Report No: P WMA 19/G10/00/2413/3

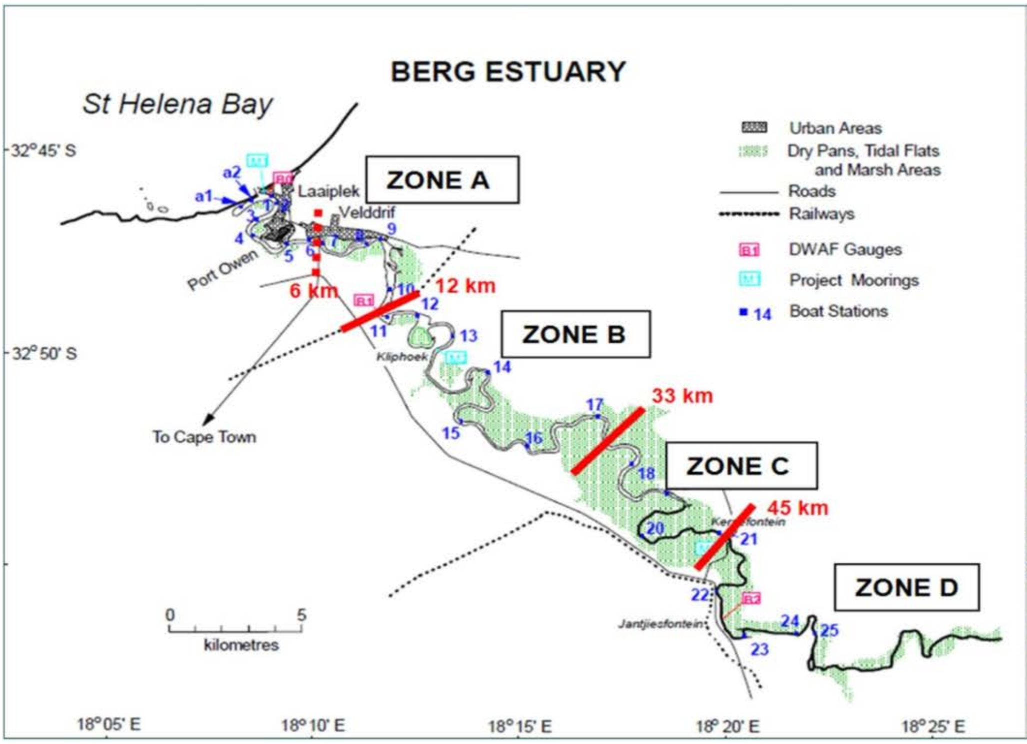
Department of Water Affairs
Directorate: Options Analysis

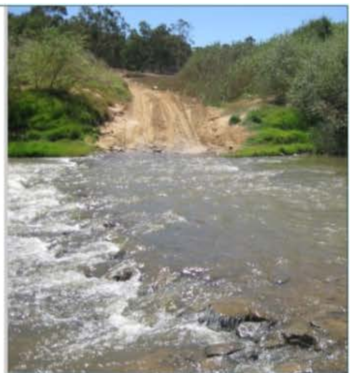
PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

REPORT No.1 – VOLUME 3
Berg Estuary Environmental Water Requirements

APPENDIX No.F

Specialist Report - Invertebrates






June 2012

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PWMA19 G10/00/2413/7

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PREPARED FOR THE WCWC JV BY:
Nelson Mandela Metropolitan University
P O Box 77000
Port Elizabeth
6031

AUTHORS:
T.H. Wooldridge

REVIEWER:
C.A. Brown

LEAD CONSULTANT:
Anchor Environmental

EDITOR:
B. Clark

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1 INTRODUCTION

1.1 GENERAL CHARACTERISTICS OF THE GREAT BERG RIVER

The Great Berg is the largest river in the Western Cape having a Mean Annual Runoff of 693 x 10^6 m^3 (Berg 1993, quoted in Bennett 1994). The river flows northwards from its source near Franschhoek, draining a catchment area of about 7715 km^2 (Slinger & Taljaard 1994). Stream flow in the 294 km long river is highly seasonal, varying between 0.2-2.0 m^3s^{-1} in summer (November-February) and 15-60 m^3s^{-1} during winter (May-August). At times of flooding, flow rates may increase to 700 m^3s^{-1} (Berg 1993, quoted in Bennett 1994). Two major impoundments are currently located on (Voelvlei Dam - full capacity 168 x 10^6 m^3) or adjacent to the river; (Wemmershoek Dam - 59 x 10^6 m^3)(Dept of Water Affairs 1986). The latter receives diversions from the Klein Berg and the Twenty Four River, both tributaries of the Great Berg.

1.2 GENERAL CHARACTERISTICS OF THE GREAT BERG ESTUARY

The estuary (Figure 1) is river-dominated and sediment dispersal occurs seaward of the river mouth. Only two other South African estuaries have large offshore mud deposit centres, namely the Orange or Gariep and the Thukela (Cooper 2001). Besides the Great Berg, numerous other examples of river-dominated estuaries occur in South Africa. In all of them, river flow is critical to the maintenance of an outlet channel and the impact of impoundments is especially notable in these systems (Cooper 2001).

The estuarine floodplain is extensive and tidal influence is measurable up to 70 km from the mouth (Slinger & Taljaard 1994). Over the last 50 km, the estuary bed falls only 1 m (Day 1981). Near the mouth, the estuary bypasses Veldrif, a marina and the fishing harbour of Laaiplek (Figure 1). In 1966, a new estuary mouth was cut through the sand dunes about 1 km north of the original mouth (Slinger & Taljaard 1994). The new mouth was stabilized between concrete walls and fishing vessels are now able to enter the port safely. The original

