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THE STATUS OF THE INTRODUCED MARINE FANWORM *SABELLA SPALLANZANII* IN WESTERN AUSTRALIA: A PRELIMINARY INVESTIGATION

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1. SUMMARY

In September 1994, large patches of sabellid polychaetes were discovered in Cockburn Sound, Western Australia. The sabellids were tentatively identified as *Sabella spallanzanii,* a species believed to have been introduced from the Mediterranean. This species has also been reported from Port Phillip Bay in Victoria and Adelaide in South Australia. Recent reports from Port Phillip Bay indicate that the worm is spreading rapidly in the bay and threatens local scallop fisheries.

This study was undertaken to gather preliminary information on the taxonomy, distribution and biology of the species in Western Australia. A total of 79 sites were sampled in Cockburn Sound, Fremantle, Bunbury, and Albany. *S. spallanzanii* was found to occur throughout Cockburn Sound, and in harbours at Fremantle, Bunbury and Albany. The worm was not found in the Swan River estuary or at the offshore islands of Carnac and Mewstone, which border Cockburn Sound to the west.

Patches of *S. spallanzanii* on the Southern Flats of Cockburn Sound cover approximately 20 ha of shallow sand bank (3-6 m depth) and are clearly visible in aerial photographs. Attempts to spectrally distinguish patches of *S. spallanzanii* from seagrass beds using enhanced aerial digital video images were unsuccessful. Whilst the patches were clearly visible against the bare sediment background, there was insufficient difference in their spectral signature to easily distinguish them from seagrass beds. Historical aerial photographs and anecdotal evidence suggest that the species may have been in Cockburn Sound for at least 10 years and there is strong evidence that the Southern Flats patches have previously been mapped as seagrass beds.

In the Southern Flats patches, worm tubes were found to be attached to shell fragments, dead seagrass rhizomes, solitary ascidians or anchored directly into the sediment. In other areas *S. spallanzanii* appeared to preferentially attach to man-made structures such as jetties, navigational markers, wrecks and breakwaters. Hull fouling may be an important vector in its spread.

No species were observed feeding on *S. spallanzanii.* However, some specimens when collected lacked crowns, suggesting predation by fishes. Observations made during this and earlier studies indicate that *S. spallanzanii* has the capacity to regenerate damaged body parts and to generate several new worms from severed pieces of a parent individual. This observation would caution against the use of dredging or similar destructive techniques to control the worm.

A description is given of specimens collected from Cockburn Sound.

2. INTRODUCTION

2.1 BACKGROUND

The marine fan worm *Sabella spallanzanii*[1] was first reported in Australian waters in the Geelong arm of Port Phillip Bay, Victoria. Although it had not been seen in the bay prior to the early 1980's (Carey and Watson, 1992), by 1991 it had become abundant in Corio Bay, being described as the "visually dominant organism of the muddy bottom habitat" (Carey and Watson, 1992). It is currently regarded as a pest in Port Phillip Bay where it is reported to pose a significant threat to the local scallop fishery. *S. spallanzanii* has recently been reported from Adelaide in South Australia (pers. comm. S. Rainer). The species, is a native of the Mediterranean and the Atlantic east coast as far north as the English Channel; its mode of introduction into Australian waters is unknown.

In September 1994, dense beds of sabellid worms were found in Cockburn Sound, Western Australia, by university students, Geordie Clapin and Ed Greenway during a collaborative study between the CSIRO Division of Fisheries, the West Australian Department of Environmental Protection, and Edith Cowan University. The sabellids were provisionally identified as *Sabella* cf. *spallanzanii.*

This report is the result of a preliminary study on *S. spallanzanii* initiated by the CSIRO Centre of Research on Introduced Marine Pests (CRIMP) and the CSIRO Division of Fisheries' Marine Environment Research Program. Geordie Clapin was awarded a nine-week CSIRO Vacation Scholarship to conduct the study.

The aims of the study were to:

- review the recent taxonomic and biological literature on *S. spallanzanii*;
- positively identify the specimens from Cockburn Sound and provide descriptions of this species and similar native sabellids occurring in the area;
- gather preliminary information on the distribution of the species within Cockburn Sound and associated harbours, in the Swan River Estuary, and in other Western Australian harbours as available survey time allowed;
- gather information on the biology, ecology and behaviour of the species;
- using available historical and anecdotal information, estimate how long the species has been present in Western Australian waters, and
- examine the possibility of detecting infestations using remote-sensing techniques.

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[1]As is discussed below, the taxonomic status of *Sabella spallanzanii* is under review and specimens of the West Australian sabellid dealt with in this report have not yet been examined by the taxonomist undertaking that review. Our specimens have been closely compared with unpublished descriptions and drawings from the review and we believe that they are indeed *Sabella spallanzanii.* In anticipation of definitive identification we have adopted the name *Sabella spallanzanii,* instead of the more technically correct *S.* cf. *spallanzanii,* in line with the fact that the morphologically similar sabellid found in Victorian waters was identified as *S. spallanzanii.*

2.2 LITERATURE REVIEW

2.2.1 TAXONOMY

The taxonomy of the family Sabellidae is poorly documented in published literature. Day and Hutchings (1979) recorded several species from the family Sabellidae in southern Australia, but not *Sabella spallanzanii*.

Dr Phyllis Knight-Jones, University of Wales, Swansea, (pers. comm. 1992 to Jeanette Watson, Marine Science & Ecology Laboratory, Essendon) noted that:

- *Sabella spallanzanii* (Gmelin, 1791) has usually been put in the genus *Spirographis* and attributed to Viviani (1805);
- the specific name (*Spirographis spallanzanii*) has been wrongly attributed to Viviani in the literature;
- Ewer (1946) synonymised the genera *Spirographis* and *Sabella* and both Knight-Jones and Thomas Perkins (Florida Marine Research Institute) agree with his decision; and
- the species is very common in the Mediterranean, particularly in harbours, and is also known from the Azores, and Rio de Janeiro where it is thought to be an introduction.

Hartman (1959, p. 567) records several specific synonyms under *Spirographis*, including *brevispira, elegans, gracilis,* and *longispira*.

Knight-Jones has confirmed the identification of specimens from Port Phillip Bay as *Sabella spallanzanii* (Gmelin, 1791) and supported Thomas Perkins' opinion that the species was most likely an immigrant. Knight-Jones and Perkins are currently revising the taxonomy of the genera *Sabella* and *Bispira* and it is anticipated that this revision when completed, will resolve the taxonomic confusion surrounding the species.

Very few descriptions of *S. spallanzanii* are to be found in the published literature. Fauchald (1977, p. 140) gave the following description of *Spirographis spallanzani* (sic) (see figs 2-4 or refer to Fauchald (1977) for an explanation of technical terms): "Radioles spiralled, with one half very much larger than the other, only one part spiralled. Stylodes and webbing absent; eyes present. Collar four-lobed. All uncini avicular." This description, although not detailed, is consistent with that of *Sabella spallanzanii*, made available by Dr Knight-Jones from her unpublished revision, and used in identifying specimens collected from Cockburn Sound during this study.

2.2.2 BIOLOGY AND ECOLOGY

Giangrande and Petraroli (in press) note that *S. spallanzanii* is common along the Italian coast. It is found in the open sea from 1 to 30 m depth, and on hard substrates in shallow harbour areas, where it reaches high densities (150–300 individuals m^{-2}). They also note that differences in "behaviour and resistance" under laboratory conditions suggest that specimens from each of these habitats are probably distinct ecotypical forms.

Giangrande and Petraroli observed the reproduction and growth of a population of *S. spallanzanii* on an "artificial cliff" in the Mediterranean sea (Gulf of Taranto, Ionian Sea) from May 1991 to August 1992. In situ measurements of tube length were compared with variables such as body length and biomass, to calculate growth-rate. Subsequent monthly observations were made to examine gonad maturation and minimum size at maturity, and to determine population sex ratios.

On the basis of this study, the authors concluded that *S. spallanzanii* is characterised by a rapid growth rate. The mean tube length increased 10 cm between July 1991 and August 1992 and estimated biomass from 60 g m^{-2} to 75 g m^{-2} over the same period. Mortality was high with density decreasing from 300 to 150 individuals m^{-2} over the observation period.

The minimum body length at which gonad maturation occurred was found to be 15 cm. The sex ratio varied with body length: worms between 15 and 20 cm were all male, and those over 30 cm were all female. The male:female ratio of worms between 25 and 30 cm was 1:1. According to Giangrande and Petraroli, this variation strongly indicates that *S. spallanzanii.* is a protandric hermaphrodite. Oogenesis was reported to be extraovarian with eggs attaining a size of 250 *m*m. Spawning occurred during February. Gravier (1923) described *S. spallanzanii.* as being a broadcast spawner, with strings of mucus containing eggs and sperm ejected into the water from the tubes.

Kiortsis and Moraitou (1965) conducted experiments on the regenerative capacity of *Spirographis spallanzanii* (= *Sabella spallanzanii*). They found that regeneration was rapid, two to four days after the body had been operated on, and that the capacity for head regeneration was high, even after removal of the nerve cord or the intestine.

3. METHODS

3.1 DISTRIBUTIONAL SURVEY

A total of 79 stations (Tables 1 & 2) were surveyed for the presence of *S. spallanzanii*. Sites were distributed throughout Cockburn Sound from the Causeway to Fremantle, and also included several spot checks in harbours and estuaries at Bunbury, and Albany. Site selection was based on evidence of infestations from aerial video and photographic images, anecdotal evidence, and on assumptions about the substrate and wave exposure preferences of the species.

