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Te Tautiaki i nga tini a Tangaroa

**Settlement indices for 2001 for the red rock lobster
(*Jasus edwardsii*)**

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EXECUTIVE SUMMARY

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This report addresses the one objective of Ministry of Fisheries project CRA200101.

To estimate monthly and annual indices of puerulus settlement at key sites over the main area of the fishery (one site in CRA 1, Tauranga [Bowentown], 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. Levels of settlement in 2001 on the east coast of the country, at least from Gisborne to Kaikoura, were generally low to moderate compared with the time series of previously estimated settlement levels. At most sites, settlement in 2001 was higher than in 2000, in turn greater than the particularly low settlement of 1999. Although still low along the southeast coast of the South Island compared with further north, the significantly higher settlement levels of 2000, the highest since the early 1980s, continued into 2001. Settlement in 2001 was moderate in the southwest of the South Island. We also update the mid-year abundances of 1, 2, and 3-year old juveniles at Wellington where the main change in mid 2002 was a large and unexplained influx of 2 and 3-year olds into two of the sites.

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. 2002a). In so doing, we address the objective of Ministry of Fisheries project CRA200101. We also update the indices of juvenile abundance in relation to the settlement indices at Wellington.

To estimate monthly and annual indices of puerulus settlement at key sites over the main area of the fishery (one site in CRA 1, Tauranga [Bowentown], 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 2002: they were presented to the NRLMG and the Rock Lobster Research Planning Meeting on 26 September 2002 and to the RLWG on 27 September 2002.

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. New sites were recently established in CRA 1 and CRA 2. 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 only publications on early life history and larval recruitment in *J. edwardsii* appearing since those referred to by Booth et al. (2002a) were popular articles on the possibility of enhancing juvenile abundance in the wild through the provision of artificial shelters (Anon 2002, Booth et al. 2002b).

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.

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. (Notable recently is the high correlation in Tasmania between settlement of *J. edwardsii* and subsequent fishery CPUE — Gardner et al. (2001)).

Abundance of juveniles soon after settlement has been an associated estimate at some of the settlement-monitoring sites. There have been good correlations between levels of settlement and juvenile abundance at the sites for which there is sufficient information, although recent work has shown that postlarval recruitment pulses are more efficiently measured on crevice collectors than through dive surveys (Booth et al. 2001). However, provisional results from a comparison of the collector indices, standardised, with the estimated status of the stocks based on the length-structured stock assessment model (which primarily uses fishery CPUE and size frequency data) suggest that the settlement data have limited value in explaining or predicting changes in the year by year status of the substocks (Bentley et al., *Trophia*, unpubl. results). This may be because of the many years delay between settlement and recruitment to the fishery.

The usefulness of the settlement data in predicting *trends* in recruitment has not yet, however, been tested. It is only since the early to mid 1990s that several fisheries have become largely single-sex (male) fisheries, thus reducing the confounding influence of males and females recruiting at very different ages. Further, it is only recently that for the east coast (at least from Gisborne to Kaikoura) a trend in settlement level over time has become established: among the highest-recorded settlements occurred in the early 1990s, declining to among the lowest-recorded settlements in the late 1990s, followed by a recovery in settlement levels beginning in the early 2000s. Consistent with this, a) the periods of high settlement on the east coast of central New Zealand were followed by periods of high CPUE, and declines in CPUE followed declines in levels of settlement, and b) the stock assessment models suggest that a large recruitment pulse occurred in the northern and central substocks, NSN and NSC, in the early to mid 1990s, followed by much lower recruitment in subsequent years (Sullivan & O'Brien 2002).

The settlement indices remain the only widespread fishery-independent data collected in this fishery. Continuation of the settlement time series will allow the usefulness of the settlement data in predicting trends in recruitment 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). The recent changes in the key sites include collectors being installed near Jackson Head in 1999 and in CRA 1 and CRA 2 in 1999–2000.

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). The 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, so the nominal values of the annual index are not always directly comparable between sites.

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 which 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, previously referred to as surface/midwater crevice collectors) provide an index mainly of the number of pueruli in the water column minus emigration. This is because there is less opportunity for immigration from the sea floor (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.

The main settlement season varies according to region (see Booth 1994). Adjacent sites have similar seasons, except for those pairs of sites that straddle regional boundaries. Winter is the most widespread main settlement season.

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 Collector catches, 2001

Catches for key sites by group and by month are given in Table 2, and for most sites in Figures 2–9. The figures and table also show the 2001 catches against those of previous years.

2.2.1 Houhora

This is a new site, so settlement data are still sparse. Collector catch rates during 2001 were very low, most lobsters being taken during winter (not shown).

2.2.2 Bowentown

Again, this is a new site. Collector catch rates during 2001 were low, most lobsters being taken during summer and winter (not shown).

2.2.3 Gisborne

Although well up on the record low of 1999, 2001 was a low to moderate settlement year (Figure 2). As in previous years, settlement on all collectors peaked in winter and there was little summer settlement. Outside the port, the Whangara collectors had highest levels of settlement, while Kaiti catches were the lowest (Table 2).

2.2.4 Napier

Although well up on 1999, the record recent low year, 2001 was only a moderate settlement year (Figure 3, Table 2). The Harbour collectors had the highest catches of all groups, Cape Kidnappers the lowest. Settlement peaked during winter.

2.2.5 Castlepoint

Settlement in 2001 remained low, at similar levels to 2000 but up on the record low year of 1999 (Figure 4). On all groups of collectors, settlement took place throughout the year, except for late winter and early spring. There was unusually high settlement on all collectors in November. The Castlepoint collectors had the highest settlement rates, Mataikona the lowest (Table 2). The Orui collectors (including additional ones installed in an attempt to deal with collectors becoming filled with sand) remained sanded for most of the year.

2.2.6 Wellington

Settlement on all collectors peaked in summer and autumn (Figure 5). Catch rates during 2001 were moderate, at similar levels to 2000 but up on the recent record low year of 1999. Highest settlement was again recorded at Island Bay, the lowest at Breaker Bay (Table 2).

2.2.7 Kaikoura

In 2001, catch rates were down on 2000, and were the lowest since 1990 (Figure 6, Table 2). Most settlement was during autumn and winter with no summer peak evident.

2.2.8 Moeraki

The upturn in settlement levels seen in 2000 continued into 2001, with most settlement taking place during winter (Figure 7). Collectors installed in Moeraki Bay continue to have the highest catches (Table 2).

2.2.9 Halfmoon Bay

The slight improvement in settlement levels seen in 2000 continued into 2001, most settlement taking place during late winter (Figure 8, Table 2).

2.2.10 Chalky Inlet

Settlement was highest in winter and low in spring but the remoteness of this site meant several of the monthly checks were missed (Figure 9, Table 2). Like 2000, 2001 was a moderate settlement year.

2.2.11 Jackson Bay

Settlement levels continued at about the same (low) level seen in 2000 (Table 2), the most successful collectors being the wharf ones (not shown). This is a relatively new site for which the logistics of monthly checks of all groups of collectors are still being determined.

2.2.12 Summary

Generally, 2001 was a low to moderate settlement year on collectors from Gisborne to Halfmoon Bay compared with the time series of estimated settlement levels for each site. At most sites, 2000 and 2001 were up on 1999, which had among the lowest recorded levels of settlement. The most dramatic change in settlement levels for the east coast of the country was in the southeast of New Zealand (southeast South Island and east coast Stewart Island, SENZ), particularly Moeraki, where the greatly increased levels of settlement in 2000 continued into 2001. At Chalky Inlet, settlement in 2001 was moderate compared with the time series of estimated settlement levels.

The within-site patterns reported by Booth et al. (2000) persisted: there were often significant differences in the levels of settlement between groups of collectors within sites and sometimes this difference was large. Seasonality between groups at particular sites was, however, generally consistent. The most widespread main settlement season is winter, but along the east coast of central New Zealand (Castlepoint to Kaikoura), settlement in summer and autumn can be at least as high as in winter. However, in 2001 no summer settlement was registered at Kaikoura. The reasons for these seasonalities, and their variation between areas, remain unclear.

