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EXECUTIVE SUMMARY

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New Zealand Fisheries Assessment Report 2002/12. 34 p.

This report addresses the one objective of Ministry of Fisheries project CRA200002.

1. To estimate monthly and annual indices of puerulus settlement at key sites over the main area of the fishery (Tauranga, 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. We also summarise records from New Zealand and Australia of pueruli and young juveniles of *J. edwardsii* in the wild, both in their natural habitat as well as on man-made structures. Like 1999, the year 2000 saw low settlement on the east coast of the country, at least from Gisborne south. However, although still low along the southeast coast of the South Island compared with further north, it was significantly higher there than it was in 1999 and the highest since the early 1980s. Settlement in 2000 was moderate in the southwest of the South Island. As a validation check on the Wellington settlement levels, we update the mid-year abundances of 1, 2, and 3-year old juveniles. Settlement indices remained significantly correlated with the previous levels of settlement at most, but not all, sites. The two Island Bay sites continued to have juvenile abundances at odds with the settlement record, this possibly being related to local, small-scale patterns of settlement and dispersion.

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 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. 2001a). In so doing, we address the objective of Ministry of Fisheries project CRA200002.

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

We also update the indices of juvenile abundance in relation to the settlement indices at Wellington, this being an opportunity to validate the local settlement index and to follow post-settlement processes.

The estimates of settlement have been made available to the National Rock Lobster Management Group (NRLMG) and the Rock Lobster Working Group (RLWG) during 2001: they were presented to the NRLMG and the Rock Lobster Research Planning Meeting on 6 September 2001, to the RLWG on 26 September 2001, and to the Mid-year Plenary on 6 November 2001. Selected estimates were incorporated as a sensitivity into the 2001 length-structured assessment model of CRA 3 developed for the Ministry of Fisheries.

For the most part we refer only to *J. edwardsii* in New Zealand, but this species also occurs in southern Australia and we summarise the ecology of pueruli and recently settled juveniles in the wild in both countries.

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 to nine key sites within the main rock lobster fishery since the early 1980s. New sites have now been 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

This is a summary of publications on early life history and larval recruitment in *J. edwardsii* appearing since those listed by Booth et al. (2001a).

The puerulus is capable of very rapid (up to 36 cm/s) and sustained (at an average 16 cm/s) forward swimming (Jeffs & Holland 2000). Jeffs et al. (1999, 2001a) found that lipid, particularly phospholipid, is the primary format for energy storage and that these lipid reserves have sufficient energetic capacity to allow the puerulus to actively swim across the shelf and settle on the coast. Jeffs et al. (2001b) found that attaining a threshold of larval energy reserve is unlikely to be responsible for triggering metamorphosis, but rather some exogenous trigger or triggers, as yet unknown, may be involved. In contrast to earlier results, Jeffs et al. (2001b) reported that a significant proportion of pueruli may not have sufficient reserves to reach the coast. This may have important implications for seasonal and interannual variability in patterns of puerulus settlement and subsequent recruitment of lobsters to coastal populations and their associated fisheries.

Based on laboratory tank studies on habitat choice, Booth (2001) found that both pueruli and first-instar juveniles primarily sought shelter rather than needing to be associated with conspecifics or any of the other marine life tested. The lobsters preferred conditioned refuges (those that had been immersed at the study site for at least a year) over those unconditioned, horizontal apertures over upward-facing vertical ones, and rough surfaces over smooth. Although some structurally complex seaweed and bryozoan species seemingly provide suitable refuge, they were less often used by young lobsters than were hard-walled shelters. The availability of such situations in nature may strongly influence lobster survival and abundance, and hence productivity. Both pueruli and first-instar juveniles are capable of almost completely burying themselves in sand, but they are intolerant of deep silt. Booth et al. (2001b) reported the abundance of 1, 2, and 3 year old juveniles in relation to the previous settlement levels for several sites near Wellington. For most sites, the juvenile abundance reflected the settlement index. However, at two sites this was not so. The reasons for this disparity between sites remain obscure, but the observation points to the need for sufficient site replication if juvenile year class strengths are to accurately reflect settlement patterns. Where puerulus numbers are great enough to register on collectors, crevice collectors appear to be a more accurate and cost-effective means of following highs and lows in larval recruitment in *J. edwardsii* than juvenile abundance dive surveys.

Popular articles dealt with the possibility of enhancing juvenile abundance in the wild through the provision of artificial shelters (Jeffs & Booth 2001) and with the growth and survival of juvenile lobsters in sea cages (Jeffs & James 2001).

1.3 Why estimate relative abundance of early life history stages?

Knowing the relative abundance of 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. A knowledge of seasonal, annual, and geographic variation in settlement will help us to understand larval recruitment processes. For example, geographically different settlement levels 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.

2. OCCURRENCE OF *J. EDWARDSII* POST-SETTLEMENT PUERULI AND YOUNG JUVENILES IN AUSTRALASIA

Inference regarding settlement behaviour and preferences of *J. edwardsii* can be made from observing young lobsters both in nature as well as on man-made structures, including collectors. Settled pueruli and first instar juveniles in New Zealand and Australia are more commonly encountered on static man-made structures than they are in their completely natural habitat. However, this probably reflects less effort having been put into exploring the natural settlement environment, with its often more difficult sampling conditions. This section summarises such records from the wild.

2.1 Natural habitats

Seasonally in New Zealand, large numbers of newly settled *J. edwardsii* can be found intertidally at Castlepoint and, to a far less extent, at Kaikoura (Booth 1979, Booth & Bowring 1988). These are among the few places in the world where substantial palinurid settlement on natural surfaces has been followed. At Castlepoint, tens to hundreds of pueruli at all stages of development (and, less commonly, first and second instar juveniles) may be encountered, the lobsters most often hiding in crevices, holes, and indentations under boulders which are in pools, or which at least remain damp, at low water. Available holes are mainly 6–16 mm in diameter, while those occupied average 12 mm (S.D. 2.64 mm) (Booth & Forman 1995). Multiple occupancy of holes is seldom observed, but when present in indentations, lobsters are found both alone as well as in groups in which individuals are in direct physical contact.

Most *J. edwardsii* settlement in Australasia is, however, subtidal, with most lobsters reported being found in holes and crevices (Lewis 1977, Booth & Forman 1995, Edmunds 1995) and where light levels are low. Settlement, at least on collectors, takes place to depths of at least 50 m (Booth et al. 1991), but most is in the uppermost 12 m, particularly 5–12 m. Our widespread diving has found recently settled lobsters almost exclusively in relatively sheltered environments, although these are also the areas most dived and those most easily examined. In Tasmania, Edmunds (1995) reported pueruli and first instar juveniles present in depths to 15 m, occupying roughly round holes 10–20 mm in diameter and 20–30 mm deep. Pholad (bivalve) holes containing pueruli in Port Gisborne (at depths of 0–3 m) averaged 18 mm diameter (S.D. 3.29 mm) and first instar juveniles 17.5 mm (S.D. 4.38 mm) (Booth & Forman 1995). All occupied holes had single entrances; the pueruli withdraw when disturbed, but generally the tips of the second antennae remain protruding. Crevices are also occupied, such as those that exist among small boulders and between stones and the seafloor.

There is little evidence for any strong association of pueruli or first instar juveniles with plants. Lewis (1977) reported pueruli present in seagrass in some sheltered South Australian waters and Frusher et al. (1999) suggested that seaweed may play a role in puerulus recruitment, but the primary settlement site appears to be holes and crevices in hard substrates.

2.2 Rock lobster fishing and associated gear

There are numerous records from throughout Australasia of *J. edwardsii* pueruli associated with growth on the undersides of buoys, clinging to pot (trap) lines, and present within bait containers and in holes and indentations in weights inside pots (unpubl. NIWA data; Frusher et al. 1999). Usually these are very recently settled, unpigmented pueruli, probably because the gear is generally hauled daily and so lobsters have not had time to develop. Most commonly single animals are seen, but groups of lobsters have been reported. For example, dozens of pueruli were among floating fish boxes moored in June 1983 off the west coast of Stewart Island (Booth et al. 1991). The impression is that holes, crevices, and hides in the fishing gear and associated growth are sought by the pueruli, except for pot lines where the grasping response of the puerulus has been evoked.

2.3 Marine farms

High settlement along the east coast of central New Zealand during 1991 and 1992 led to large numbers of pueruli and small juveniles on green mussel (*Perna canaliculus*) commercial longlines in Port Underwood (Booth 1992). The lines provide vast amounts of creviced shelter among the mussels for settling lobsters and there is also abundant food present for juveniles. An average of almost one lobster per metre of mussel longline was estimated.

J. edwardsii pueruli and small juveniles have been reported from numerous other marine farms (mussel and scallop) throughout mainland New Zealand (unpubl. NIWA data). Frusher et al. (1999) reported pueruli in oyster racks and on mussel lines in Australia.

2.4 Boat fouling

Both in New Zealand and Australia, pueruli and small juvenile lobsters have been found on the hulls of moored vessels that have developed extensive growth after long periods of disuse (Lewis 1977, Booth et al. 1991, Frusher et al. 1999). The lobsters are usually found among the growth when the vessel is hauled ashore for cleaning. At Moeraki, the prominent growth in which the lobsters lived consisted of the stalked ascidian *Pyura pachydermatina*, the fleshy bryozoan *Elzerina binderi*, and hydroids, mainly *Amphisbetia bispinosa* (R.J. Street, 8 Gala St., Dunedin, pers. comm.)

2.5 Wharf piles

Wharves and piers, both within and outside harbours, commonly shelter young *J. edwardsii*. When wooden piles were removed at Port Gisborne, New Zealand, in the mid 1960s, numerous pueruli and young juveniles were found in cracks and crevices in the piles (unpubl. NIWA data). The concrete piles that replaced the old wooden ones were driven into oversized holes. These holes, along with the growth that developed on the piles, are now occupied by many young lobsters. Presumably the directional aspect, shelter from large swells, associated food, and presence of suitable habitat that many wharves and their associated debris provide can make them prime habitat for both settling and young *J. edwardsii* (Frusher et al. 1999, Booth unpubl. data).

