# THE SPREAD AND ECOLOGICAL EFFECTS OF THE EXOTIC POLYCHAETE *SABELLA SPALLANZANII* WITHIN PORT PHILLIP BAY.

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## ABSTRACT

Gregory D. Parry, Matthew M. Lockett and Dianne P. Crookes. (1996) The spread and ecological effects of the exotic polychaete *Sabella spallanzanii* within Port Phillip Bay.

The sabellid polychaete *Sabella spallanzanii,* a native to the Mediterannean, established in Port Phillip Bay in the late 1980s. Initially it was found only in Corio Bay, but during the past five years it has spread so that it now occurs throughout the western half of Port Phillip Bay. Densities in many parts of the bay remain low but densities are usually higher (up to13/$m^2$) in deeper water and the worm's distribution extends into shallower depths in calmer regions. Larvae probably require a 'hard' surface (shell fragment, rock, seaweed, mollusc or sea squirt) for initial attachment, but subsequently they may use their own tube as an anchor. The only measurable effect of the spread of *S. spallanzanii* on fish communities was an increase in the abundance of little rock whiting, which uses the habitat created by the forest of *S. spallanzanii* tubes. No fish has been found to prey on *S. spallanzanii,* possibly because their feeding crowns contain particularly high levels of vanadium.

The channelling of particulate food away from native filter-feeders may have considerable long term effects on fish communities. As the density and coverage of *S. spallanzanii* increases more energy may be channelled into trophic pathways that appear to lead only to bacterial breakdown upon the death of the worms. *S. spallanzanii* may also significantly affect the growth and survival of other epifauna with which they compete for food and suitable settlement surfaces.

## INTRODUCTION

The transfer of species across natural oceanic barriers by international shipping has led Carlton and Geller (1993) to suggest that bays, estuaries and inland deepwater ports may be amongst the world's most threatened ecosystems. Major disruptions to the Great Lakes in North America have been caused by introduction of the zebra mussel, *Dreissena polymorpha,* which occurs in densities up to 700,000/$m^2$ (Griffiths *et al.* 1991; Strayer 1991) and to fisheries in the Black Sea by the exotic ctenophore *Mnemiopsis leidyi* (Vinogradov *et al.* 1989), which within two years of its establishment had a biomass of 1.5-2 kg/$m^2$, an order of magnitude greater than that of all other plankton.

All exotic species alter natural interactions in the invaded ecosystems, but not all pose serious threats to these ecosystems. Unfortunately identifying species likely to establish in new ecosystems is difficult, as is predicting their likely impact (Hengeveld 1989). There are now approximately 20 species that are known to have established in Victorian waters (Coleman and Sinclair 1996). Not all of these species appear to be causing major disruptions but a number of species are causing concern as they occur in large numbers. Of these 'pest' species *Sabella spallanzanii,* a native of the Mediterranean (Clapin and Evans 1995), is clearly the most conspicuous. It is large, up to 50 cm in length, and may occur in high densities (up to 300/$m^2$). In parts of the Geelong Arm of Port Phillip Bay it forms a continuous covering over areas of 100's of square metres.

In contrast to the situation with many introductions *Sabella spallanzanii* was detected shortly after its establishment in Port Phillip Bay and the first semi-quantitative data on its distribution were obtained within approximately two years of its establishment. That this introduction was detected early, before the entire habitat was affected, has enabled changes to fish communities to be measured during its spread to new areas. This study documents the spread of the exotic polychaete *S. spallanzanii* and interprets quantitative data on its density and possible ecological effects, particularly on fish communities.

## METHODS

### Trawling

Fish and *Sabella spallanzanii* were collected annually using a wing trawl net (47 m long, 13 m wing spread, 5m opening height and 45 m between trawl doors) at 22 depth-stratified stations in Port Phillip Bay (Fig. 1) between 1990 and 1996. Sampling stations were located on 6 transects perpendicular to the coastline. Two trawl shots were taken at depths of 7, 12, 17, and 22 m on all transects except those in the Geelong Arm where depths permitted trawling only at 7 and 12 m. The duration of each trawl shot was 5 minutes, measured from the time load cell clamps were attached until the winch commenced the retrieval of the net. Data obtained using a

netsonde indicated that the net was probably fishing for an additional 2 minutes during its retrieval. A Furuno GP 500 GPS Navigator connected to a colour video plotter was used for all position fixing and was accurate to within 15-25 m in 95% of fixes. Where inaccuracy exceeded 25 m due to intentional degradation of the system (selective availability) this was obvious on the plotter. The speed of the net across ground, 2.1-2.5 knots, was estimated from the latitude and longitude at the start and finish of each shot and the duration of each shot.

Fish were sorted on deck and the number and total weight of each species was recorded. The total number of *Sabella spallanzanii* in each trawl was also counted. Where very large numbers of *S. spallanzanii* were collected the number of fish bins of worms was determined and the number of *S. spallanzanii* in a fish bin measured subsequently.

The number of *Sabella spallanzanii* attached to different substrates was recorded for all trawl shots, except when rough weather or large catches of jelly fish made this task difficult. The numbers of scallops, oysters and *Pyura stolonifera* available as settlement substrate and the numbers of these on which *S. spallanzanii* had recruited were also recorded.

**Diver surveys of *Sabella* distribution**

Each March during 1994, 1995 and 1996 the number of *Sabella spallanzanii* at 65-70 sites in Port Phillip Bay was counted by divers. Sites were well-distributed throughout the bay, but were concentrated in regions which usually supported commercial scallop populations. At each site two 50 × 1 m transects were surveyed and the number of *S. spallanzanii* on each transect was recorded. When the number of *S. spallanzanii* exceeded 10 the number of worms per 50 m transect was recorded as an abundance class, either 11-100, or >100. Where abundance classes differed between both transects on the same site the transect with the higher number of worms was used to plot distribution maps.

During April 1995 divers surveyed the number of *Sabella spallanzanii* and other epifaunal species on 25 piers located around the perimeter of Port Phillip Bay. On each pier weighted lines marked at 1 m intervals were attached at approximately the low water level on 4 pylons. Divers recorded a visual estimate of the percentage cover of all epifauna on these pylons in 1 m depth intervals. At each site the average percentage cover of epifaunal species was calculated for each depth interval. Where no *S. spallanzanii* were recorded on the four pylons a further 16 pylons were examined to determine whether *S. spallanzanii* was attached to any of these. If *S. spallanzanii* was not recorded on 20 pylons it was considered absent from that site. During April 1996, 20 pylons on ten of the piers without *S. spallanzanii* during 1995 were again searched for *S. spallanzanii.*

**Video survey of Geelong Arm**

The density of *Sabella spallanzanii* was estimated in the Geelong Arm where this species was most abundant and it impact likely to be greatest. The survey was undertaken using an underwater video camera attached to a towed sled. A video camera was located 0.5 m above the seabed and had a field of view 0.60 m (wide)×

1.0 m (long). A Trimblenavigation NavtracXL differential GPS, connected to a Traxar MRB-1A MSK radiobeacon receiver was used to record the position of the tow vessel and a Furuno FCV-581 sounder used to record depth. A computer was used to integrate information from the GPS and sounder to enable latitude, longitude, time and depth to be recorded continuously on the video tape. The underwater video was towed at ~1.5 knots on 13 transects perpendicular to the shoreline. On each transect the video was towed for 7 min. along the 2, 4, 6 and 8 m depth contours. The number of *S. spallanzanii* in each 1:45 min segment of the video tape was counted and the latitude and longitude at the start and finish of each 1:45 min period used to calculate the area swept during this period. For each depth interval on each transect the mean density and standard error were then calculated from the average of the density estimates for each 1:45 min sector of the video. (At 1.5 knots the video will travel ~ 80 m in 1:45 min). Where reef occurred on a transect it was not possible to use the video sled.

**Statistical analysis of changes to fish communities**

Significant expansions in the range of *Sabella spallanzanii* occurred after 1991 (when *S. spallanzanii* first became established at the Geelong 12 m site, Fig 2a) and after 1994 (when *S. spallanzanii* first became established at many sites, Fig 2a). Thus differences in fish community structure were compared between three periods: 1990-91, 1993-94 and 1995-96. Differences between fish community structures before and after establishment of *S. spallanzanii* were examined for these three periods using both multidimensional scaling (MDS) and analysis of variance (ANOVA).

Spatial differences between fish communities at the 22 stations and temporal differences between the three periods were examined with MDS using Bray-Curtis (B-C) dissimilarity measures (Bray and Curtis 1957). The B-C dissimilarity measure is given by the following relationship:

$$\delta_{jk} = \frac{\sum_{i=1}^{s} \left| n_{ij} - n_{ik} \right|}{\sum_{i=1}^{s} \left( n_{ij} - n_{ik} \right)}$$

where $n_{ij}$ = the number of the $i$th species in the $j$th sample, $n_{ik}$ = the number of the $i$th species in the $k$th sample and $\delta_{jk}$ = dissimilarity between the $j$th and $k$th samples summed over all $s$ species. This dissimilarity measure was chosen because it is not affected by joint absences, it gives more weighting to abundant than rare species, and it has consistently performed well in preserving 'ecological distance' in a variety of simulations on different types of data (Field *et al.* 1982; Faith *et al.* 1987). Double square root (=$N^{1/4}$) transformations were applied to all data before calculating B-C dissimilarity measures. These transformations were made to prevent abundant species from influencing the B-C dissimilarity measures excessively (Clarke and Green 1988; Clarke 1993). MDS plots were used to ordinate B-C dissimilarity measures. MDS translates a measure of similarity between measurements into 2 or more dimensional space so that distances between measurements correspond closely to their input similarities. While the computational algorithm for MDS is complex the graphical representation is easily communicated (Clarke 1993) and ecologically meaningful patterns are made more apparent (Gamito and Raffaelli 1992). The PATN computer

package (Belbin 1990a, b) was used for the non-metric MDS ordinations used in this study. The goodness of fit of each MDS plot is given by its stress value. Stress values <0.1 correspond to a good ordination, values >0.1 and <0.2 are useable, but those near 0.2 may mislead and values >0.2 are likely to yield plots that are difficult to interpret (Clarke 1993).