Scuba dives were made at all sites, and records made of substrate type, depth, and estimated worm density. A four-level scale was used to record estimates of worm density :

dense:	>100 individuals m^{-2};
medium to dense:	50 - 100 individuals m^{-2}
medium:	1 - 50 individuals m^{-2}
sparse:	< 1 individual m^{-2}

Video footage and still photographs were taken of colonies and individuals of *S. spallanzanii* to be used for reference, identification, and communication of the results of the study.

3.2 SAMPLE COLLECTION AND SPECIMEN DESCRIPTION

Approximately 250 *S. spallanzanii* were collected from infested sites and preserved in the field for later laboratory examination. Samples were fixed in 10% buffered formalin for several days, then rinsed thoroughly in water before being transferred to 70% alcohol for preservation. Specimens were examined as soon as possible after final preservation to minimise loss of body or crown pigmentation. Tube length and width, body length and width, crown length, number of spiral whorls in the crown, thorax length, number of thoracic segments, and abdomen length were recorded for each specimen examined.

Tube length was measured with the tube straightened out and allowed for the U bend at the posterior end of the tube. Tube width was measured as the diameter at the top of occupied tubes. Worm bodies were carefully removed for measurement by cutting open the tube with a scalpel inserted between tube and body. Body length was calculated by adding together the crown, thorax and abdomen lengths, as discussed below. Body width was measured as the diameter at the junction between the fourth and fifth thoracic segments, but not including the height of the tori and chaetae, which varied in preserved specimens from being erect to flat against the body.

Crown length was measured from the anterior tips of the radioles to the dorsal junction of the crown and body. The number of whorls of radioles on the single, spiralled crown lobe was counted and its left or right positioning noted (viewed dorsally). Thorax length was measured from the dorsal junction of the crown and body to the junction between the thoracic and abdominal segments. The number of thoracic segments were counted. Abdomen length was measured from the junction between the thoracic and abdominal segments to the posterior tip of the abdomen. Every specimen measured was examined for evidence of damage to, and/or regeneration of, parts of the body.

3.3 AERIAL PHOTOGRAPHY AND VIDEO IMAGING

In October 1994 an aerial video image was recorded of the large patches of *S. spallanzanii* on the Southern Flats, using a Digital Multi-Spectral Video (DMSV Specterra Systems). Four colour bands were used with wavelengths centred on 450, 550, 650 and 770 nm, and the bandwidth of each was 25 nm. Digital video images were computer enhanced by the CSIRO Division of Minesite Regeneration to reduce surface effects of the water and improve image clarity.

Aerial photographs of Cockburn Sound dating from 1967 to 1993 were obtained from the West Australian Department of Land Administration and those including the Southern Flats region were examined in reverse chronological order to determine when patches of *S. spallanzanii* first became visible from the air. Particular attention was paid to one patch (site 3) which had a distinctive shape and was easily tracked in time-series photographs, and which was clearly visible in photographs from 1993, and in the 1994 aerial video image.

In the more recent aerial photographs, five large patches of what appeared to be *S. spallanzanii* were clearly visible near patches of seagrass. Using the aerial video image as a guide, the patches were located and marked by surface floats, then verified by divers. The surrounding seagrass patches were also verified and examined to determine whether *S. spallanzanii* extended into them. A manta-board towing technique was used by divers to determine the extent of the large patches of the worm and to locate smaller, isolated clumps. The co-ordinates of each site was recorded with a hand-held GPS and backed up with visual land fixes.

3.4 ANECDOTAL INFORMATION

Following media publicity over the initial discovery of *S. spallanzanii* in Western Australia, over 30 reports of *S. spallanzanii* sightings were received from local divers and fishermen. Each report was documented and followed up with a phone interview to gain as much information as possible. Information recorded included the date of sighting, location, and any anecdotal evidence as to when and how the species may have been introduced to a particular location.

4. RESULTS AND DISCUSSION

4.1 TAXONOMY OF COCKBURN SOUND SABELLIDS

4.1.1 GENERAL CHARACTERISTICS OF THE FAMILY SABELLIDAE

Sabellids characteristically have cylindrical, apparently smooth bodies, which taper posteriorly, with large, often maroon or red-coloured tentacular crowns. Most species, particularly those that grow to a large size, are strictly sessile and never leave their tubes. Fauchald (1977) gives the general characteristics of the family as: "Body cylindrical with a thorax of few setigers (segments) and abdomen with few to many. Uncini crested or with teeth in several rows; long- or short-handled. Tube present in most species, made of varying material, but never calcareous."

In the areas covered by this study several different species of large sabellids (50–400 mm tube length), all fitting Fauchald's description, were found inhabiting soft muddy bottom and rocky reef habitats. Although several of the local sabellids are similar in size to *Sabella spallanzanii*, the latter is visibly distinct, and reasonably easy to distinguish both underwater and when preserved.

4.1.2 SPECIES DESCRIPTIONS

The following are descriptions of *S. spallanzanii* and two other similar Cockburn Sound sabellids:

Sabella spallanzanii (figs 1–4)

Large tube-dwelling polychaete. Tube constructed of tough but flexible, semi-transparent material, with the outer layer combined with greyish silt or mud and often supporting a range of epiphytic organisms. Tube length between 90 and 400 mm; tube width 3.9 to 11.3 mm[2]. Tube usually cemented posteriorly to a hard substrate such as shell fragments, jetty pylons or wrecks. Posterior part of the tube, which is often buried in sediment, tapered and often recurved ('U' shaped). Tube usually protruding 50–300 mm above the sediment.

Branchial crown 9–64 mm long, formed by two asymmetric lobes of many radioles; one lobe forming a semicircle, the other having many more radioles and forming a spiral of 1–5 whorls.[3] Spiralled lobe situated either on the right or left side and tending to have fewer whorls in smaller specimens. Radioles with bases webbed for about the first 5 mm of their length; outer surface of each, rounded. Four-lobed collar, 3–6 mm high, at base of crown, with two fleshy lappets placed

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[2]Measurements are from Cockburn Sound specimens collected during this study.

[3]The asymmetry of the lobes is possibly a useful distinguishing characteristic as it is not found in other sabellid species collected during the survey.

ventrally, usually orange in colour and often folded down in specimens removed from tube prior to preservation. Crown pigmentation varying from distinct orange, white, and red-brown bands to pale fawn throughout and banding indistinct.

Thorax with 6–9 segments (mean 8) and 5.9–13.4 mm long (mean 9.5 mm); anterior end with 1–3 mm gap between shields and neuropodia; gap diminishing posteriorly. Interramal eye-spots small, black, visible on thorax between the notopodia. First ventral shield much wider than subsequent shields. Junction between thoracic and abdominal segments distinctly marked by setal types becoming reversed. The thoracic chaetae long, slender and slightly curved; abdominal chaetae more curved or bent. Thoracic and abdominal uncini avicular (Z-shaped) with a finely toothed crest; small companion chaetae present.

Abdomen with many segments (50–200), and 52–234 mm in length (mean 151 mm). Total body length 80–302 mm (mean 204.7-mm).

Sabellastarte cf. *indica*

A large sabellid, generally with a thicker body (8–18 mm) than *Sabella spallanzanii* (5–10 mm). The crown is arranged in two symmetrical semicircles of radioles which do not form a spiral. When the crown is fully extended and viewed from above, the base of the crown and mouth-parts are visible including two slender palps, 8–17 mm long. The crown varies in colour and pattern from being pale cream with fawn bands to dark purple with thin, lighter bands. The radioles have two distinct ridges on the outer surface. There is little or no gap between the ventral shields and the neuropodia at the anterior end of the thorax. Specimens of *Sabellastarte* cf. *indica* were identified by comparing them with a Western Australian Museum specimen (Reg. No. 262-75 *Sabellastarte indica,* Yallingup, Southwestern WA., B. R. Wilson & S. Slack-Smith, 25/2/1975).

Sabellastarte indica were found on rocky reefs at Albany, Mewstone Rocks and Marmion Marine Park. The species may prefer a more exposed habitat than *S. spallanzanii* but some overlap in distribution does occur. Single specimens of *S. indica* were found amongst *S. spallanzanii* at sites 7, 14b, 15, 22 and 39, while at Woodman Point, single *S. spallanzanii* were found amongst *S. indica.*

Sabellastarte cf. *sanctijosephi*

Fauchald (1977) gave the following description of this species: "Radioles spiralled; eyes present, webbing and external stylodes absent. Collar well developed, widely separated dorsally. Spatulate and companion setae absent." This species was found only at Woodman Point and is easily distinguished from *S. spallanzanii* by its crown which is made up of two symmetrical spirals of radioles. The colour of the crown in all the specimens observed was pale mauve. The tube protrudes only 10–15 mm above the sediment, the remainder buried to a depth of 100–300 mm and firmly cemented to underlying limestone rock.

4.1.3 OTHER SABELLID MATERIAL FROM THE WA MUSEUM

Sabellid specimens from the collection of the Western Australian Museum were examined for previous records of *Sabella spallanzanii* (or *Spirographis spallanzanii*). A specimen from Naples (undated) was found, labelled as *Spirographis spallanzanii* (Reg. No. WAM 1–95). Upon examination, this specimen appeared to be the same species as specimens from Cockburn Sound, Bunbury and Albany, and also fitted the unpublished description of *Sabella spallanzanii* by Knight-Jones and Perkins. Three unidentified specimens from Albany also appeared to be *Sabella spallanzanii.* These were collected from Oyster Harbour in 1965 and 1978, and Princess Royal Harbour, 1979 (Reg. Nos. WAM 3–95, 4–95 and 2–95 respectively). There is therefore, a strong indication that the species may have been present in the Albany region as early as 1965.