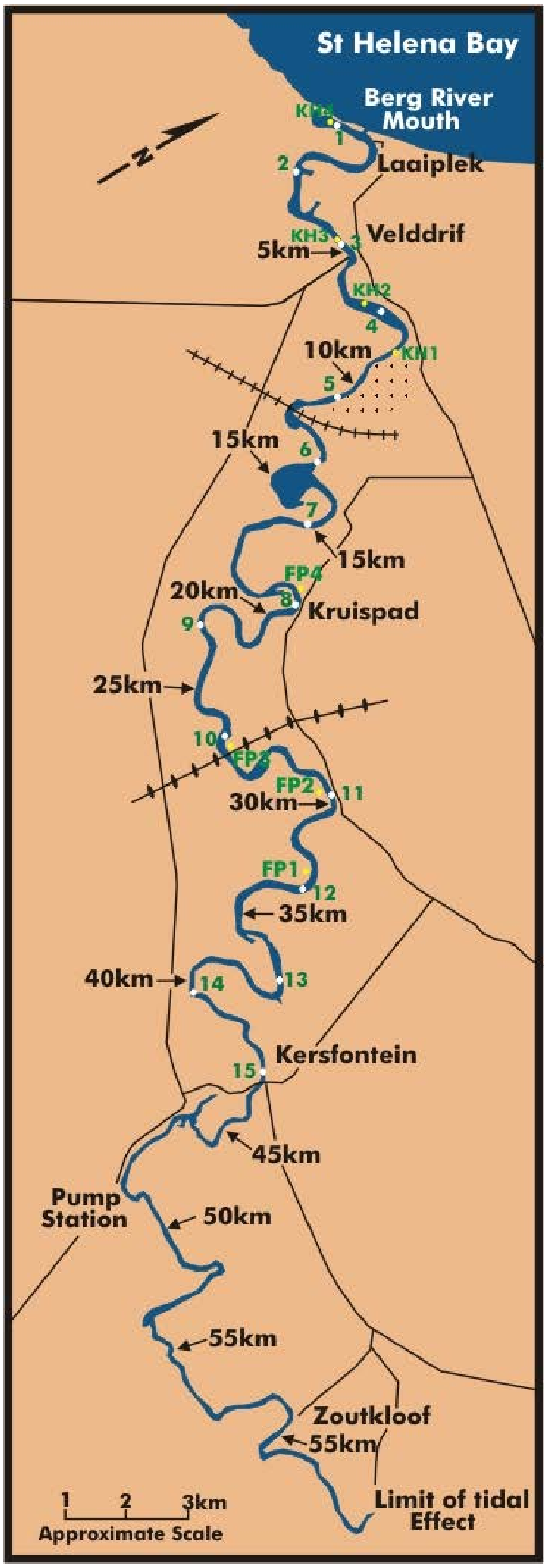

Figure 1. Map of the Great Berg estuary. Distance from the mouth indicated in kilometres. Sites 1 to 15 refer to the subtidal invertebrate sampling stations in the monitoring programme, 2003 - 2006. KH1-KH4 represent the intertidal sites; FP1-FP4 represent the floodplain sampling sites (Modified from Bennett 1994). Co-ordinates are given in Table 1.

mouth has silted up and the former channel currently forms a blind arm or lagoon running parallel to the coast. The lower 4 km of the estuary is also dredged to a depth of at least 4 m to allow for boat navigation.

The main channel at Veldrif is about 100-200 m wide, becoming progressively narrower and shallower upstream. Average width and depth of the channel is about 100 m and 3 m respectively. In the uppermost 15 km, steep banks covered in riparian woodland bound the estuary. Downstream, the estuary is flanked by a floodplain that varies in width from 1.5 to 4 km in the middle reaches to <1.5 km in the lower 15 km. This floodplain is seasonally inundated and supports large numbers of wading birds.

2 SAMPLING METHODS

Invertebrate population in the Berg estuary were sampled as part of the Berg River Baseline Monitoring Programme. No new data were collected for this RDM study. Methods are as for the BRBMP and are described below.

Fifteen subtidal invertebrate sampling sites were located along the estuary (Figure 1). A further four intertidal sites (KH1-KH4) and four floodplain pan sites (FP1-FP4) were sampled in September 2003 and February 2006. The channel beyond Kersfontein is relatively shallow and choked with debris. It is therefore difficult to deploy sampling equipment effectively along these reaches. In order to more accurately document changes in biological communities along the estuary, a relatively large number of sites were chosen (15).

Table 1. Coordinates for sampling stations (1-15) and K & H sites shown in Figure 1.

Station	Latitude	Longitude
1	32°46.414'S	18°08.456'E
2	32°47.319'S	18°08.697'E
3	32°47.329'S	18°09.821'E
4	32°47.301'S	18°11.152'E
5	32°48.541'S	18°11.826'E
6	32°49.053'S	18°12.465'E
7	32°49.650'S	18°13.337'E
8	32°50.515'S	18°14.217'E
9	32°51.694'S	18°13.594'E
10	32°52.234'S	18°15.155'E
11	32°51.489'S	18°16.779'E
12	32°52.452'S	18°17.914'E
13	32°53.402'S	18°18.722'E
14	32°54.240'S	18°17.964'E
15	32°54.309'S	18°18.900'E
K & H1	32°46.430'S	18°08.348'E
K & H2	32°47.283'S	18°09.872'E
K & H3	32°47.285'S	18°10.261'E
K & H4	32°48.017'S	18°11.927'E

2.1 BIOLOGICAL SAMPLING

Collection of samples was done from the deck of a 4.5 m twin-hull fibreglass boat equipped with a 40 hp outboard motor at sites 1 – 15. Core samples were collected at intertidal and floodplain pan sites (KH1 – KH4, FP1 – FP4). Approximately five days were spent in the field on each sampling occasion. Seven series of samples were collected (**Error! Reference source not found.**). Three series were collected in summer, one series in autumn, two series in winter and one series in spring. On each occasion, macrozooplankton (nocturnal), hyperbenthic (diurnal) and zoobenthic (diurnal) samples were collected.

Analysis of samples was completed in the laboratory. Invertebrates were identified to species level wherever possible and the data analysed using multivariate statistics from the statistical package, PRIMER V.5 (Plymouth Routines in Multivariate Ecological Research). If multivariate techniques were not appropriate, other packages using MS Excel or Statistica for Windows were used.

2.1.1 Macrozooplankton

Samples were all collected after dark using two slightly modified WP2 plankton nets (57 cm diameter and 200 µm mesh), fitted with calibrated Kahlsico flowmeters. Two replicates were collected per station. Each net was attached to a 1 m boom extending laterally on either side of the bow of a flat-bottomed boat (4.5 m length). Midwater net tows continued for 2 to 3 minutes (at a speed of 1 to 2 knots) at all 15 stations indicated in Figure 1. Although finer nets may be used, this usually leads to excess clogging of the mesh. Filtration efficiency is reduced and larger organisms such as small shrimps (e.g. mysids – often extremely abundant in estuaries) are then under-represented in samples because of increased net avoidance. Animals retained by nets were stored in 10% formaldehyde solution in 500 ml plastic bottles. In the laboratory animals were identified to species level under a microscope and final abundance expressed as the average number per m^3 of water calculated from the two replicates collected at each site.

2.1.2 Hyperbenthos

Hyperbenthic animals were sampled at all 15 subtidal stations (Figure 1) using a sled mounted on broad skids. Two replicates were collected at each site. The rectangular opening to the sled measured 75 x 70 cm, to which is attached a 500 µm mesh net. A calibrated flow meter mounted in the entrance quantified water volume passing through the net. Animals collected were then stored in 500 ml plastic bottles and preserved in 10% formaldehyde solution. In the laboratory animals were identified to species level under a microscope and final abundance expressed as numbers per m^3 of water calculated from the two replicates collected at each site. Animals captured in sled samples are usually fairly large, measuring up to 1-2 centimetres. Most of the smaller organisms such as copepods escape through the mesh and were therefore not enumerated or identified in sled samples.

