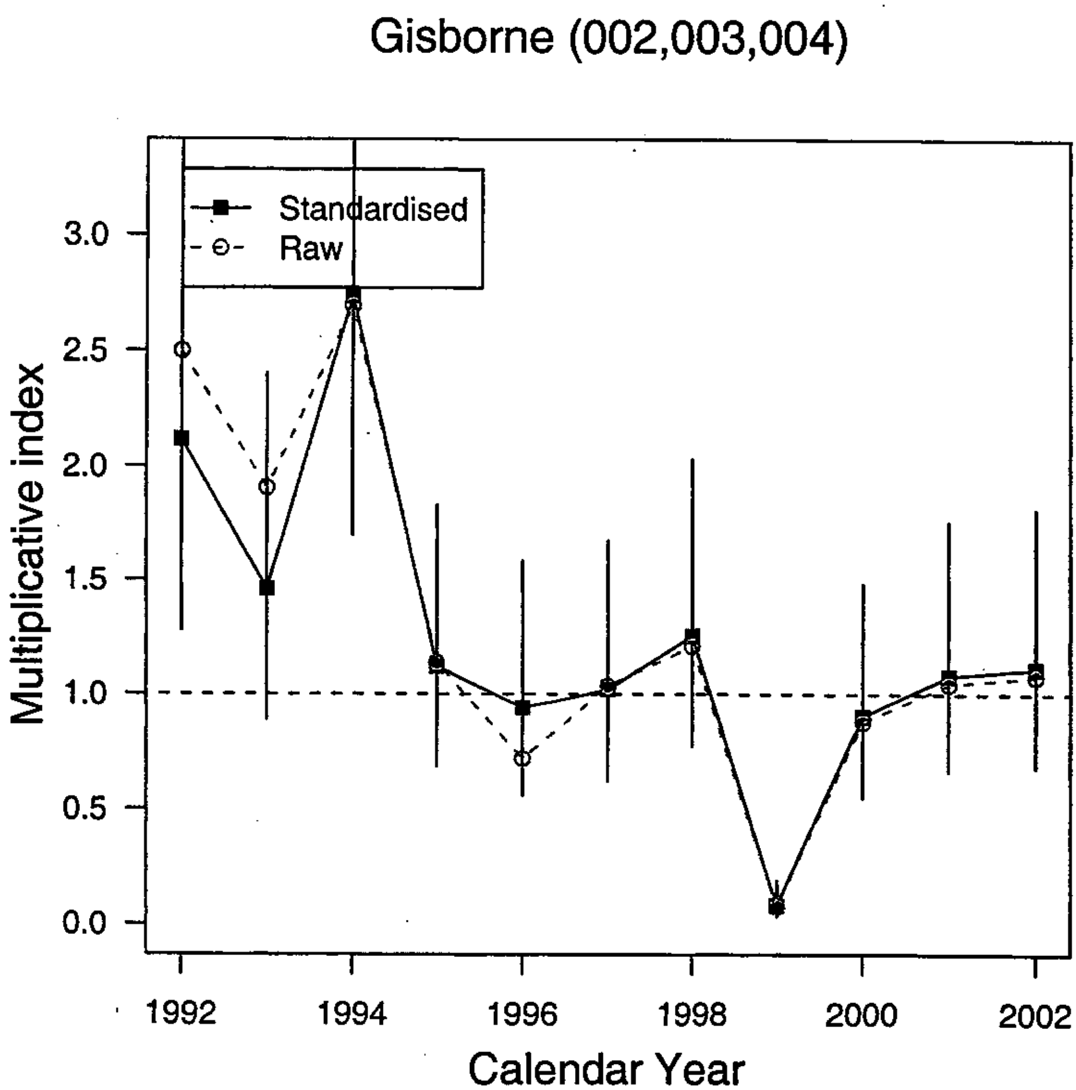

Figure 4: Gisborne – standardised and raw indices of annual settlement.

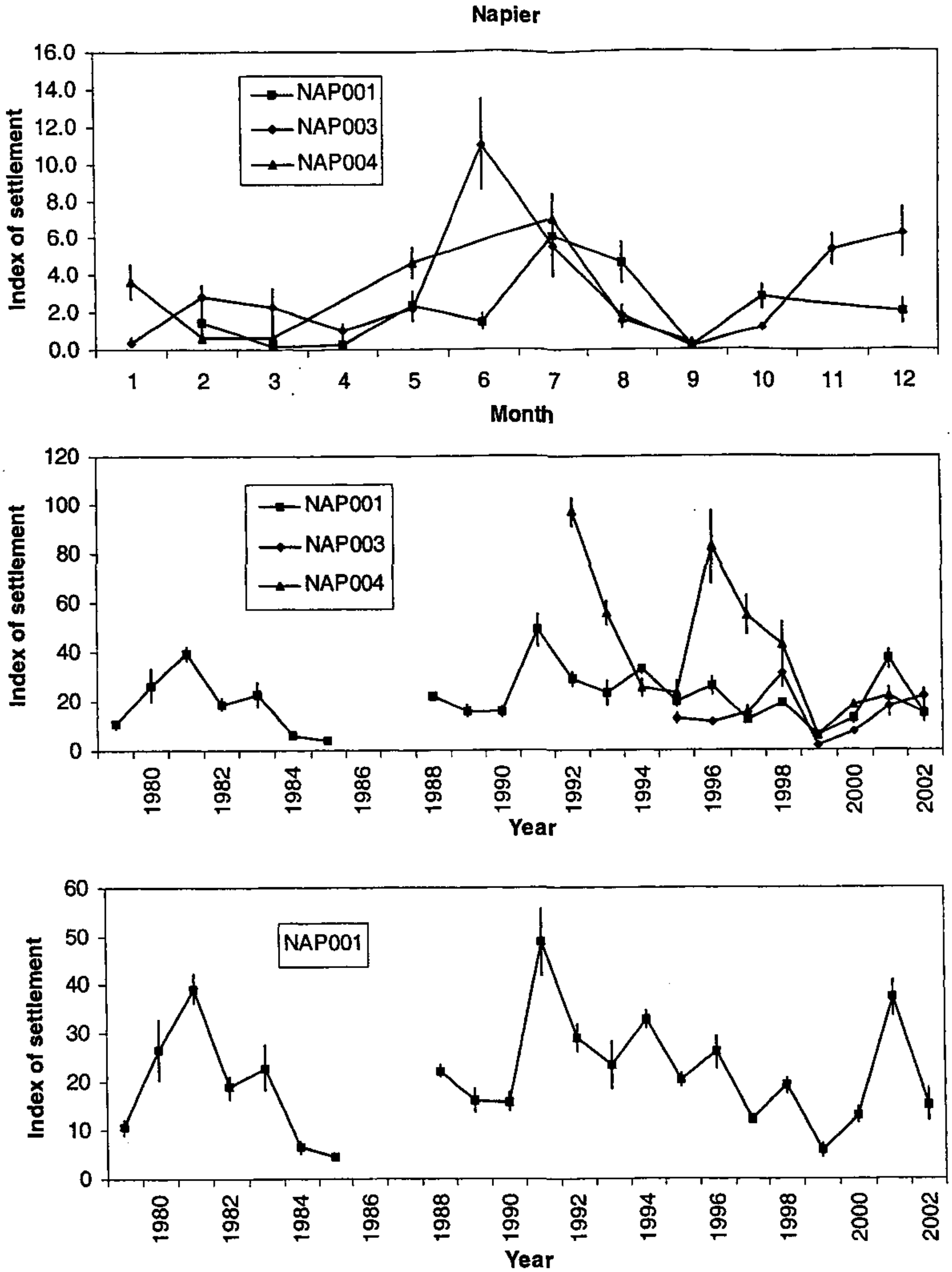

Figure 5: Napier – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, April to September) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). NAP001 is the Harbour group (core); NAP003 is Cape Kidnappers; NAP004 is Breakwater (see Figure 1). Collector positions and deployment changed after 1985; no data available for 1986–87.