4.2 DISTRIBUTION

4.2.1 COCKBURN SOUND (MAPS 2 & 3; TABLE 1)

The distribution of *Sabella spallanzanii* in Cockburn Sound is centred around several large patches on the southern edge of the Southern Flats (sites 1–5) but extends north throughout the sound to Fremantle and several of its associated harbours.

Dense cover of *S. spallanzanii* was recorded on several wrecks within the Sound (sites 7, 15 and 25), on the underside of an old yacht moored in Mangles Bay (site 33), near the Garden Island Causeway (site 32) and on a channel marker opposite Kwinana (site 17). Most of the jetties and channel marker pylons on the eastern side of the sound had moderately dense to sparse cover of *S. spallanzanii* (sites 9 to 13, 18 and 21). On the Eastern Flats clumps were found on reef and near seagrass beds (sites 14, 16 and 20).

S. spallanzanii was found on most of the Gage Roads channel-marker pylons (sites 22, 23, 39, and 40) and further north at Fremantle. In Fremantle Harbour *S. spallanzanii* was found close to the harbour entrance at the TAFE fish farm (site 49) and on the State Ships Wharf (site 50) but was not found any further up river. In Rous Head Harbour there was a dense cover of the worm on jetty pylons (site 48).

S. spallanzanii was found at several sites at Garden Island, including the Navy Armament Jetty, and on a navigational leading light north of Garden Island (sites 25, 26, 28, 29 and 44), but not at Carnac Island or Mewstone Rocks (sites 41 and 43).

4.2.2 BUNBURY (MAP 5; TABLE 2)

In early October 1994, CSIRO received a report that a giant fan worms, similar to those shown in media coverage of the *S. spallanzanii* discovery in Cockburn Sound, had been present for several years on the walls of the Bunbury power station water intake enclosure at No. 1 Groyne in Koombana Bay. A visit to Bunbury was arranged in January 1995 to follow up this sighting and to see if the worms had spread to other areas of the harbour. A total of 18 sites were examined in the inner and outer harbours, and in the Leschenault Inlet and Estuary. Abundant worms, which later proved to be *S. spallanzanii,* were found in and outside the power station water-intake enclosure. Other colonies, sometimes dense, were found in other areas in and around the harbour. A brief report on the findings of this survey was prepared for Bunbury maritime authorities (Evans and Clapin, 1995). Site data and locations from that report are included at the end of this report.

4.2.3 ALBANY (MAP 4; TABLE 2)

Although not within the original scope of this study, Albany was briefly surveyed in March 1995. Six sites were selected on the basis of information obtained from reported sightings, museum sample data, and previous experience of likely habitats. Both Albany harbours, Oyster Harbour and Princess Royal Harbour, were surveyed and specimens of *S. spallanzanii* were found in both.

At the Emu Point Boat Harbour (in Oyster Harbour) there was dense cover of large specimens (150–350 mm) on the pylons of the southern jetty. There were also specimens on the hull of a large yacht berthed at the jetty, and on several navigational markers in the Emu Point channel.

At Princess Royal Harbour specimens were found on the pylons of the Town Jetty (Fishing Boat Jetty). At the shore end of the jetty were the water depth was 3–4 m, there were only sparse individuals of small size (50-90 mm). Further along the jetty where water depth was 6–7 m, there were dense clumps of larger specimens (150–250 mm).

4.3 REMOTE DETECTION OF WORM PATCHES

The potential for using aerial photography and enhanced digital video images to locate and differentiate patches of seagrass and *S. spallanzanii* in shallow areas of Cockburn Sound, was tested using historical photographs, and video images of the Southern Flats taken in October 1994. Differences in the colour, density and texture of seagrass and worms patches were visible in both video and photographic images, with patches of each clearly visible against the sediment background to a depth of approximately 6 m. Seagrass beds appeared darker and denser than worm patches, and often had characteristic crescent-shaped blowouts.

With the band-widths used in the digital video recording, it was not possible to differentiate seagrass from worm patches on the basis of their spectral signatures. Enhanced discrimination may be achieved using different band-widths to those selected for the present study, but this will require further testing. In areas where water clarity and depth are not limiting, aerial photography or digital video imaging may be useful to detect changes in the size of patches. This would greatly assist future efforts to monitor the spread of *S. spallanzanii* in the large shallow areas of Cockburn Sound, and possibly also in parts of Port Phillip Bay.

4.4 PATCH CONTINUITY ON THE SOUTHERN FLATS

Five main patches of worms were clearly visible in aerial photographs of the Southern Flats and were verified as *S. spallanzanii* by scuba divers. The distinctive shapes of the patches, particularly at site 3, could be seen in photographs dating back to at least 1983. In photographs taken before 1983 the shapes were not readily discernible. This and anecdotal evidence suggest that the species may have been in Cockburn Sound for at least ten years. Specimens which appear to be *S. spallanzanii* were photographed by one of the authors at Woodman Point in 1985.

The area of the Southern Flats now occupied by *S. spallanzanii* patches was mapped by Hillman (1986, p.19) in 1977 and again in 1985. During the period 1977–85 the area, described as bare sand, previously seagrass meadow, decreased, in part becoming patchy *Posidonia* meadow, or patchy deteriorating *Posidonia* with patches of fibre and mussels. Aerial photographs from 1985, however, clearly show the distinctive shapes of what we now know to be patches of *S. spallanzanii*; it is not known whether replacement of *Posidonia* by *S. spallanzanii* has occurred.

4.5 BIOLOGY, ECOLOGY AND BEHAVIOUR

4.5.1 HABITAT PREFERENCES

S. spallanzanii was found in depths ranging from just below the surface to 18 m. The species has, however, been reported on a sunken barge off Mindarie Keys in 30 m of water. In all areas examined in the study, population densities of *S. spallanzanii* were highest at sites which provided suitable attachment substrate and were also relatively sheltered from wave action. Such sites included those protected by depth. For example, many of the channel-marking pylons in the exposed middle of Cockburn Sound carried *S. spallanzanii*. Typically, the worms were very sparse on the pylons from the surface to 7 m depth, however, thick clumps occurred below that depth. It is possible that periodic cleaning of the top parts of pylons, evidence of which was seen, has some bearing on this distribution, but many pylons with a similar pattern of worm distribution had obviously not been cleaned for a long time. The D9 wreck (site 15), situated in 7-12 m in an often exposed part of the Sound, is also heavily infested with worms.

Anecdotal evidence suggest that *S. spallanzanii* rapidly colonises man-made structures such as wrecks and pylons, particularly after disturbance creates new space for attachment. Prior to 1991, three small wrecks at Rockingham (site 7) were observed to be covered predominantly with mussels and ascidians, with only a few sabellids present (Clapin, personal observations). During 1992, the wrecks were thoroughly denuded by local mussel fishermen (pers. comm. S Syurgeon) and have since become densely covered with *S. spallanzanii*. The wreck of the *Day Dawn* (site 25) was moved by the Western Australian Maritime Museum in May 1991, at which time no sabellids were observed on the wreck. By January 1994 large numbers of sabellids were present (pers. comm. P Baker) and the wreck is currently densely covered by worms.

Conditions in parts of Cockburn Sound appear to be particularly favourable for the development of large, dense populations of *S. spallanzanii*. When the patches of *S. spallanzanii* on the Southern Flats (site 4) were first discovered in September 1994, they were sampled to determine density, biomass and tube length. The mean number of individuals was 256 m^{-2} (S.D.±72.1 m^{-2}) with a biomass of 458.9 g ash free dry weight m^{-2} (S.D.±125.6 g m^{-2}) and a mean tube length of 32.7 cm (S.D.±1.5 cm) (Lemmens unpublished; Clapin unpublished).

In comparison, the Mediterranean population studied by Giangrande and Petraroli (in press) attained a maximum density of about 300 individuals m^{-2} for what they described as "only small individuals" (no size given). However, 12 months later. the Mediterranean population had decreased in density to 150 individuals m^{-2}, estimated biomass was 75 g m^{-2}, and mean tube length only 20 cm. Density, biomass and tube length were all far greater in the Southern Flats population which indicates that conditions in this part of Cockburn Sound are very favourable for the growth and survival of *S. spallanzanii*.

4.5.2 SETTLEMENT, CLUMPING AND PATCH STABILITY

The Southern Flats patches appear dense and continuous in aerial photographs, but in reality, they generally consist of discrete, closely-spaced clumps of *S. spallanzanii*. Aerial photographs indicate that the shapes of the patches, particularly at site 3, did not change significantly from 1983 to 1994. This lack of change in the patches suggests that the worms might be limited in forming new clumps by the availability of suitable substrate. If, for example, worms preferred to attach to either dead seagrass rhizomes or shells from old mussel beds, patch size could be limited by the extent of these old beds.

Two transects, approximately 60m long, were run across the large patch at site 3, and clumps of worms were sampled at 5 m intervals. Each clump was carefully dug out of the sediment, turned upside-down, and examined to determine what it had been attached to. In 55 percent of samples worm-tubes were found to be cemented to shell fragments, mainly mussels (*Mytilus edulis*), razor shells (*Pinna* sp.), and scallops (*Pecten* sp.). 45 percent of clumps included small pieces of dead seagrass rhizomes (*Posidonia* sp.) in the anchoring material, and 15 percent of samples were attached to solitary ascidians such as *Herdmania* sp. and *Phallusia* sp. There was a degree of overlap with some clumps attached to all, or different combinations of the three types of anchoring substrate. 35 percent of clumps were not anchored to any hard substrate.