Table 2. Sampling dates and season when invertebrates were sampled in the Great Berg Estuary. The estuary was sampled on seven occasions.

Session	Sampling dates	Season
1	10 – 14 February 2003	Low flow, summer
2	16 – 20 September 2003	High flow, winter
3	25 – 29 February 2004	Low flow, summer
4	24 – 29 April 2005	Low flow, autumn
5	15 – 19 July 2005	High flow, winter
6	14 – 18 November 2005	Low flow, spring
7	17 – 22 February 2006	Low flow, summer

2.1.3 Subtidal benthic invertebrates

Subtidal benthic invertebrates were collected using a Van Veen type grab and the contents sieved through a 500 µm mesh screen bag. The grab has a 200 cm^2 bite that penetrated the sediment down to about 10 cm depth. Six replicates were collected in February 2003, while nine replicates were collected on all other sampling occasions. Replicates were collected over an area of about 10 m^2 in the channel area at each site. Animals retained by the sieve were stored in 500 ml plastic bottles and preserved with 10% formaldehyde solution. Final abundance was expressed as the average number of each species per m^2 of substratum at each site, obtained from the six or nine replicates respectively.

2.1.4 Intertidal benthic invertebrates

Intertidal benthic organisms were sampled on the 20th September 2003 and 20th February 2006 at four sites just above the low tide level. Sites KH1 to KH4 (Figure 1) represent the same sites sampled by Kalejta & Hockey (1991). Four other sites (FP1 – FP4, Figure 1) were located in temporary pans on the floodplain adjacent to the estuary and were sampled in September 2003 only (wet season). At each site a corer having an internal diameter of 10.3 cm was pressed into the sediment to depth of ±25 cm and the contents sieved through a mesh bag (500 µm mesh).

Animals retained by the sieve were stored in 500 ml plastic bottles and preserved with 10% formaldehyde solution. Final abundance was expressed as the average number of each species per m^2 of substratum at each site, obtained from the six replicates. Each core sample therefore represents ca 1/120th m^2.

2.1.5 Abiotic measurements

A YSI 6600 multi-parameter sonde was deployed at all 15 stations (Figure 1) during a continuous run up the estuary each trip. Variables were measured near the surface, at 0.5 m depth, at 1 m and thereafter at 1 m depth intervals. The following parameters were recorded at every depth level sampled: Dissolved oxygen (percent saturation and in mg per litre), salinity (ppt), temperature (^{o}C), conductivity (mS per cm), turbidity and pH.

A sediment sample collected at each station provided information on particle size distribution and percent organic content. Dry samples (dried at 60^{o}C for a minimum of 48 h and then weighed) were incinerated at 550 ^{o}C for 12 h to burn off the organic matter. The difference in weight of the sample after incineration provided information on organic content, expressed as a percentage. Three replicates from each sediment sample were used to obtain a final value. Samples were then soaked in distilled water for 24 h to remove salts. Excess water was carefully siphoned off and the sample again dried at 60^{o}C for 72 h. Dried sediment was then vibrated through a series of metal test sieves (2 mm, 1 mm, 500 µm, 355 µm, 250 µm, 180 µm, 125 µm, 90 µm, 63 µm and <63 µm). General descriptive categories of particle size classes are shown in Table 3.

Table 3. General description of the different categories of particle size classes.

Particle size class	Category
< 2 mm	Very coarse sand
<1 mm	Coarse sand
<500 µm	Medium sand
<250 µm	Fine sand
<125 µm	Very fine sand
<0.63 µm	Silt/mud

Percent organic content was obtained after incinerating pre-weighed dry sediment samples (dried at 60^{o}C) for 24 hrs at 660^{o}C.

3 RESULTS

Abiotic and biotic spreadsheet data are presented separately in Appendix 3.1 and Appendices 3.2-3.5 respectively. Abiotic data may reflect a mean value for all water column readings at each station (integrated) as well as values recorded for near-surface and/or near-bottom horizons. This allows for a more sensitive analysis to detect possible relationships between abiotic driving forces and different taxa within invertebrate groups (e.g. zooplankton is more likely to respond to integrated water column values while the benthos may be more sensitive to bottom salinity values).

3.2 ABIOTIC STRUCTURES

3.2.1 Salinity

Clear seasonal patterns were apparent for salinity, with marine penetration extending further upstream compared to winter (Fig. 2). Using Stations 6 and 12 as guidelines, salinity values during low-flow periods (summer) were around 30 and 10- 25 respectively. The corresponding salinity value at the same stations during high-flow periods (winter) was around zero for both sites. In spring (November), salinity was around 20 at Site 6 and near-zero at Site 12.

The water column in the lower 10 km of the estuary (Stations 1 – 5) tended to be relatively well mixed (the difference between surface and bottom values was usually <2), except in September 2005 when strong stratification persisted below Station 4 (<8 km from the mouth). Above Station

4, strong freshwater flow resulted in salinity values of close to zero. Similar values were recorded in July 2005. Stratification was maximal in the middle and upper estuary, decreasing again at the uppermost stations. A maximum difference between near-surface and bottom waters of 13 was recorded in April at Station 12.