Changes to the abundance of individual species of fish following the establishment of *S. spallanzanii* at particular trawl stations were assessed by comparing changes with those that had occurred in other similar areas but where *S. spallanzanii* had not yet established. This BACI (Before, After, Control, Impact) experimental design (Stewart-Oaten *et al.* 1986) should discriminate between the effects caused by *S. spallanzanii* and other temporal trends. Statistical significance of the effect of *S. spallanzanii* was tested using nested ANOVA in which area × time interactions were tested against the mean square for the area × year (effect) term. This test is equivalent ( (Underwood 1991), Table 2c) to the t-test recommended by Stewart-Oaten *et al.* (Stewart-Oaten *et al.* 1986). Homogeneity of variance was examined using Cochran's test and heterogeneity removed by $\log_{10}(N+1)$. Previous studies (Parry *et al.* 1995) had indicated that Corio Bay has a distinctive fish community, but throughout the remainder of the bay there are only three depth-related fish community types. These three community types were used to match *Sabella* impacted sites with suitable control sites that had not yet been affected by *Sabella.* Four BACI analyses were undertaken: changes at the Geelong 12 m site (g12, Fig. 1) were compared with changes at Mornington 12 m site (m12, Fig. 1) and the St Leonards 12 m site (s12), before and after 1992 (when *Sabella* established at g12, Fig.1), changes at w7 were compared with changes at s7, h7, b7 and m7, before and after 1994 (when *Sabella* established at w7, Fig.1), changes at w12 and w17 were compared with changes at m12 and s12, before and after 1994 (when *Sabella* established at w12 and w17, Fig.1), and changes at w22 and h22 were compared with changes at h17, b22 and m22, before and after 1994 (when *Sabella* established at w22 and h22, Fig.1).

## Analysis of fish diets

During late February 1994 the gut contents of 10 individuals of all abundant fish species were analysed from fish collected at the 2 trawl stations in the Geelong Arm (Fig. 1). During March 1995 these trawl stations were resampled as were three additional stations near Pt Henry, near Wilson Spit and east of Pt Wilson (Fig. 1). Stomach contents were analysed from the 16 species of fish considered most likely to eat *Sabella spallanzanii,* based on recent analyses of stomach contents of more than 6500 fish of 35 species in Port Phillip Bay (Parry *et al.* 1995; Officer and Parry 1996a). Fish were collected from two stations in the Geelong Arm in 1994 and from five stations in 1995 and stomach contents of no more than 10 individuals of a species were analysed from a single trawl shot. Stomachs were removed from larger fish as soon as possible after capture and placed in buffered formalin. The body cavities of smaller fish were opened on the vessel to ensure formalin penetrated quickly into their digestive system which was removed later in the laboratory. While fish were stored by shot on the vessel they were re-sorted by species in the laboratory to increase the speed and accuracy of the identification of stomach contents. The number and total volume of individual prey items in each stomach were recorded for each fish species. Volume was estimated by evenly spreading each prey item over graph paper next to an

L-shaped perspex segment of known height (1.5 mm, 2.5 mm, 4 mm or 6 mm) and counting the number of 2 mm by 2 mm squares covered by the prey (Windell 1971).

Species of prey were identified by comparison with an extensive reference collection of benthic invertebrates from Port Phillip Bay. The identity of each species in the reference collection was confirmed by Drs G. Poore (Crustaceans) and R. Wilson (Polychaetes) and Ms S. Boyd (Molluscs) from the Museum of Victoria.

**Feeding preference trials**

As no fish appeared to eat *S. spallanzanii* in the field, laboratory feeding trials were conducted to determine whether fish actively rejected *S. spallanzanii*. King George whiting were chosen for these trials as they feed extensively on polychaetes in Port Phillip Bay (Parry *et al.* 1995) and, unlike eastern shovelnose stingarees which also feed extensively on polychaetes (Parry *et al.* 1995), they have no obvious morphological constraints that may prevent them from feeding on *S. spallanzanii* in the field.

On 23 November 1996, 12 King George whiting (24.5 $\pm$ 1.5 cm length) were collected and maintained in four 60 L glass aquarium tanks. Tanks were surrounded by black plastic to reduce disturbance. Three fish were placed in each tank and acclimated until food added one day was eaten by the following day. After 7 days, food was being consumed by fish in all tanks and feeding trials were commenced. In each trial three worms (Fam. Arenicolidae, Neridae and obtained from sand flats at Queenscliff) were placed in two (control) tanks, three *S. spallanzanii* were removed from their tubes and placed in another tank and three *S. spallanzanii* still in their tubes were placed in a further tank. All worms offered to fish were of similar size (6.5-10 cm). For nine days the number of worms eaten was recorded daily and any eaten worms replaced. After 3 days and 6 days the treatment applied to each tank was changed so that all fish were exposed to every treatment.

**Chemical analyses**

As King George whiting actively rejected *Sabella spallanzanii* in laboratory feeding trials the possible chemical basis for this rejection was investigated. Ten *S. spallanzanii* were collected from Queenscliff 'cut' during October 1995. The feeding crowns were separated from the remainder of the worms, each fraction weighed, then frozen and freeze-dried. The dried material was weighed and homogenised in a blender, and stored over silica gel until required for analysis. The digestion and analytical procedure used for determination of Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Vanadium and Zinc was based upon that of the United Nations Environment Programme (UNEP/FAO/IAEA 1982), with the modification that boro-silicate glass tubes were used for the digestions. A sample of each freeze-dried tissue was heated with 10 mL concentrated nitric acid at 90°C on a hot plate until all the tissue had been digested. After cooling, solutions were diluted to 30 mL with water. All metals were determined by flame atomisation AAS. A deuterium arc was used for background correction in all cases.

## RESULTS

During 1990 Corio Bay was the only one of 22 stations in Port Phillip Bay at which *Sabella spallanzanii* was recorded. By 1993 *S. spallanzanii* had spread to the central part of the Geelong Arm (Fig. 2a) and by 1994 to the eastern end of the Geelong Arm (Fig. 2b). By 1995 *S. spallanzanii* had spread further north to regions off Werribee and to deeper sites off Hobsons Bay and St Leonards (Figs 2a, b). Between 1995 and 1996 *S. spallanzanii* established at all but the shallowest areas off Hobsons Bay and spread further east to the region off Beaumaris (Figs 2a,b). However between 1995 and 1996 the density of *S. spallanzanii* off Werribee appeared to increase based on captures in the trawl net (Fig. 2a) but clearly decreased based on diver counts (Fig. 2b).

The distribution of *S. spallanzanii* on piers in 1995 and 1996 was consistent with the pattern of their spread further offshore. *S. spallanzanii* was found on all piers on the west of Port Phillip Bay between Pt Henry and Williamstown as well as on Portarlington pier and at one of three sites sampled at Queenscliff. *S. spallanzanii* was not found on any pier on the east of Port Phillip Bay between St Kilda and Portsea during 1995 or 1996.

Typically *S. spallanzanii* occurs in clumps on the seabed and 200-300 may be found in an area of 1 $m^2$. The Geelong Arm was the area of highest density in 1995 and quantitative estimates of density in this area indicated that the density varied from 0 to 13/$m^2$ averaged over areas of ~ 50 $m^2$ (Fig. 3, Table 1). Densities were low in shallow (2 m depth) regions and on most transects densities increased with depth.

The most common attachment surfaces for *Sabella spallanzanii* caught in trawl nets were bubble weed, oysters, scallops and *Pyura stolonifera* (Table 2). Bubble weed only occurs near Werribee (particularly at site w7), where it occurs attached to *Pyura stolonifera* and dead mollusc shells, although most occurs as drift algae. The highest density of *S. spallanzanii* identified in the video survey occurred on this drift weed near Werribee (Table 1, Fig. 3). Elsewhere in the bay most *S. spallanzanii* that attached to hard substrate were attached to oysters, scallops or *P. stolonifera.* The number of *S. spallanzanii* attached to each of these substrates varies throughout the bay depending on the relative abundance of these substrates, but a higher proportion of *P. stolonifera* and oysters than scallops were colonised by *S. spallanzanii* (Table 2). Most of the *S. spallanzanii* collected in trawls were in clumps and most *S. spallanzanii* were attached to other *S. spallanzanii.* Often the clump was not clearly attached to any hard substrate and at one site (w22-1995, Table 2) two of the three *P. stolonifera,* to which >30 *S. spallanzanii* were attached, were dead and decaying.

*Sabella spallanzanii* have established on fouling communities on pylons with several different dominant taxa (Fig.4). They have established on communities in which bare space, algae, *Mytilus planulatus* and *Pyura stolonifera* were the dominant organisms, but they have not yet established where sponges are the dominant taxa (Fig. 4). The minimum depth to which *S. spallanzanii* occurred varied between piers and was lower on more sheltered piers in Corio Bay and Williamstown, than on more exposed piers such as Pt Wilson (particularly), Pt Henry, Pt Cook and Altona. On most piers the

density of *S. spallanzanii* increased with depth, except where sediment scouring occurred near the base of some pylons.

MDS of fish community structure at 22 trawl sites sampled during 3 periods: 1990-91, 1993-94 and 1995-96 suggest that fish communities have not changed markedly in most areas following the establishment of *Sabella spallanzanii* (Fig. 5). There is no evidence that low densities of *S. spallanzanii* are affecting fish communities (Fig. 5). However fish community structure at sites g12 and w22 changed markedly in 1992 and 1994-95 respectively, when high densities of *S. spallanzanii* established at these two sites. Significantly both sites became more similar to site g7 in Corio Bay, where *S. spallanzanii* has been abundant since our trawl surveys commenced in 1990 (Fig. 5). The MDS indicates that Corio Bay is distinct from fish communities elsewhere in Port Phillip Bay and that fish communities change along a sediment/depth gradient as shown previously by Parry *et al.* (Parry *et al.* 1995). The high stress value (0.29, Fig. 5) is cause partly by the large number of points in the MDS (Clarke 1993) and partly because there are few clear patterns in the data, which provides further evidence that changes to fish communities due to *S. spallanzanii* are small.