The Jackson Head site has not been long enough established for patterns of settlement to be evident. It usually takes at least a year for collectors to fully condition and at least 1–2 years for groups of

collectors to be set up to adequately represent the prevailing settlement levels. Settlement on the four groups of collectors currently in place (Jackson Bay Wharf, two groups just inside Jackson Head, and one group at Smoothwater Bay) has been highest in spring.

2.3 Variability among sites over the long term

The geographic pattern in settlement on the collectors in 1994–98 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 on the east coast of the South Island, although it improved slightly in 2000, and still further in 2001. However, in both 2000 and 2001 there was a marked increase in settlement levels in SENZ, at Moeraki, to a level similar to that of the early 1980s. In the southwest of the South Island, at Chalky Inlet, the levels of settlement on the collectors for most years have been moderate to high compared with those in SENZ.

2.4 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 (see Booth et al. 2001). 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 not any more recent data on phyllosoma distributions 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 2000–01 could have been a result of increased numbers of advanced phyllosomas there. It is interesting that this increased settlement in SENZ took place in the face of La Niña conditions, which would normally be expected to act against higher settlement, given the pattern further north.

2.5 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. (2002a). Levels of annual settlement remain 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).

On the east coast of the country, there was generally high settlement in 1981, 1983, 1987, and 1989. Settlement in 1991, 1992, and 1993 was also high, and in 1998 moderate, for sites at least as far south as Kaikoura. This suggests that factors that drive larval recruitment affect wide areas.

Settlement in SENZ has been low, except in the early 1980s, and in 2000–01 when it increased markedly at Moeraki.

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 1992, 1993, 1995, and 1998–99.

3. JUVENILE ABUNDANCE IN RELATION TO LEVELS OF SETTLEMENT

3.1 Introduction

The abundance of 1, 2, and 3 year old juveniles can be a check on the usefulness of collectors to distinguish high and low years of puerulus recruitment and can also provide insight into the ecological processes taking place after settlement. Here we report the mid-year abundances of juveniles for Wellington for 2002. 0+ lobsters are those immediately post-settlement and up to but less than 1 year of age, 1+ lobsters are 1 but under 2 years of age, and so on.

3.2 Wellington

The abundance of juveniles has been followed at least quarterly since 1993 or 1994 until 2000 at several sites on the south Wellington coast (Palmer Head [End Rock and Split Rock], Moa Point, and Island Bay [Coast and Island]) and one site within Wellington Harbour (Kaiwharawhara) (Booth et al. 2002a). After 2000, surveys have taken place mid-year only.

The juvenile abundance survey method was described by Booth et al. (2002a). To summarise, the same spots (isolated reef, crevice, hole, most being at 5–9 m depth) at each site were surveyed each sampling period. Sites were approached cautiously so as to minimise disturbance to any lobsters present. If lobsters moved back into crevices where they could not be clearly observed, the site was surveyed later in the dive. Sizes of lobsters were estimated in 5 mm intervals for animals 30–80 mm CL; those bigger than 80 mm CL were grouped. A lobster at 30 mm CL was estimated to be between 27.5 and 32.5 mm CL. Divers each ensured the accuracy of their lobster size estimations before and during surveying. Surveys were conducted in one of two ways depending on the diver, the site, and the number of lobsters present. In the first method, all individual lobsters of the same size were counted at once, usually starting with the smallest size groups. In the second, the size of each individual was estimated and recorded as the diver worked through the group of animals; this method was best when the lobsters were in a row, such as in a crack, or were in small groups. With both methods, the measuring stick was frequently used during counts to confirm lobster sizes. Animals moving during the count were sometimes a problem, addressed by starting the count again or returning to the den later in the dive. Juveniles at 1+ were uncommon in all sampling, probably because of their small size and cryptic behaviour. Surveys made at individual sites over successive days showed small variation in counts (Stotter, pers. obs.).

The results for Kaiwharawhara, sampled almost every 3 months from June 1993 to September 2000 and again in mid 2001 and 2002, are consistent with low settlement since the high settlement years of 1991 and 1992: 2 and 3 year olds were present in large proportion only until 1994 and 1995 respectively (Figure 10). However results from the other sites are less consistent with the settlement record. The abundances of 2+ and 3+ juveniles at Palmer Head and Moa Point, although reasonably consistent with the previous settlement levels until mid 2001, were disproportionately high in mid 2002 (Figures 11–12). At Island Bay (two areas combined), 2+ and 3+ lobsters were not particularly well represented when sampling began in mid 1994, then became generally more abundant but with large year to year variations (Figure 13). Correlation values and significances between settlement levels and juvenile abundances, and correlations of abundance between different annual cohorts, were given in detail in Booth et al. (2002a). The reasons for the differences between sites, as well as the unexpected increases in abundance of 2+ and 3+ juveniles at Palmer Head and Moa Point by mid 2002, remain obscure but

may be related to local, small-scale spatial patterns of settlement and dispersion of juveniles varying over the study period.

4. MANAGEMENT IMPLICATIONS

Although the 1999 and 2000 settlement levels for nearly all SENI sites were very low in relation to the time series of settlement estimates — about 20% or less of those of the recent peak years 1991–92 — settlement in 2001 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 recorded in CRA 3 in 1999, with only a modest increase in 2000, is likely to contribute to even lower recruitment and fishery CPUE than have been seen there in recent years, beginning around 2003. The much improved settlement in 2001 over that in 1999 should mean, however, that any such period of particularly poor recruitment will be short-lived. As always, however, the validity of such predictions can be confounded by variable growth and survival — including density-dependence in these which can smooth peaks and troughs in recruitment — between years, predation, migration, and high levels of illegal fishing.

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Table 1: Collector type and number by site, and main settlement season. 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	Suspended	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	KAI001		South 13-15	Shore	Jan-Sep
	3		KAI002	South 31-33	Shore	Jan-Sep
	3		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
	3				Wharf	Suspended
Halfmoon Bay	3	HMB001		Thompsons	Closing	May-Oct
	3		HMB003	Old Mill	Closing	May-Oct
	3		HMB004	The Neck	Closing	May-Oct
	3		HMB005	Marmaku Point	Closing	May-Oct
	3				Shallow Passage	Closing
Chalky Inlet	6	CHA001		Jackson Bay	Suspended	Mar-Oct
	3		JAC001	Wharf		
	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 -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
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	

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

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

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	0

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

Table 2 -continued

Chalky Inlet	CHA001		CHA001		CHA001
1987	53.3 ± 5.3	1992	13.5 ± 1.7	1997	47.3 ± 9.5
1988	49.1 ± 5.2	1993	5.3 ± 0.7	1998	5.0 ± 1.1
1989	67.0 ± 9.0	1994	90.5 ± 21.3	1999	12.3 ● 1.7
1990	35.5 ± 4.2	1995	19.0 ● 2.9	2000	33.7 ± 2.9
1991	37.9 ± 6.1	1996	37.6 ● 4.7	2001	29.6 ± 4.8
Jackson Head	Overall				
2000	5.9				
2001	6.3				

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 (1992–2001); NAP, Napier (1979–85, 1988–2001); CPT, Castlepoint (1983–2001); KAI, Kaikoura (1982–2001); MOE, Moeraki overall (1981–2001); HMB, Halfmoon Bay (1981–2001); CHA, Chalky Inlet (1987–2001); 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	0.74(8)*					
CPT	0.80(8)**	0.45(15)				
KAI	0.61(8)	0.53(16)*	0.70(17)***			
MOE	-0.21(8)	0.29(17)	-0.24(17)	-0.18(18)		
HMB	0.31(8)	0.42(17)	0.22(17)	-0.06(18)	0.71(19) ***	
CHA	0.11(8)	0.17(12)	-0.09(13)	-0.38(13)	0.07(13)	0.15(13)