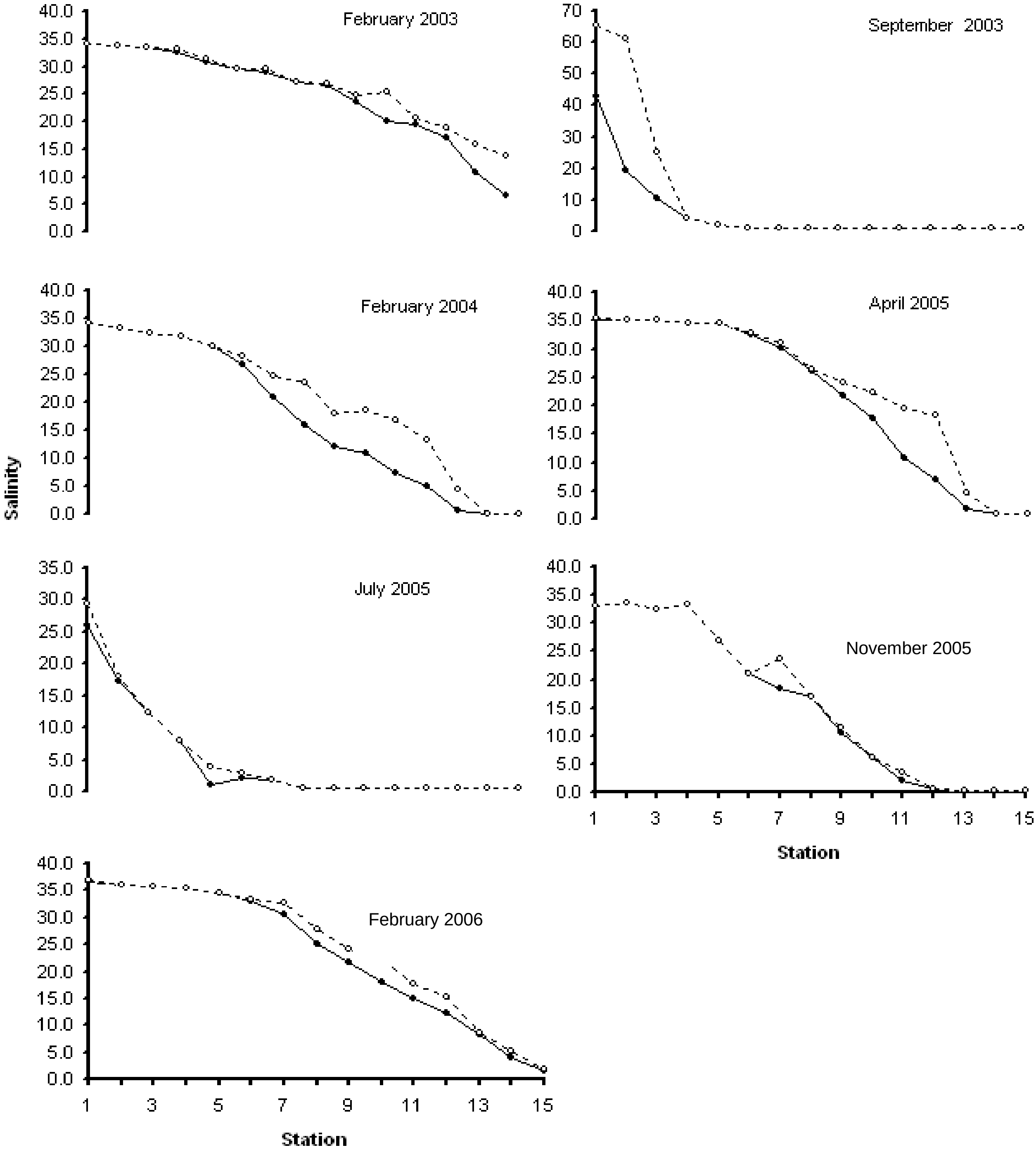

Figure 2. Salinity values recorded in near-surface (solid line) and bottom waters (dashed line) at 15 stations in the Great Berg estuary. Seven series of samples collected between February 2003 and February 2006.

3.2.2 Temperature

The water column was generally well mixed, with relatively little difference in the vertical temperature profile. On most occasions the difference did not exceed 0.5°C. A strong temperature gradient was evident along the estuary, with the uppermost stations in mid-summer (February) averaging 6.2°C warmer than the mouth. Winter temperatures (July) ranged between 0.1 and 3.7°C warmer in the upper estuary compared to the lower stations. Maximum difference was recorded in November 2005 (Δ 7.4°C). The most rapid change occurred at lower stations.

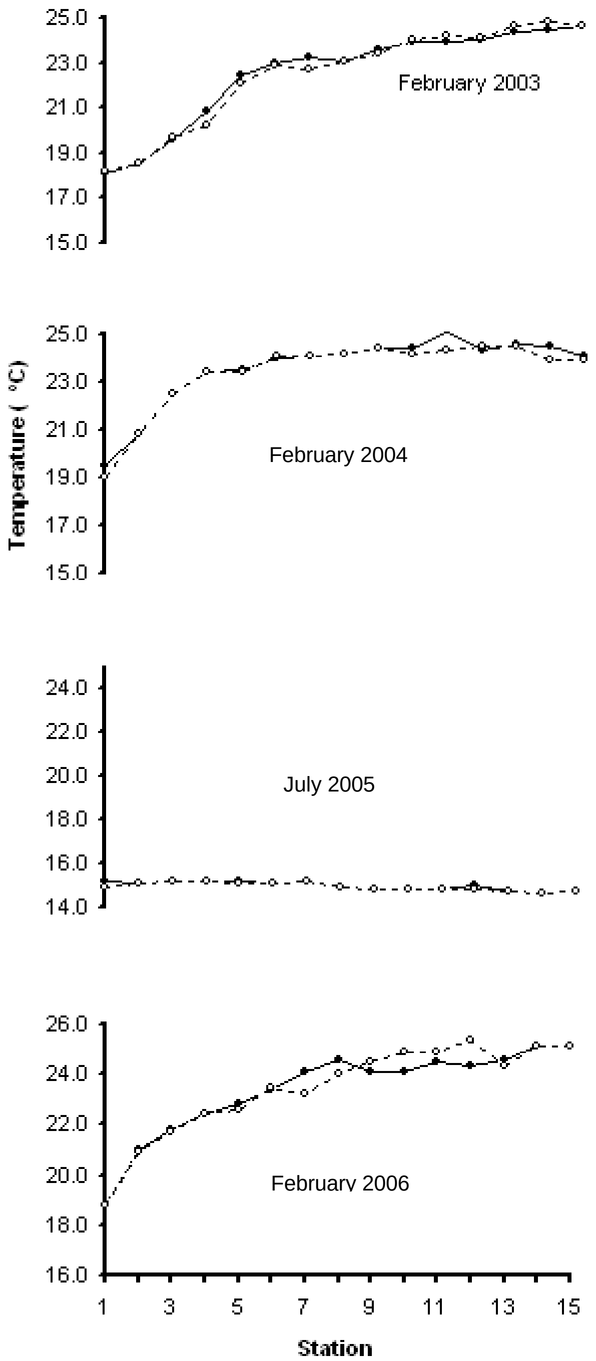

Figure 3. Temperature values recorded in near-surface (solid line) and bottom waters (dashed line) at 15 stations in the Great Berg estuary. Seven series of samples collected between February 2003 and February 2006.

Figure 2 represents the percentage mud (<0.065 mm) and organic matter along the estuary, averaged for six visits where data are available. The two parameters mirror the same pattern along the estuary, with maximum values recorded in the blind arm at the mouth and in the middle estuary (Stations 1, 10, 11 and 12 respectively).

Mean water turbidity (Figure 6) was similar at the first ten stations (20 - 40 NTU's), increasing to a maximum of 143 NTU's at the uppermost station. Variability was lowest near the mouth (Stations 1-4) and in the upper estuary (Stations 13 – 15).