ANOVAs of changes to the abundance of each species of fish on sites where *S. spallanzanii* had established compared those sites pre-impact and other unimpacted control sites detected significant change ($p<0.10$) in the abundance of only one species, little rock whiting (Table 3) at one site (g12, Fig. 1). Little rock whiting was not found at g12 during 1990 and 1991, but became abundant from 1992 when *S. spallanzanii* established at this site (Fig. 2a).

Analysis of the diets of 298 fish of 16 species obtained from an area of high *S. spallanzanii* density in the Geelong Arm found no fish to have consumed any *S. spallanzanii*. During laboratory feeding trials with King George whiting no *S. spallanzanii* inside its tube was ever eaten and very few of those removed from their tubes were eaten (Table 4). Indeed 2 of the 3.5 *S. spallanzanii* eaten during the trials were eaten on the last day of the trials when the fish had been under-nourished for nearly a month (Table 4). Polychaetes other than *S. spallanzanii* were invariably eaten by the following day.

Concentrations of several heavy metals, including vanadium, were found to be high in *S. spallanzanii* and particularly high in their feeding crowns (Table 6).

## DISCUSSION

*Sabella spallanzanii* was first noticed in Corio Bay by divers in 1988 (A. Stephens, EPA, personal communication), but was not detected in a quantitative benthic survey of this same area the previous year (Coleman 1993). The pattern of spread of *S. spallanzanii* is consistent with its establishment in Corio Bay from shipping in the late 1980s. While it may have established from international vessels visiting the Port of Geelong, it seems more likely that it was transported via Western Australia as *S. spallanzanii* appears to have been in Western Australia since at least 1965 (Clapin and Evans 1995) and there are many vessels that travel between Cockburn Sound and Geelong.

*S. spallanzanii,* in common with all sabellids, does not have feeding larvae (Rouse and Fitzhugh 1994). Consequently its larval life is probably less than 4 days and it would be unlikely to survive in ballast water long enough to be transported to Australia from the Mediterranean. As it is frequently found attached to the hulls of inadequately anti-fouled vessels hull transport seems the most probable mechanism of translocation for this species (Rainer 1995).

Most of the expansion of the range of *Sabella spallanzanii* in Port Phillip Bay during the 1990s appears consistent with the dispersal of short-lived larvae by the typically clockwise currents in Port Phillip Bay (Anon.1973). The distribution has expanded progressively eastward and then northward from Corio Bay. The establishment of *S. spallanzanii* in Queencliff 'cut' and at Portarlington pier was probably the result of scallop fishermen discarding worms caught in their dredges in their home port. Significantly *S. spallanzanii* has not yet established on Mornington pier but 6 individuals were observed growing on the seabed during May 1996 near the berths of several scallop vessels. Similarly during May 1996 *S. spallanzanii* was found in Sandringham boat harbour (between St Kilda and Half Moon Bay, Fig. 1) (Lockett, personal observations) where it is likely to have been transported by pleasure craft.

On piers *Sabella spallanzanii* were found attached to *Pyura stolonifera, Mytilus planulatus* as well as attaching directly to pylons. Significantly *S. spallanzanii* has not yet invaded any sponge dominated communities, although these are mostly near the entrance to Port Phillip Bay and few larvae may have dispersed into this area. Significantly within this area the abundance of *S. spallanzanii* differed greatly between three sites at Queenscliff. *S. spallanzanii* were abundant on steel structures at the end of Queenscliff 'cut', near where they were discarded from scallop vessels, but they were absent from adjacent concrete pylons with nearly 100% cover of *Pyura stolonifera* and from wooden pylons dominated by sponge communities on Queenscliff pier. Significantly during 1995 and 1996, 50-60 *S. spallanzanii* were found within large concrete seawater storage tanks at Victorian Fisheries Research Institute (VFRI) which obtain their water from an intake beneath Queenscliff pier. Consequently communities at Queenscliff pier must have been exposed to larvae from *S. spallanzanii.* The growth of sponges on the pier may inhibit settlement of *S. spallanzanii* as there was minimal growth of any fouling organisms on the inside the dark cave-like storage tanks at VFRI where *S. spallanzanii* established.

Most *Sabella spallanzanii* found on the seabed occurred in clumps where it appeared that gregarious settlement had caused small individuals to recruit on the tubes of those which had already established. However asexual reproduction may also contribute to the formation of clumps. *S. spallanzanii* has considerable capacity to regenerate severed body parts (Kiortsis and Moratiou 1965) and in both Western Australia (Clapin and Evans 1995) and in this study animals that had clearly divided within a tube were observed where the animal in the basal section of the tube was growing a new crown and the animal in the front of the tube was regenerating the base of the tail.

Near Werribee where the highest densities were observed *S. spallanzanii* were mostly attached to drifting weed. Elsewhere in the bay most clumps were attached to a fragment of shell, oyster, *Pyura stolonifera* or scallop, which was probably the substrate upon which initial settlement had occurred. That a higher proportion of

oysters and *Pyura stolonifera* than scallops had *S. spallanzanii* attached to them suggests that the scallops may limit settlement of larval *S. spallanzanii* by burying themselves just below the sediment surface. Approximately 25% of clumps on areas of soft sediment had no obvious hard substrate to which the first member of the clump had attached. Furthermore even when worms were attached to a shell fragment this was usually well below (10-15 cm) the sediment surface. As the hard substrate was probably on the surface of the seabed when initial settlement occurred it appears that *S. spallanzanii* is able to grow down into the substrate and form an anchor with its own tube. All tubes in soft sediment have a pronounced U-shaped bend at their base, in which the inner edges of the U are joined. It appears likely from the growth lines on the U-shaped section that this part of the tube grows downwards and functions as anchor. As a hard surface is probably required for settlement, hard surfaces may be limiting in some locations but the remaining hard surfaces are probably at high risk of colonisation. In one location two dead *Pyura stolonifera* were found with many *S. spallanzanii* attached and it is likely that they were starved by the clump of *S. spallanzanii* surrounding them. Thus epifauna may be at particular risk from *S. spallanzanii.*

Changes to fish communities are not detectable where *Sabella spallanzanii* densities remain low. Where densities are high there appears to have been an increase in the abundance of the little rock whiting. This species is only common in areas of high *S. spallanzanii* density in Corio Bay and in the Geelong Arm where it is found swimming amongst *S. spallanzanii* tubes. Furthermore this species was not found in the Geelong Arm, outside Corio Bay, until *S. spallanzanii* established at station g12 (Fig.1) in 1992 which strongly suggests that *S. spallanzanii* is providing a habitat for little rock whiting. Little rock whiting do not eat *S. spallanzanii* nor do they appear to feed on epifaunal species that have settled on *S. spallanzanii* tubes (Table 4). It seems likely that the tubes primarily provide a refuge from predators for this small (20 cm) species.

Fish have not been observed feeding on *Sabella spallanzanii* in Western Australia (Clapin and Evans 1995) nor have they been found in the gut contents of any fish in Port Phillip Bay. This is distinct contrast to the consumption of other recently established exotic species in Port Phillip Bay, including *Corbula gibba*, *Pyromaia tuberculosa* which are consumed by a wide variety of fish (Parry *et al.* 1995; Officer and Parry 1996a). Although we have received reports from three recreational fishermen that sand flathead caught in Port Phillip Bay have regurgitated *S. spallanzanii* following capture. It is clear *S. spallanzanii* are actively avoided by King George whiting in laboratory trials and it seems likely that this avoidance is due to high levels of metals and particularly vanadium in their feeding crowns. Ishii *et al.* (Ishii *et al.* 1994) found very high levels (5500 µg/g dry weight) of vanadium in the crowns of the Japanese sabellid *Pseudopotamilla occelata,* and noted that vanadium concentrations in most marine organisms, including other species of sabellids, are less than 25 µg/g dry weight. They suggested that since the brachial crown is the site of gas exchange that vanadium may have a role in oxidation-reduction reactions. However ascidians have been known to concentrate vanadium since early this century and there is no evidence that vanadium functions as an oxygen binding pigment in ascidians (Macara *et al.* 1979). Instead the functions suggested for vanadium in ascidians are anti-microbial, antipredation mechanisms and roles in excretion, tunic formation and

ornamentation (Martoja *et al.* 1994). The clear lack of palatability of *S. spallanzanii* to King George whiting supports that view that vanadium has an antipredation role in both ascidians and sabellids. Martoja *et al.* (1994) considered antipredation an unlikely role simply because all ascidians do not contain high levels of vanadium. However this is a spurious argument as it implies that predator avoidance is of equal significance to all species of ascidians. The argument is analogous to arguing that green is not an effective camouflage for birds because they are not all green. The functions of vanadium favoured by Martoja *et al.* (1994) are roles in tunic formation and ornamentation. But these roles are certainly inconsistent with vanadium having similar roles in both ascidians and sabellids, as sabellids do not have tunics.

The long term effect of *Sabella spallanzanii* on the ecology of Port Phillip Bay is difficult to predict. The diversion of particulate food into a trophic pathway that results in increased production of a species that appears to have no fish (or other) predator would be expected to reduce fish production. Interestingly, the region of Port Phillip Bay with the lowest consumption of invertebrates by fish is Corio Bay (Officer and Parry 1996b) where *S. spallanzanii* is most abundant. The only measurable effect of *S. spallanzanii* on fish communities at present is an increase in the abundance of the little rock whiting, apparently because the forest of tubes forms a suitable habitat.