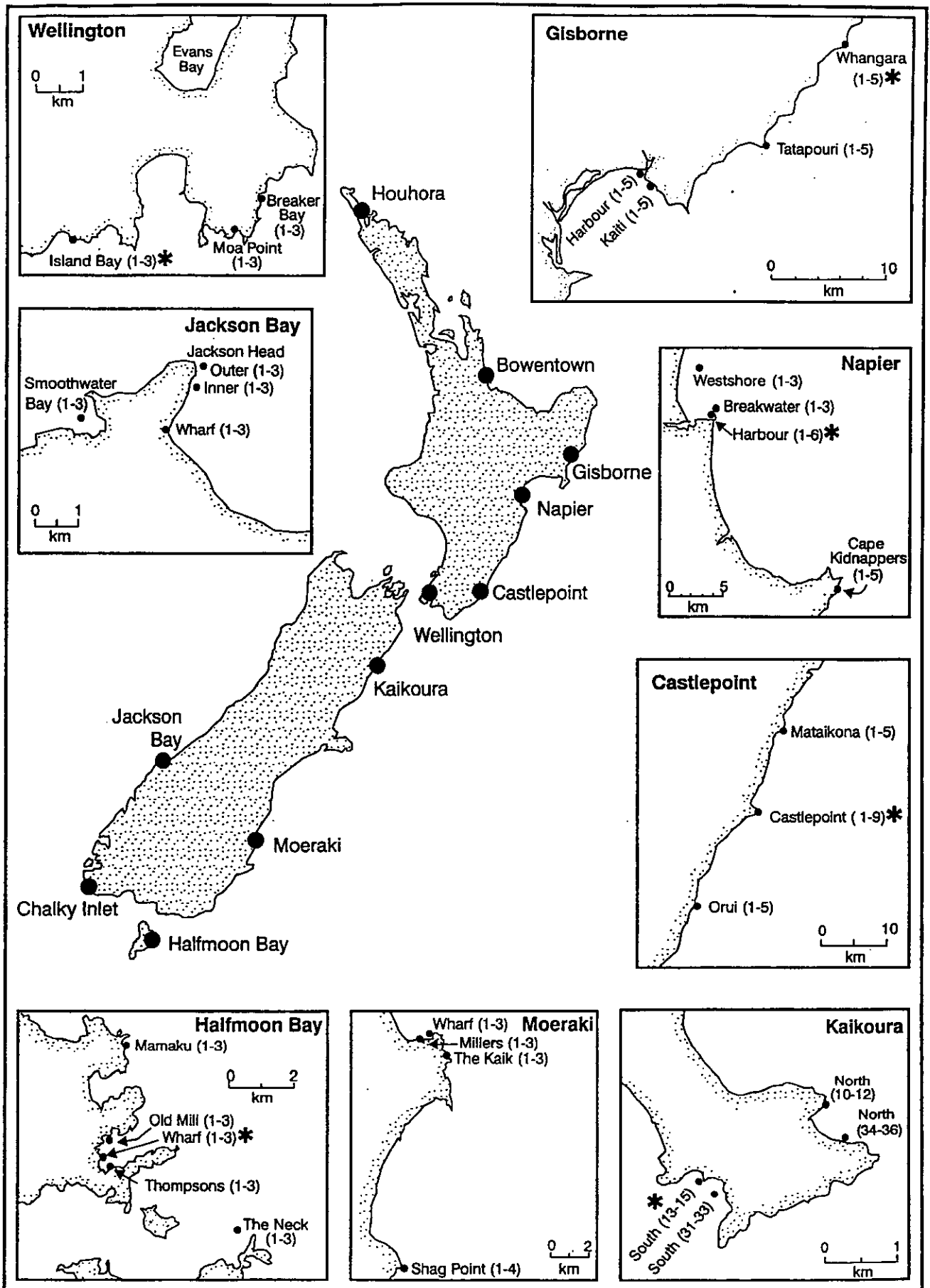


Figure 1: Map of New Zealand showing location of collectors at the key monitoring sites. The insets show the numbers and arrangement of collectors at sites with more than one set of collectors. *, core group of collectors where one has been nominated.

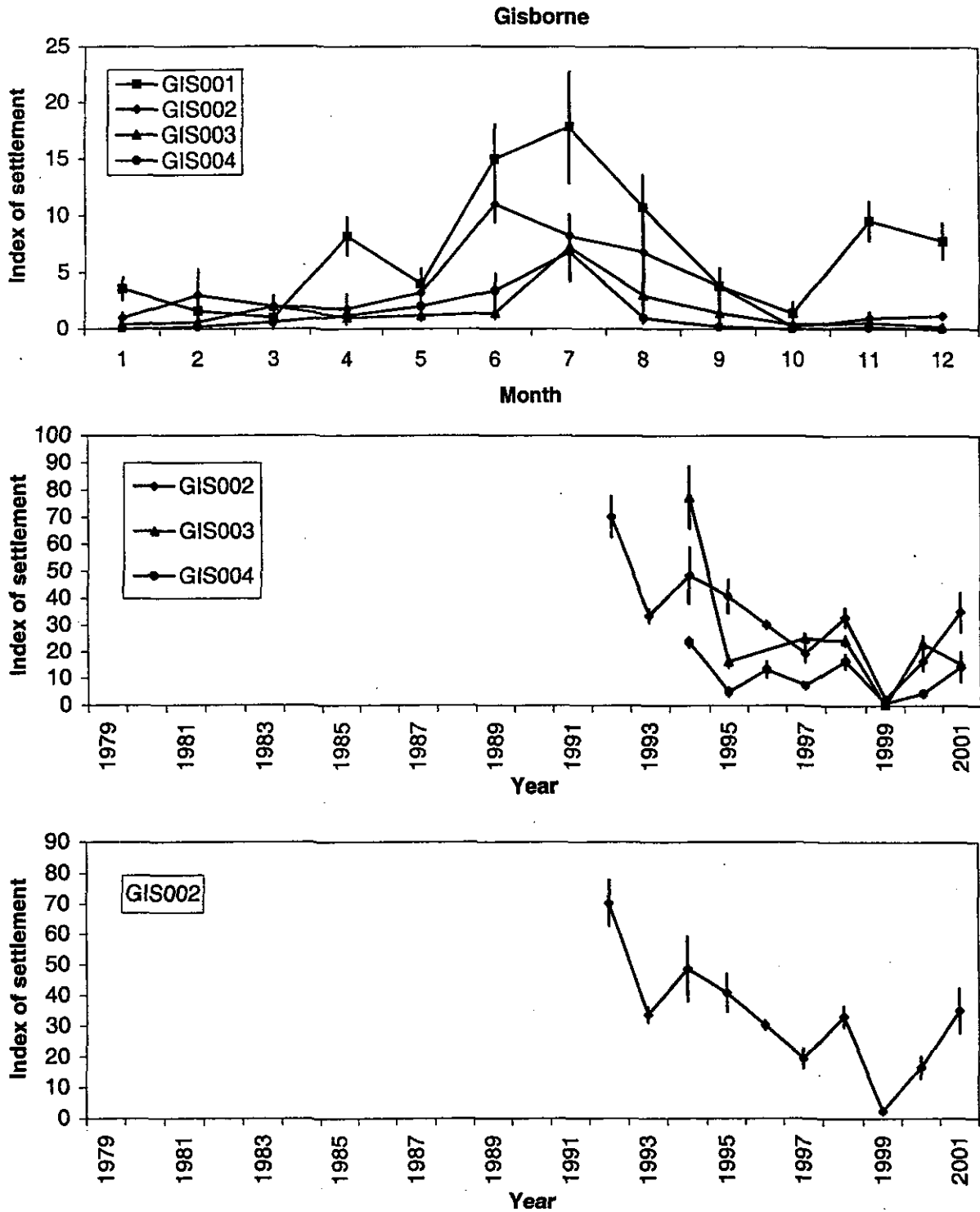


Figure 2: Gisborne – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, April to October) on groups of collectors ± 1 standard error (*middle*) and on the core group (*lower*). GIS001 is the Harbour group; GIS002 is Whangara (core); GIS003 is Tatapouri; GIS004 is Kaiti (see Figure 1). GIS001 is not shown on the middle panel because it obscures and confuses the interannual pattern (see Booth et al. 1998).