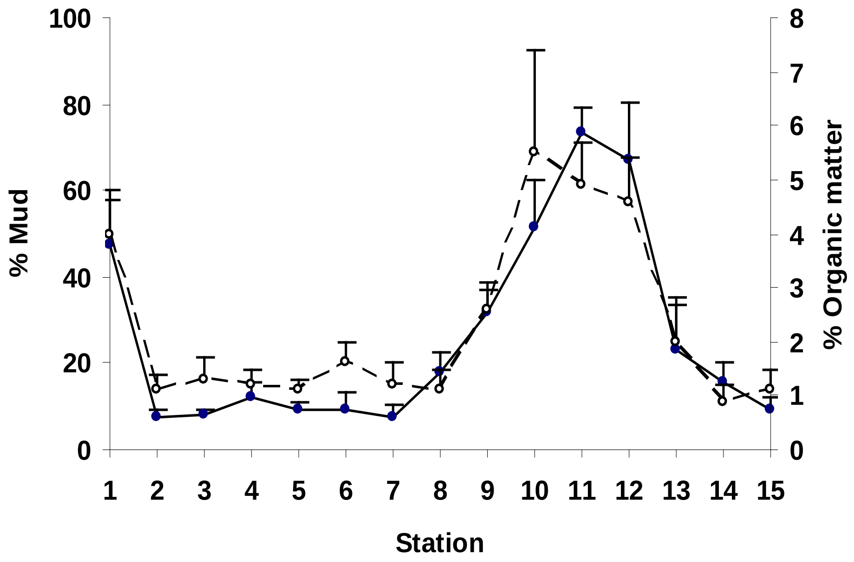

Figure 4. Percentage mud (solid line) and percentage organic matter (broken line) at 15 stations in the Great Berg estuary, Data are the average for five visits, +1SE.

3.3 BIOTIC SPECIES COMPOSITION AND ABUNDANCE

Zooplankton species composition and abundance for the seven series is given in Appendix 3.2. Forty-nine taxa were identified, with copepods numerically dominating the zooplankton. The contribution of copepods to total abundance (14 taxa) only fell below 85% on a single occasion (Table 4), with *Pseudodiaptomus hessei* usually exceeding 60% of copepod numbers.

If copepods are removed from the data base, then peracarid crustaceans (mysids, isopods and amphipods) and crab larvae (mainly *Hymenosoma orbiculare*) were the most abundant zooplankter groups (Figure 5).

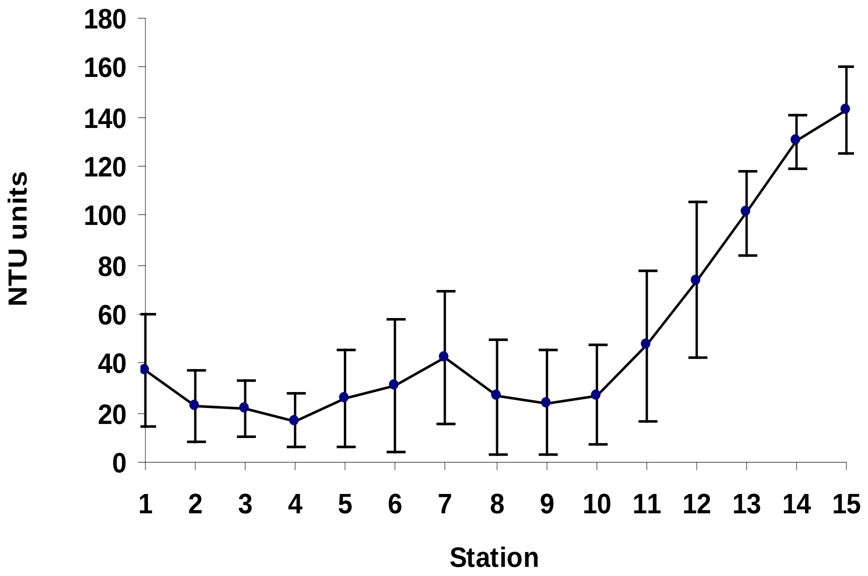

Figure 5. Mean turbidity at 15 stations in the Great Berg estuary, Data are the average for three visits, ±1SE (data not available for all visits).

Pseudodiaptomus hessei was the most abundant species in the zooplankton and was recorded at all stations. This species is described as a pioneer species, attaining maximum abundance after floods or strong freshwater pulsing (Wooldridge 1999) that may occur during any season. Although distribution along the Great Berg estuary was variable between trips (Figure 7), variation in abundance and distribution could not be explained by salinity (P>0.5). Abundance was least in July 2005 (Figure 7E) when freshwater dominated much of the estuary (<10 above Station 4). Such low abundance is probably explained by flushing effects during winter when zooplankton is lost to the system.

Table 4. Total contribution of copepods (%) to total abundance of all zooplankton collected in the Great Berg Estuary.

Sampling dates	% copepod contribution to total zooplankton abundance	% contribution of *P. hessei* to total copepod abundance
February 2003	99	68
September 2003	98	81
February 2004	97	75
April 2005	92	68
July 2005	47	22
November 2005	87	89
February 2006	91	92