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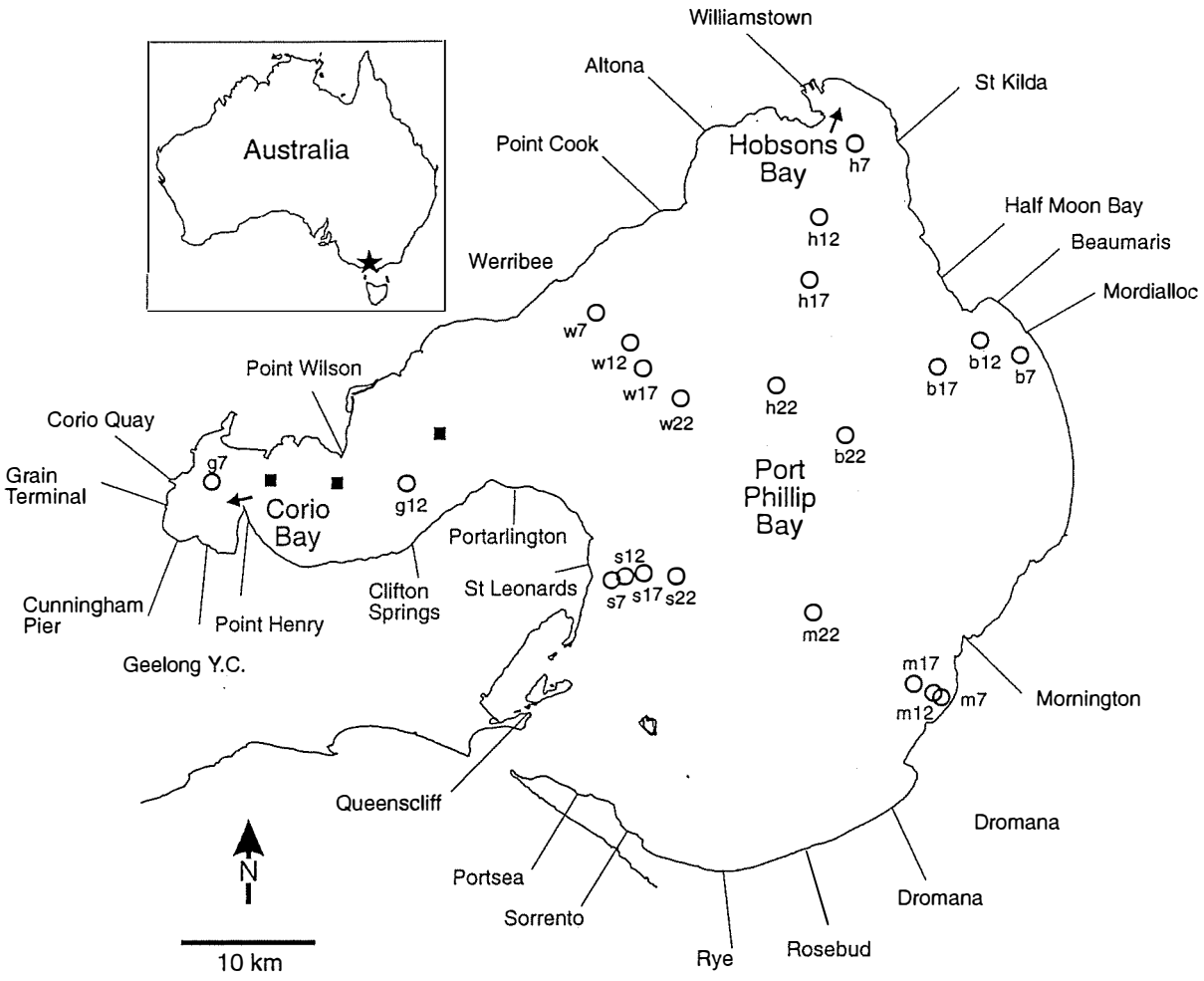



**Figure 1.** The location of Port Phillip Bay (inset) and the location of 22 trawl stations sampled between 1990 and 1996, and piers examined by divers in 1995. The code for each trawl station, which includes the depth in metres, is given. Filled squares indicate locations of additional trawl stations sampled in 1995 for analysis of fish diets.

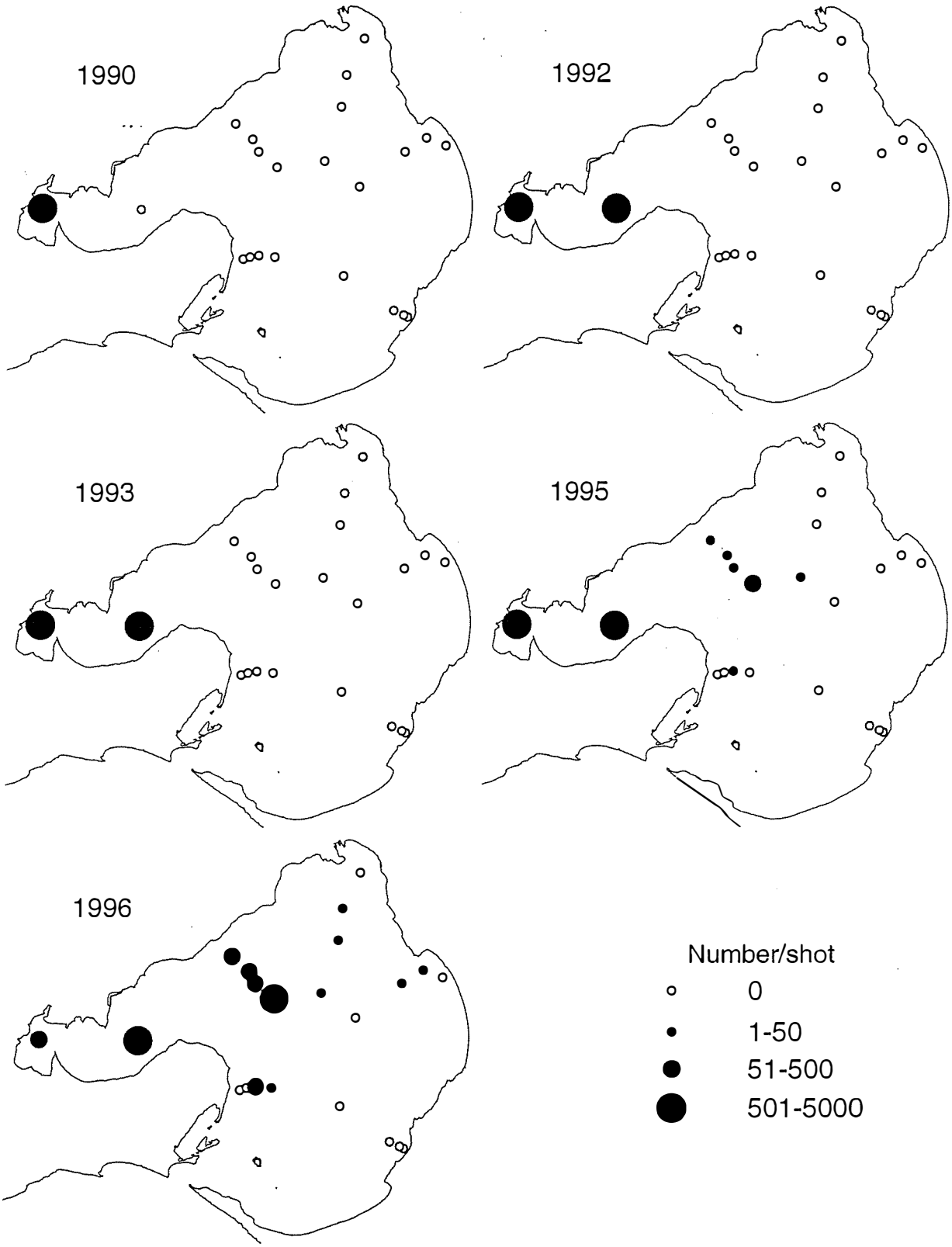



**Figure 2 a.** The density of *Sabella spallanzanii* at trawl stations sampled between 1990 and 1996.

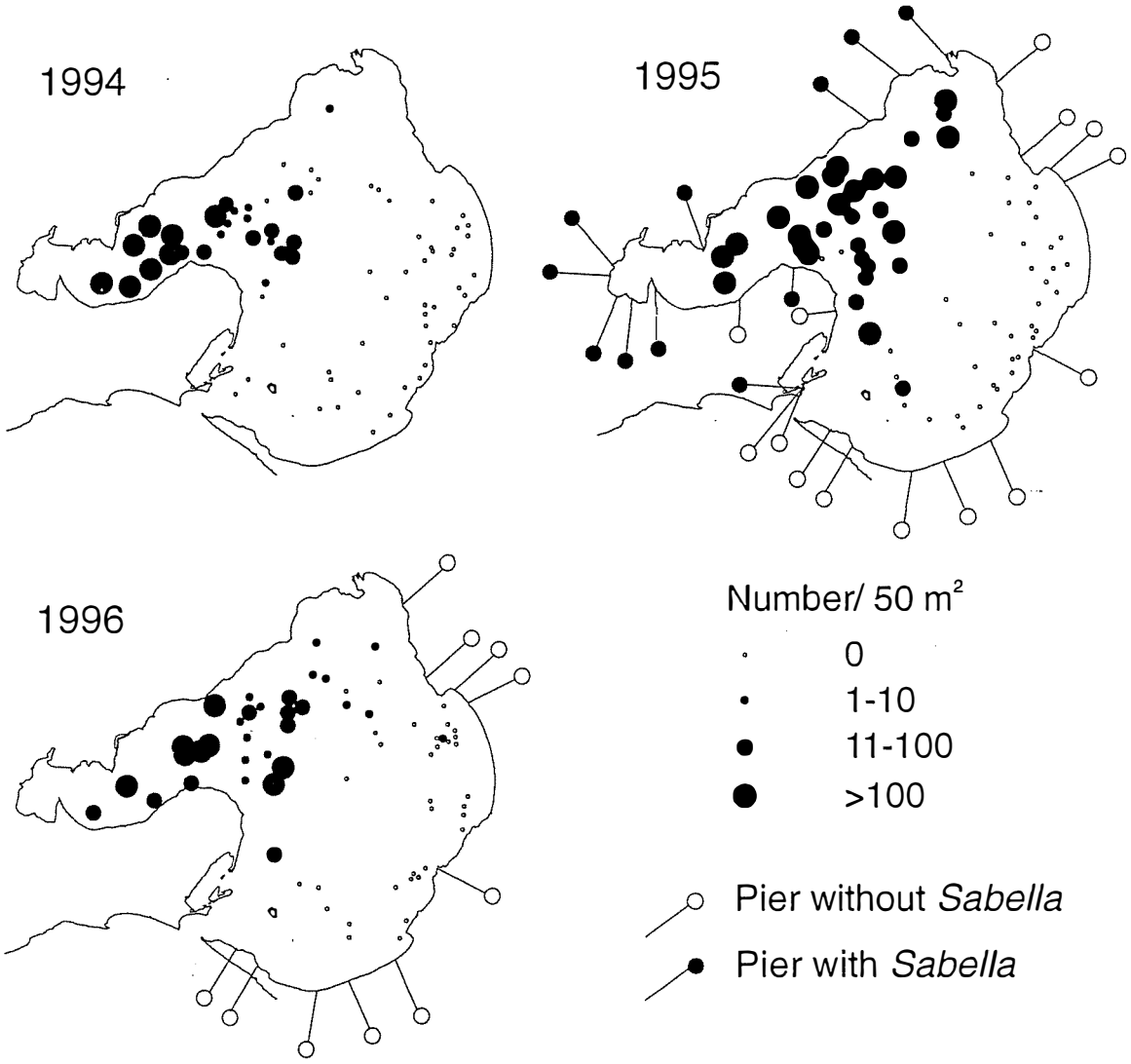



**Figure 2 b.** The density of *Sabella spallanzanii* based on diver counts on 50 m x 1 m transects sampled between 1994 and 1996, and the locations of piers examined for *S. spallanzanii* in 1995 and 1996.