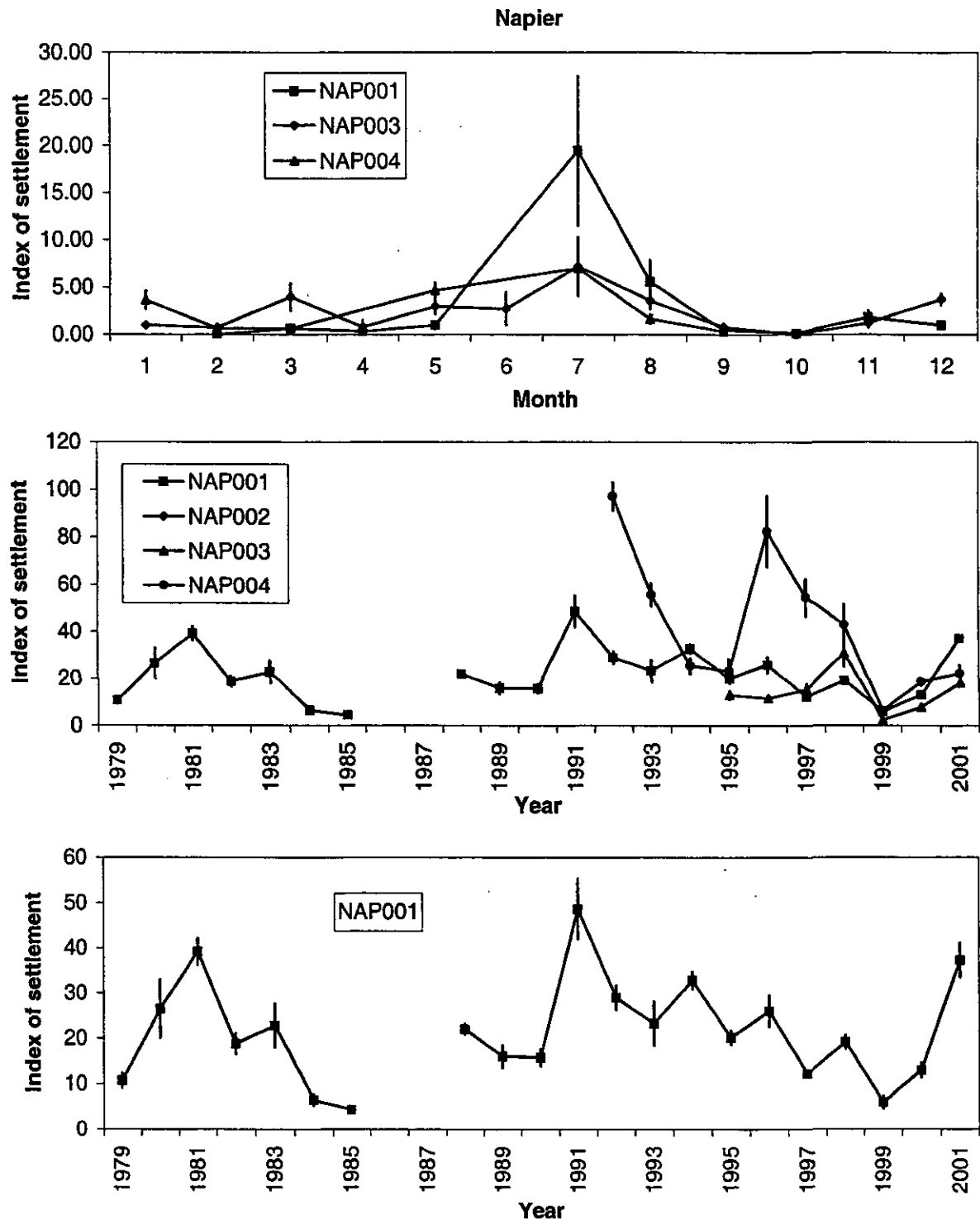


Figure 3: Napier – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, April to September) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). NAP001 is the Harbour group (core); NAP002 is Westshore; NAP003 is Cape Kidnappers; NAP004 is Breakwater (see Figure 1). Collector positions and deployment changed after 1985; no data available for 1986–87.

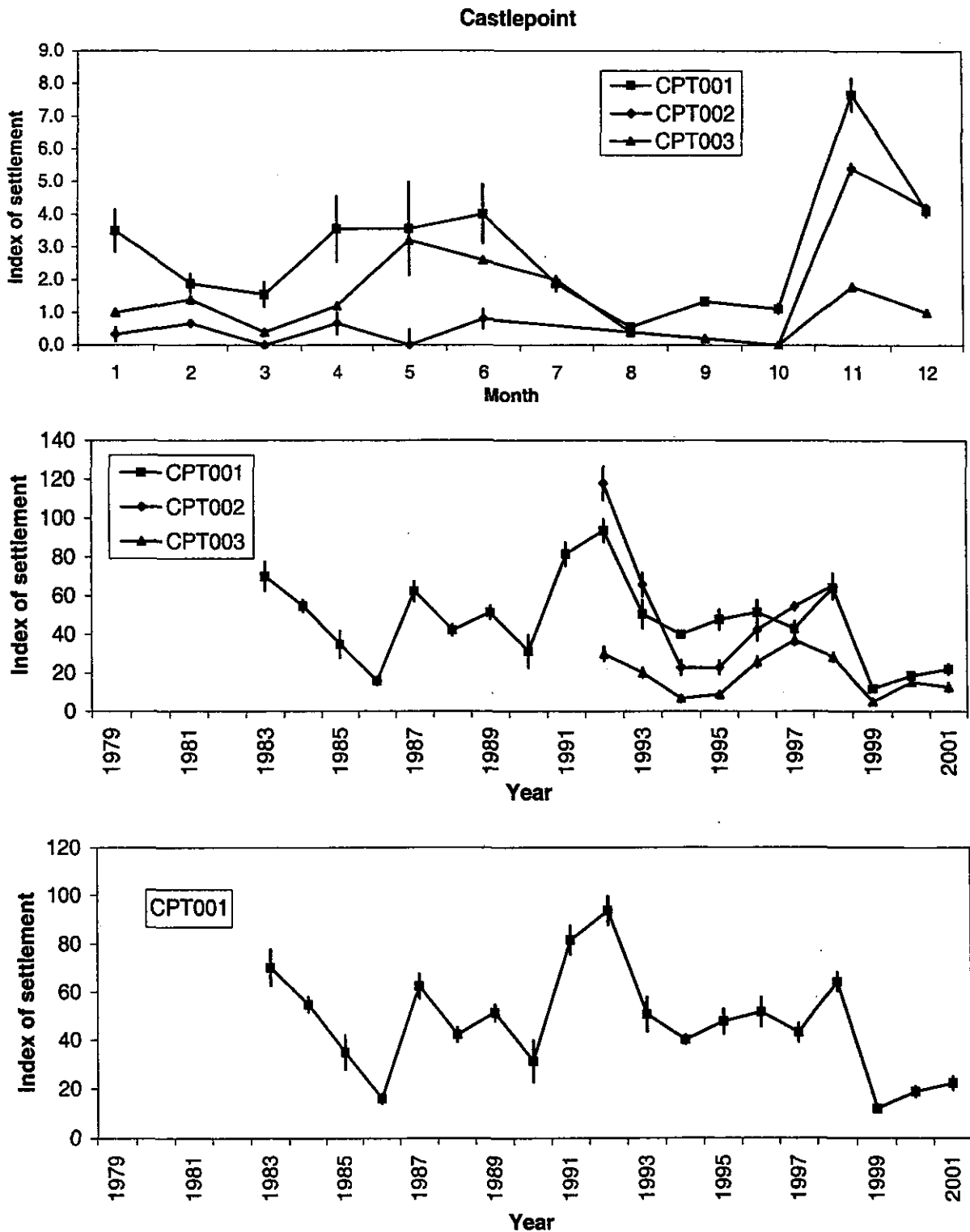


Figure 4: Castlepoint – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, December to September) on each group of collectors ± 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 or 2000 because the collectors were sanded over.