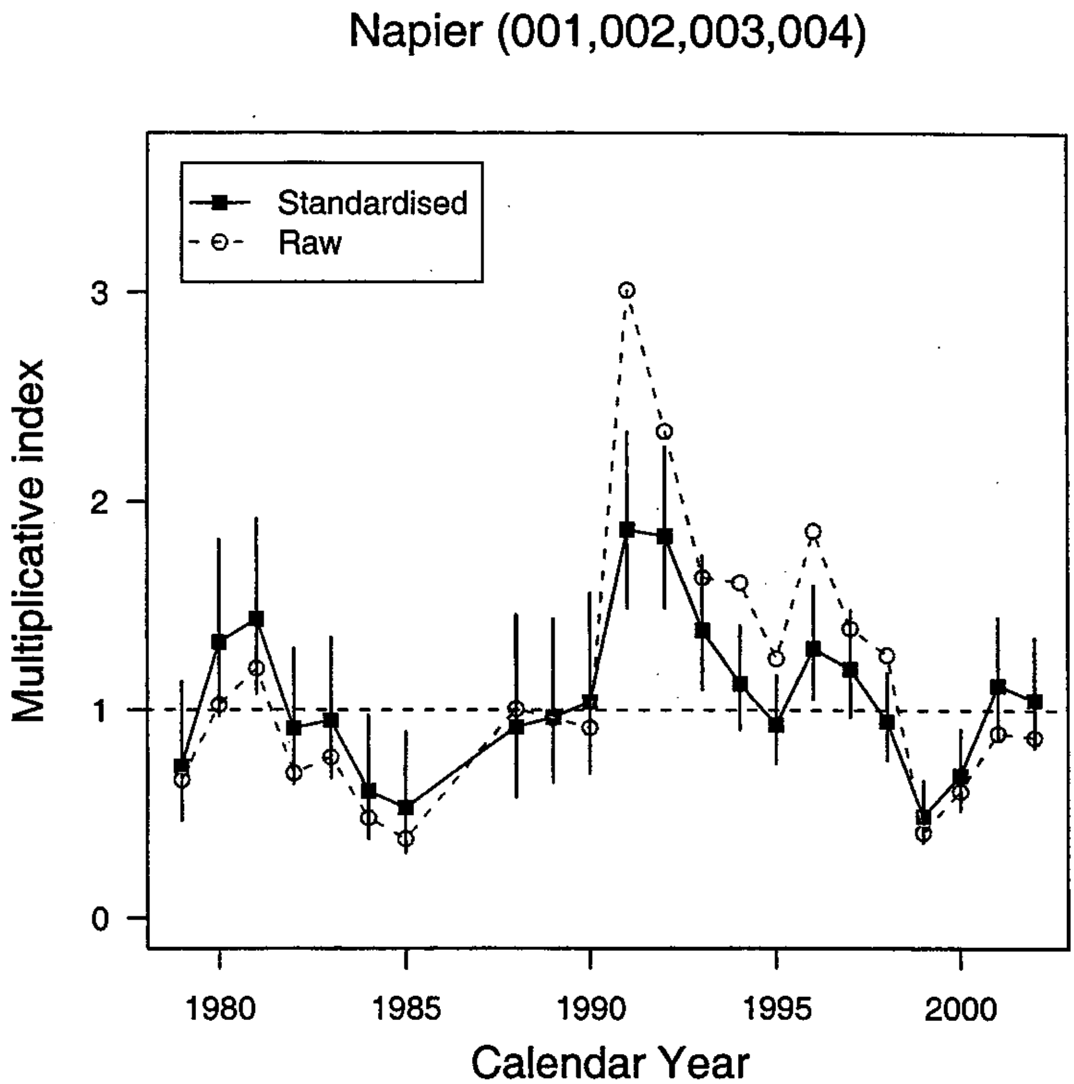

Figure 6: Napier – standardised and raw indices of annual settlement.

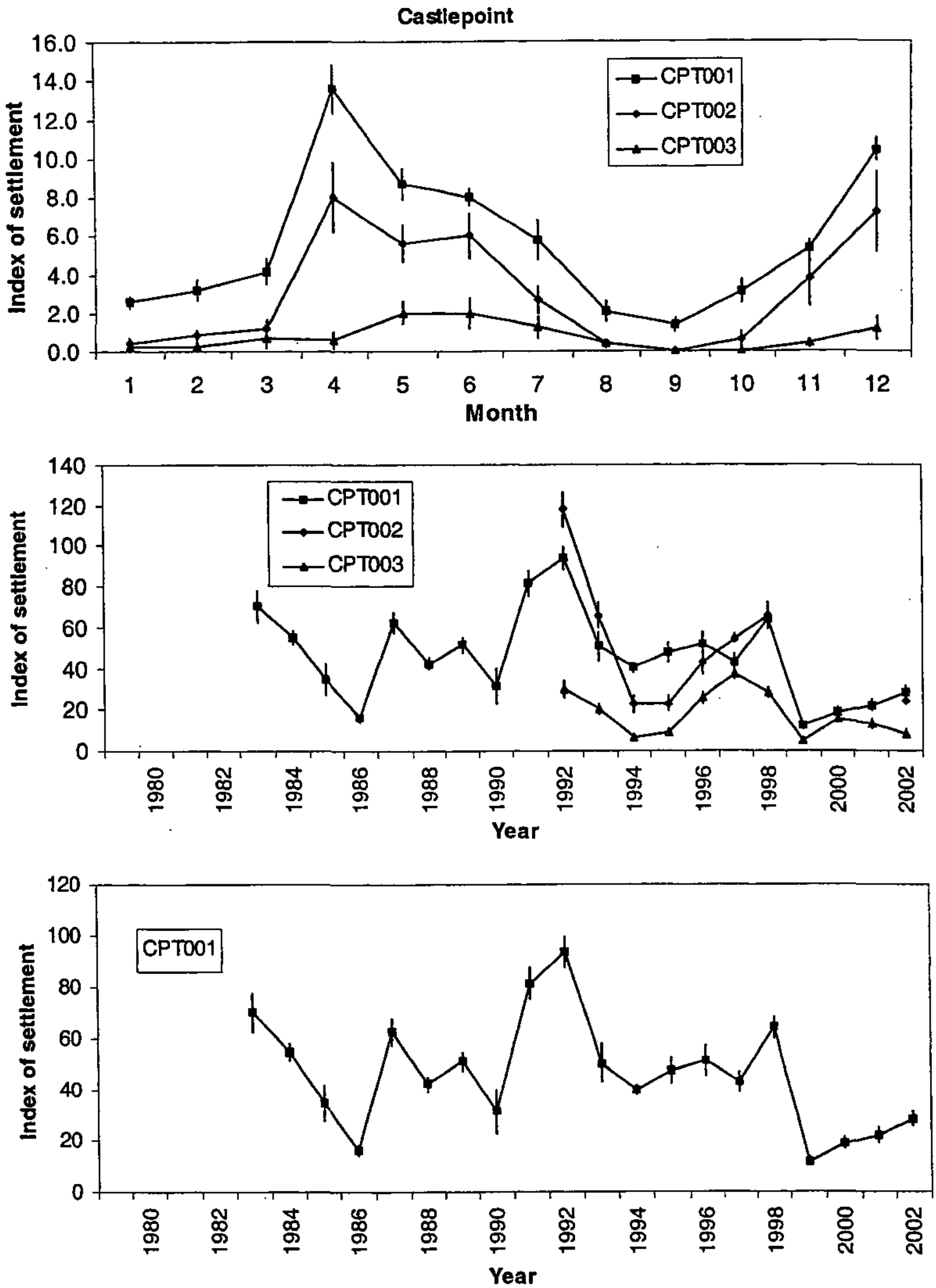

Figure 7: Castlepoint – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, December to September) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). CPT001 is the core group at Castlepoint; CPT002 is Orui; CPT003 is Mataikona (see Figure 1). There were no data for CPT002 for 1999–2001 because the collectors were sanded over.