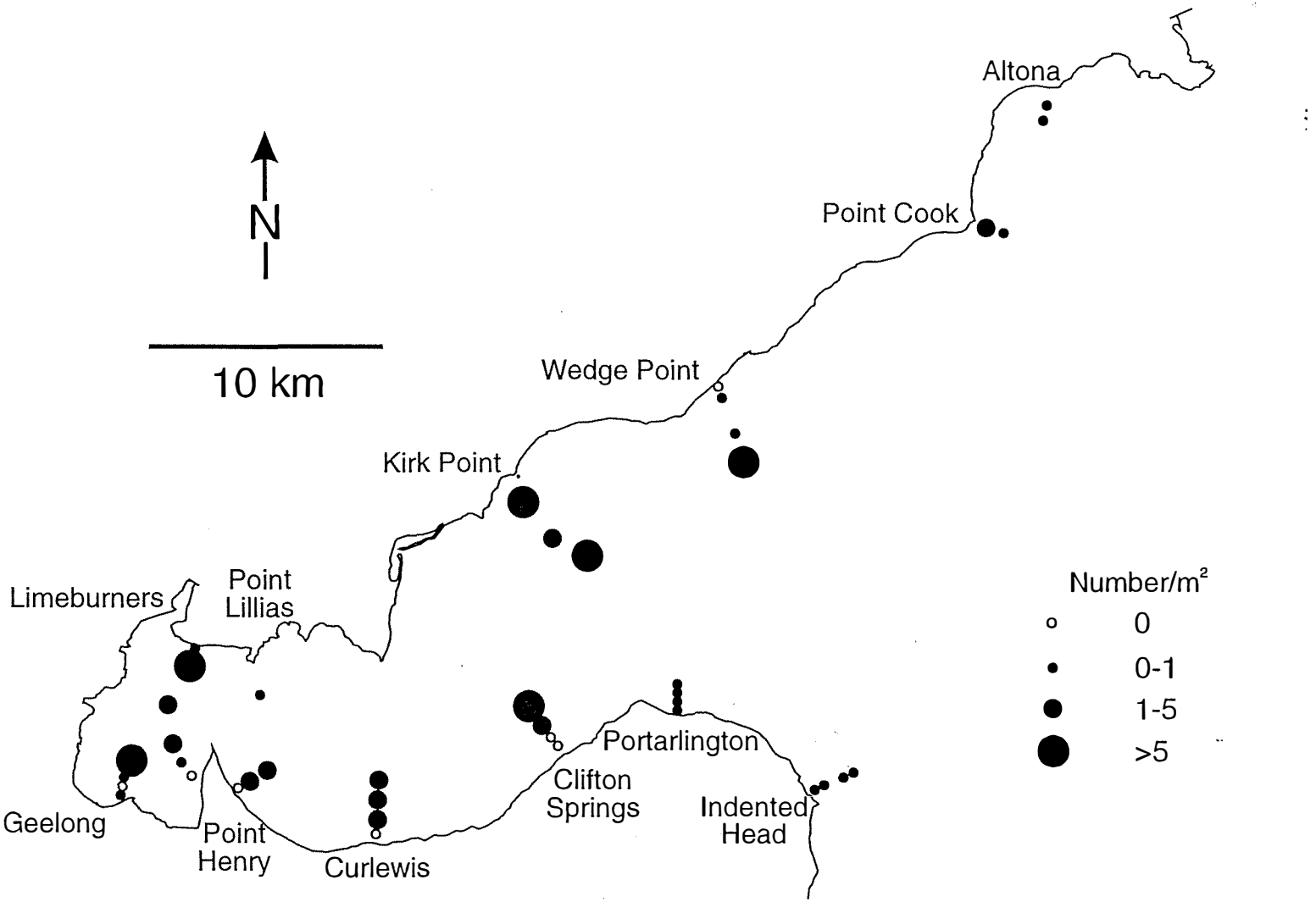
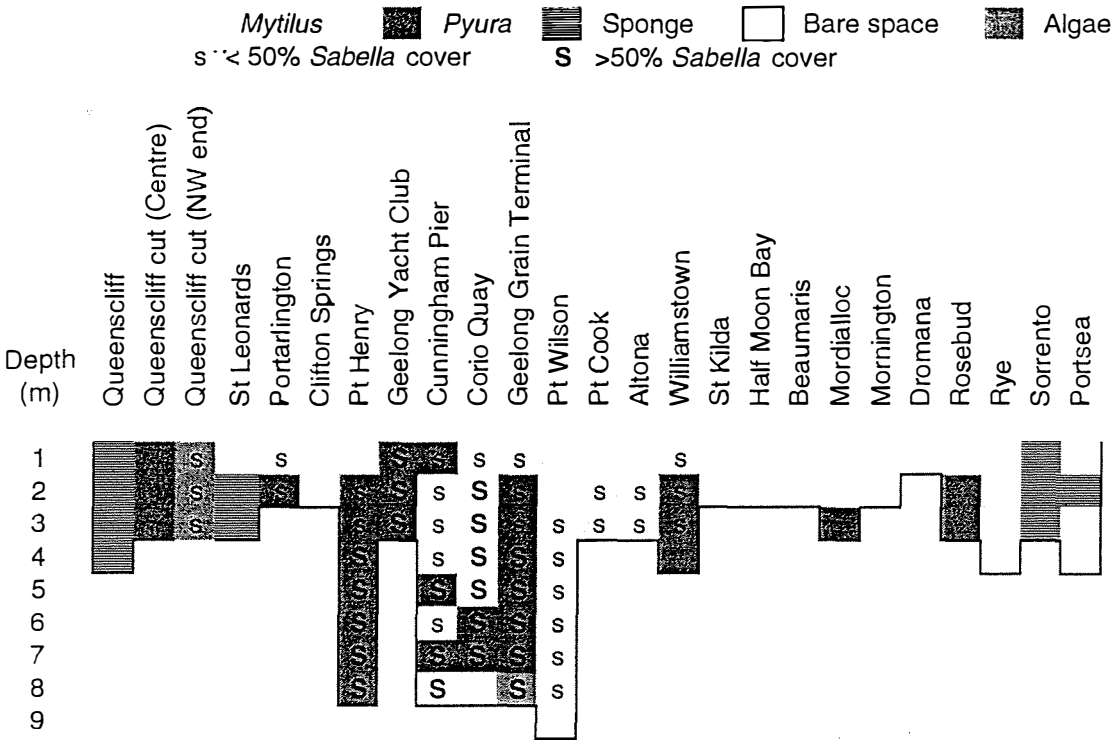



**Figure 3**. Density of *Sabella spallanzanii* in the Geelong Arm of Port Phillip Bay determined from video transects during 1995.

**Figure 4**. Dominant taxa in communities at different depths on pylons on piers and other structures in Port Phillip Bay, April 1995.