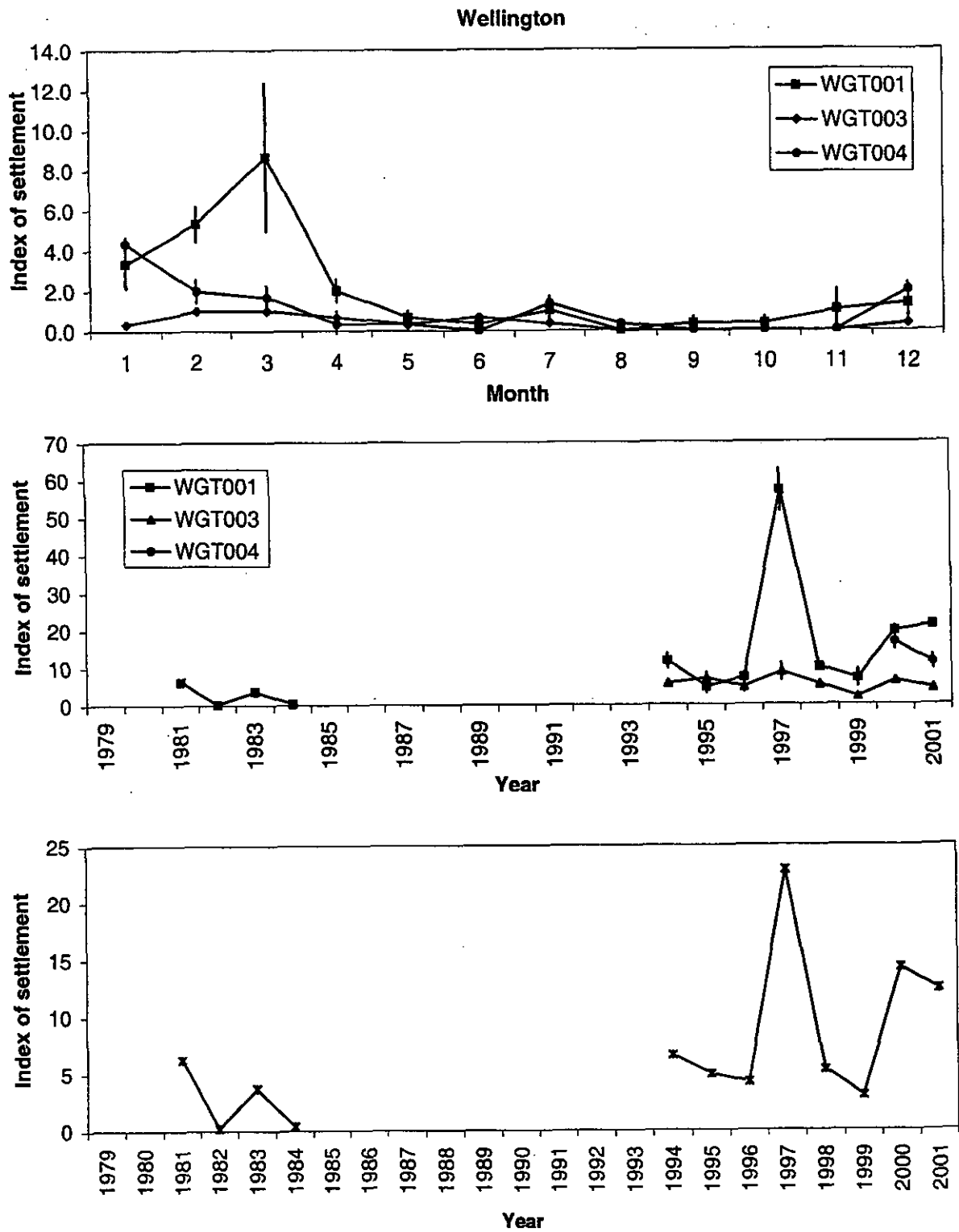


Figure 5: Wellington – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, January to May) on each group of collectors ± 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).

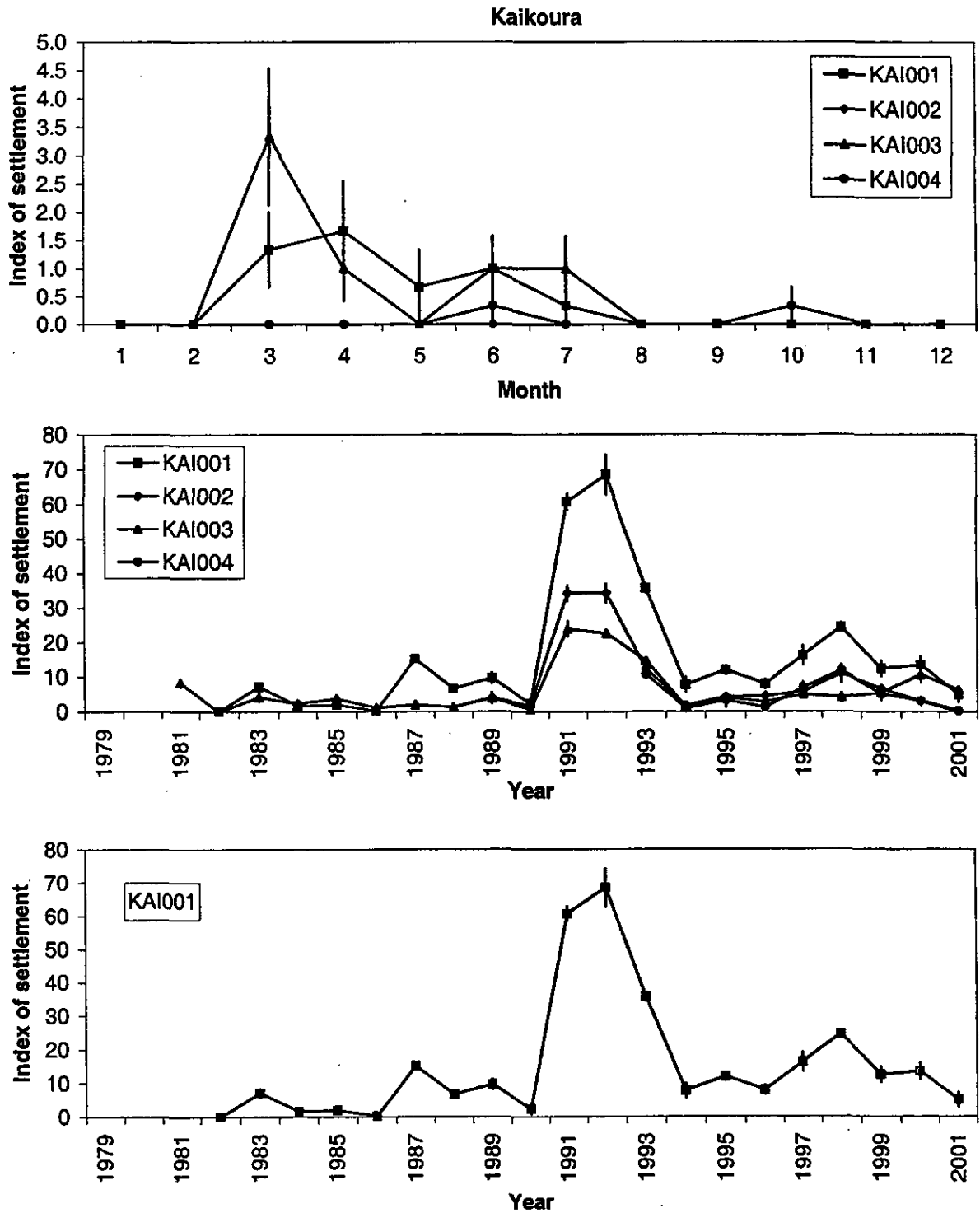


Figure 6: Kaikoura – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, January to September) on each group of collectors ± 1 standard 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).