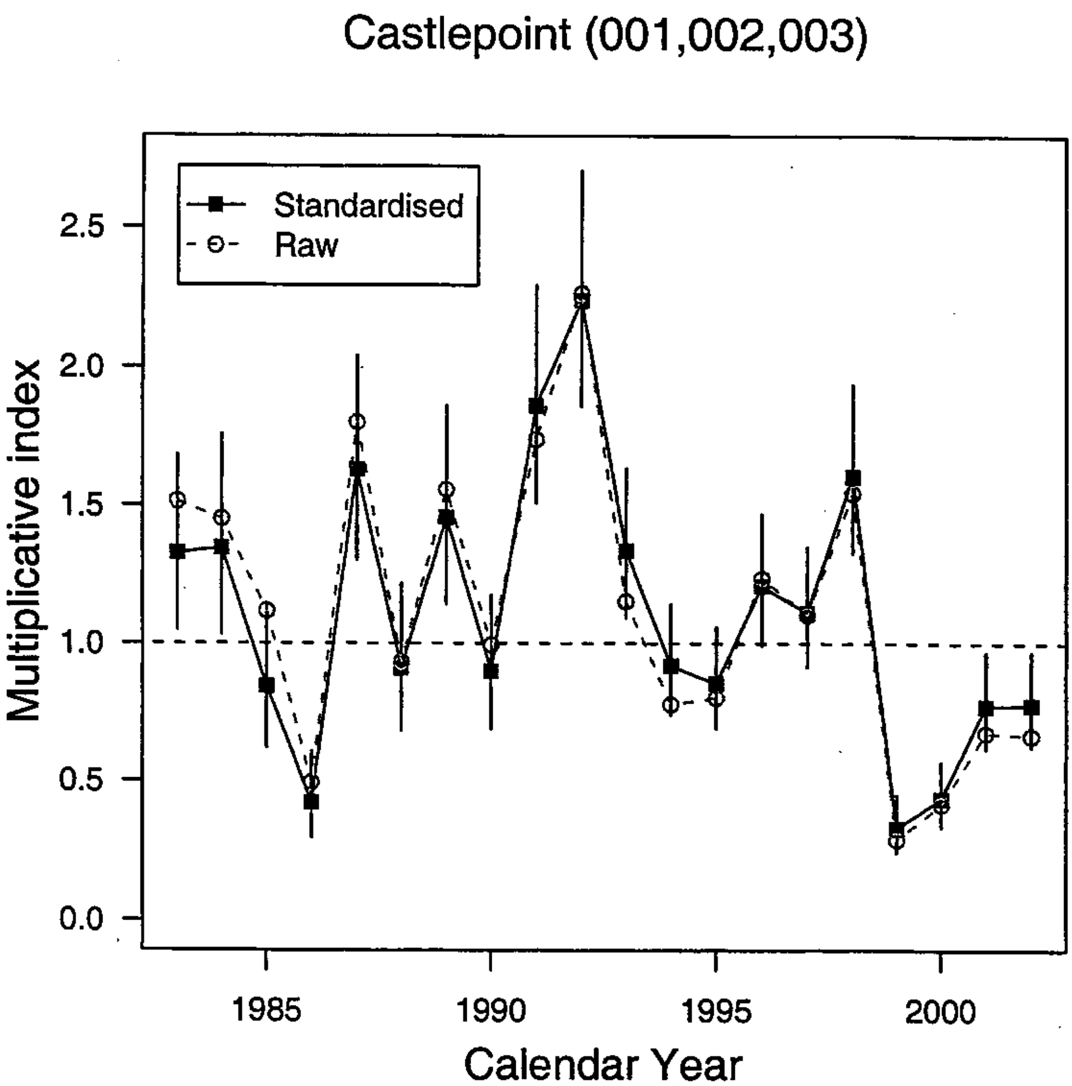

Figure 8: Castlepoint – standardised and raw indices of annual settlement.

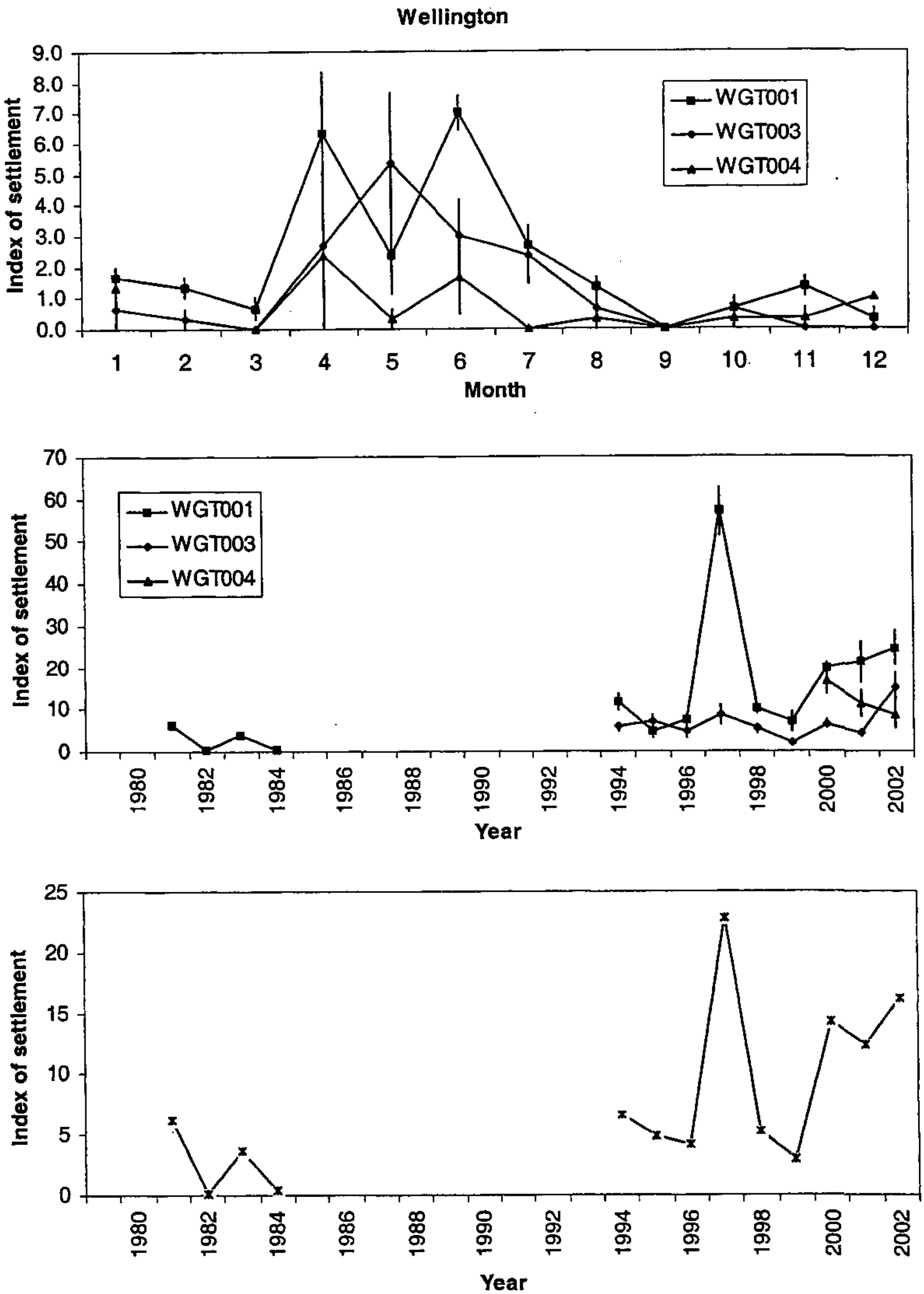

Figure 9: Wellington – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, January to May) on each group of collectors ± 1 standard error (*middle*) and an index based on all collectors each month (but the collectors checked were not always the same) (*lower*). WGT001 is Island Bay (core); WGT002 is Lyall Bay; WGT003 is Breaker Bay; WGT004 is Palmer Head (see Figure 1).