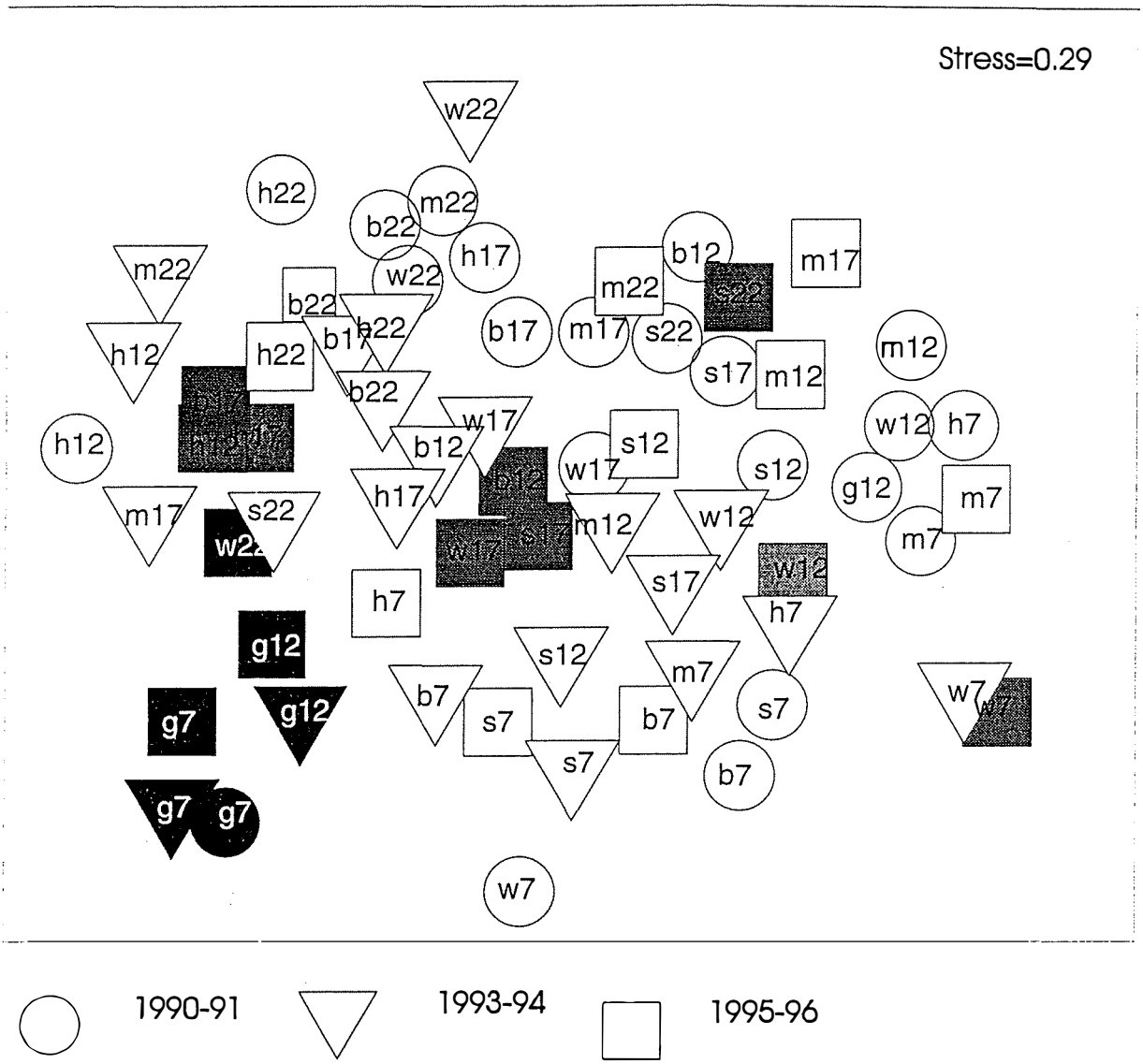



**Figure 5.** Multidimensional scaling (MDS) plot showing differences in the structure of fish communities between 1990-91, 1993-94 and 1995-96 at 22 stations. Ordinations are based on Bray-Curtis dissimilarities of double square root number. The code for each station is shown and the abundance of *Sabella spallanzanii* at each station is shown by the shading: >50 *S. spallanzanii* (black), 1-50 *S. spallanzanii* (grey) and no *S.spallanzanii* (no shading).

Table 1: Mean densities of *Sabella spallanzanii* (Number/$m^2$ ± s.e.) determined by video survey at different depths on transects in the west of Port Phillip Bay (see Fig. 3). Sites containing reef were not surveyed.

| Transect | Depth (m) | | | |
|---|---|---|---|---|
| | 2 | 4 | 6 | 8 |
| Altona | - | - | 0.05 ± 0.02 | 0.41 ± 0.23 |
| Pt. Cook | - | - | 2.18 ± 0.16 | 0.14 ± 0.11 |
| Wedge Point | 0 | 0.90 ± 0.38 | 0.48 ± 0.10 | 12.90 ± 3.85 |
| Kirk Point | - | 9.34 ± 3.67 | 1.94 ± 0.76 | 6.28 ± 1.18 |
| Pt Lillias | - | - | 0.30 ± 0.21 | - |
| Limeburners | 0.68 ± 0.26 | 7.86 ± 2.99 | 2.47 ± 0.82 | - |
| Geelong | 0.80 ± 0.11 | 0 | 0.79 ± 0.38 | 7.2 ± 0.71 |
| Pt. Henry West | 0 | 0.79 ± 0.14 | 1.22 ± 0.23 | - |
| Pt. Henry | 0 | 1.13 ± 0.39 | 1.72 ± 0.57 | - |
| Curlewis | 0 | 4.61 ± 1.03 | 3.54 ± 1.56 | 3.52 ± 0.10 |
| Clifton Springs | 0 | 0 | 1.65 ± 0.23 | 11.55 ± 1.70 |
| Portarlington | 0.01 ± 0.01 | 0.06 ± 0.05 | 0.13 ± 0.04 | 0.79 ± 0.42 |
| Indented Head | 0.01 ± 0.01 | 0.52 ± 0.14 | 0.07 ± 0.07 | 0.01 ± 0.01 |
| All sites | 0.17 ± 0.11 | 2.52 ± 1.10 | 1.27 ± 0.30 | 4.76 ± 1.67 |

Table 2. The number of *Sabella spallanzanii* attached to different substrates in trawl samples taken at different sites during 1995 and 1996. The percentage of oysters, scallops, and *Pyura stolonifera* which had *S. spallanzanii* attached to them is also shown.

| Site / Year | b12 | g12 | h12 | h17 | h22 | s12 | s17 | | s22 | w7 | w12 | | w17 | | w22 | | Pt Wilson | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1995 | 1996 | 1996 | 1996 | 1995 | 1995 | 1996 | 1996 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | 1996 | 1995 | |
| Oyster | 0 | 2 | 19 | 8 | 0 | 2 | 10 | NR | 13 | NP | 0 | NP | 2 | 12 | 14 | NR | NP | 82 |
| Oyster shell | 4 | 15 | | | | | | 44 | | | | | | | | 6 | 5 | 74 |
| Scallop | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | NP | 2 | 0 | 5 | 10 | 39 | NR | 0 | 59 |
| Scallop shell | | 35 | | | | | | | | 2 | | 2 | | | | 8 | 13 | 60 |
| *Pyura stolonifera* | NP | 36 | 0 | 0 | NP | NP | NP | 1 | 0 | # | 3 | NP | 4 | NP | 3* | NP | 9 | 56 |
| *Herdmania momus* | | | | | | | | 1 | | | | | | | | | | 1 |
| *Anadara trapezia* | | | | | | | | | | | | 1 | | | | | 2 | 3 |
| Bubble weed | | | | | | | | | | 150 | 1 | 2 | | | | | | 153 |
| Sponge | | | | | | | | | | | 2 | 1 | | | | | | 3 |
| Plastic/rope | | | | | | | | | | | | | | | | | 2 | 2 |
| Unattached | NR | 45 | 60 | 60 | 5 | 0 | 0 | NR | 3 | ~0 | NR | 100 | NR | 160 | NR | 700 | 11 | 1144 |
| Oysters % (N) | 0(400) | 100 | 31 | 16 | 0(2) | 14 | 24 | NR | NR | NP | 0(2) | NP | 100 | 50 | 100 | NR | NP | . |
| Scallops % (N) | 0(53) | 100 | 0(8) | 0(24) | 0(27) | 0(22) | 2 | 0 (62) | 0(22) | | 2 | 0(1) | 1 | 7 | 61 | NR | 0(3) | . |
| Pyura % (N) | NP | 90 | 0(2) | 0(1) | NP | NP | NP | 50 | 0(12) | NP | 50 | NP | 27 | NP | 100 | NP | 90 | . |

NP Not present, NR Not recorded. * 2 dead # Bubble weed to which *S. spallanzanii* was attached was itself attached to *P.stolonifera* and shell.

Table 3. Analysis of variance table showing significance of changes in abundance of little rock whiting on areas impacted by *Sabella spallanzanii* (g12) and controls (m12, s12) before and after 1992 when *S. spallanzanii* established at g12.

| Source of variation | DF | MS | F | *p* |
|---|---|---|---|---|
| Effect (Before vs After) | 1 | 3.00783 | 93.56 | 0.0001 |
| Area | 1 | 3.85733 | 119.99 | 0.0001 |
| Area x Effect | 1 | 2.86545 | 89.13 | 0.0001 |
| Year (Effect) | 5 | 0.58382 | 18.16 | 0.0001 |
| Area x Year (Effect) | 5 | 0.56445 | 17.56 | 0.0001 |
| Area x Effect vs Area x Year (Effect) | 1 | 2.86545 | 5.08 | 0.074 |

Table 4. Diets of 16 species of fish trawled at 5 sites in the Geelong Arm during March 1994 and March 1995. N = Number of fish analysed. Lav = average length of fish analysed.