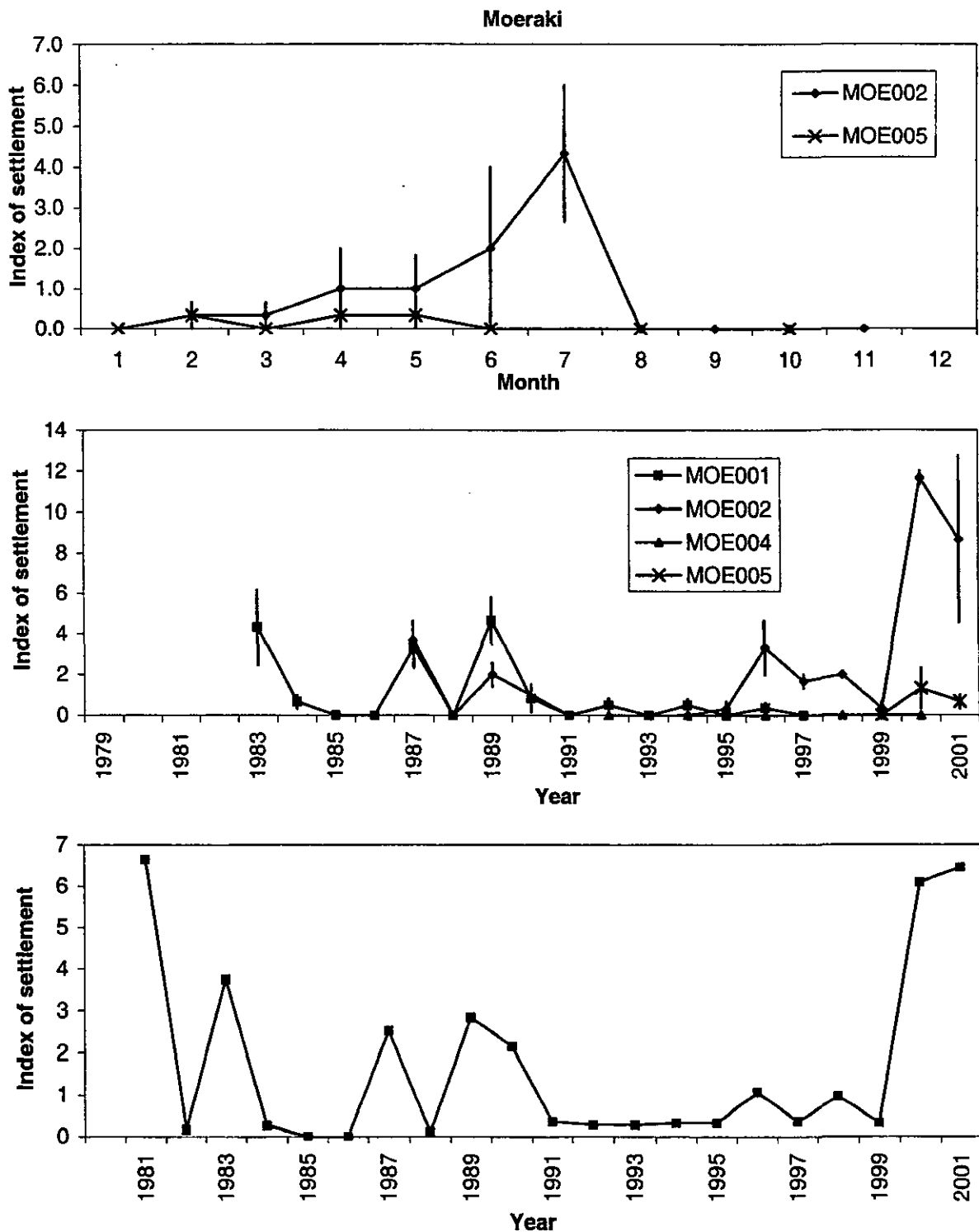


Figure 7: Moeraki - mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual index of settlement based on the main settlement period (March to October) (*middle*) and an index based on 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 for 1998-2000 for MOE001.

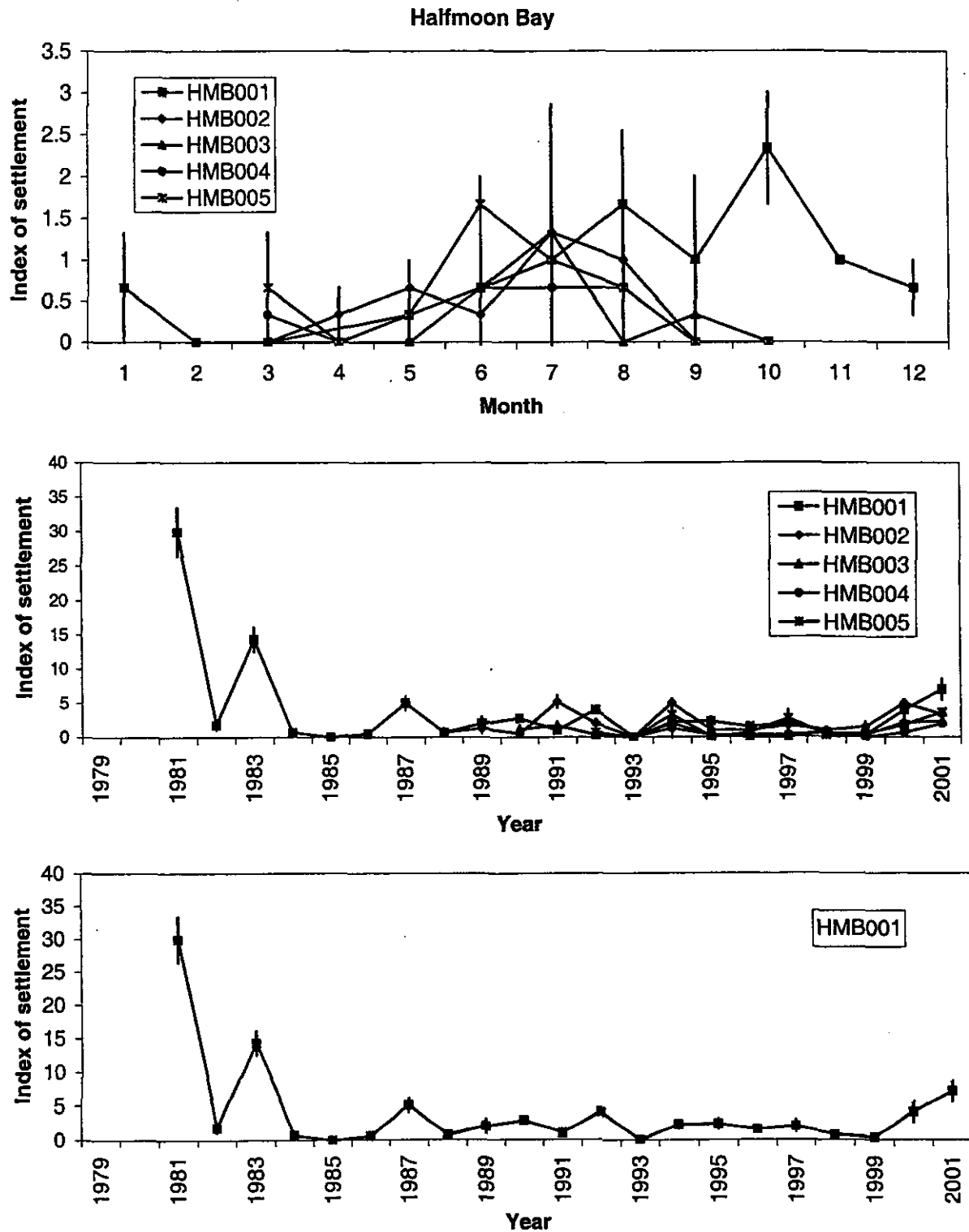


Figure 8: Halfmoon Bay – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, May to October) on each group of collectors ± 1 standard 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).