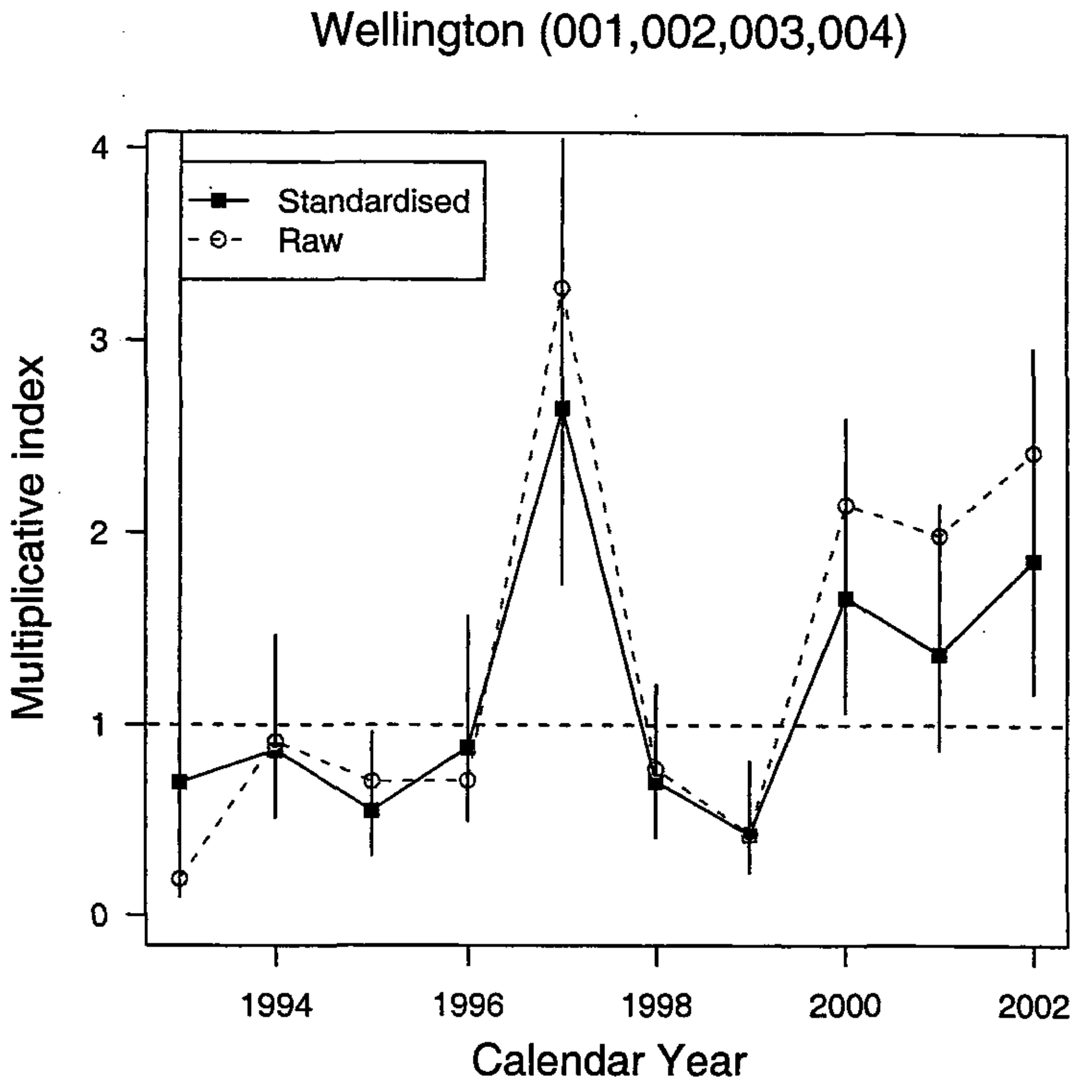

Figure 10: Wellington – standardised and raw indices of annual settlement.

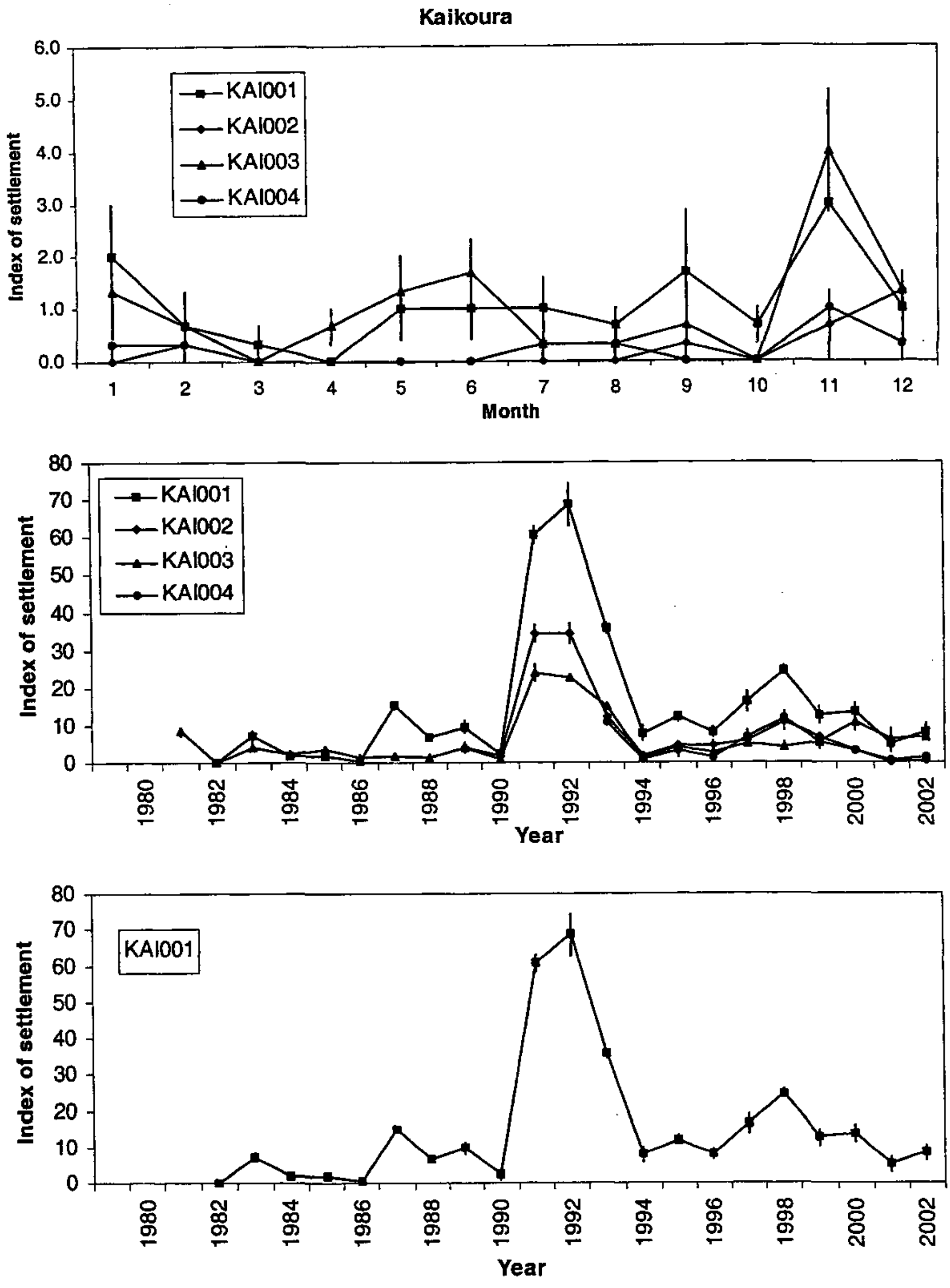

Figure 11: Kaikoura – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, January to September) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). KAI001 is 13–15 on the south side of the peninsula (core); KAI002 is 31–33 on the south side of the peninsula; KAI003 is 10–12 on the north side of the peninsula; KAI004 is 34–36 on the north side of the peninsula (see Figure 1).