| Fish | Prey | Percentage of total volume of prey eaten | Percentage of non-empty stomachs containing prey | Average no. of prey in non-empty stomachs |
|---|---|---|---|---|
| Snapper | Digested fish | 26.13 | 25.40 | 0.17 |
| (N=63, Lav = 97) | *Halicarcinus rostratus* | 17.00 | 50.79 | 1.11 |
| | *Trochdota allani* | 13.31 | 31.75 | 0.35 |
| | *Diplocirrus* sp.1 | 8.03 | 19.05 | 0.19 |
| | Digested matter | 6.59 | 26.98 | 0.02 |
| | *Ophiura kinbergi* | 5.97 | 9.52 | 0.17 |
| | *Pontophilus intermedius* | 3.27 | 3.17 | 0.05 |
| | Digested crustacean | 2.22 | 7.94 | 0.05 |
| | *Leptosynapta dolabrifera* | 2.11 | 4.76 | 0.05 |
| | Digested brachyuran | 1.91 | 6.35 | 0.05 |
| | *Aglaja taronga* | 1.84 | 1.59 | 0.03 |
| | *Philine angasi* | 1.46 | 7.94 | 0.13 |
| | Digested polychaete | 1.18 | 11.11 | 0.10 |
| | Digested polynoid sp. | 1.13 | 6.35 | 0.06 |
| | Digested echiuran | 0.84 | 1.59 | 0.02 |
| | Digested ophiurid | 0.76 | 9.52 | 0.10 |
| | *Anelassorhynchus porcellus* | 0.75 | 1.59 | 0.02 |
| | *Phlyxia intermedia* | 0.75 | 1.59 | 0.02 |
| | *Hiatella subulata* | 0.50 | 1.59 | 0.05 |
| | *Leucifer* sp.1 | 0.47 | 11.11 | 0.33 |
| | *Idiosepius notoides* | 0.42 | 1.59 | 0.02 |
| | Digested mollusc | 0.35 | 3.17 | 0.03 |
| | Digested nereid | 0.33 | 3.17 | 0.03 |
| | *Tenagomysis* sp.1 | 0.33 | 9.52 | 0.19 |
| | Digested anthozoan | 0.30 | 1.59 | 0.02 |
| | *Asychis* sp.1 | 0.30 | 1.59 | 0.02 |
| | *Phyllodoce* sp.1 | 0.30 | 1.59 | 0.02 |
| | Green algae | 0.25 | 3.17 | . |
| | *Glycera cf. americana* | 0.20 | 1.59 | 0.02 |
| | Digested decapod | 0.18 | 9.52 | 0.17 |
| | Red algae | 0.17 | 1.59 | . |
| | *Byblis mildura* | 0.15 | 1.59 | 0.02 |
| | *Halicarcinus ovatus* | 0.10 | 1.59 | 0.02 |
| | Digested isopod | 0.10 | 1.59 | 0.02 |
| | *Theora cf. lubrica* (exotic ?) | 0.10 | 1.59 | 0.02 |
| | Brown algae | 0.08 | 1.59 | . |
| | Digested mysid | 0.05 | 3.17 | 0.03 |
| | *Paradexamine lanacoura* | 0.03 | 1.59 | 0.02 |
| King George whiting | *Glycera cf. americana* | 19.63 | 14.29 | 0.16 |
| (N=56, Lav = 229) | *Trochdota allani* | 14.89 | 58.93 | 1.18 |
| | Digested fish | 13.61 | 7.14 | 0.05 |
| | *Diplocirrus* sp.1 | 8.90 | 28.57 | 0.41 |
| | Echiuran proboscis | 8.77 | 44.64 | 0.46 |
| | Digested polychaete | 5.74 | 28.57 | 0.29 |
| | *Metabonellia haswelli* | 4.72 | 8.93 | 0.09 |
| | *Anelassorhynchus porcellus* | 3.39 | 3.57 | 0.07 |
| | Digested bivalve | 3.13 | 28.57 | 0.29 |
| | *Aglaja taronga* | 3.03 | 7.14 | 0.09 |
| | Digested polynoid sp. | 2.49 | 10.71 | 0.20 |
| | *Theora cf. lubrica* (exotic ?) | 2.09 | 3.57 | 0.18 |

Table 4 (Cont.)

| Fish | Prey | Percentage of total volume of prey eaten | Percentage of non-empty stomachs containing prey | Average no. of prey in non-empty stomachs |
|---|---|---|---|---|
| King George whiting (cont) | Digested echiuran | 1.56 | 7.14 | 0.05 |
| | *Athanopsis* sp.1 | 0.99 | 1.79 | 0.02 |
| | *Cymodoce gaimardii* | 0.95 | 3.57 | 0.04 |
| | Digested crustacean | 0.85 | 3.57 | 0.04 |
| | *Philine angasi* | 0.85 | 3.57 | 0.05 |
| | Digested matter | 0.80 | 12.5 | 0.02 |
| | *Leptosynapta dolabrifera* | 0.69 | 7.14 | 0.09 |
| | *Pinnotheres hickmani* | 0.62 | 1.79 | 0.02 |
| | Digested brachyuran | 0.34 | 7.14 | 0.07 |
| | *Tellina (Macomona) mariae* | 0.33 | 1.79 | . |
| | Digested mollusc | 0.28 | 1.79 | 0.04 |
| | *Harmothoe* sp.1 | 0.27 | 1.79 | 0.02 |
| | *Liloa brevis* | 0.25 | 1.79 | 0.13 |
| | *Natatolana corpulenta* | 0.16 | 1.79 | 0.02 |
| | *Artacamella dibranchiata* | 0.11 | 1.79 | 0.02 |
| | *Halicarcinus ovatus* | 0.10 | 1.79 | 0.02 |
| | *Byblis mildura* | 0.06 | 5.36 | 0.14 |
| | *Paraleucothoe novaehollandiae* | 0.06 | 1.79 | 0.02 |
| | Digested *Natatolana* sp. | 0.06 | 1.79 | 0.02 |
| | *Goniada cf. emerita* | 0.06 | 1.79 | 0.02 |
| | Red algae | 0.05 | 1.79 | . |
| | *Halicarcinus rostratus* | 0.05 | 3.57 | 0.04 |
| | Seagrass | 0.05 | 1.79 | . |
| | Green algae | 0.03 | 1.79 | . |
| | Digested ophiurid | 0.02 | 1.79 | 0.02 |
| | *Nebalia* sp.1 | 0.01 | 1.79 | 0.02 |
| | *Tenagomysis* sp.1 | 0.01 | 1.79 | 0.02 |
| Little rock whiting | Digested matter | 23.1 | 57.45 | 0.02 |
| (N=47, Lav = 125) | *Echinocardium cordatum* | 22.91 | 44.68 | 0.47 |
| | Digested mollusc | 11.39 | 27.66 | 0.06 |
| | *Ophiura kinbergi* | 8.02 | 10.64 | 0.36 |
| | *Liloa brevis* | 5.11 | 19.15 | 0.4 |
| | Digested gastropod | 3.68 | 19.15 | 0.21 |
| | *Halicarcinus rostratus* | 3.28 | 12.77 | 0.19 |
| | *Exosphaemora* sp.1 | 3.21 | 10.64 | 0.11 |
| | Digested brachyuran | 3.01 | 14.89 | 0.15 |
| | Digested polychaete | 2.88 | 17.02 | 0.11 |
| | Digested ophiurid | 2.17 | 10.64 | 0.11 |
| | *Phlyxia intermedia* | 2.05 | 2.13 | 0.02 |
| | *Philine angasi* | 1.99 | 2.13 | 0.02 |
| | *Musculista senhousia* (exotic) | 1.38 | 4.26 | 0.06 |
| | Digested fish | 1.29 | 2.13 | 0.02 |
| | *Electroma georgiana* | 1.24 | 14.89 | 0.15 |
| | *Trochdota allani* | 0.95 | 2.13 | 0.02 |
| | *Philomedid* sp.1 | 0.53 | 4.26 | 0.13 |
| | Modiolus inconstans | 0.53 | 8.51 | 0.17 |
| | Red algae | 0.45 | 8.51 | . |
| | Digested polynoid sp. | 0.29 | 4.26 | 0.04 |
| | *Empoulsenia* sp.1 | 0.14 | 2.13 | 0.09 |
| | Digested bivalve | 0.14 | 2.13 | . |

Table 4 (Cont.)

| | | | | |
|---|---|---|---|---|
| | *Ostrea angasi* | 0.1 | 4.26 | 0.02 |

| Fish | Prey | Percentage of total volume of prey eaten | Percentage of non-empty stomachs containing prey | Average no. of prey in non-empty stomachs |
|---|---|---|---|---|
| Little rock whiting (cont.) | Green algae | 0.05 | 2.13 | . |
| | *Nebalia* sp.1 | 0.05 | 2.13 | 0.02 |
| | Brown algae | 0.02 | 2.13 | . |
| | *Paradexamine lanacoura* | 0.02 | 2.13 | 0.02 |
| | Digested echinoderm | 0.02 | 2.13 | . |
| Eastern shovelnose stingaree | *Glycera cf. americana* | 26.59 | 48.72 | 1.77 |
| (N=39, Lav = 477) | *Trochdota allani* | 15.7 | 76.92 | 5.00 |
| | *Artacamella dibranchiata* | 12.36 | 46.15 | 3.41 |
| | *Terebellides* sp.1 | 12.01 | 23.08 | 2.62 |
| | Digested polychaete | 6.14 | 41.03 | 0.36 |
| | *Goniada cf. emerita* | 5.67 | 43.59 | 1.18 |
| | *Terebellid* sp.1 | 5.03 | 23.08 | 1.10 |
| | *Leptosynapta dolabrifera* | 4.70 | 28.21 | 1.49 |
| | *Anelassorhynchus porcellus* | 2.41 | 10.26 | 0.13 |
| | *Diplocirrus* sp.1 | 2.30 | 46.15 | 0.82 |
| | Digested matter | 1.57 | 12.82 | . |
| | *Leitoscolopolos bifurcatus* | 1.22 | 20.51 | 0.79 |
| | *Drilonereis* sp.1 | 0.86 | 2.56 | 0.03 |
| | *Tharyx* sp.1 | 0.59 | 15.38 | 0.33 |
| | *Notomastus* sp.1 | 0.41 | 7.69 | 0.10 |
| | *Metabonellia haswelli* | 0.38 | 2.56 | 0.03 |
| | *Abarenicola affinis* | 0.38 | 2.56 | 0.03 |
| | *Clymenella* sp.1 | 0.35 | 5.13 | 0.05 |
| | Nemertean sp.4 | 0.26 | 12.82 | 0.13 |
| | *Harmothoe* sp.1 | 0.21 | 2.56 | 0.08 |
| | Digested fish | 0.16 | 2.56 | 0.03 |
| | *Corbula gibba* (exotic) | 0.15 | 2.56 | 0.05 |
| | Monhysterid sp.1 | 0.14 | 7.69 | 0.21 |
| | *Lumbrineris cf. latreilli* | 0.14 | 15.38 | 0.23 |
| | Digested polynoid sp. | 0.08 | 7.69 | 0.08 |
| | *Platyneris antipoda* | 0.08 | 2.56 | 0.08 |
| | Digested nereid | 0.06 | 5.13 | 0.05 |
| | *Malmgrenia microscala* | 0.03 | 2.56 | 0.03 |
| | *Harmothoe spinosa* | 0.02 | 2.56 | 0.05 |
| Sand flathead | Digested fish | 54.23 | 40.00 | 0.30 |
| (N=20, Lav = 262) | *Gobius* sp.1 | 20.17 | 5.00 | 0.05 |
| | Digested mollusc | 9.4 | 15.00 | 0.10 |
| | Digested brachyuran | 4.48 | 5.00 | . |
| | *Philine angasi* | 2.75 | 10.00 | 0.10 |
| | *Macrobranchium intermedium* | 2.18 | 5.00 | 0.15 |
| | Digested polychaete | 1.71 | 10.00 | 0.10 |
| | *Philyra undecimspinosa* | 1.59 | 5.00 | 0.05 |
| | *Byblis mildura* | 1.01 | 5.00 | 0.80 |
| | Digested matter | 0.9 | 20.00 | . |
| | Digested Leucosiidae | 0.75 | 5.00 | 0.05 |
| | Echiuran proboscis | 0.45 | 5.00 | 0.05 |
| | Digested cephalopod | 0.15 | 5.00 | . |
| | *Glycera cf. americana* | 0.11 | 5.00 | 0.05 |
| | Digested isopod | 0.07 | 5.00 | 0.05 |