The results do not provide unequivocal support for the idea of patch spread being limited by availability of suitable substrate, nor do they answer the question of why the patches have not changed shape over the past 10 years. Although shell fragments, being larger and more rigid than seagrass rhizomes, may provide better anchorage, the percentage of clumps found attached to seagrass rhizomes was reasonably high, and many did not use either as an anchoring mechanism.

In many cases clumps sampled consisted of many individuals attached to a central core of one or several larger tubes which, in turn, provided the principle substrate attachment for the whole group. The resulting "colony" appears as a tangle of tubes, the basal portions of which are partly buried in the substrate. A similar arrangement was found on hard substrates, such as jetty pylons and wrecks. This suggests that the tubes of early colonisers provide a new substrate upon which subsequent colonisers can settle.

4.5.3 PREDATION

At no time during our observations was *S. spallanzanii* seen to be attacked by any predatory species, however some specimens collected lacked crowns, possibly as a result of being attacked by fish. Leatherjackets are reported to attack the crowns of specimens kept in home aquaria (pers. comm. David Bloch) and, while some fishermen regard the worm bodies as being good fishing bait, others regard them as ineffectual. It is not known which fish species will take the worm bait. During survey dives worms were, on occasions, cut up fed to various fish species but none showed particular interest in them.

4.5.4 REGENERATION

Evidence of regeneration of damaged body parts was seen in specimens from several sites (Nos. 7, 15, 21, 34a, 35 & 37). In most cases this involved the regeneration of a new head and crown. In some specimens, where the body had been severed in the abdominal region, a new head was regenerating on the posterior section and a new tail on the anterior section within the same tube. In one specimen, which had been severed into four sections, the three longest sections (185, 60 and 29 mm, respectively) showed signs of regeneration, the 60 mm piece, having regenerated a crown which protruded from the posterior part of the damaged tube. The smallest section (13 mm) had healed over at each end but showed no sign of regeneration.

4.5.5 SPAWNING

In the Mediterranean *S. spallanzanii* is known to spawn in winter (Giangrande and Petraroli, in press). Several juveniles *S. spallanzanii* 10–15 mm in length were collected from Cockburn Sound in mid-January 1995. The size of these specimens suggests that spawning occurred shortly prior to this date, i.e., in summer. Further work is needed to clarify the breeding patterns of *S. spallanzanii* in Australian waters.

4.6 IMPACTS AND POTENTIAL FOR SPREAD

4.6.1 THREAT TO NATIVE FAUNA AND FISHERIES

Despite the fact that *S. spallanzanii* is reportedly threatening scallop fisheries in Port Phillip Bay, Victoria, this study found little evidence to suggest it directly threatens any fishery in Western Australia. Most of the survey sites were not in commercially fished areas, except a few close to mussel farms in Cockburn Sound. The farm enclosures were not surveyed but mussel farmers who were interviewed reported that worms only occurred very occasionally on their grow-out ropes, and these constituted little more than a slight nuisance. Worms only occurred on ropes which had lost floats and been allowed to sink to the bottom. There is a mussel farm and an oyster hatchery in Oyster Harbour, Albany, but no reports were received that would indicate that *S. spallanzanii* is a nuisance there.

This study found no evidence that *S. spallanzanii* was, at this stage, having any obvious impact on native species. In Western Australia the worm occurs principally in disturbed habitats or on man-made structure and it is not possible, without further study, to assess its potential impacts on natural communities.

4.6.2 IMPACT ON SEAGRASS BEDS

The study found no evidence of *S. spallanzanii* invading healthy seagrass beds and replacing them. At several sites on both the Southern and Eastern Flats (sites 2, 3 and 16) patches of *S. spallanzanii* were found in sand patches between, and in some cases, in close proximity to, relatively healthy seagrass beds. Seagrass beds at these sites and other sites were carefully searched but no worms were found in them. This suggest that healthy seagrass beds do not offer suitable substrates for worm settlement and/or survival.

4.6.3 POTENTIAL FOR SPREAD BY HULL FOULING

S. spallanzanii were observed attached to the hulls of several vessels moored in Cockburn Sound and at Albany and it is likely that vessels, particularly slow-moving ones such as barges, dredges, or even sailing vessels, could be a major factor in the translocation and spread of the species from port to port. In-water cleaning of vessel hulls, where hull scrapings collect on the sea bottom, may also be a source of infection. A specimen of an unidentified sabellid, labelled as "hull scrapings, Fremantle WA. 16/4/1959" (Reg. No. 469-75) was found in the collection of the Western Australian Museum. Although this specimen was not *S. spallanzanii*, it does indicate that sabellids apparently have survived transport on the hulls of ships.

The dredge *Kingfisher* was reported to carry many worms matching the description of *S. spallanzanii* on its hull while in Bunbury Harbour in September 1993 (pers. comm. B. Hesson). The dredge has often been towed between Cockburn Sound and other ports.

The steel barge *Gemini*, which had been moored at Jervoise Bay in Cockburn Sound, was moved approximately 50 km north in September, 1993 and sunk off Mindarie Keys. The barge still has *S. spallanzanii* attached to the hull (pers. comm. J. Clarke); presumably the slow speed at which it was towed (7 to 8 knots) prevented worms being washed off during the transit. The wreck now lies in approximately 30 m of water and still supports live sabellids.

5. CONCLUSIONS

S. spallanzanii is well established in Western Australian waters, its current known distribution being throughout Cockburn Sound, and in the harbours at Fremantle, Bunbury, and Albany. Historical aerial photographs and museum collection data suggest that the species has gone unnoticed in Western Australia for at least 10 years and it is quite possible that the species has invaded other harbours, such as at Esperance and Geraldton, which were beyond the scope of this survey. This study concentrated on habitats where the worm was most likely to be found and a far more extensive survey will be required to ascertain the true distribution of the species and assess its impacts in Western Australian waters.

Current evidence suggests *S. spallanzanii* is confined to relatively calm waters in depths ranging from 0–18 m. It prefers hard substrates or objects upon which to settle and readily colonises man-made structures such as wharf pylons, wrecks and channel markers. Although occasionally seen anchored in coarse sand, it was not found in soft, muddy sediment except on isolated hard objects or patches of hard substrate. The species may well be found at greater depths than those surveyed in this study as it is reported to occur down to 30 m along the coast of Italy (Giangrande and Petraroli, in press). No specimens were found at the offshore islands of Carnac and Mewstone which suggests that *S. spallanzanii* cannot successfully colonise natural reef areas, at least not those in exposed waters. The lack of sightings from the Swan River estuary may indicate that the species cannot tolerate the fluctuating salinities that are characteristic of the Swan River.

The mode of introduction of *S. spallanzanii* into Western Australian water is unknown, but anecdotal evidence suggests that hull fouling may be a major vector for its spread into new areas.

While a detailed assessment of the impacts of *S. spallanzanii* on either native communities or fisheries operations was outside the scope of this study, no evidence was found to challenge the view that *S. spallanzanii* is currently little more than a fouling nuisance in Western Australia. On the basis of what is known of the distribution and habitat requirements of the species in Western Australian waters, *S. spallanzanii* is unlikely to have significant direct affects on state fisheries, most of which exist in more exposed waters. The species' apparent preference for hard, man-made substrates and disturbed habitats suggests that its impact on native communities in Western Australia is also likely to be minimal. However, that the species can form large monospecific patches and rapidly colonise disturbed habitats, suggests that *S. spallanzanii* is capable of excluding or physically displacing native species and almost certainly competing with them for food. If the species becomes widespread, such behavior could have far reaching ecosystem impacts and indirect flow-on effects for commercial fisheries.

Observations made during this and other studies suggest that *S. spallanzanii* has a well-developed capacity to regenerate damaged body parts. While this commonly involves the crown and head, which are the most exposed and therefore the most vulnerable parts of the animal, our observations indicate that the species can generate new individuals from parts of a parent individual. This would caution against the use of dredging or similar destructive techniques to control the worm. Such techniques could, at best, prove ineffectual because of the species' regenerative ability and, at worst, could actually increase numbers through the regeneration of new individuals from severed pieces. Complete removal of worms can probably only be accomplished by divers, but for large dense beds, such as those on the Southern Flats, this approach may be logistically impossible.

Substantial further research is required if the scale of the infestation and the impacts of *S. spallanzanii* in Western Australian are to be fully assessed. There is a need to develop and apply cost effective survey techniques so that the spread of the worm can be monitored; aerial photographic and video imaging techniques, trialled in this study, may be useful in this regard but require further development. The general biology of the species is poorly known and information on reproduction and spawning, regeneration, predation, and the interaction of the worm with native species needs to better understood if effective management or control strategies are to be implemented. The current problems being experienced with *S. spallanzanii* in Port Phillip Bay are an indication of the ecosystem and fishery impacts that the species can have in Australian waters. Given the Victorian experience, it would be unwise to assume that, because *S. spallanzanii* has existed in Western Australia for at least 10 years without apparently causing problems, it will not do so in the future.