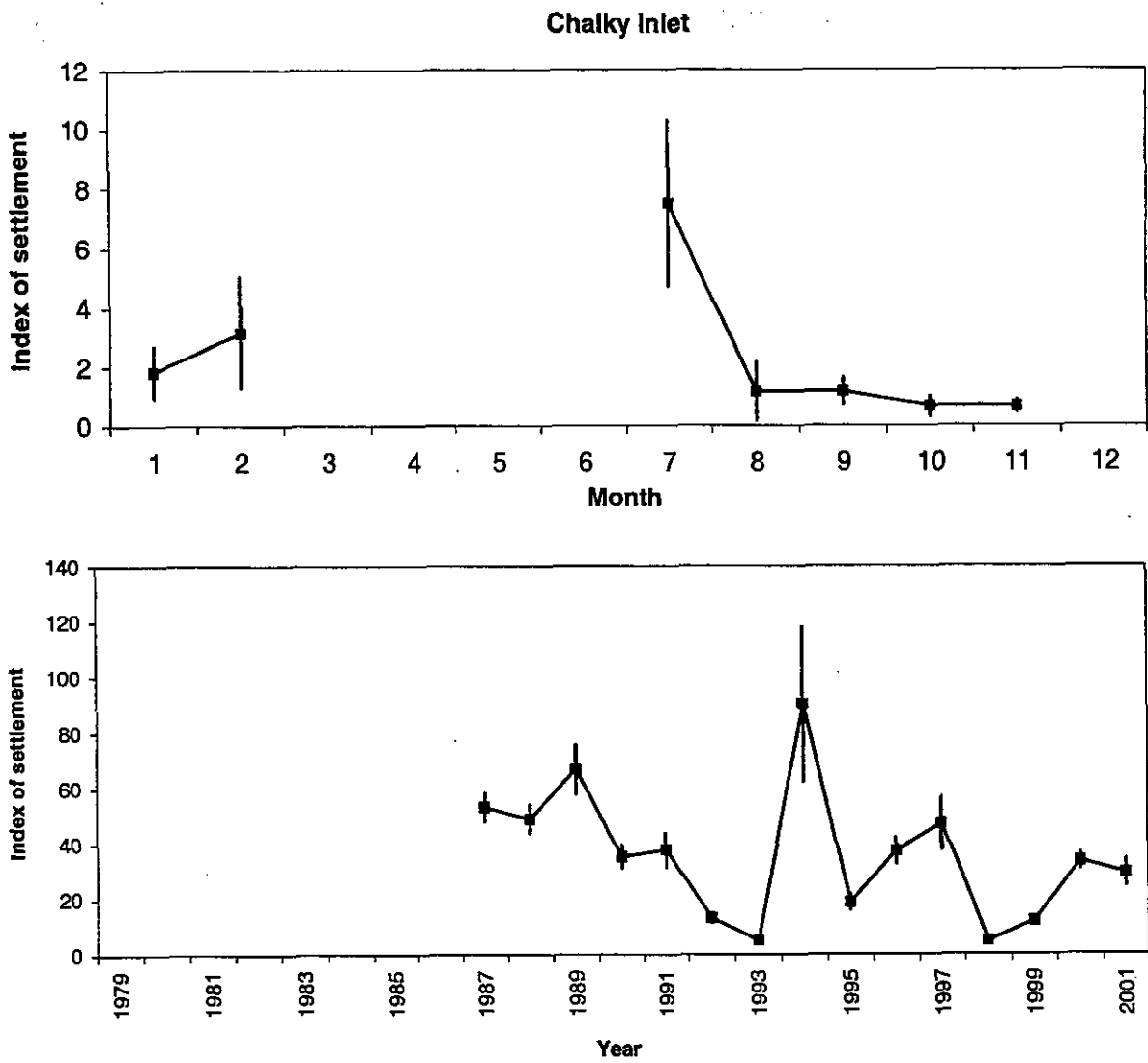


Figure 9: Chalky Inlet (Blind Entrance) – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2001, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, March to October) on the one group of collectors (± 1 standard error, *lower*).

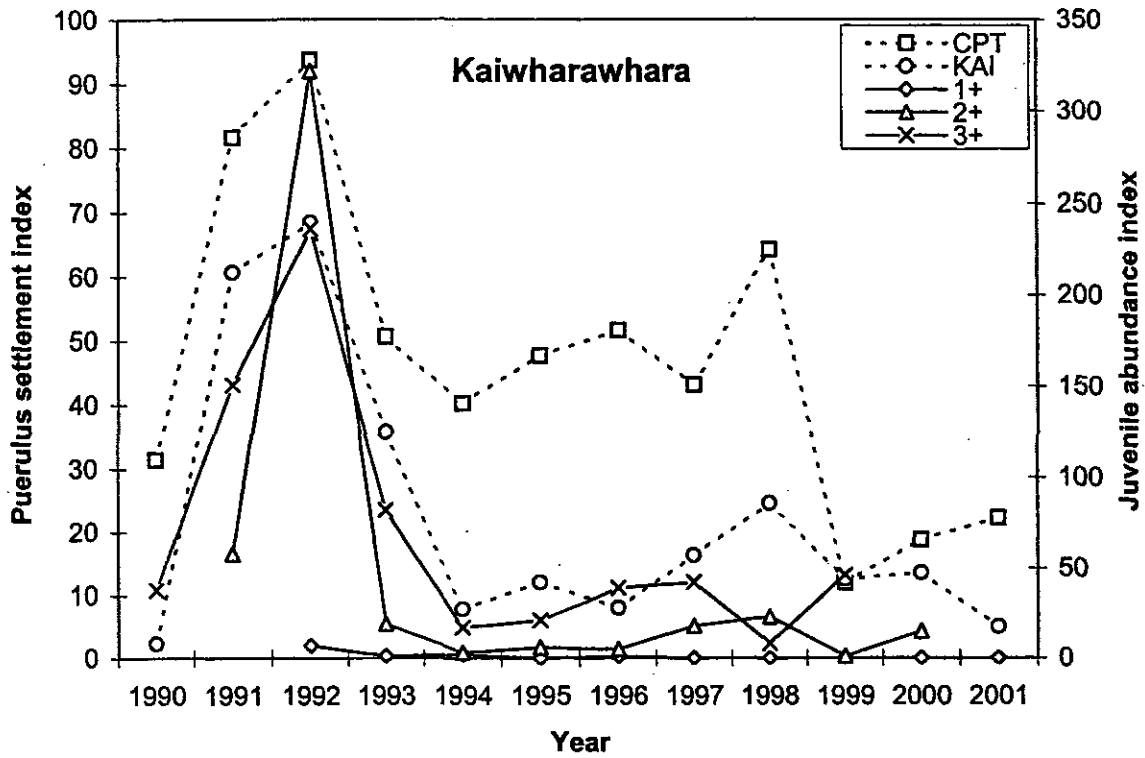


Figure 10: Juvenile year-class abundance of *Jasus edwardsii* at Kaiwharawhara, Wellington Harbour, each June 1993–2002 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