2.6 Collectors

The observation that *J. edwardsii* pueruli often occupy holes, crevices, and depressions in rock led to the development of the crevice collector (Booth & Tarring 1986). Subsequently, the most successful designs for catching *J. edwardsii* pueruli and first instar juveniles have been collectors containing holes, crevices, and recesses (Booth & Stewart 1993, Phillips & Booth 1994, Mills et al. 2000). The addition of a panel of trawl mesh above a crevice collector can increase its catch rate (Frusher et al. 1999), possibly because it increases the effective surface area of the collector. Artificial seaweed collectors, like those used in Western Australia (Phillips 1972), successfully caught *J. edwardsii* pueruli, but at rates significantly lower than on nearby crevice collectors checked at the same times (Booth 1979, Booth & Stewart 1993). Other imitation seaweed devices (including kinran, Christmas tree rope used for mussel settlement, Christmas tree decoration, synthetic fibre oil boom) all caught pueruli, but never as many as nearby crevice collectors of similar external surface area checked at the same times.

Crevice collectors become increasingly effective, at least up to 12 months as they condition (Booth & Forman 1995). Because the growth projecting from the collector surfaces is scraped off at the monthly check, it is probably the biofilm and associated small organisms that make the conditioned collector more successful; it is unknown how much that same growth left undisturbed would affect levels of puerulus settlement, but eventually the crevices become choked.

Crevice collectors are probably successful because they provide the right shaped retreats, they harbour food for juveniles, and they provide shade. The crevice of the standard crevice collector is 25 mm high at the mouth; catch rates were significantly lower when the crevice opening was smaller (12 mm) or larger (60 mm) (Booth & Forman 1995). However, neither for this observation, nor for the one of increasing effectiveness with conditioning, is it possible to exclude predation being an important factor: predators may be less successful in catching lobsters in conditioned collectors and in collectors with a 25 mm high crevice.

2.7 Nursery areas in New Zealand

Shallow and extensive inshore settlement and nursery areas that are clearly differentiated from the adult habitat, such as those of *Panulirus argus* in the Caribbean and *P. cygnus* in Western Australia (Butler & Herrnkind 2000) and which lead to well defined, one-way ontogenetic migrations to the adult grounds, are not obvious for *J. edwardsii*. It appears that *J. edwardsii* settlement mainly takes place along most near-ocean rocky shores, over a greater depth range (commonly to 15 m) than in the *Panulirus* spp., and at depths also occupied by older lobsters (Booth et al. 1991). For example, during spring it is common for large male lobsters to be in very shallow (less than 5 m) inshore waters, later returning to greater depths (Street 1969), this and other such movements being related to seasonal moulting and mating. Well-differentiated nursery areas, occupied only by small, immature lobsters, also appear to be absent or rare in all other *Jasus* group 'lalandii' species (Grua 1960, Pollock 1986, 1991, Beurois 1987, Arana Espina 1992, Frusher et al. 1999).

Nevertheless, the impression is that, within the common diving depth of 25 m, the greatest abundances of small *J. edwardsii* in New Zealand are inshore, at depths of 2–10 m. Consistent with this, MacDiarmid (1991) reported that juveniles less than 85 mm CL were always more abundant in shallow areas than deep; 55% were at the shallow (less than 10 m) sites, 33% at the mid-depth sites (10–17 m) and only 12% at the deep sites (to 25 m). Possibly there is higher settlement (or perhaps higher survival) within coves and backwaters and in the lee of sheltering headlands. Indeed, some of the best-known settlement sites are man-made backwaters, such as Port Gisborne and Port Napier. It appears that at about age 2–3 y, juveniles move to deeper waters – but this is a movement yet to be confirmed through tagging.

As for other palinurids, the highest settlement areas and those with greatest abundance of very young juveniles are not necessarily the areas that contribute most to stocks of older juveniles. For example, most of the high numbers of recent settlers at Castlepoint appear not to survive, large numbers of small juveniles being cast up from time to time on tide lines (Booth & Forman 1995). Similarly in Port Gisborne, there is considerable discrepancy between the large numbers of pueruli settling on collectors and the much lower numbers of 1–3 year old juveniles present nearby (Booth unpubl. observations.)

3. SHORE SETTLEMENT AT CASTLEPOINT IN 2000

A goal for research has been to see if a useful index of natural settlement can be derived from monthly shore counts at Castlepoint, but this has proved difficult because the study area is often covered by sand, as it was during most of 2000. The indices of shore settlement to date are given in Table 1. The crevice collectors at Castlepoint (see Section 4.3) provide a much more useful index of seasonal and annual larval recruitment than do the intertidal shore counts.

4. SPATIAL AND TEMPORAL PATTERNS OF SETTLEMENT

4.1 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). There have been recent changes in the key sites: for the west coast, regular checks of collectors at Punakaiki were not possible, so in 1999 collectors were installed near Jackson Head. Additional sites were established in CRA 1 and CRA 2 (described in Section 4.2), in accordance with Objective 2 of CRA1999/02. Monthly settlement for exploratory sites (sites at which settlement was followed for only a few years and where monitoring no longer continues) shown in Booth (1994, including sites A–D, F, H, M, and N), and others in the Wairarapa, at Port Underwood, Cape Campbell, Kaikoura, Timaru, and Oamaru, and various parts of Stewart Island, Fiordland, and the Chatham Islands, are now available on the NIWA-administered Ministry of Fisheries *rocklob* database.

At the key sites, crevice collectors are set in groups of three to nine, 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, Booth et al. 1991, and Phillips & Booth 1994 for collector design) (Table 2). 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. Concerns have been expressed as to whether or not all sources of variability are being included. Another possible source of error arises from the interpolated values when observations are missing. To investigate these concerns, the index estimation process was bootstrapped using the data collected at Castlepoint (Booth et al. 2000a). The conclusion was that the current method of estimating the index standard error is not grossly in error and gives results that are adequate until indices with a more reliable estimate of the standard error are specified by the Rock Lobster Working Group.

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 as 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 (e.g., Booth et al. 2001a). 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 collecting techniques have been used at several sites over a number of years: settlement over the past 17 years has 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).

4.2 New sites in CRA 1 and CRA 2

Objective 2 of CRA1999/02 was to set up one site to estimate settlement in each of CRA 1 and CRA 2. In discussions with the Ministry of Fisheries and with local industry it was agreed that three sites in each CRA area, each with five collectors, be established, and that later one site in each CRA area be selected for long-term monitoring. This approach recognised the difficulty often encountered when setting up puerulus monitoring in a new area, where often two or more years of trial and change is required before an estimate of settlement that might be considered representative of the area is being obtained (Phillips & Booth 1994). The three sites within each CRA area were chosen to give as broad coverage as possible of the CRA area, at the same time taking into account previous puerulus monitoring experience there and any reports of high densities of small juveniles.

In CRA 1, the sites at which five collectors were installed in February 2000 were Houhora Bay, just north of the entrance to Houhora Harbour; Taupiri Bay, just south of the Bay of Islands; and Home Point at the northern entrance to Whangarei Harbour. Houhora Bay was the site chosen for long-term monitoring and additional collectors were installed at the northern end of Henderson Bay, just north of Houhora Bay, in July 2001. Approximately monthly checks of collectors have produced only small catches of lobsters in Houhora Bay; the Henderson Bay ones are yet to condition.

In CRA 2, the sites at which five collectors were installed and checked were inside Papatu Point at the Katikati Entrance to Tauranga Harbour, Mt Maunganui wharves (later replaced by Okurei Point near Maketu), and Little Awanui about 5 km southwest of Te Kaha. Only Papatu Point has produced young lobsters, and this is now the long-term CRA 2 monitoring site. An additional set of five collectors was installed there early in 2001, about 1 km inshore of the original set.

4.3 Collector catches at the established key sites, 2000

Catches for most key sites by group and by month are given in Figures 2–9. These graphs also show the 2000 catches against those of previous years.

Generally, 2000 was a low settlement year on collectors from Gisborne to Halfmoon Bay. However, it was not as low as it was in 1999 and also there was a significant increase in settlement in the southeast of the South Island (SESI), at Moeraki and Halfmoon Bay. At Chalky Inlet, settlement in 2000 was moderate.

The within-site patterns reported by Booth et al. (2000a) persisted: there were often significant differences in the levels of settlement between groups of collectors within sites and sometimes, as at Kaikoura, 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 can be at least as high as in winter. Some summer settlement also takes place further north, at Gisborne and Napier, but it is seldom as strong as it is further south. In 2000, summer settlement everywhere was either low or absent. The reasons for these seasonalities, and their variation between areas, remain unclear. Late stage phyllosomas are present throughout the year off SENI which suggests that, at least there, settlement is possible at any time of the year. The Wairarapa Coastal Current may be a factor in settlement season along SENI (Booth et al. 2000b), as could be the energy levels of the pueruli (Jeffs et al. 2001b).

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.

4.4 Between-site variability 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. However, 2000 saw a marked increase in settlement levels in SESI, 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 has been moderate to high compared with those on the east coast of the South Island.

4.5 Reasons for spatial variation in settlement

The much higher levels of settlement usually seen on collectors along SENI compared with those along SESI 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. 1999, Chiswell & Booth 1999). Advanced phyllosomas (those at and beyond Stage 5) were widespread and abundant off SENI, catches being orders of magnitude greater than off SESI. We 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 SESI. This in turn seemed to be closely related to the abundance of breeders, the oceanography, and strength of certain environmental factors, such as the persistence of southerly storms (see Booth et al. 1999, 2000b). Unfortunately there are no data on phyllosoma distributions or abundance for 2000, but the low levels of settlement along SENI in 1999–2000 were probably due mainly to the La Niña conditions rather than to lower offshore abundance of phyllosomas. The increased settlement off SESI could have been a result of increased numbers of advanced phyllosomas there. It is interesting that the increased settlement in SESI took place in the face of La Niña conditions, which would normally be expected to act against higher settlement.