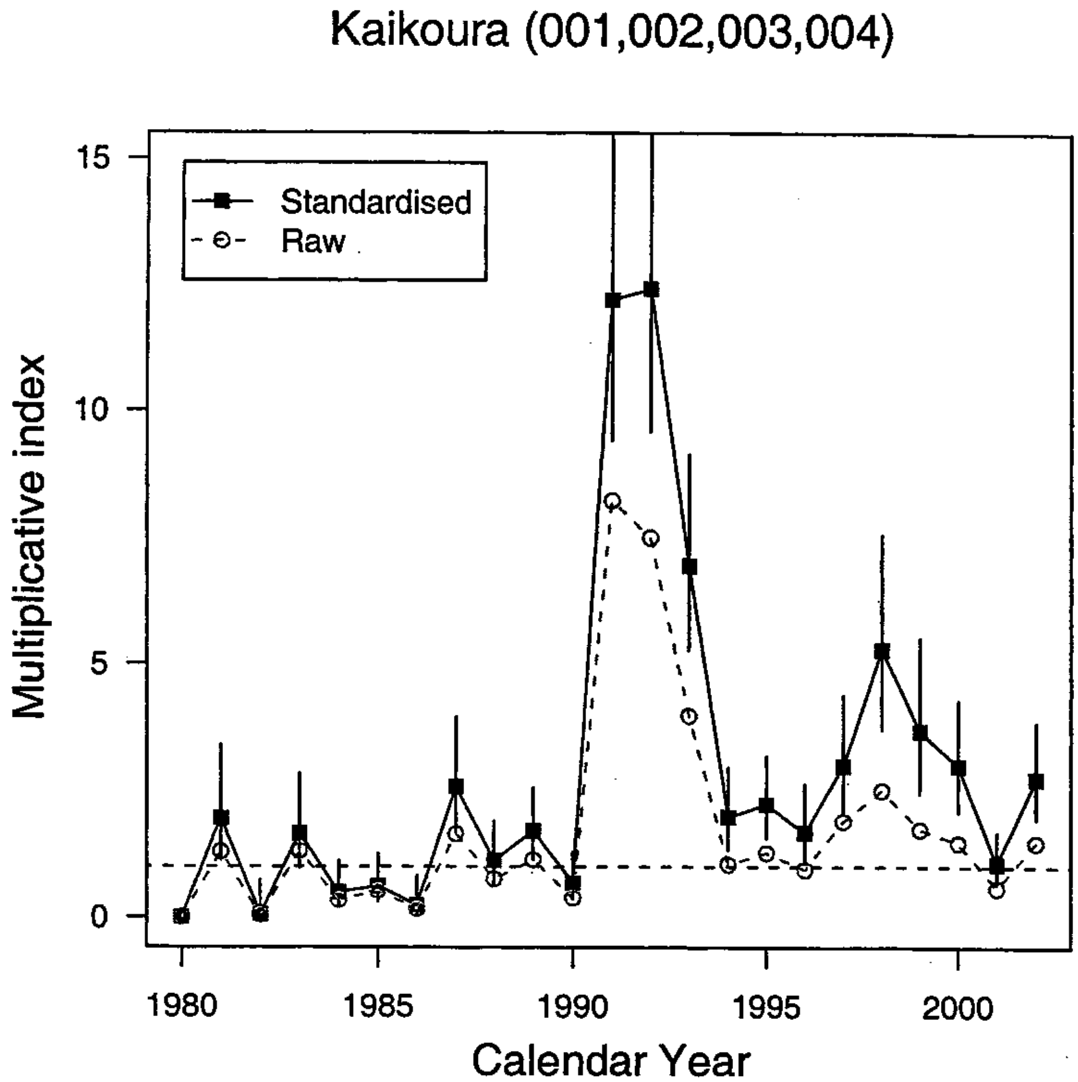

Figure 12: Kaikoura – standardised and raw indices of annual settlement.

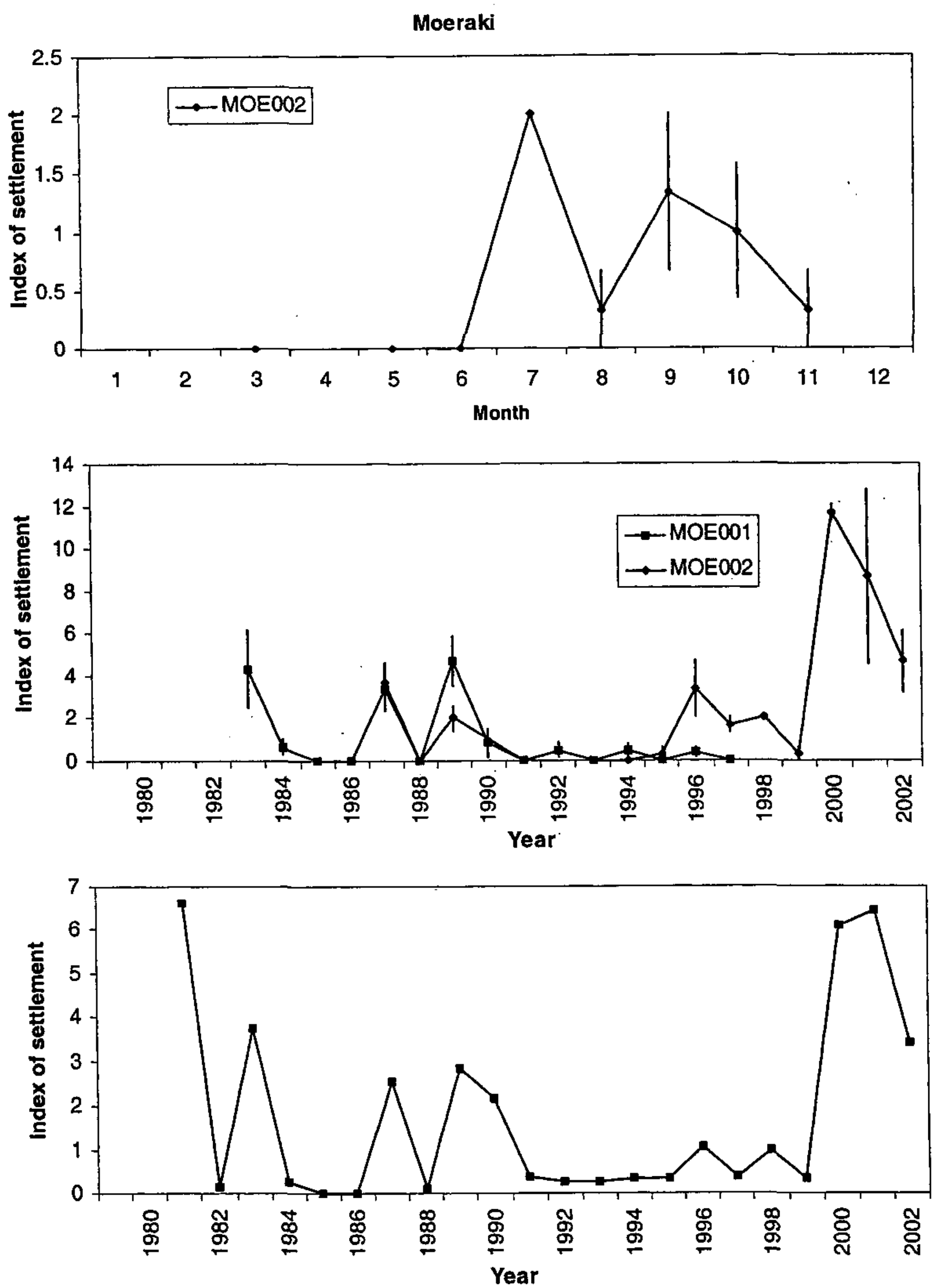

Figure 13: Moeraki – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual index of settlement (settlement season index, based on the main settlement period March to October) (*middle*) and an index based on at least nine collectors each month (but the collectors checked were not always the same) (*lower*). MOE001 is Shag Point 1-4, MOE002 is Pier 1-3, MOE004 is Millers Beach 1-3, MOE005 is The Kaik 1-3, MOE006 is Kakanui 1-3 (see Figure 1). No data since 1998 for MOE001.