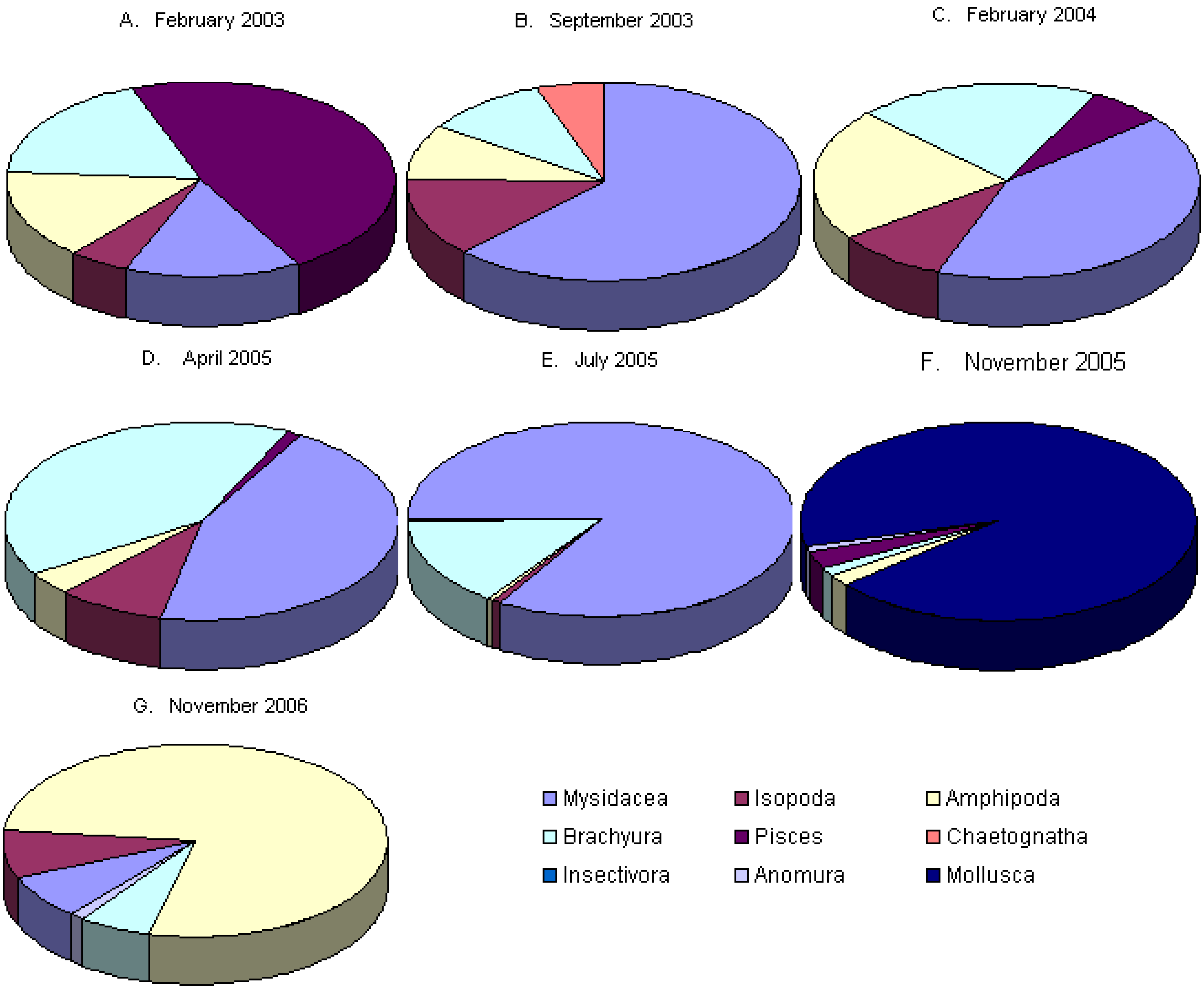

Figure 6. **After removal of copepods from the zooplankton assemblage, peracarid crustaceans (mysid shrimps, isopods and amphipods) were regularly represented in abundance. Fish larvae and small gastropods were each common on a single occasion (February 2003 and November 2005 respectively).**

Maximum abundance of *P. hessei* exceeded 52000 ind.m^{-3} in November 2005 at Station 6 (salinity 21) following the high-runoff period in winter. Relatively high abundance when numbers exceeded 25000 m^{3} was recorded on three other occasions; at Station 5 in September 2003 (Figure 7B) and at the same station in February 2006 (Figure 7G). Salinity at these sites was ca 2 and 35 respectively. On the third occasion, *P. hessei* abundance exceeded 25000 ind.m^{-3} in February 2003 at Station 11 (Figure 2A).

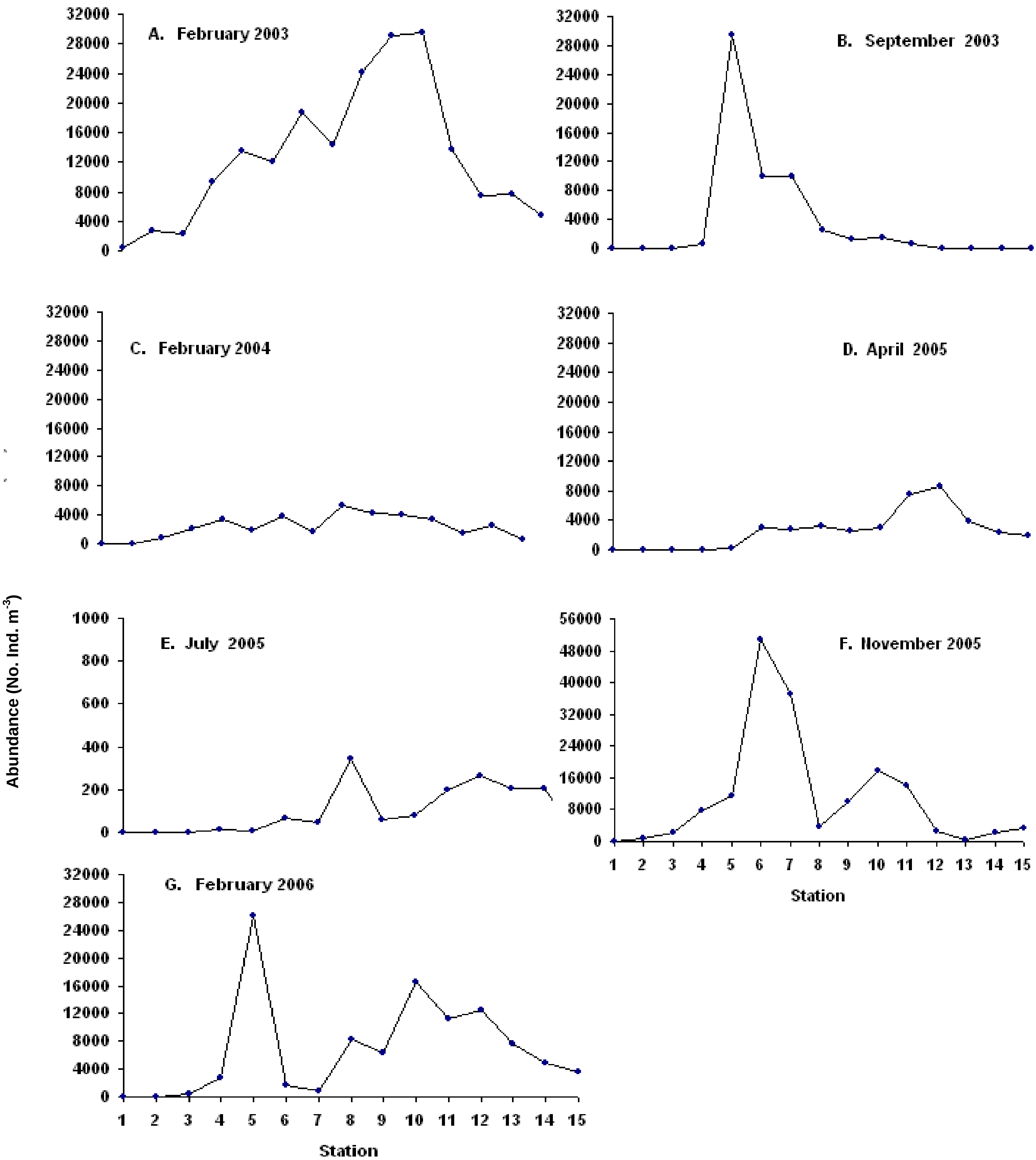

Figure 7. Distribution of the copepod *Pseudodiaptomus hessei* at 15 stations in the Great Berg estuary. *P. hessei* was the most abundant species recorded in the zooplankton. Seven series of samples collected February 2003 – February 2006.