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Table 1 : *S. spallanzanii* Sample Site Details; Cockburn Sound to Fremantle

Site	Location	*S. spallanzanii* found ✓= YES; - = NO.	Density	Substrate	Depth (m)
1	Southern Flats, patch 1	✓	D	Sand, shell & seagrass rhizome	4
2	Southern Flats, patch 2	✓	D	Sand, shell & seagrass rhizome	4
3	Southern Flats, patch 3	✓	D	Sand, shell & seagrass rhizome	3.5
4	Southern Flats, patch 4	✓	D	Sand, shell & seagrass rhizome	3
5	Southern Flats, patch 5	✓	D	Sand & mussel shell	6 to 14
6	Mangles Bay, sand spit	✓	S	Sand	6 to 9
7	Rockingham Wrecks	✓	D	Wreck & tyres	4 to 15
8	Sand flats from Rockingham to CBH jetty	✓	S	Sand, shell and old tyre	3 to 4
9	CBH grain terminal jetty	✓	M	Pylons and bottom	2 to 12
10	Jetty at Kwinana Wreck site	✓	S	Pylons and bottom	2
11	Kwinana Bulk Cargo Jetty	✓	M	Pylons and bottom	2 to 12
12	BP jetty & service vessel marina	✓	S	Pylons and rocks	3
13	Stirling channel, starboard marker	✓	D	Pylon and bottom	1 to 14
14	Eastern flats	✓	S	Reef	4 to 5
15	Wreck of the "D9" barge	✓	D	Steel wreck & on bottom	7 to 12
16	Eastern Flats seagrass beds, *P. sinuosa*	✓	MD	Sand & shell	5
17	Calista channel, port marker "F"	✓	D	Pylon and bottom	7 to 14
18	Jervoise channel, port marker "A"	✓	D	Pylon and bottom	7 to 10
19	Seagrass beds north of Alcoa	-	-	Seagrass	2 to 5
20	South of Jervoise Bay Ship Yards	✓	M	Reef	4
21	Woodman channel, port marker "A"	✓	D	Pylon	9
22	Gage roads, southern leading mark No. 2	✓	S	Pylon and bottom	7 to 18
23	Gage roads, southern marker buoy No. 12	✓	S	Chain	6
24	Minstrel channel, outer mark	✓	S	Concrete footings of pylon	5 to 7
25	Wreck of the Day Dawn	✓	D	Wooden wreck and tyres	4 to 7
26	Garden Island Causeway, Minstrel Channel	✓	S	Pylon	3 to 7
27	Garden Island, Buchanan Bay	-	-	Seagrass and bare sand	3 to 14
28	Garden Island, Navy Armament Jetty	✓	M	Pylon	2 to 12

Table 1 : *S. spallanzanii* Sample Site Details; Cockburn Sound to Fremantle, Continued

Site	Location	*S. spallanzanii* found	Density	Substrate	Depth (m)
29	Garden Island, Second Head	✓	S	Under reef ledge	1
30	Garden Island pylons at mussel farm	-	-	Wooden pylon	7
31	Garden Island, Cliff Point	-	-	Reef	1
32	Garden Island Causeway, southern bridge	✓	D	Rocks - reef	2 to 4
33	Mangles Bay, Yacht mooring	✓	D	Old ferro-cement yacht	1
34	Jervoise Bay Power Boat Club Marina	✓	S	Concrete pylon	1 to 3
35a	Woodman Point Groyne	✓	S	Limestone rocks	4 to 7
35b	Woodman Point Wastewater Pipe	✓	M	Pipe	3 to 12
36	Explosives Jetty	✓	M	Wooden pylons	1 to 7
37	Coogee beach jetty	✓	D	Pylons and wooden debris	3
38	Wreck at Coogee	✓	M	Steel hull	2
39	Gage Roads, Pylon "F"	✓	S	Pylon	10 to 14
40	Gage Roads, Pylon "B"	✓	S	Pylon	10 to 14
41	Mewstone Rocks	-	-	Reef ledge	2 to 4
42	Carnac Island, north marker buoy	-	-	Buoy and chain	5
43	Carnac Island	-	-	Reef ledge	1 to 3
44	Garden Island, northern passage	✓	S	Pylon and under reef ledge	5 to 10
45	Garden Island, North	-	-	Reef	3 to 5
46	North Mole, Fremantle	✓	S	Steel Wreck	7
47	Challenge Harbour	✓	S	Rock	2
48	Rous Head Harbour	✓	D	Steel	0.5 to 6
49	Fremantle Harbour, Fish Farm	✓	S	Steel	2
50	Fremantle Harbour	✓	S	Concrete pylon	6 to 10
51	Fremantle Harbour	-	-	Wooden pylon	10
52	Fremantle Harbour	-	-	Pylon	10
53	Swan River, Fremantle Traffic Bridge	-	-	Pylon	5
54	Swan River, Stirling Bridge	-	-	Pylon	5
55	Swan River, Rocky Bay	-	-	Pylon	4
56	Swan River, Bicton Baths	-	-	Pylons and bottom	0 to 12
57	Swan River, Mosman Park	-	-	Wreck & bottom	0 to 12

Table 2 : Sample Site Details — Bunbury and Albany

Site	Location	*S. spallanzanii* found	Density	Substrate	Depth (m)
	Bunbury	✓= YES; - = NO.			
B1	Bunbury Power Station	✓	D	Concrete	0 to 2
B2	Bunbury Power Station	✓	D	Steel bars	0 to 3
B3	Bunbury Harbour Channel entrance	-	-	Pylon	12
B4	Bunbury Harbour Channel marker	✓	S	Pylon	10
B5	Bunbury Old Wooden Jetty	✓	D	Wooden pylon	1 to 8
B6	Bunbury Outer Harbour old jetty	✓	D	Wooden pylon	0 to 3
B7a	Leschenault Inlet	-	-	Wooden pylon	2
B7b	Leschenault Inlet	✓	S	Silty bottom, on ascidian	2
B8a	Leschenault Inlet	✓	S	Wooden post	2
B8b	Leschenault Inlet	✓	D	Steel post	2
B8c	Leschenault Inlet	-	-	Steel wall	1.5
B9	Bunbury Inner Harbour	✓	S	Concrete pylon	8 to 9
B10	Bunbury Inner Harbour	✓	D	Steel wall	0 to 2
B11	Bunbury Inner Harbour	-	-	Concrete pylons	12
B12	Bunbury Inner Harbour	✓	MD	Pylon and on rocks	5 to 10
B13	North of Power Station	✓	S	Wooden post and rock	2 to 4
B14	Lechenault Estuary	-	-	Sand	1 to 2
B15	Lechenault Estuary, "The Cut"	-	-	Rock	1 to 3
	Albany				
A1	Emu Point Boat Harbour	✓	D	Wooden pylons	0.5 to 2
A2	Emu Point Channel marker	-	-	Wooden pylon	3
A3	Emu Point Channel marker	✓	S	Wooden pylon	2
A4	Emu Point outer cardinal	✓	D	Steel	2 to 3
A5	Emu Point Breakwater	✓	S	Rock	1 to 2
A6	Princess Royal Harbour	✓	M	Wooden pylons	3 to 7

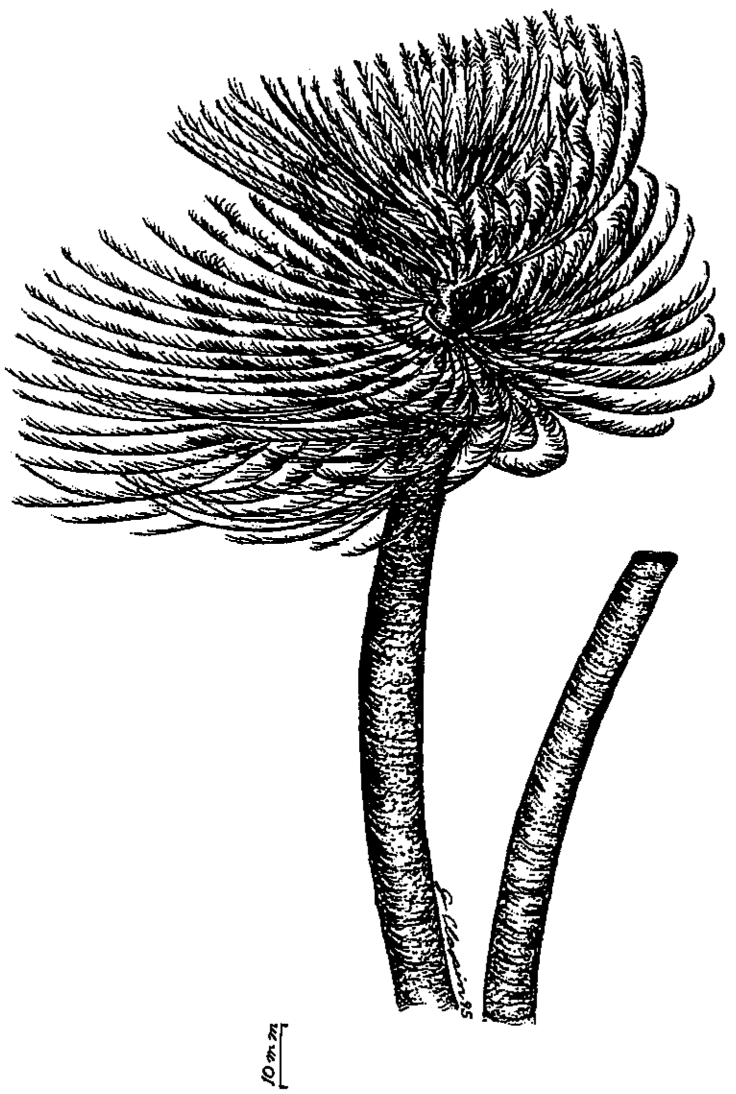


FIGURE 1. ***Sabella spallanzanii***

Left - worm with crown fully extended, showing characteristic single spiral of radioles