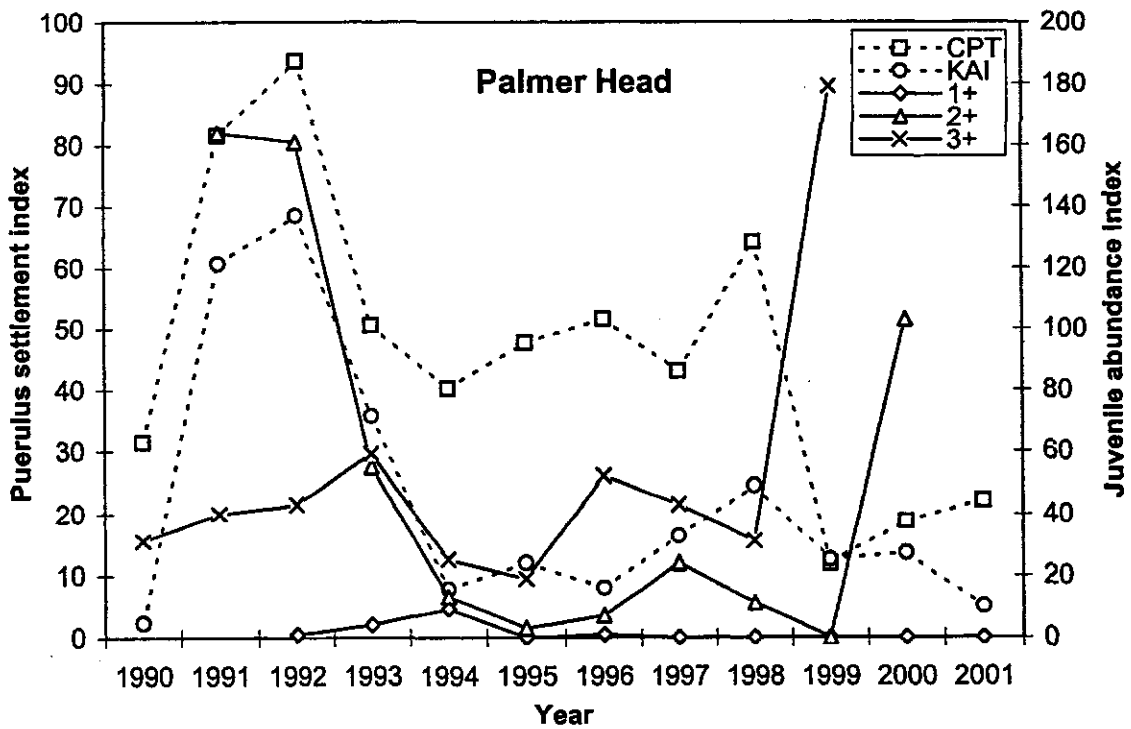


Figure 11: Juvenile year-class abundance of *Jasus edwardsii* at Palmer Head, Wellington, each June 1993–2002 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

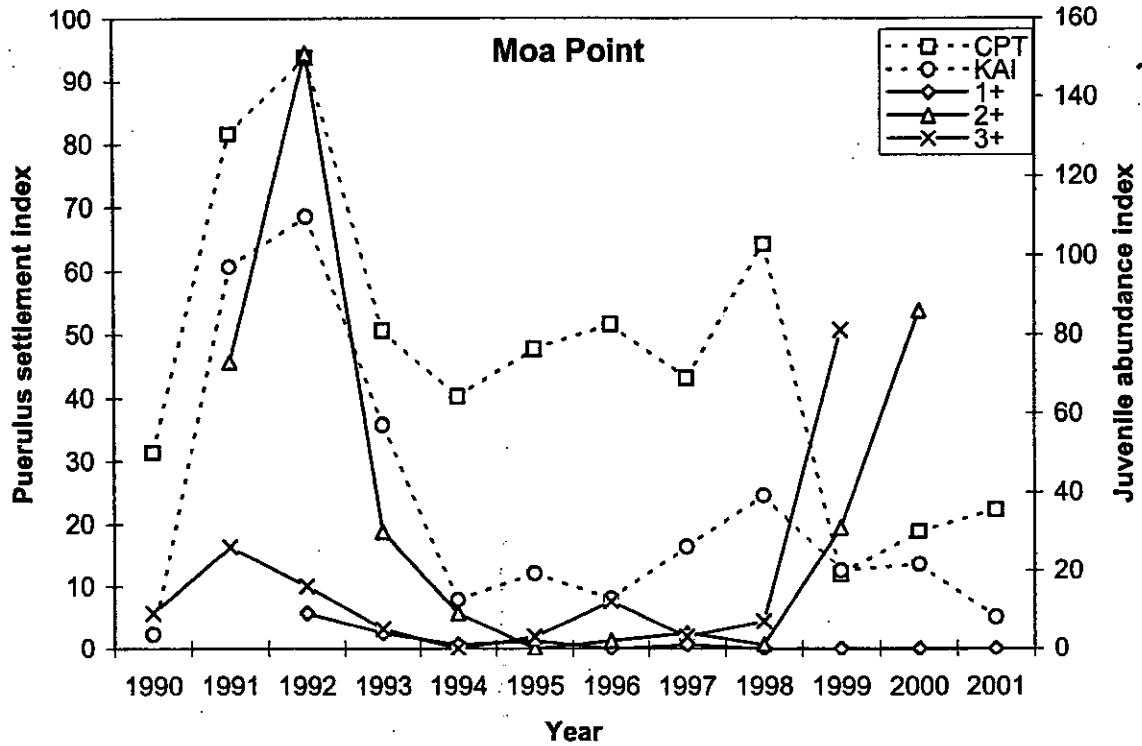


Figure 12: Juvenile year-class abundance of *Jasus edwardsii* at Moa Point, Wellington, each June 1993–2002 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

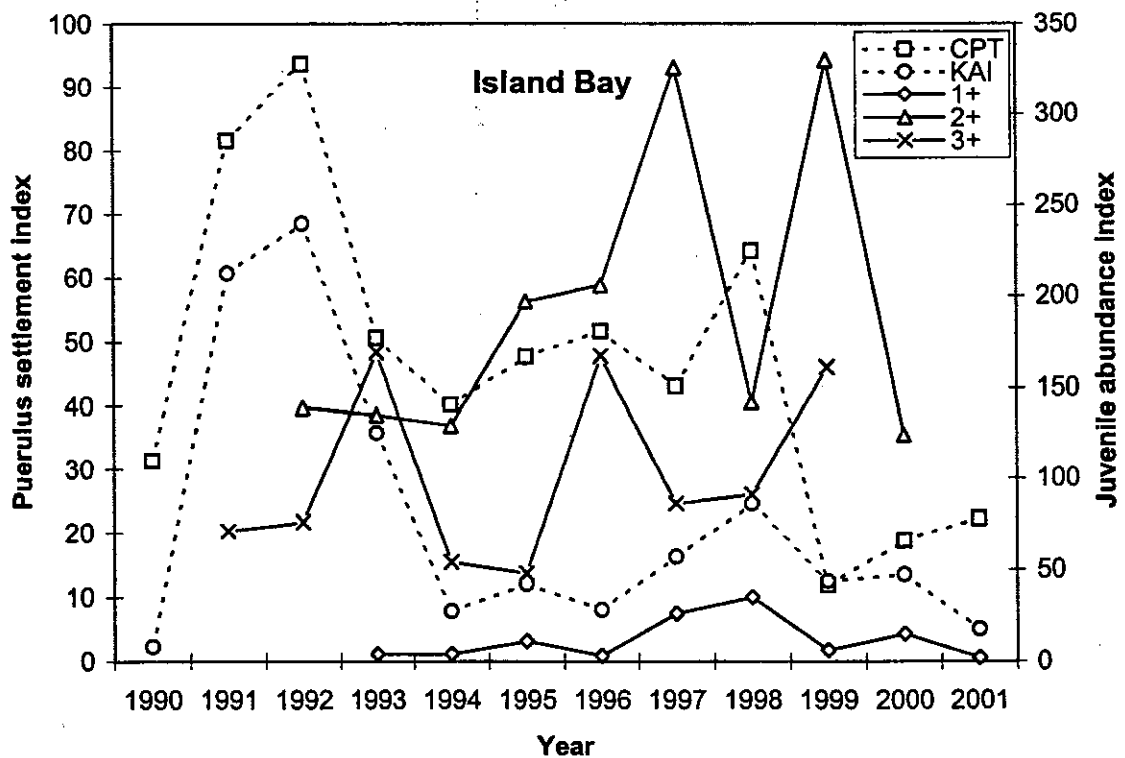


Figure 13: Juvenile year-class abundance of *Jasus edwardsii* at Island Bay, Wellington, each June 1994–02 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.