Other numerically important copepods in the estuary were *Acartia longipatella* (abundance >15 000 ind.m^{-3} at Station 3 and >5 500 at Station 8 in February 2003, Appendix 3.2), an unidentified species of *Halicyclops* (abundance exceeded 13000 ind.m^{-3} in February 2003 at Station 9, Appendix 3.2) and an unidentifired *Daphnia* species (abundance exceeded 28 500 ind.m^{-3} in February 2003 at Station 13). *Acartia longipatella* is associated with relatively high salinities while the other two species are linked to freshwater. Numerous marine associated species were recorded in the lower estuary (particularly *Paracalanus* and *Oithona* species).

Mysid shrimps were represented by four species and of these, only *Mesopodopsis wooldridgei* and *Rhopalophthalmus terranatalis* were common. Highest numbers of *M. wooldridgei* were recorded in July 2005 when numbers exceeded 2 800 ind.m^{-3} of water. The center of abundance of *R. terranatalis* was usually recorded further upstream compared to *M. wooldridgei,* peaking at over 250m^3 in April 2005. Such levels of abundance are high when compared to other estuaries around the coast.

The amphipods, *Corophium acherusicum*, *Grandidierella lutosa* and *Melita zeylanica* were occasionally common in the plankton, *C. triaeonyx* exceeding 45 00 ind.m$^-$3 in February 2006. Both species are more benthic in distribution and most of the individuals recorded in the plankton were juveniles.

Mudprawn larvae (*Upogebia africana*) were relatively abundant in the plankton on a single occasion (November 2005) when over 200 ind.m^{-3} were recorded at Station 1. This species breeds during the warmer months and requires a marine phase of development. Stage 1 larvae are flushed from estuaries on the nocturnal ebb tide, eventually returning as postlarvae.

Larvae of the crown crab *Hymenosoma orbiculare* were sometimes very common in the lower estuary (numbers exceeded 1 600 ind.m^{-3} in April 2005 at Station 1), particularly during the warmer months. The life history strategy of this species is uncertain and it is still not clear whether the species also requires a marine phase of development following the pattern shown for many other estuarine crab species.

The estuarine roundherring *Gilchristella aestuaria* is one of a few fish species that spends its entire life cycle in estuaries (Whitfield & Marais 1999). In the present study larvae were relatively abundant in the zooplankton during the warmer months and in the middle and upper estuary.

Hyperbenthic species composition and abundance recorded during each survey are given in Appendix 3.3. Thirty-four taxa were identified. The five most common taxa on each sampling occasion are shown in Fig. 8. Mysids were generally the most common group numerically, although larvae of the crown crab *Hymenosoma orbiculare* (Figure 8A), gobiid and estuarine roundherring larvae (*Gilchristella aestuaria*, Figure 8F) and the amphipod *Corophium acherusicum* (Figure 8G) were relatively abundant on occasions.

Mesopodopsis wooldridgei attained maximum abundance at Station 2 in February 2003 (>700 ind.m^{-3}) and was the most common mysid encountered in samples. *Rhopalophthalmus terranatalis* exceeded 300 ind.m^{-3} of water in April 2005 at Station 12. Maximum recorded density of *M. wooldridgei* in the hyperbenthos was recoded at a different time during the year on and was an order of magnitude less when compared to its peak abundance in the zooplankton. This is not unexpected in a relatively deep estuary since the species may occupy a horizon above the sampling level of the sled during the day. No clear pattern in seasonal distribution was evident in the data, although numbers were lower during periods of high flow. Larva of the crab *Hymenosoma orbiculare* was the most common brachyuran (564 m^{-3} at Station 5 in February 2003). *Gilchristella aestuaria* larvae were more common upstream, also peaking in February 2003 (>250 m^{-3} at Station 9).

Composition and abundance of subtidal benthic species for the seven series is given in Appendix 3.3. The average number of species recorded for all surveys was 23-24, with the maximum recorded in February of 2003 (33 species). The lowest number of species recorded was 20 (February 2004). No seasonal pattern was evident in the data. Forty-three taxa were identified in total, with amphipods and polychaetes numerically dominating the community. The contribution of amphipods ranged from 18% (February 2006) to 79% (February 2003). On average, the contribution of amphipods to total abundance was 54% for the seven series, with no seasonal pattern evident in the data. The contribution of polychaetes ranged from 9% (November 2005) to

60% in February 2006. The switch in dominance from amphipods in November 2005 to polychaetes in February 2006 occurred over three months and illustrates the dynamic nature of community change in the benthos. On average, polychaetes contributed 32% to total abundance for the seven series of samples. The third most important group were isopods, contributing on average 9% to total abundance (range 2% - 17%). In summary, no seasonal pattern was evident in the number of species, nor in the dominance pattern at higher taxonomic levels (polychaetes and amphipods, for example).