Less easy to reconcile is the moderate to high settlement on collectors in Chalky Inlet, given that advanced phyllosomas have been much less abundant in plankton tows in the Tasman Sea than off SENI (although they were more abundant than off the east coast of the South Island) (see Booth & Forman 1995).

4.6 Year to year variation in settlement

Indices of year to year settlement on the core collectors at the key sites given above and in Table 3 update those given by Booth et al. (2001a). Levels of annual settlement remain significantly correlated among sites along the east coast from Gisborne south (Gisborne-Napier-Castlepoint-Kaikoura; Moeraki-Halfmoon Bay) (Table 4). 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, irrespective of the method of measurement. 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 SESI has been low except in the early 1980s and in 2000, when it was significantly greater.

Settlement was moderate to high in the southwest of the South Island from 1987 to 1991, in 1994, during 1996–97, and in 2000; it was low in 1992, 1993, 1995, and 1998–99.

5. JUVENILE ABUNDANCE IN RELATION TO LEVELS OF SETTLEMENT

5.1 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 processes taking place after settlement. Juvenile abundance has been followed at Gisborne, Wellington, and Stewart Island in relation to settlement estimates (Booth et al. 2000a) but contracted estimates of juvenile abundance at all these sites has ceased. However, we can report the mid-year abundances for Wellington for 2001. 0+ lobsters are those immediately post-settlement to 1 year of age, 1+ lobsters are over 1 but under 2 years of age, etc.

5.2 Wellington

The abundance of juveniles has been followed at least quarterly since 1993 or 1994 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. 2001b). Puerulus collectors were not re-installed on the south coast until late 1993, but since Wellington is positioned about halfway between Castlepoint and Kaikoura, and settlement events are known to take place over broad areas of coast (see Section 4.1), the puerulus settlement data from those two sites are used as recent proxy settlements for Wellington. Both sites had high settlement in 1991 and 1992 (Kaikoura also had high settlement in 1993 compared with later years), followed by much lower settlement (until 1998). At all three sites, the main settlement period is summer to late winter.

The juvenile abundance survey method was described by Booth et al. (2001b). To summarise, the same spots (isolated reef, crevice, hole, most being at 5–9 m depth) at each site were surveyed each quarter. 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. Sizes of lobsters were estimated in 5 mm intervals for animals 30–80 mm CL; those longer 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. Juveniles at 1+ were uncommon in all sampling, probably because of their small size and cryptic behaviour and their dispersed distribution. Surveys made at individual sites over successive days showed small variation in counts (Stotter, pers. obs.).

The results for mid 2001 are consistent with low settlement since the high settlement years of 1991 and 1992. The 1991 and 1992 settlement cohort has progressed through the year class distributions, and juvenile abundances are now low. For Kaiwharawhara, sampled almost every 3 months from June 1993 to September 2000, and again in mid 2001, 2 and 3 year olds were present in large proportion until March 1995. From June 1995, most of the few lobsters present were at least 3+. Figure 10 plots the June/July abundance of each year class each year against the year of settlement, using unstandardised data, with high correlations (coefficients 0.78 [P between 0.01 and 0.02] and 0.91 [$P = < 0.001$] respectively) in the abundance indices of 2+ and 3+ juveniles versus the year of settlement based on the core Kaikoura collectors (KAI001).

There was a similar, but generally less marked, correlation between settlement levels and subsequent 2+ and 3+ year class strengths at two of the three south coast sites. At Palmer Head (with the two areas combined), 2+ and 3+ lobsters were present in high proportion until mid 1995, after which 2+ lobsters became scarce. Figure 11 plots the mid-year unstandardised abundance indices against the Kaikoura year of settlement (correlation coefficients 0.97 [$P < 0.001$] and 0.35 [ns] respectively for 2+ and 3+ juveniles). At Moa Point, 2+ juveniles became scarce early in 1995 and 3+s by mid 1996 (Figure 12, correlation coefficients 0.89 [$P < 0.01$ but > 0.001] and 0.72 [$P < 0.05$ but > 0.02] respectively for mid-year abundance of 2+ and 3+ juveniles, unstandardised, plotted against Kaikoura year of settlement).

Island Bay (two areas combined) is different in that 2+ and 3+ lobsters were not particularly well represented when sampling began in mid 1994 but have become more abundant (Figure 13); there were no significant correlations between the abundance of juveniles, unstandardised, plotted against the year of settlement. The reasons for this difference from the other sites remain obscure, but may be related to the local, small-scale spatial patterns of settlement and dispersion of juveniles varying over the study period. The observation points to the need for sufficient site replication if estimated juvenile year class strengths are to accurately reflect juvenile abundance on the seafloor.

6. MANAGEMENT IMPLICATIONS

The settlement data for 2000 suggest, for the first time, a (sub)stock boundary off the east coast of New Zealand in the region between Kaikoura and Moeraki. This was because settlement was low all along the east coast, as it was in 1999, but showed a marked increase in 2000 in SESI. Previous data had suggested a boundary in the vicinity of Cook Strait-Kaikoura (Booth et al. 1999). It will be most interesting to see whether this increase in settlement along SESI translates into increased abundance of juveniles and ultimately improved fishery recruitment there.

For nearly all SENI sites, the 1999 and 2000 settlement levels were only 10–20% of what they were in the recent peak years of 1991–92. 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 will the implications of this be more marked than at Gisborne, where the record low settlements in 1999 and 2000 are likely to contribute to a period of low recruitment starting around 2003.

With the correlations between levels of settlement and abundance of juveniles outlined above for Wellington, and for Stewart Island (Breen & Booth 1989), and with the developing association seen between puerulus settlement levels and recruitment to the fishery (Booth et al. 2000b), more detailed investigation of the effect of variable interannual settlement on fishery landings is now appropriate.

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Table 1: Abundance of pueruli + juveniles at least 14.5 mm carapace length taken on Castlepoint Shore (defined in section 4.1 of Booth & Forman 1995), 1990–2000. The January to March set of data is the total numbers of lobsters collected, the number of suitable stones available and checked, and the sum of the mean monthly collection per stone for the two areas (East and West Main Beach) for January–March each year; the right set is for December–September. In some months, the search areas were partially or completely covered with sand, meaning that the number of months each year leading to the December–September index ranged between seven and ten. For January–March, all 3 months were sampled all years except for 1995, when only 2 months were sampled. –, areas heavily sanded.

	Jan-Mar				Dec-Sep		
	No. lobsters	No. stones	Index		No. lobsters	No. stones	Index
1990	2	150	0.03	1989–90	327	1090	0.47
1991	80	275	0.58	1990–91	483	812	1.35
1992	91	217	0.98	1991–92	239	621	1.10
1993	260	149	3.34	1992–93	420	362	1.97
1994	125	139	2.12	1993–94	336	467	1.61
1995	35	69	1.00	1994–95	59	265	0.40
1996	61	76	1.83	1995–96	–	–	–
1997	–	–	–	1996–97	–	–	–
1998	–	–	–	1997–98	–	–	–
1999	–	–	–	1998–99	–	–	–
2000	–	–	–	1999–2000	–	–	–

Table 2: **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
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
Halfmoon Bay	3	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		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 3: Annual settlement 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. 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 Jackson Head (JAC) was usually based on at least nine collectors checked each month (Wharf 1–3, Inner Head 1–3, Outer Head 1–3, and Smoothwater Bay 1–3), 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.

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

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

Table 3 -continued

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

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

Table 3 -continued

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

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

Table 3 -continued

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

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		

Jackson Head	Overall
2000	5.9

Table 4: 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* (1992–2000); NAP, Napier (1979–85, 1988–2000); CPT, Castlepoint (1983–2000); KAI, Kaikoura (1982–2000); MOE, Moeraki overall (1981–2000); HMB, Halfmoon Bay (1981–2000); CHA, Chalky Inlet (1987–2000); 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	0.86(7)**					
CPT	0.85(7)**	0.63(14)**				
KAI	0.65(7)	0.63(15)**	0.69(16)**			
MOE	–0.33(7)	0.16(16)	–0.09(16)	–0.13(17)		
HMB	0.43(7)	0.41(16)	0.33(16)	–0.02(17)	0.76(18) ***	
CHA	0.10(7)	0.21(11)	–0.12(12)	–0.40(12)	0.15(12)	0.27(12)