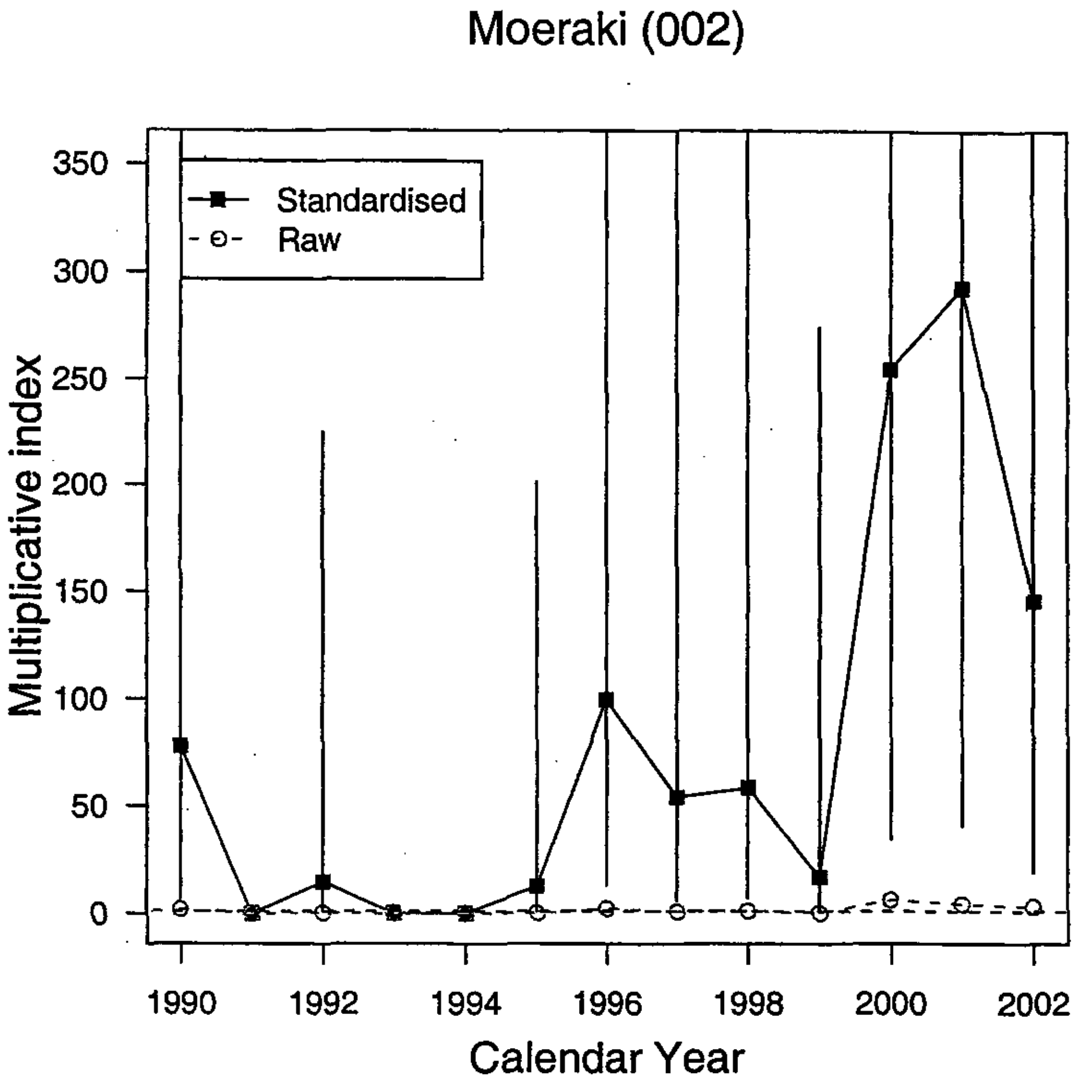

Figure 14: Moeraki – standardised and raw indices of annual settlement.

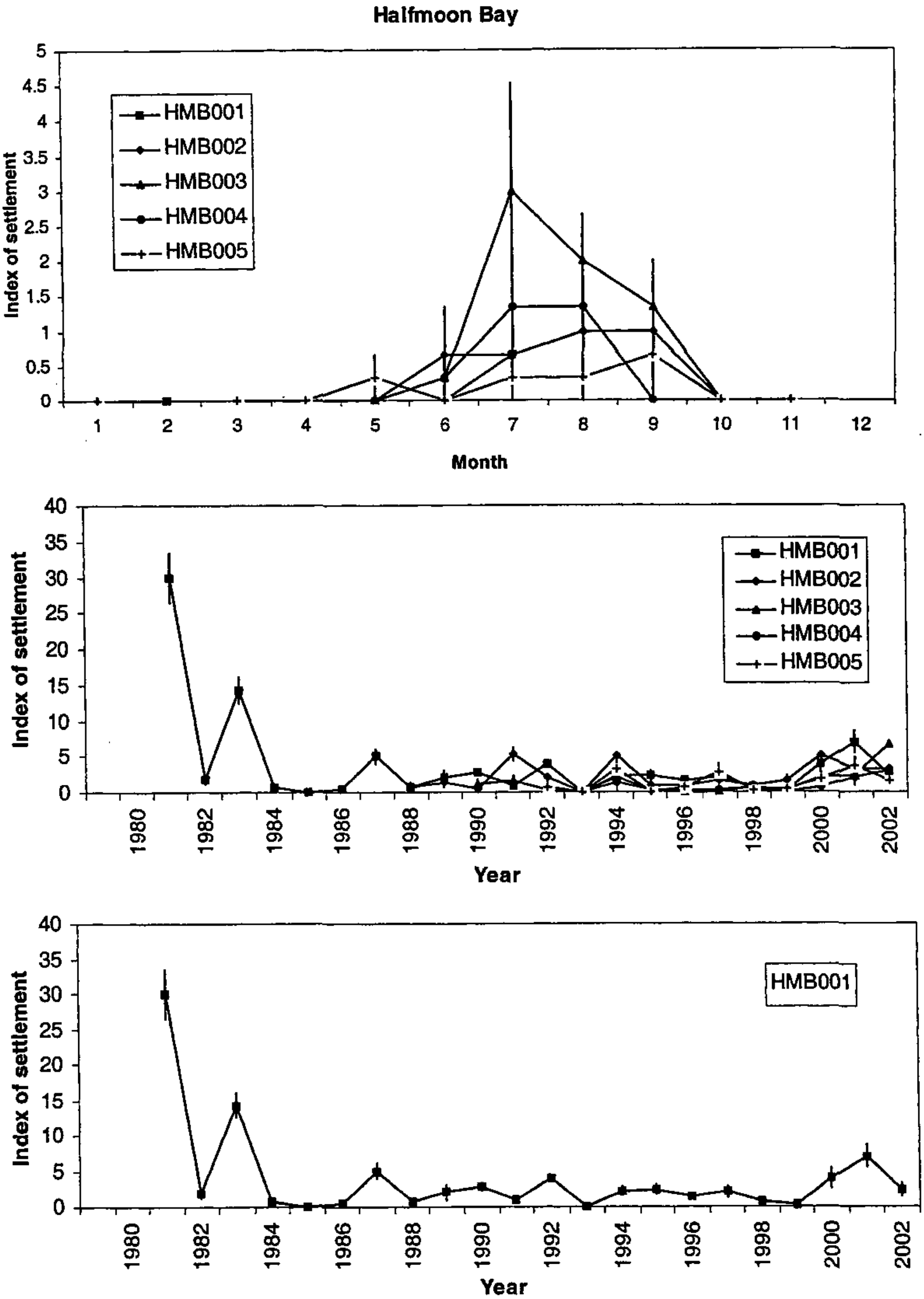

Figure 15: Halfmoon Bay – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, May to October) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). HMB001 is under the wharf (core); HMB002 is Thompson's Nugget; HMB003 is Old Mill; HMB004 is the Neck; HMB005 is Mamaku Point (see Figure 1).