Right - worm withdrawn into tube

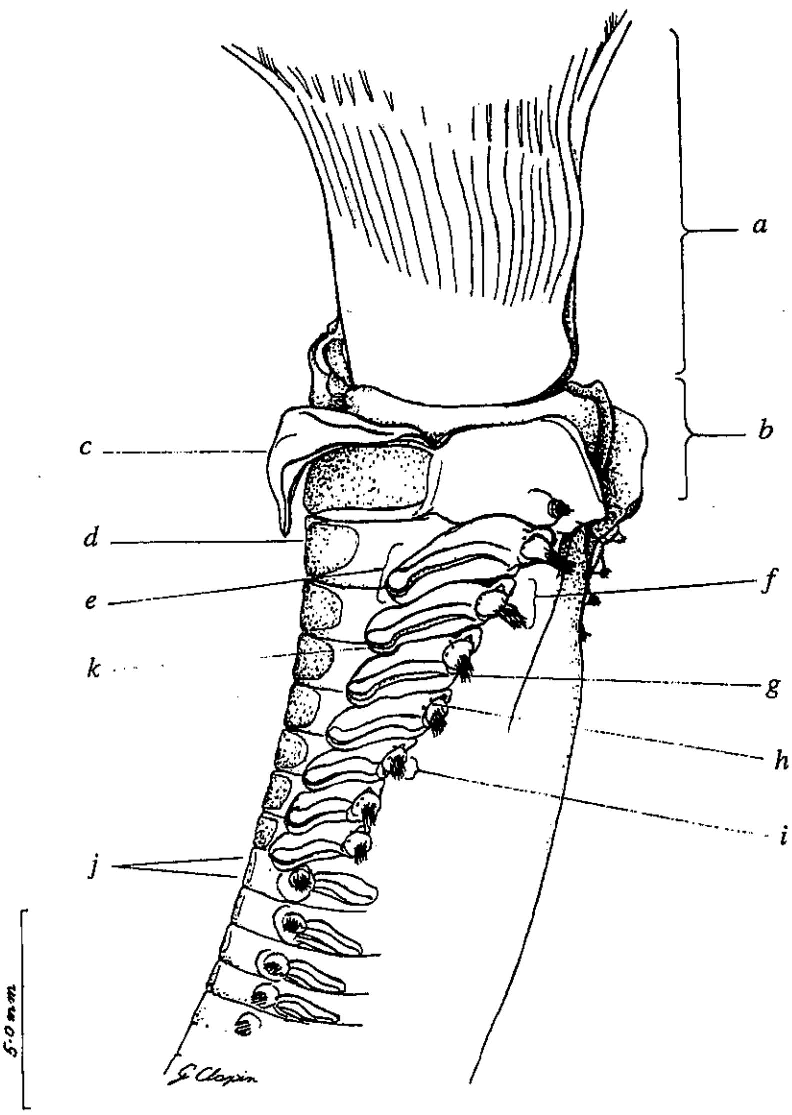


FIGURE 2. *Sabella spallanzanii*, Lateral view

a. crown
b. collar
c. lappets
d. ventral shield
e. neuropodium
f. notopodium
g. seta or chaetae
h. small black interramal eye spots
i. fascicles (bundles of chaetae) arranged in a diagonal line across lateral side of thorax
j. setal types reversed from thorax to abdomen
k. torus, (ridge with uncini and companion chaetae)

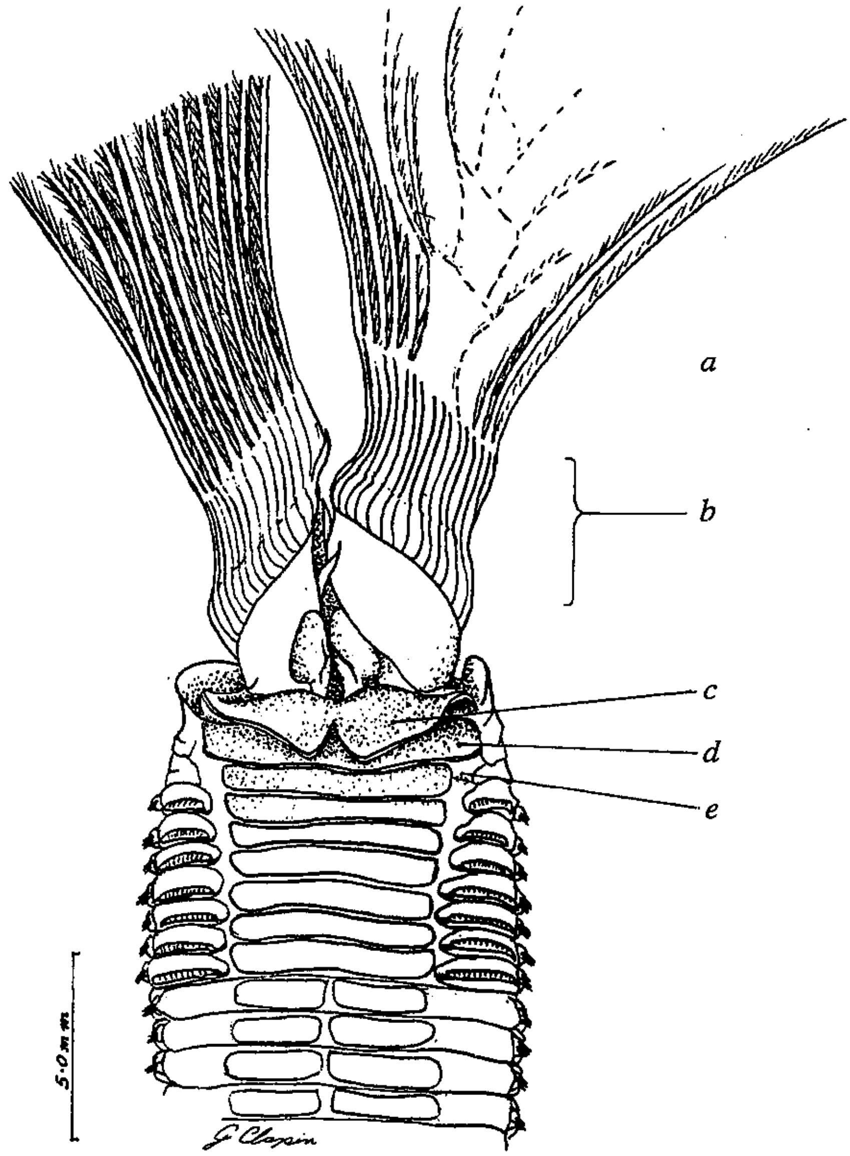


FIGURE 3. ***Sabella spallanzanii*, Ventral view**

a. crown showing two lobes of radioles, only one of which is spiraled
b. radioles webbed for the first 4 to 6 mm
c. fleshy lappets, turned down, and often orange in colour
d. first ventral shield wider than rest
e. gap between ventral shields and neuropodia at anterior end of thorax