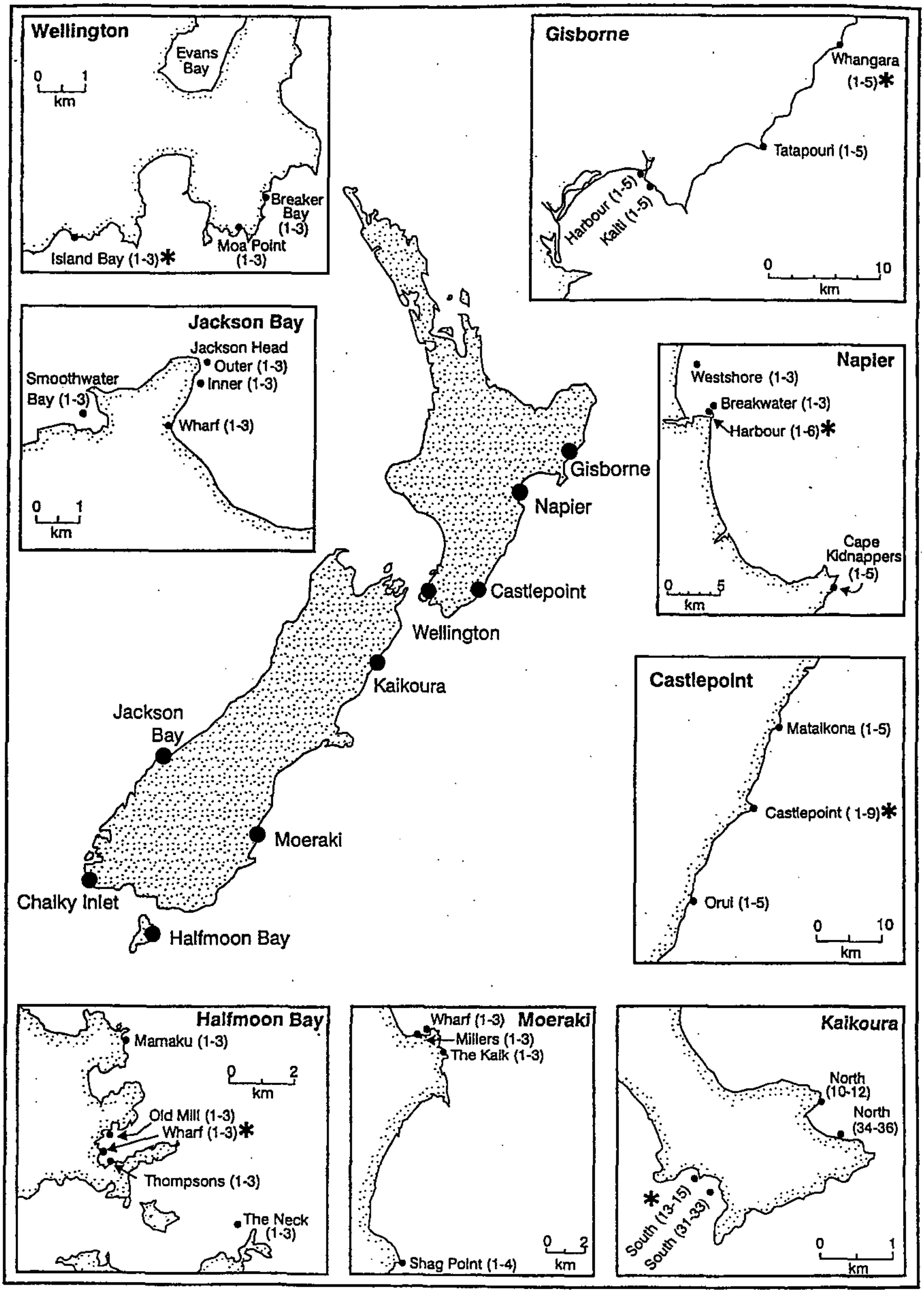
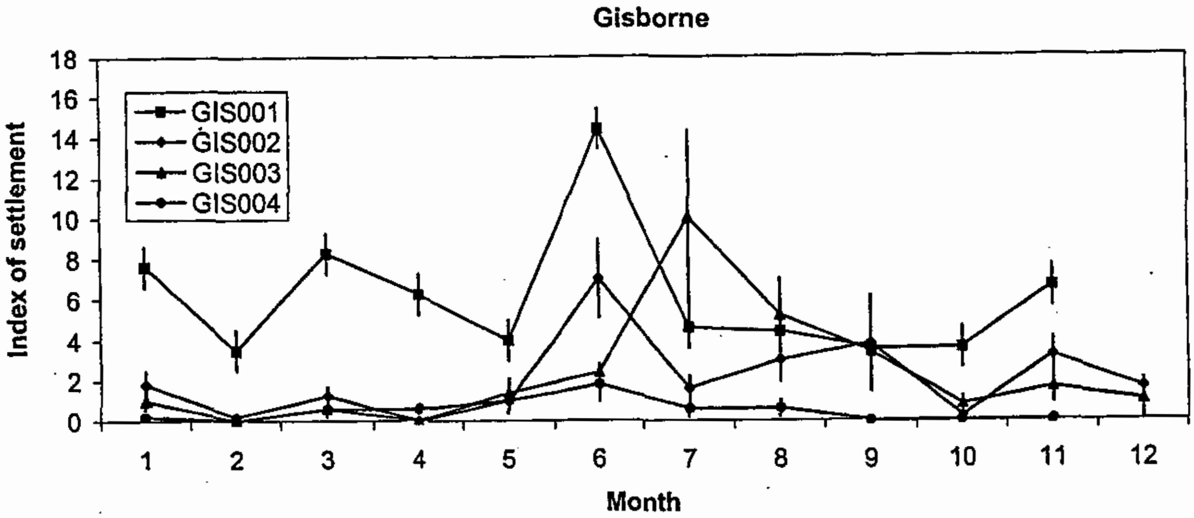
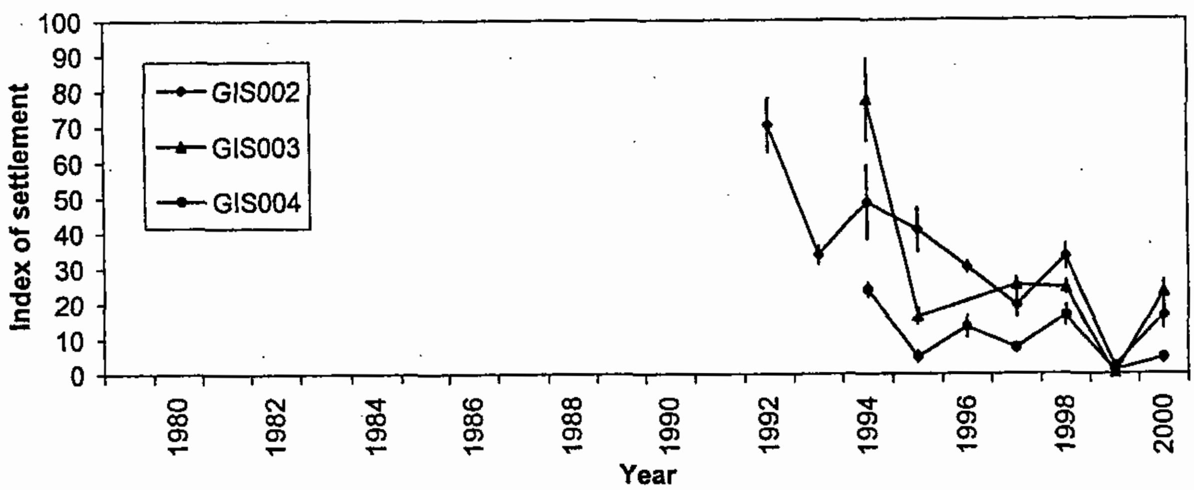


Figure 1: Map of New Zealand showing location of collectors at the key monitoring sites. The insets show the numbers and arrangement of collectors at sites with more than one set of collectors. *, core group of collectors where one has been nominated.





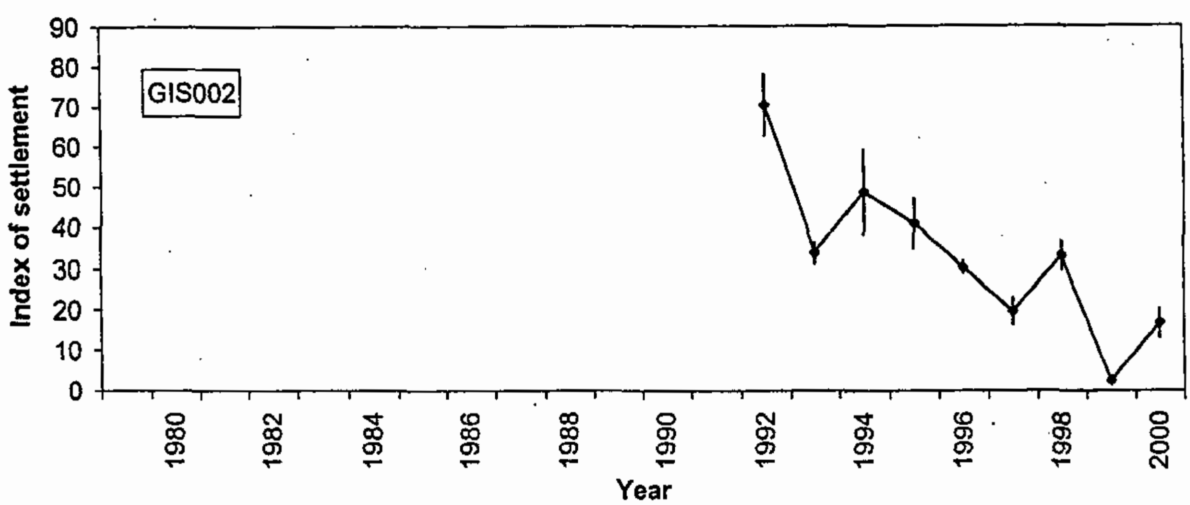


Figure 2: Gisborne – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, April to October) on groups of collectors ± 1 standard error (*middle*) and on the core group (*lower*). GIS001 is the Harbour group; GIS002 is Whangara (core); GIS003 is Tatapouri; GIS004 is Kaiti. GIS001 is not shown on the middle panel because it obscures and confuses the interannual pattern (see Booth et al. 1998).