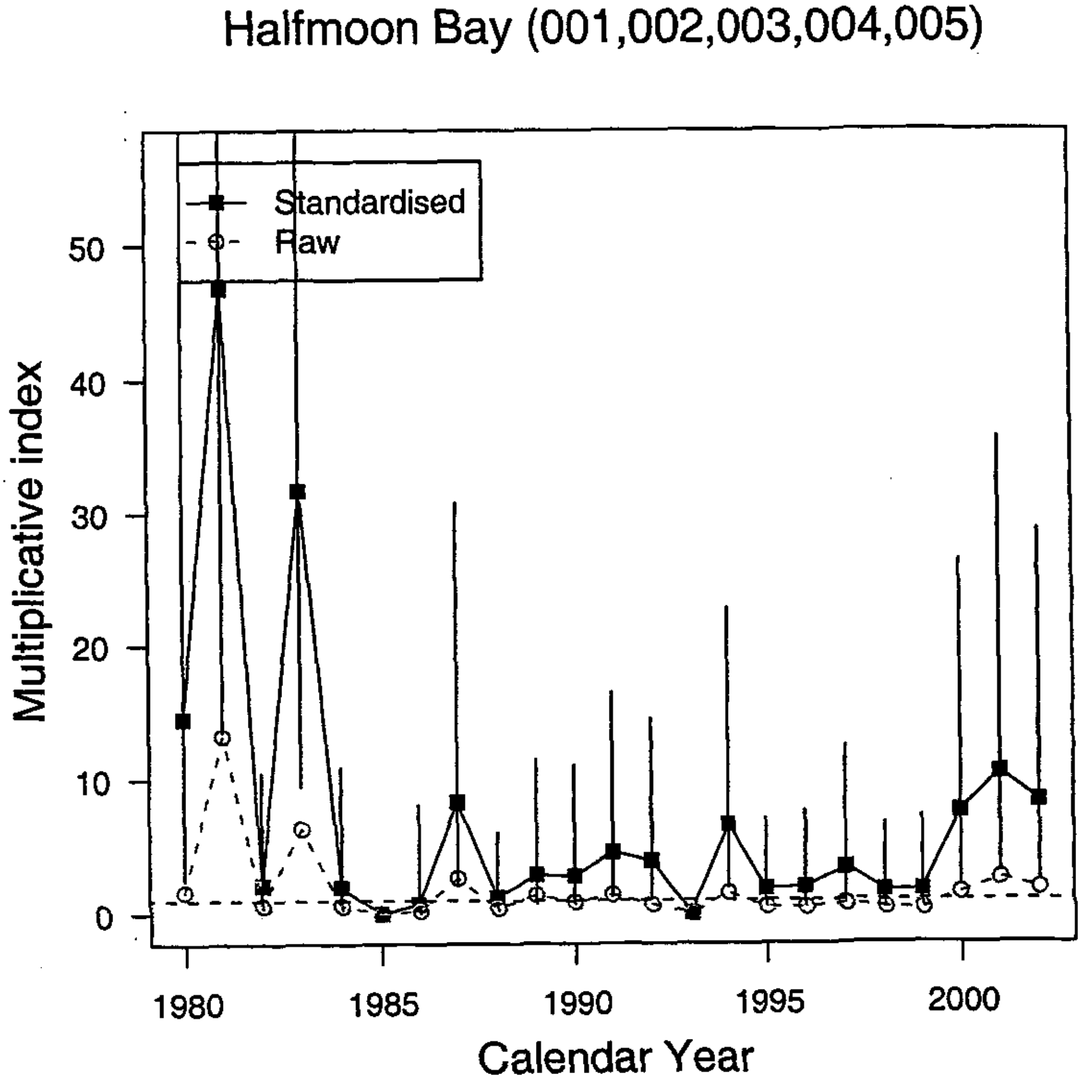

Figure 16: Halfmoon Bay – standardised and raw indices of annual settlement.

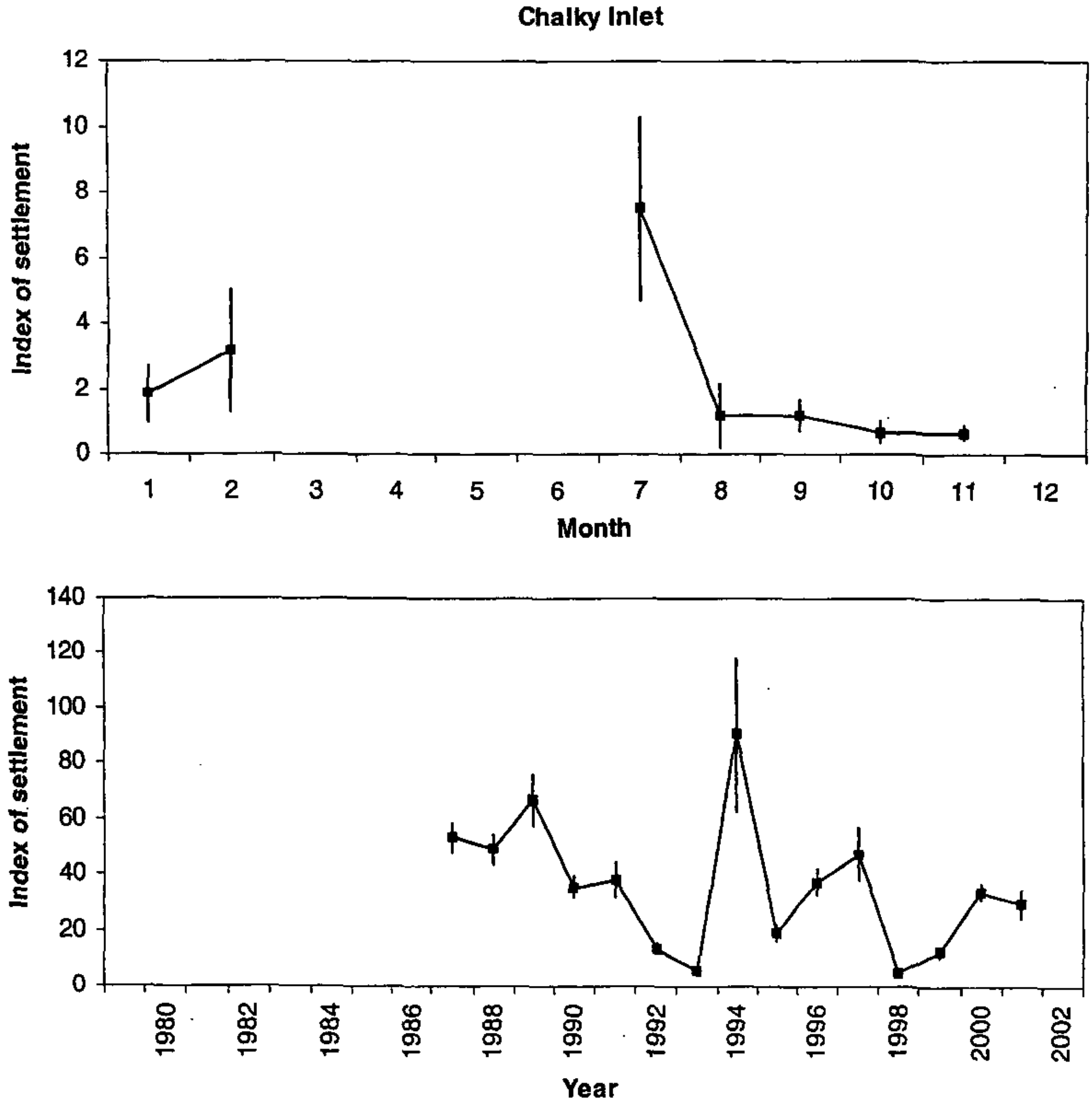

Figure 17: Chalky Inlet (Blind Entrance) – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2002, ± 1 standard error (*upper*). Annual indices of settlement (settlement season index, based on the main settlement period, March to October) on the one group of collectors (± 1 standard error, *lower*). There were insufficient data for 2002.