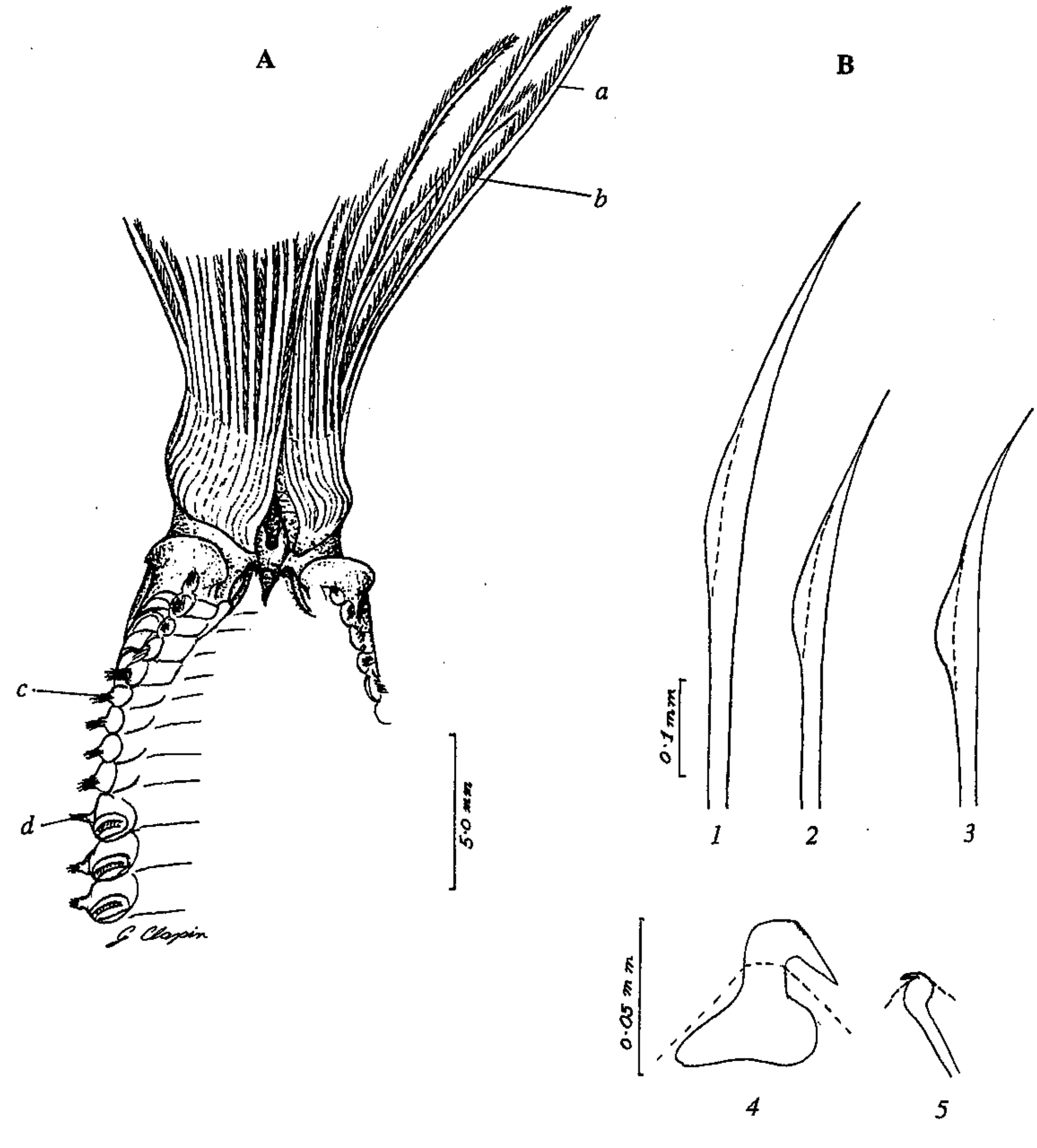


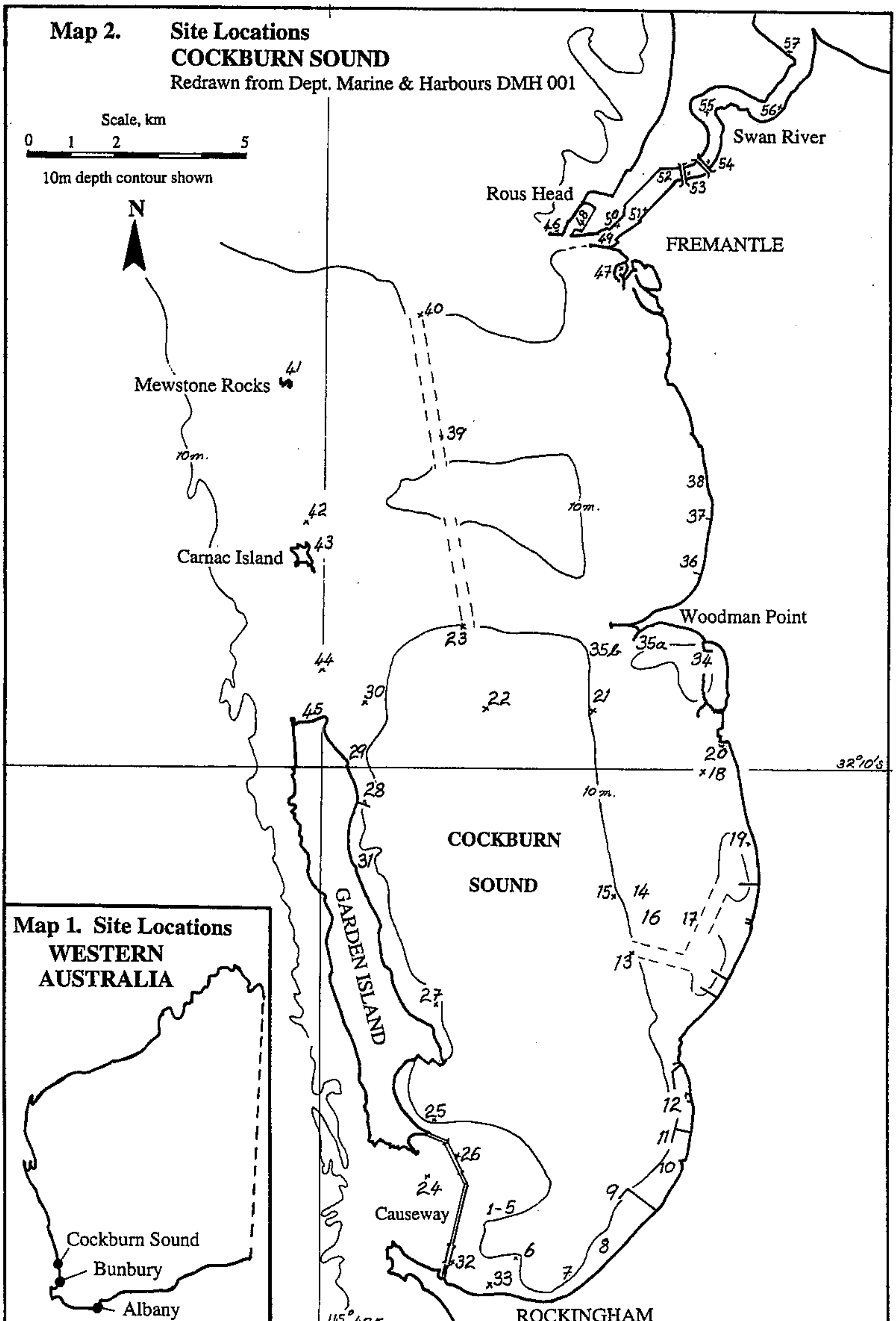
FIGURE 4. ***Sabella spallanzanii*****, Dorsal view and Setal types**

A - Dorsal view;

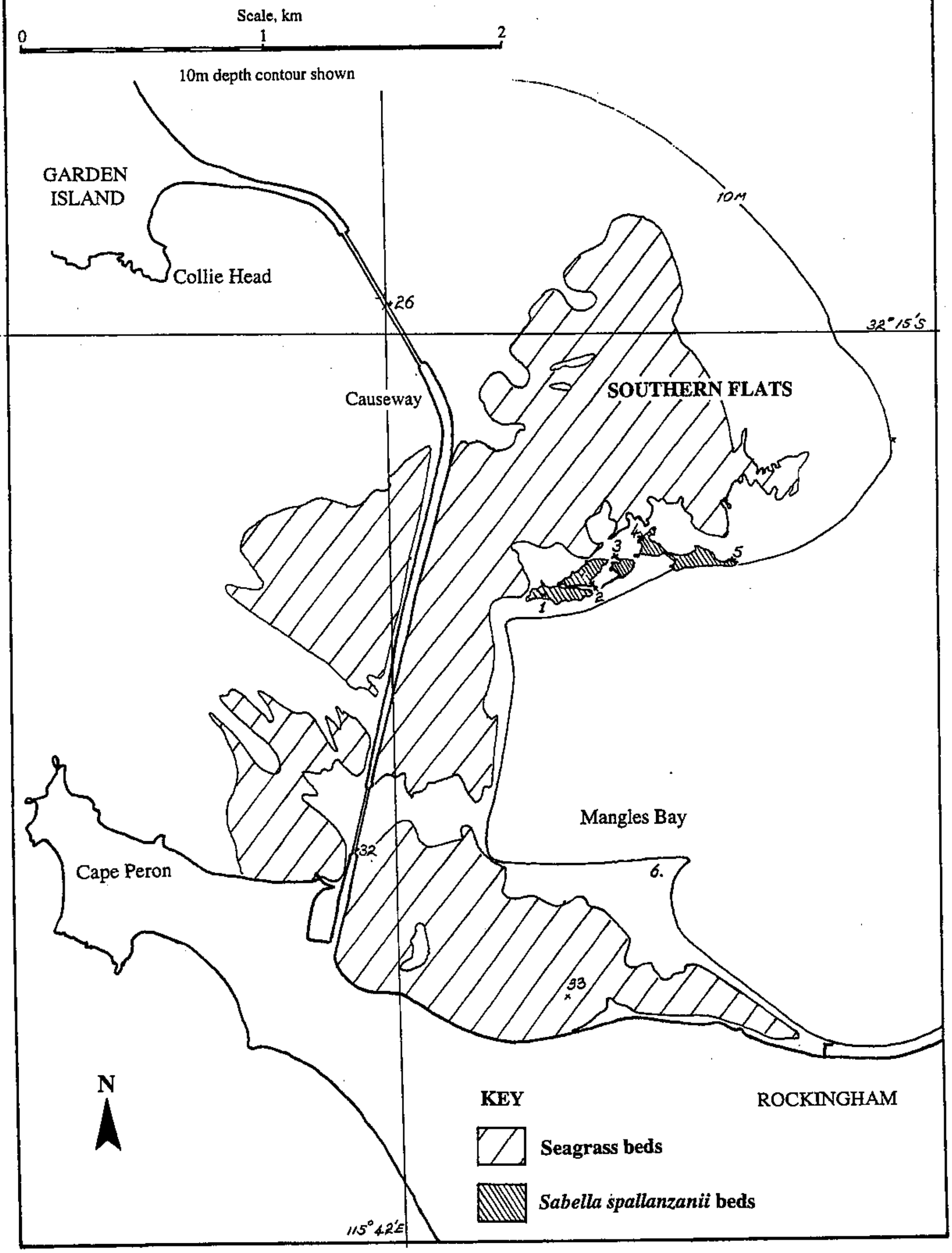
a. radioles, rounded on outer surface
b. pinnules, fine and feather-like
c. thorasic chaetae;
d. abdominal chaetae;