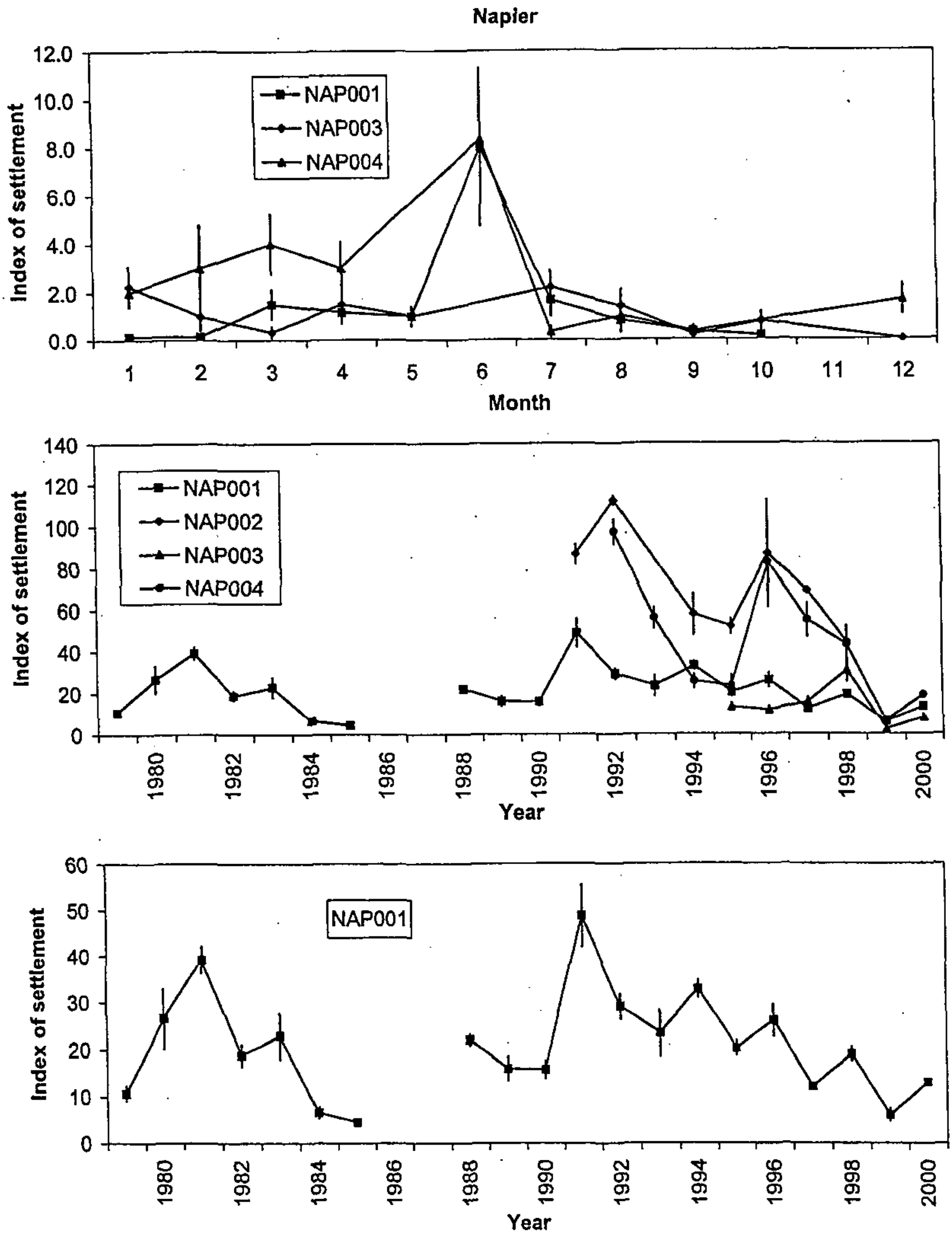


Figure 3: Napier – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, April to September) on each group of collectors ± 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. Collector positions and deployment changed after 1985; no data available for 1986–87.

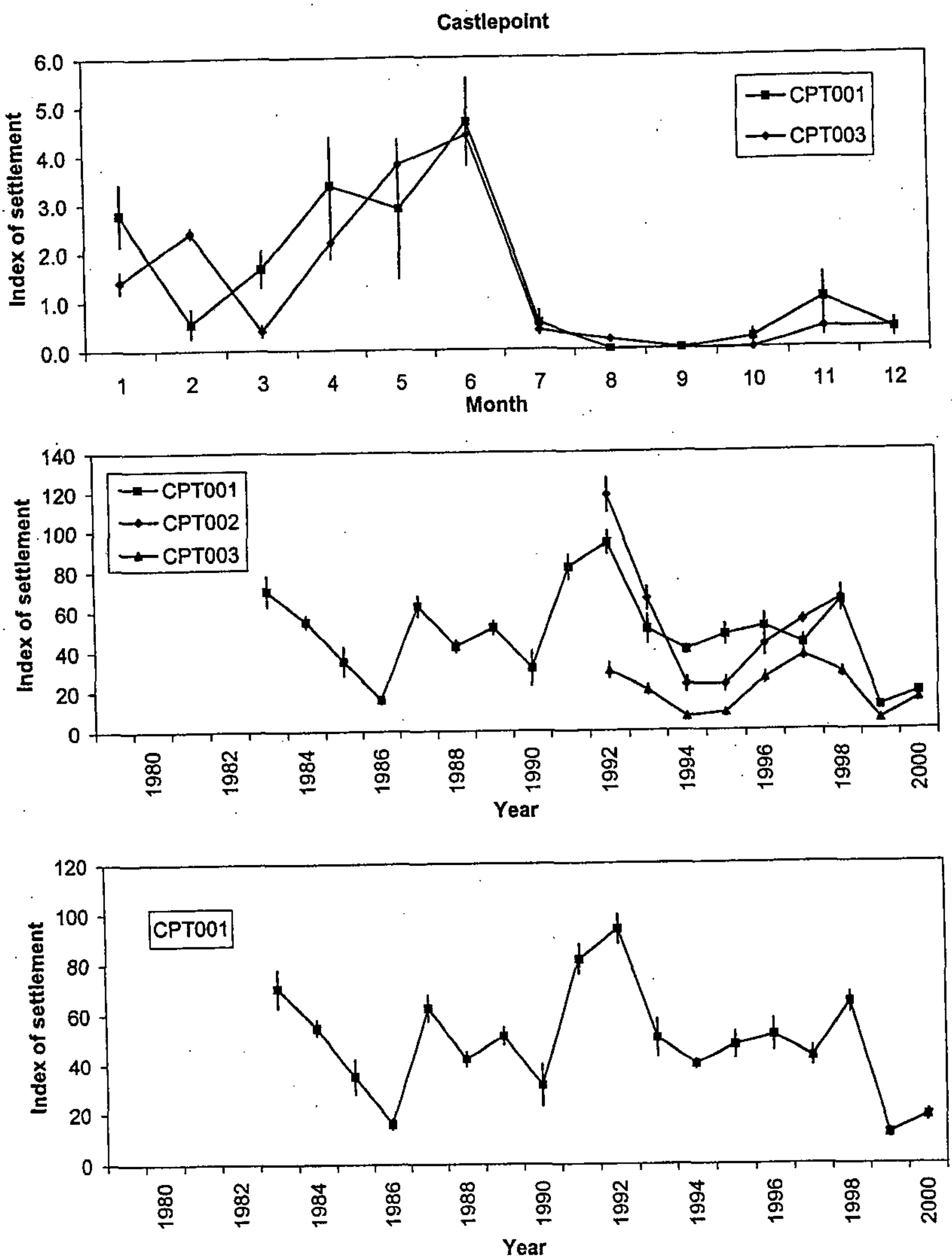


Figure 4: Castlepoint – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, December to September) on each group of collectors ± 1 standard error (*middle*) and on the core group (*lower*). CPT001 is the core group at Castlepoint; CPT002 is Orui; CPT003 is Mataikona. There were no data for CPT002 for 1999 or 2000 because the collectors were sanded over.