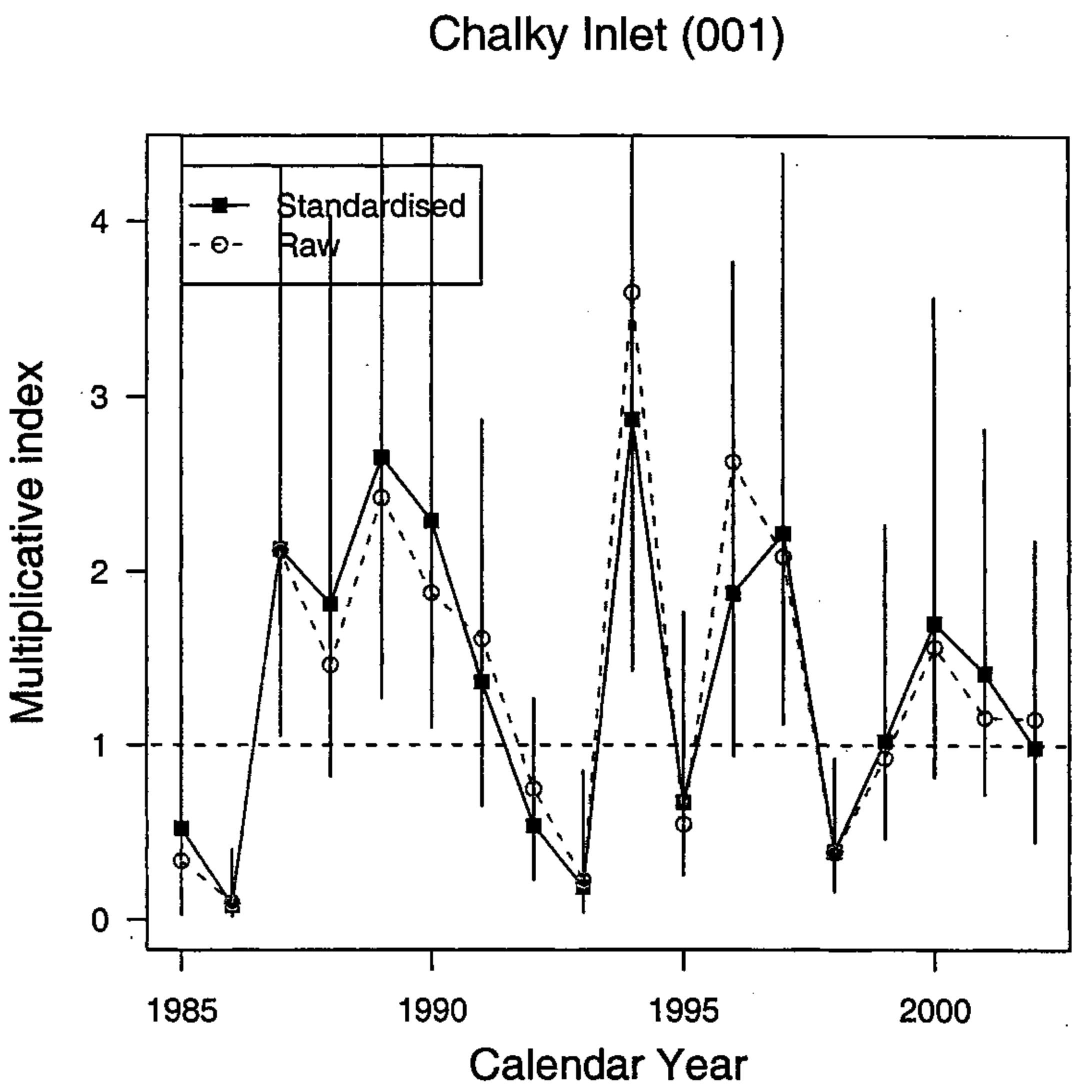

Figure 18: Chalky Inlet – standardised and raw indices of annual settlement.

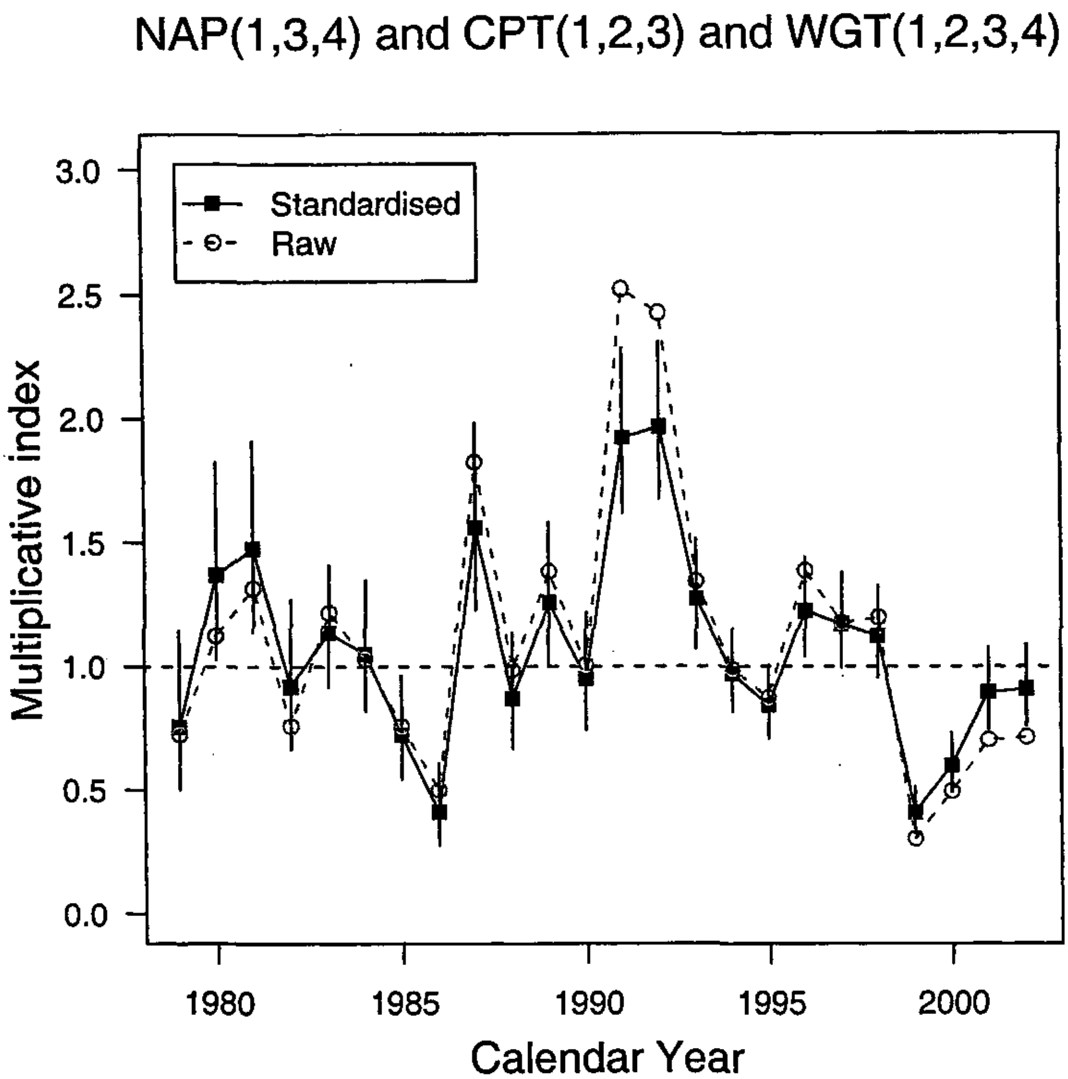

Figure 19: CRA 4 - standardised and raw indices of annual settlement.