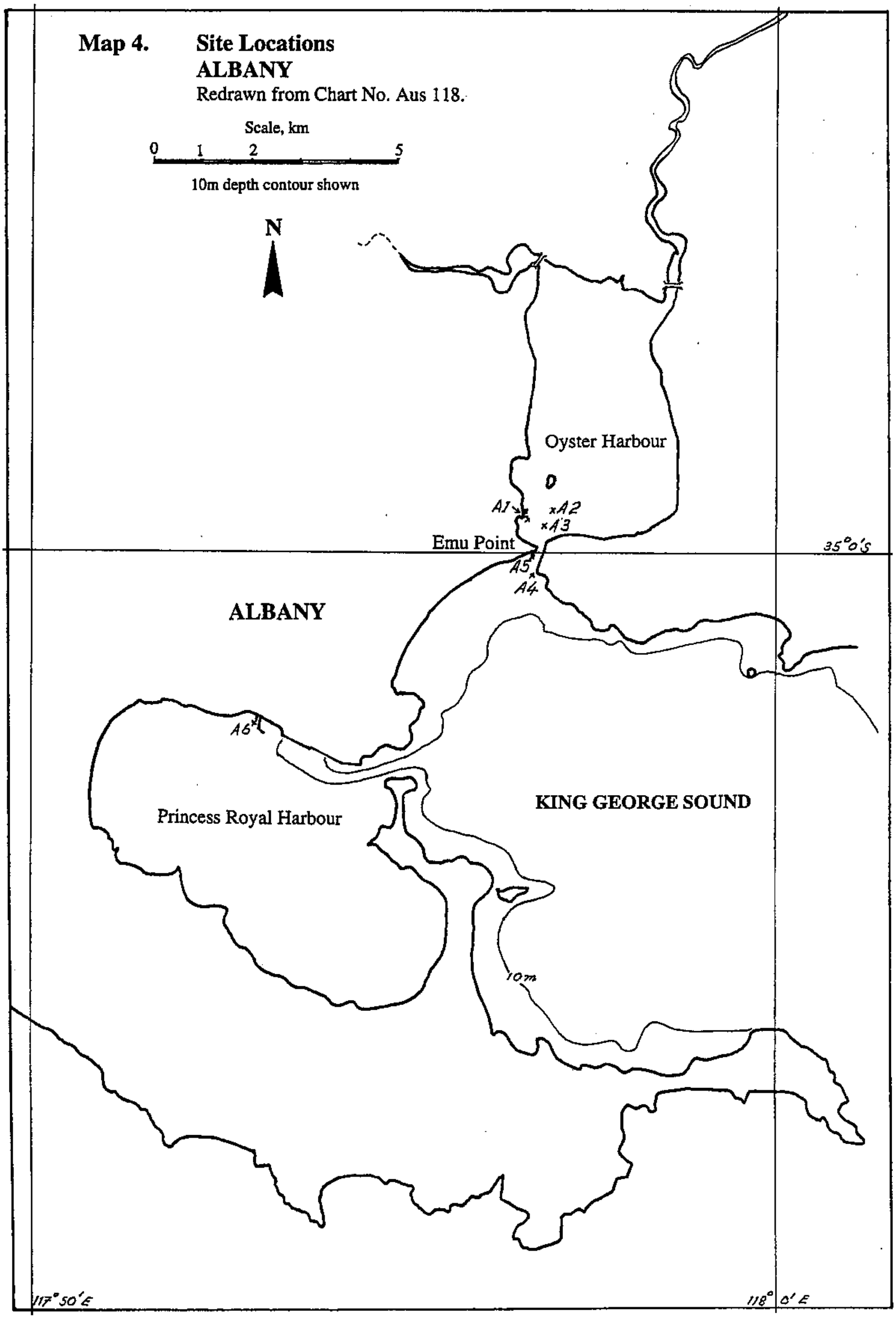
B - Setal types;

thorasic chaetae: *1* superior chaetae, long, slender and slightly curved;
2 inferior chaetae, shorter and more curved
3 abdominal chaetae, genticulate (bent)
4 thorasic and abdominal uncini, avicular with a finely toothed crest
5 companion chaetae, small and bent

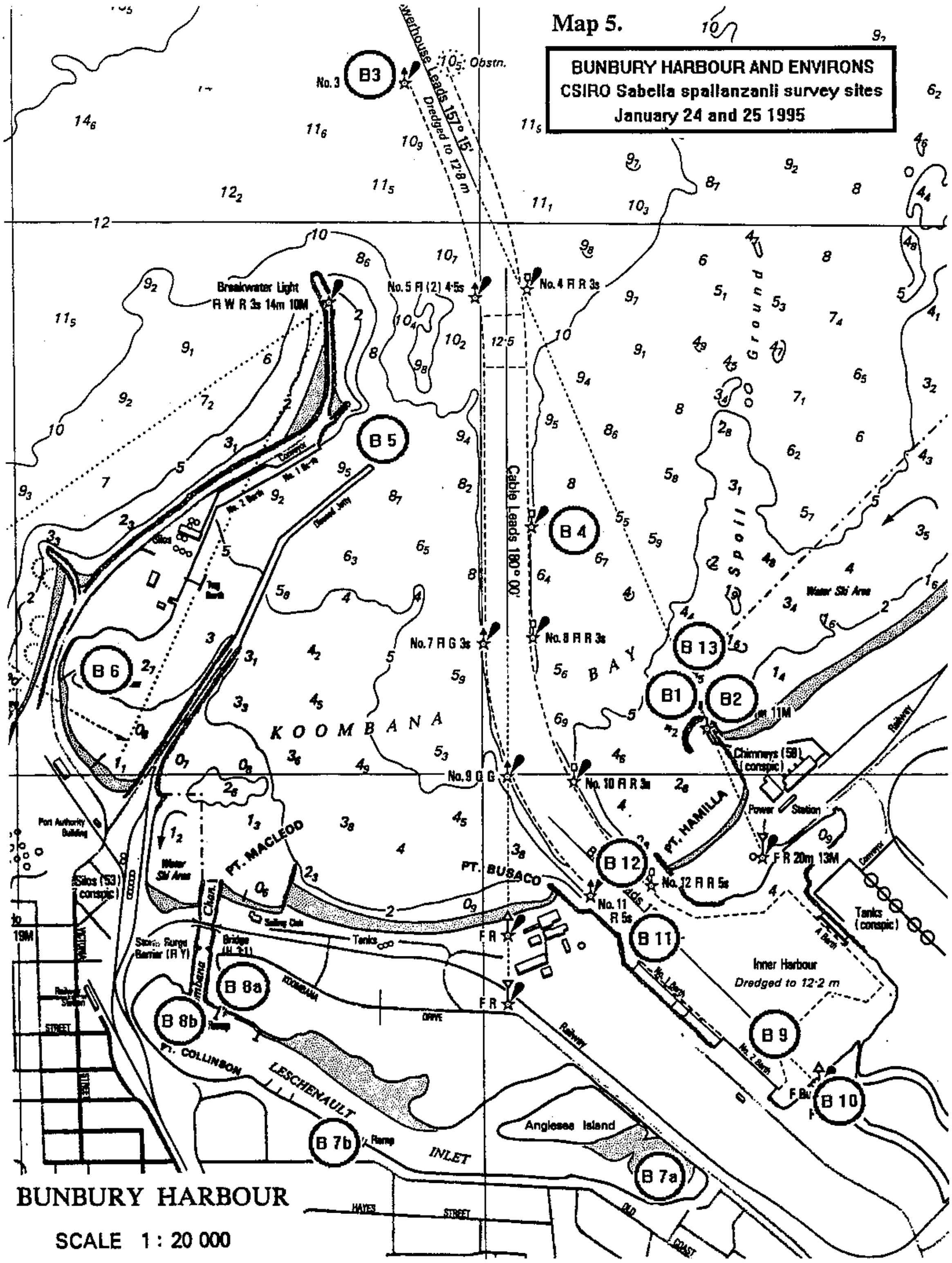

Map 2. Site Locations
COCKBURN SOUND
Redrawn from Dept. Marine & Harbours DMH 001
Scale, km
0 1 2 5
10m depth contour shown
N
Rous Head
Swan River
FREMANTLE
Mewstone Rocks
Carnac Island
Woodman Point
COCKBURN
SOUND
GARDEN ISLAND
Causeway
ROCKINGHAM
32°10'S
115°40'E
Map 1. Site Locations
WESTERN
AUSTRALIA
Cockburn Sound
Bunbury
Albany

Map 3. Site Locations
Detail of SOUTHERN FLATS, COCKBURN SOUND
Redrawn from Aerial Photograph No.5073; WA 3030(C), DOLA 1991





Map 4. Site Locations
ALBANY
Redrawn from Chart No. Aus 118.


Map 5.
BUNBURY HARBOUR AND ENVIRONS
CSIRO Sabella spallanzanii survey sites
January 24 and 25 1995
B3
B5
B4
B6
B13
B1
B2
B12
B11
B9
B10
B8a
B8b
B7b
B7a
Breakwater Light
KOOMBANA BAY
PT. MACLEOD
PT. BUSACO
PT. HAMILLA
Inner Harbour
Dredged to 12·2 m
Cable Leads 180° 00'
Water Ski Area
Spoil Ground
Anglesea Island
LESCHENAULT INLET
PT. COLLINSON
Power Station
Sailing Club
BUNBURY HARBOUR
SCALE 1 : 20 000