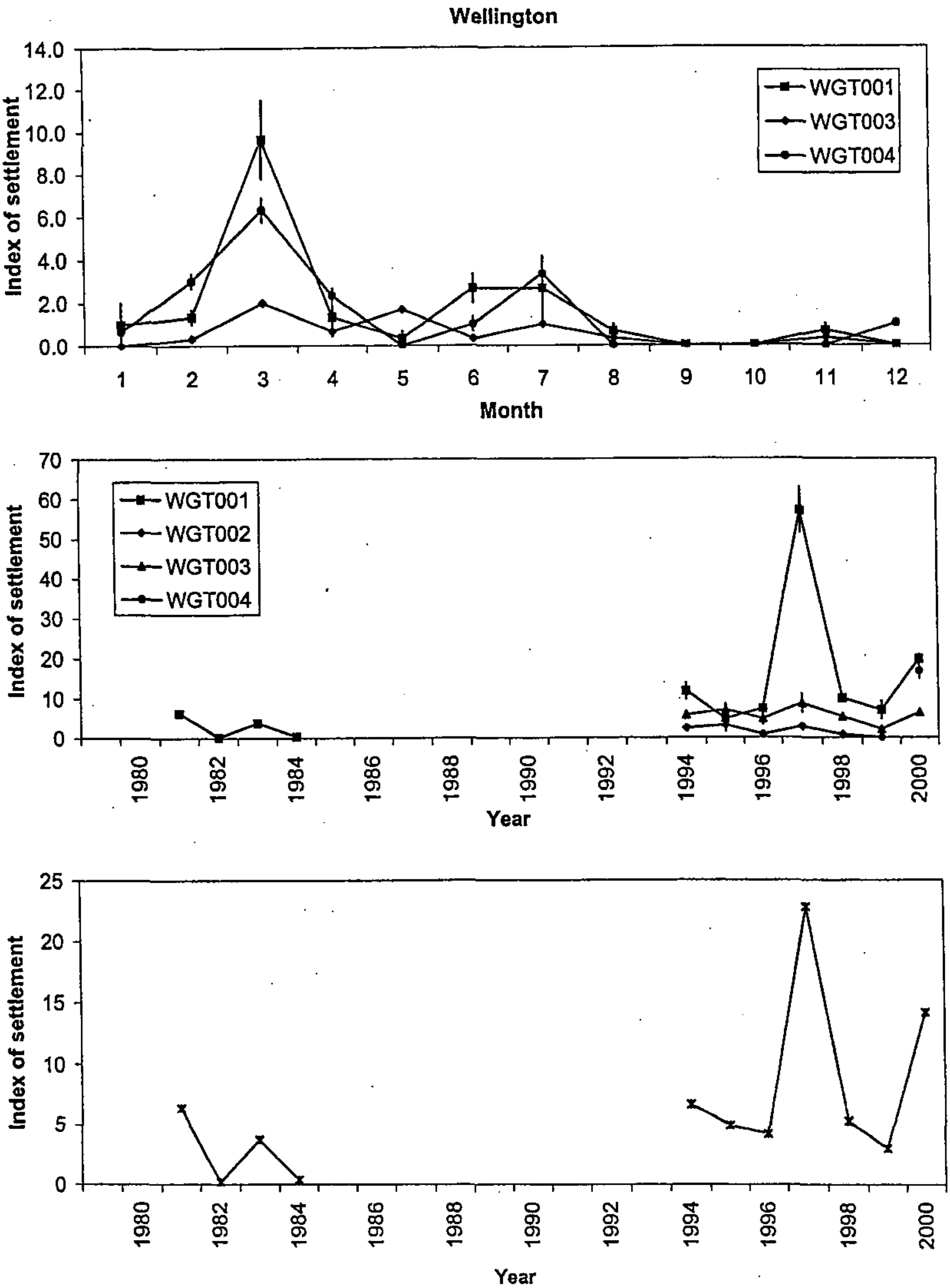


Figure 5: Wellington – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, January to May) on each group of collectors ± 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.

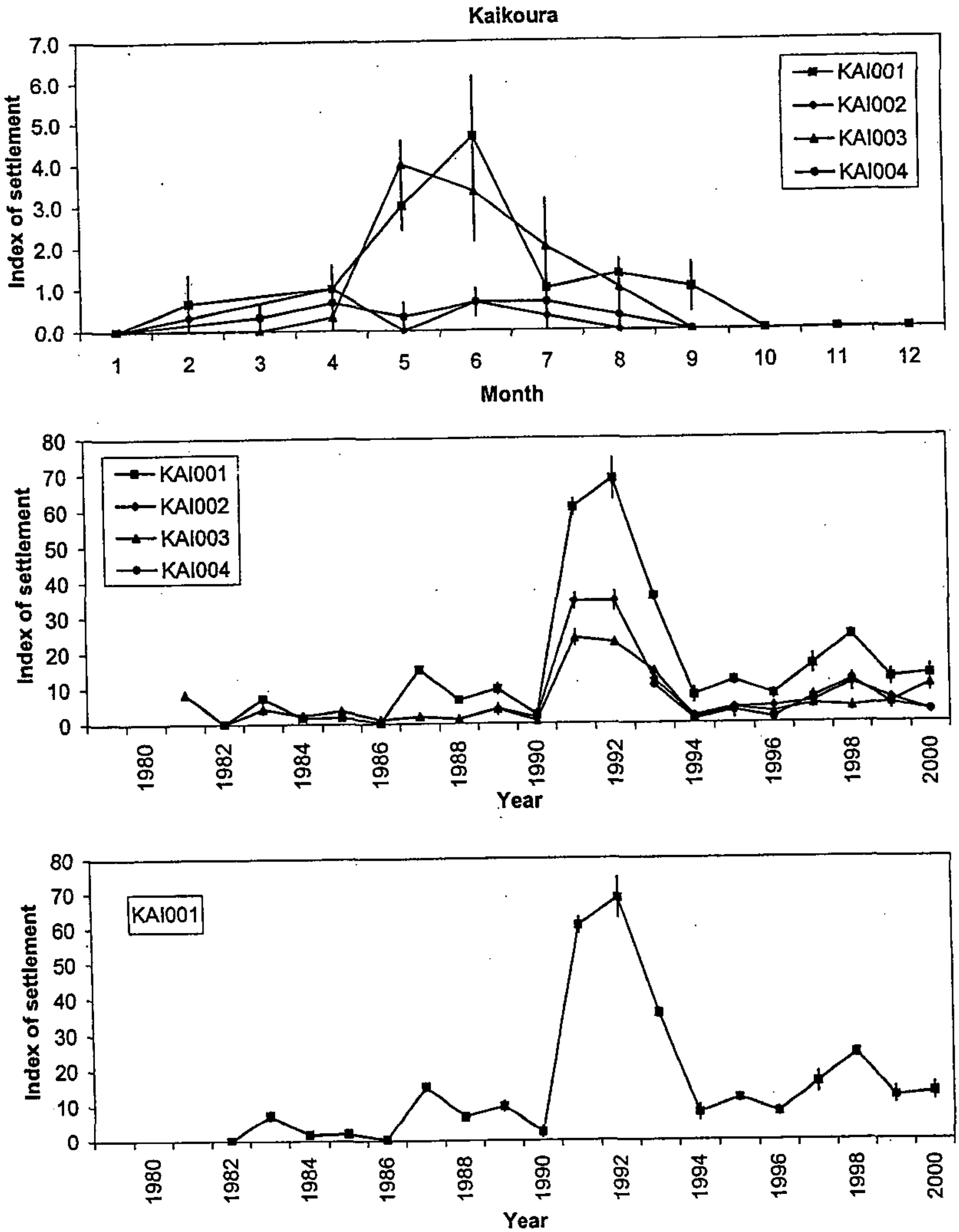


Figure 6: Kaikoura – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, January to September) on each group of collectors ± 1 standard 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.

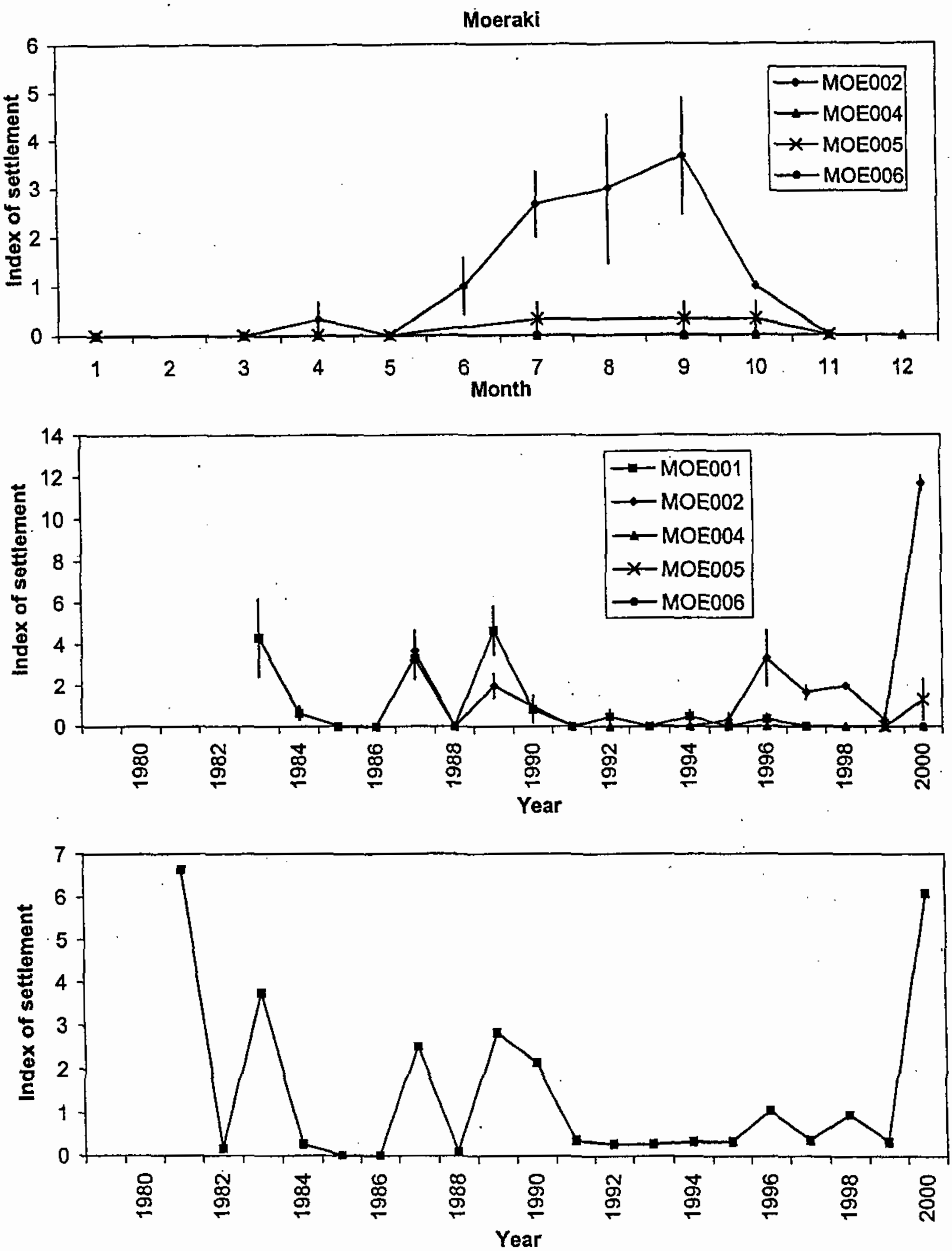


Figure 7: Moeraki – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length per collector. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual index of settlement based on the main settlement period (March to October) (*middle*) and an index based on 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. No data for 1998-2000 for MOE001.