Table 4 (Cont.)

| | | | | |
|---|---|---|---|---|
| | *Tenagomysis* sp.1 | 0.04 | 5.00 | 0.05 |

| Fish | Prey | Percentage of total volume of prey eaten | Percentage of non-empty stomachs containing prey | Average no. of prey in non-empty stomachs |
|---|---|---|---|---|
| Red mullet | *Macrobranchium intermedium* | 38.89 | 44.44 | 0.78 |
| (N=18, Lav = 173) | Digested fish | 14.40 | 33.33 | 0.17 |
| | Digested polynoid sp. | 11.51 | 16.67 | 0.39 |
| | *Harmothoe spinosa* | 7.04 | 11.11 | 0.44 |
| | *Gobius* sp.1 | 5.80 | 5.56 | 0.11 |
| | Digested matter | 5.37 | 11.11 | . |
| | Digested polychaete | 4.95 | 11.11 | 0.17 |
| | Digested Goby | 3.84 | 11.11 | 0.17 |
| | Digested crustacean | 2.76 | 16.67 | . |
| | Digested Sphaeromid sp. | 2.65 | 5.56 | 0.22 |
| | Digested *Natatolana* sp. | 1.67 | 5.56 | 0.11 |
| | *Empoulsenia* sp.1 | 0.71 | 11.11 | 0.78 |
| | *Amaryllis macrophthalmus* | 0.17 | 5.56 | 0.06 |
| | *Philomedid* sp.1 | 0.08 | 5.56 | 0.11 |
| | Digested *Birubius* sp. | 0.08 | 5.56 | 0.06 |
| | *Phoxocephalus kukathus* | 0.06 | 5.56 | 0.06 |
| Sparsely spotted stingaree | *Pontophilus intermedius* | 23.08 | 50.00 | 1.79 |
| (N=14, Lav = 365) | Digested polychaete | 12.74 | 50.00 | 0.64 |
| | *Phlyxia intermedia* | 7.96 | 35.71 | 0.86 |
| | *Paralepidonotus ampulliferus* | 7.81 | 14.29 | 0.43 |
| | *Amaryllis macrophthalmus* | 7.40 | 28.57 | 0.71 |
| | Digested mysid | 7.03 | 50.00 | 5.64 |
| | Digested matter | 5.38 | 7.14 | . |
| | *Hippolyte cardina* | 5.27 | 14.29 | 0.43 |
| | *Natatolana corpulenta* | 4.93 | 14.29 | 0.43 |
| | Digested crustacean | 3.44 | 14.29 | . |
| | *Gobius* sp.1 | 2.69 | 7.14 | 0.07 |
| | *Halicarcinus ovatus* | 2.45 | 28.57 | 0.50 |
| | *Siriella vincenti* | 2.32 | 50.00 | 3.86 |
| | Digested isopod | 1.83 | 7.14 | 0.21 |
| | *Philyra undecimspinosa* | 0.77 | 14.29 | 0.14 |
| | Digested *Natatolana* sp. | 0.75 | 7.14 | 0.14 |
| | Digested brachyuran | 0.45 | 14.29 | 0.07 |
| | Digested Sphaeromid sp. | 0.43 | 7.14 | 0.07 |
| | *Halicarcinus rostratus* | 0.39 | 7.14 | 0.07 |
| | *Tenagomysis* sp.1 | 0.39 | 14.29 | 0.71 |
| | *Australomysis incisa* | 0.35 | 28.57 | 0.86 |
| | *Paradexamine lanacoura* | 0.35 | 28.57 | 0.29 |
| | *Paranchialina angusta* | 0.19 | 14.29 | 0.36 |
| | Digested amphipod | 0.19 | 7.14 | 0.07 |
| | Digested Leucosiidae | 0.19 | 7.14 | 0.07 |
| | *Parapandalus leptorhynchus* | 0.13 | 7.14 | 0.14 |
| | Monhysterid sp.1 | 0.06 | 7.14 | 0.14 |
| | Digested polynoid sp. | 0.03 | 7.14 | . |
| Yank flathead | Digested fish | 93.73 | 85.71 | 0.93 |
| (N=14, Lav = 382) | Gobius sp.1 | 3.74 | 7.14 | 0.07 |
| | *Litocheira bispinosa* | 1.79 | 7.14 | 0.07 |
| | Digested matter | 0.39 | 7.14 | . |
| | *Parapandalus leptorhynchus* | 0.34 | 7.14 | 0.07 |

Table 4 (Cont.)

| | | | | |
|---|---|---|---|---|
| | Digested crustacean | 0.01 | 7.14 | 0.14 |

| Fish | Prey | Percentage of total volume of prey eaten | Percentage of non-empty stomachs containing prey | Average no. of prey in non-empty stomachs |
|---|---|---|---|---|
| Globefish | *Echinocardium cordatum* | 47.53 | 44.44 | 0.44 |
| (N=9, Lav = 197) | *Thacanophrys spatulifer* | 21.18 | 11.11 | 0.11 |
| | *Corbula gibba* (exotic) | 20.21 | 33.33 | 0.78 |
| | Digested mollusc | 5.49 | 33.33 | 0.33 |
| | Digested crustacean | 3.24 | 11.11 | 0.11 |
| | *Aglaja taronga* | 1.62 | 11.11 | 0.22 |
| | Digested brachyuran | 0.39 | 11.11 | 0.11 |
| | *Anadara trapezia* | 0.34 | 11.11 | 0.11 |
| Banjo ray (Southern fiddler) | Pilchard | 35.52 | 60.00 | 0.60 |
| (N=5, Lav = 664) | Digested cephalopod | 28.63 | 20.00 | 0.20 |
| | *Octopus australis* | 12.49 | 20.00 | 0.20 |
| | *Gobius* sp.1 | 11.47 | 40.00 | 1.20 |
| | *Macrobranchium intermedium* | 4.00 | 40.00 | 2.20 |
| | *Nectocarcinus integrifrons* | 3.44 | 20.00 | 0.40 |
| | Digested fish | 2.19 | 20.00 | 0.40 |
| | Digested polychaete | 1.56 | 20.00 | 0.20 |
| | *Pontophilus intermedius* | 0.39 | 20.00 | 0.20 |
| | *Sigalion* sp.1 | 0.19 | 20.00 | 0.60 |
| | Nemertean sp.1 | 0.12 | 20.00 | 0.20 |
| Greenback flounder | Digested matter | 52.61 | 60.00 | . |
| (N=5, Lav = 195) | Digested polychaete | 45.57 | 60.00 | 0.40 |
| | Red algae | 1.82 | 20.00 | . |
| Spiny gurnard | *Hemileucon levis* | 43.90 | 66.67 | 9.67 |
| (N=3, Lav = 111) | *Dimorphostylis cottoni* | 32.52 | 33.33 | 5.67 |
| | Digested crustacean | 16.26 | 33.33 | . |
| | *Tenagomysis* sp.1 | 4.88 | 33.33 | 0.67 |
| | *Empoulsenia* sp.1 | 1.63 | 33.33 | 0.33 |
| | *Philomedid* sp.1 | 0.81 | 33.33 | 0.33 |
| Smooth stingray | Pilchard | 80.00 | 100.00 | 10.00 |
| (N=2, Lav = 410) | *Macrobranchium intermedium* | 17.96 | 100.00 | 12.00 |
| | *Pinnotheres hickmani* | 1.80 | 50.00 | 0.50 |
| | Digested Sphaeromid sp. | 0.24 | 50.00 | 0.50 |
| Thornback skate | *Macrobranchium intermedium* | 100.00 | 100.00 | 5.00 |
| (N=1, L = 340) | | | | |
| Long-snouted flounder | Prey | | | |
| (N=1, L= 295) | *Ophiocentrus pilosus* | 100 | 100 | 2 |
| Rock flathead | Stinkfish, common | 100 | . | . |
| (N=1, L = 300) | | | | |

Table 5. Number of *Sabella spallanzanii*, within and removed from their tubes, and other polychaetes (Fam. Arenicolidae, Nereidae) eaten by King George whiting in laboratory food preference trials.

| Feeding trial | Day | *Sabella spallanzanii* | | Other polychaetes | |
|---|---|---|---|---|---|
| | | within tube | removed from tube | Control 1 | Control 2 |
| 30 Nov-2 Dec 1995 | 1 | 0 | 0 | 3 | 3 |
| | 2 | 0 | 1 | 3 | 3 |
| | 3 | 0 | 0 | 3 | 3 |
| 9-12 Dec 1995 | 1 | 0 | 0.5 | 3 | 3 |
| | 2 | 0 | 0 | 3 | 3 |
| | 3 | 0 | 0 | 3 | 3 |
| 12-15 Dec 1995 | 1 | 0 | 0 | 3 | 3 |
| | 2 | 0 | 0 | 3 | 3 |
| | 3 | 0 | 2 | 3 | 3 |
| Total | | 0 | 3.5 | 27 | 27 |

Table 6. Heavy metal concentrations (μg/g dry weight) and percentage water in the body and feeding crown of *Sabella spallanzanii*.

| | Body | Feeding crown |
|---|---|---|
| Arsenic | 10.2 | 11.7 |
| Cadmium | 0.03 | 3.4 |
| Chromium | 1.2 | 62 |
| Copper | 2.2 | 101 |
| Iron | 125 | 5700 |
| Lead | 4.6 | 34 |
| Manganese | 10.6 | 289 |
| Mercury | <0.01 | <0.01 |
| Nickel | 0.4 | 25 |
| Vanadium | 42 | 347 |
| Zinc | 13 | 366 |
| Percentage water | 67 | 82.7 |