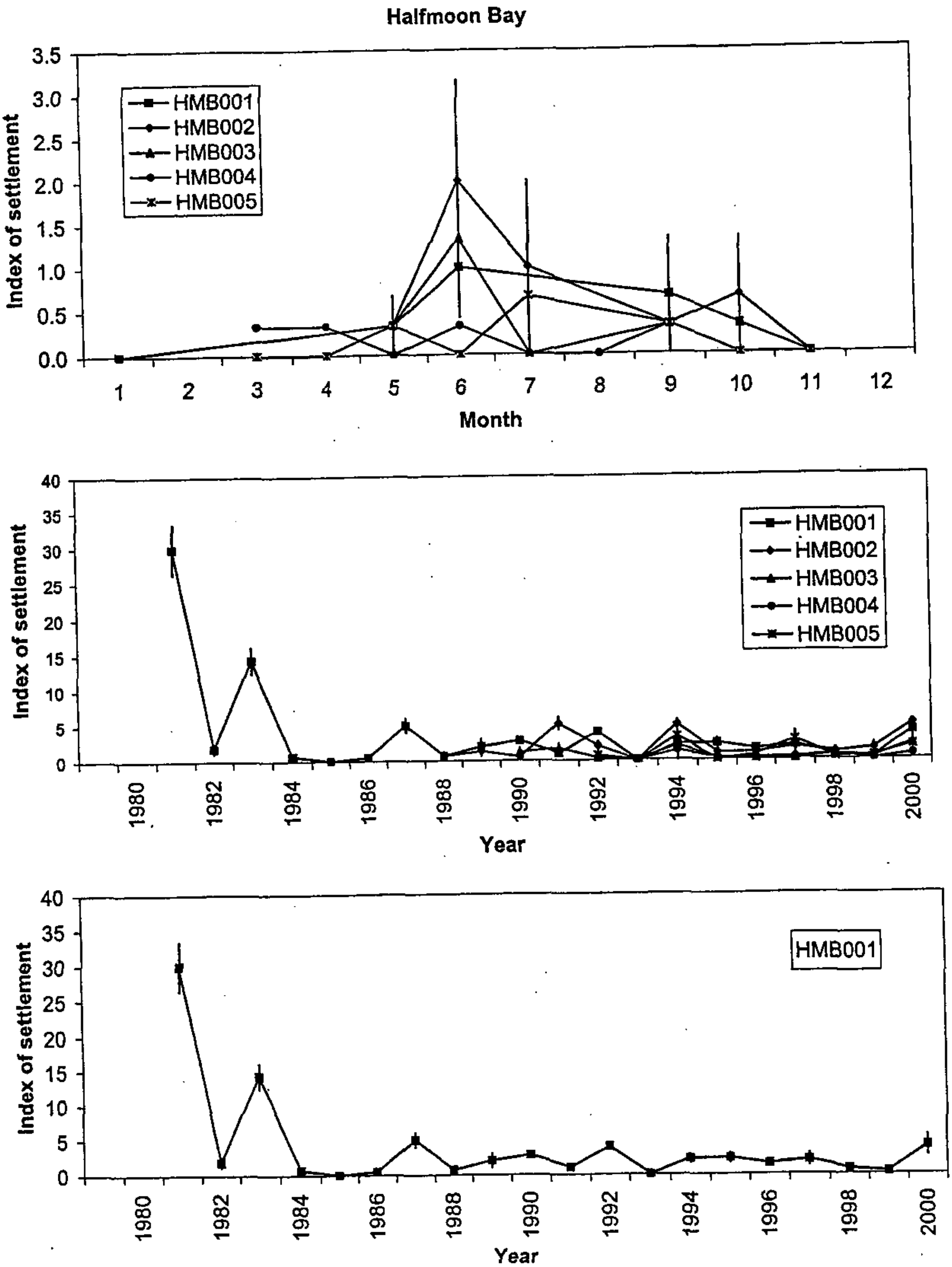


Figure 8: Halfmoon Bay – mean number of *Jasus edwardsii* pueruli + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, May to October) on each group of collectors ± 1 standard 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.

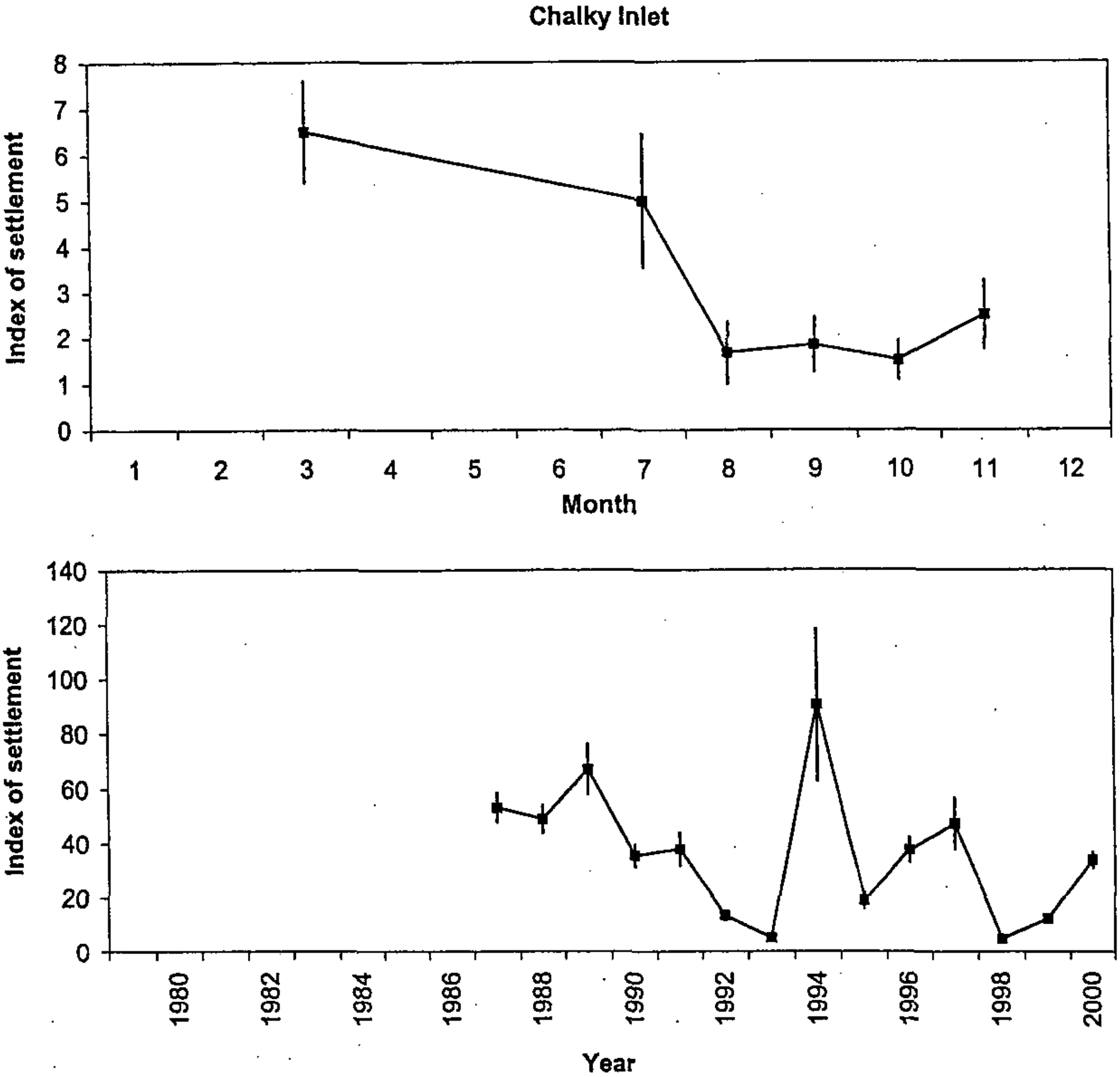


Figure 9: Chalky Inlet (Blind Entrance) – mean number of *Jasus edwardsii* puerull + juveniles at least 14.5 mm carapace length. Monthly index of settlement, 2000, ± 1 standard error (*upper*). Annual indices of settlement (based on the main settlement period, March to October) on the one group of collectors (± 1 standard error, *lower*).

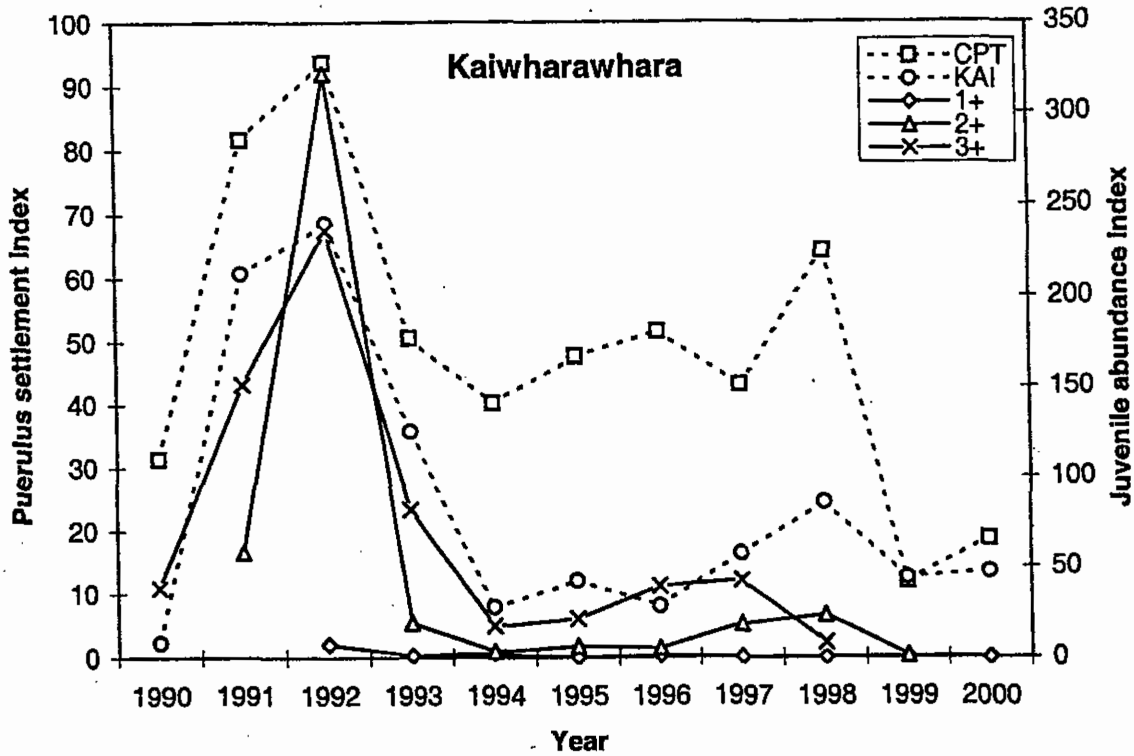


Figure 10: Juvenile year-class abundance of *Jasus edwardsii* at Kaiwharawhara, Wellington Harbour, each June 1993–2001 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

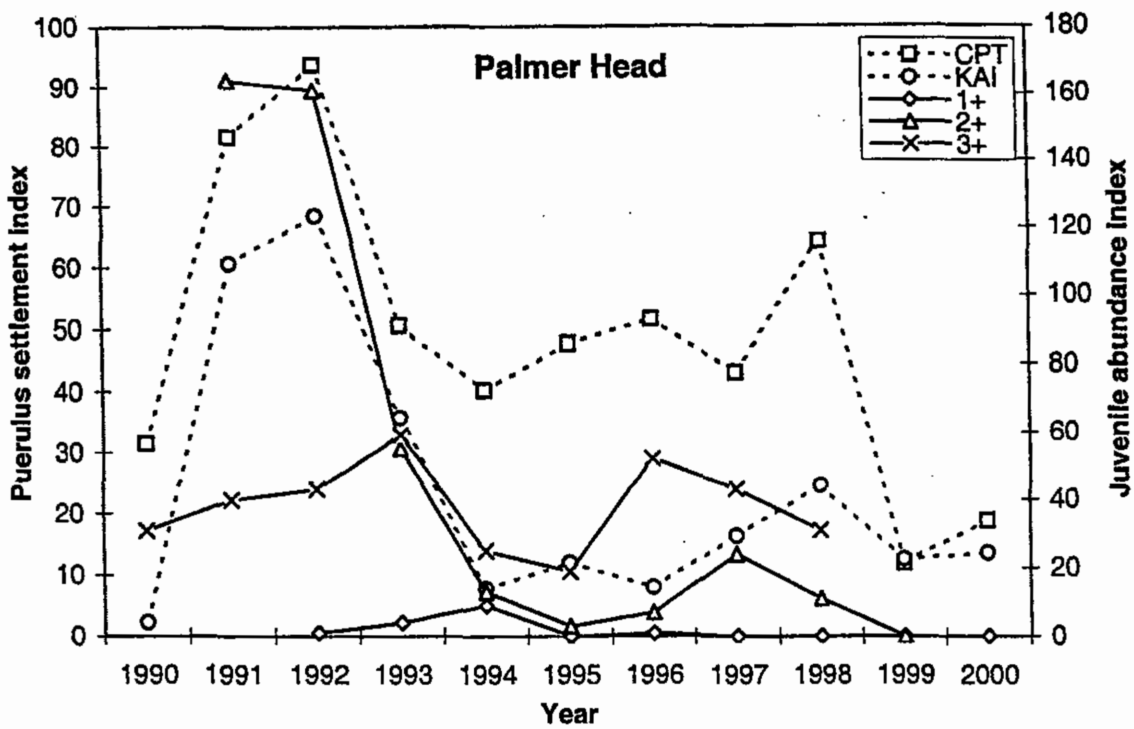


Figure 11: Juvenile year-class abundance of *Jasus edwardsii* at Palmer Head, Wellington, each June 1993–2001 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

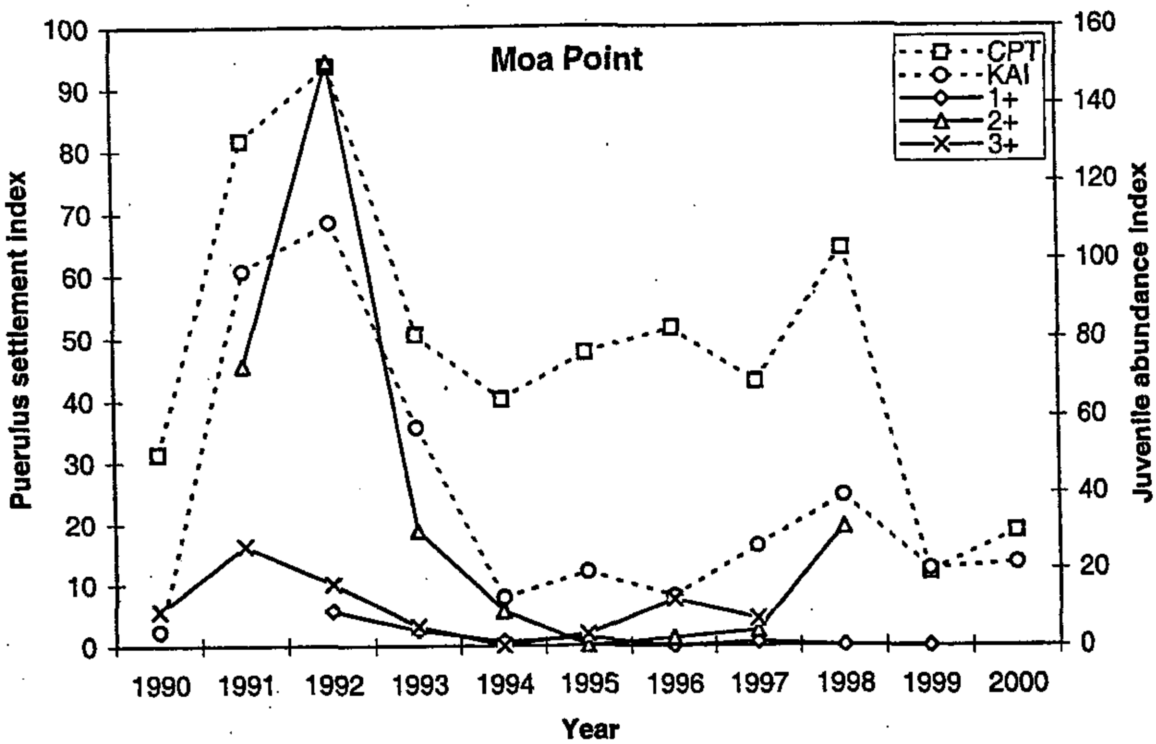


Figure 12: Juvenile year-class abundance of *Jasus edwardsii* at Moa Point, Wellington, each June 1993–2001 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.

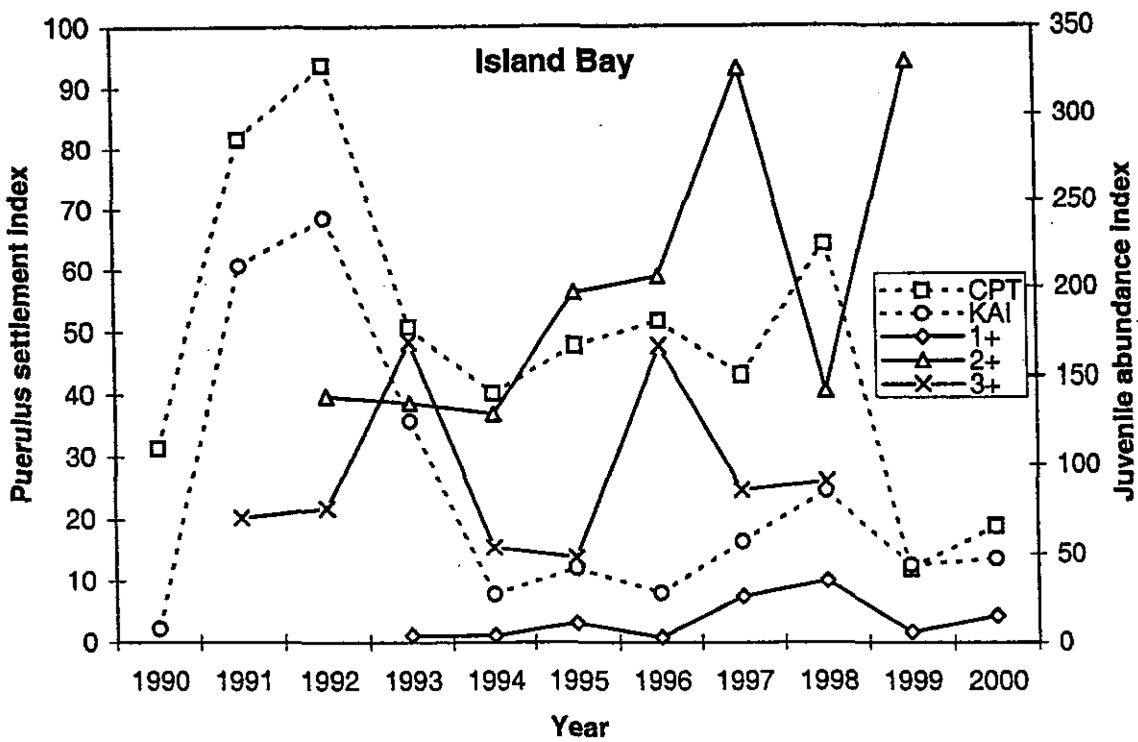


Figure 13: Juvenile year-class abundance of *Jasus edwardsii* at Island Bay, Wellington, each June 1994–2001 plotted against the year of settlement and the Castlepoint (CPT) and Kaikoura (KAI) settlement indices. See text for further details.