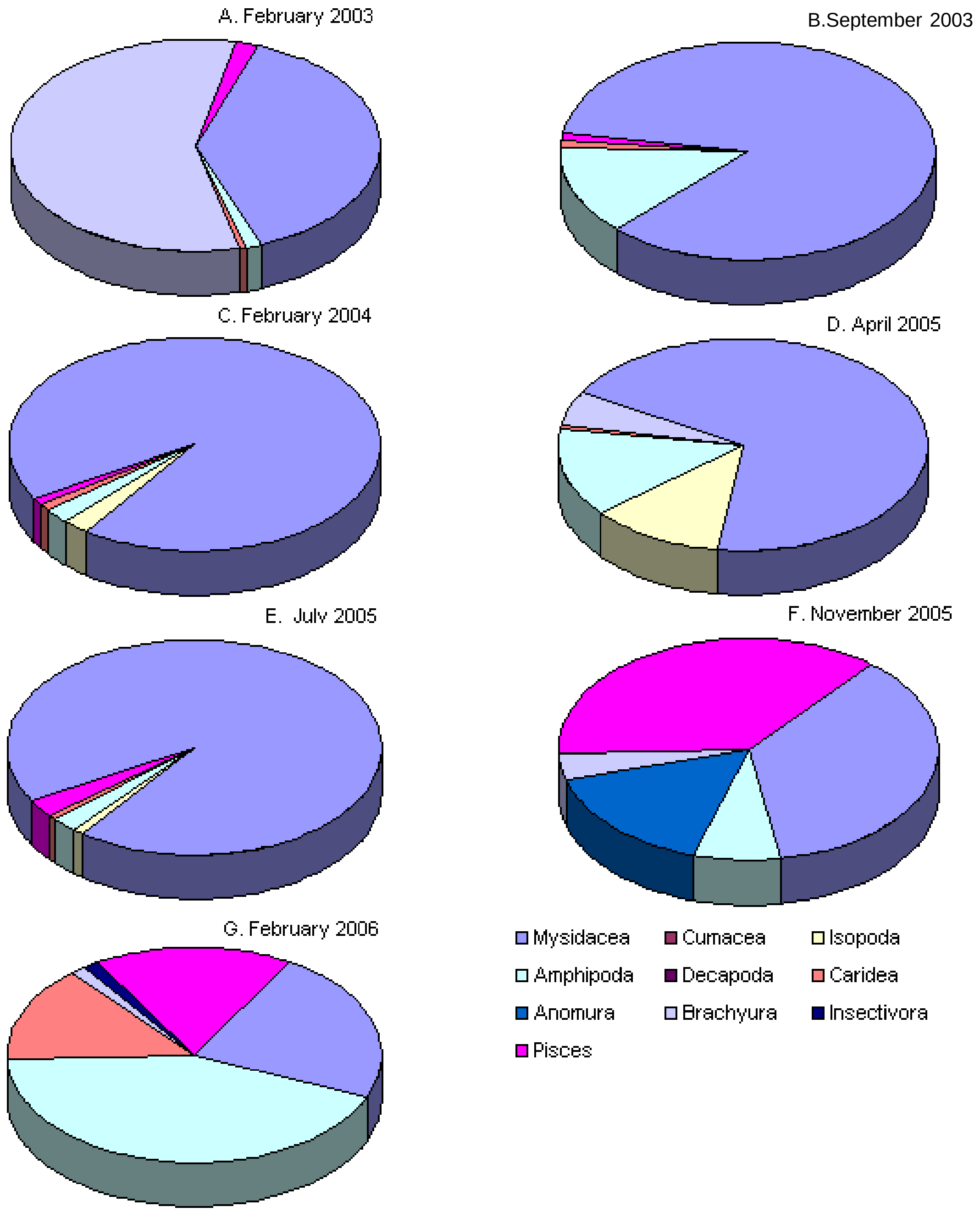

Figure 8. **Mysid shrimps (*Mesopodopsis wooldridgei and Rhopalophthalmus teranatalis*) were the most common group in the hyperbenthos. Larvae of the crown crab *Hymenosoma orbiculare*, fish larvae and the amphipod *Corophium acherusicum* were relatively abundant on occasions. Seven series of samples collected February 2003 – February 2006**

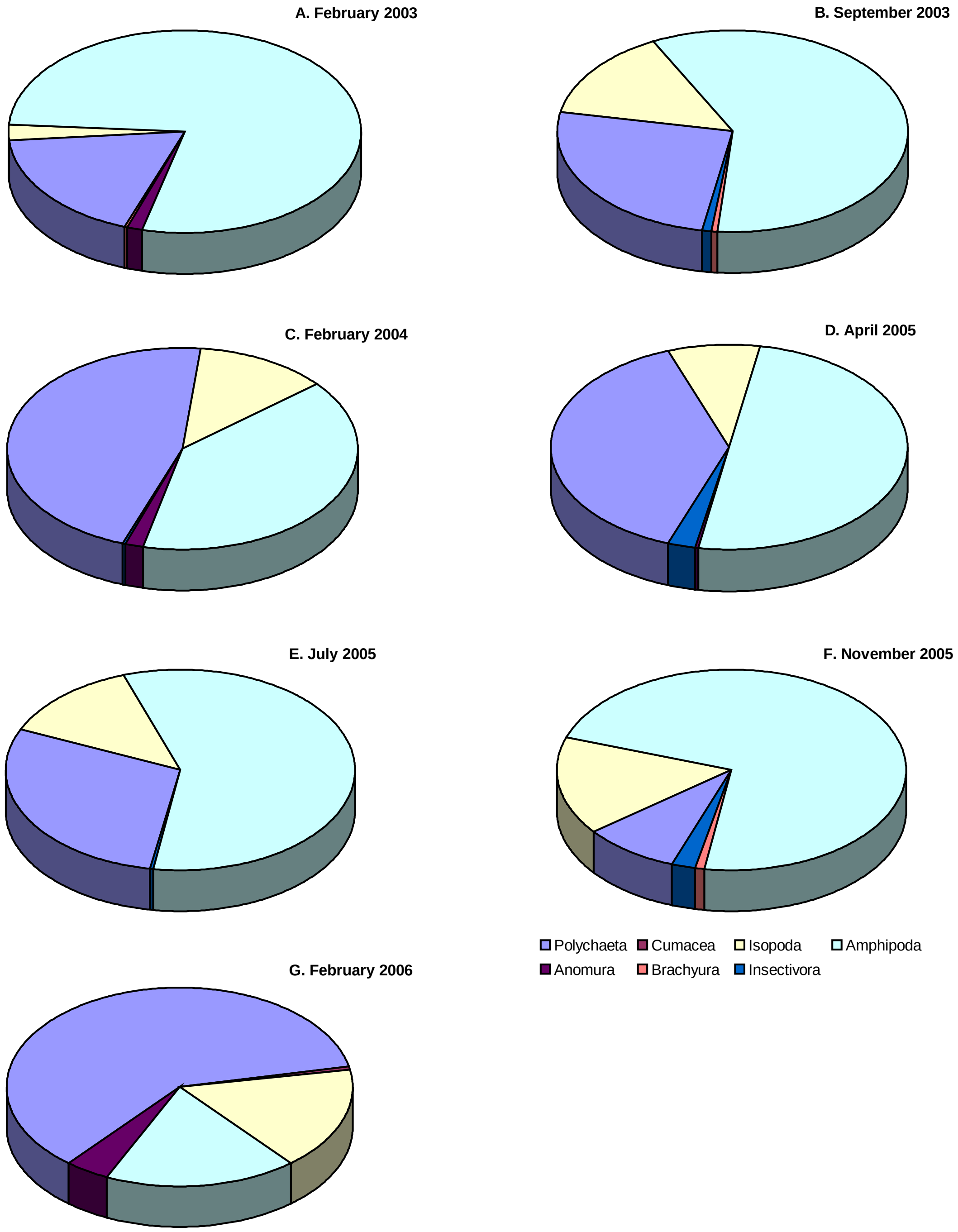

Figure 9. Amphipods (*Grandidierella lutosa* and *Corophium acherusicum*) and polychaete worms were the most common group in the subtidal benthic community. Larvae of the crown crab *Hymenosoma orbiculare*, fish larvae and the amphipod *Corophium acherusicum* were relatively abundant on occasions. Seven series of samples collected February 2003 – February 2006

Polychaete worms were most common at Stations 5 – 6 and 9 - 10 (Fig. 10). The data reflect high variance between sampling trips ascribed largely to river flow patterns. During high flow periods, numbers were generally much lower compared to the dry season (Appendices XXII – XXVIII). Four species dominated the polychaete assemblage on most occasions (*Boccardia* sp. *Ceratonereis keiskama, Capitella capitata* and *Desdemona ornata*), although spatially, abundance levels of any of the four species did not reflect any consistent pattern. Highest numbers of any species occurred at the end of a dry season ((*Capitella capitata* (16150 m^{-2}) and *Ceratonereis keiskama* (14166 m^{-2}) in April 2005)).

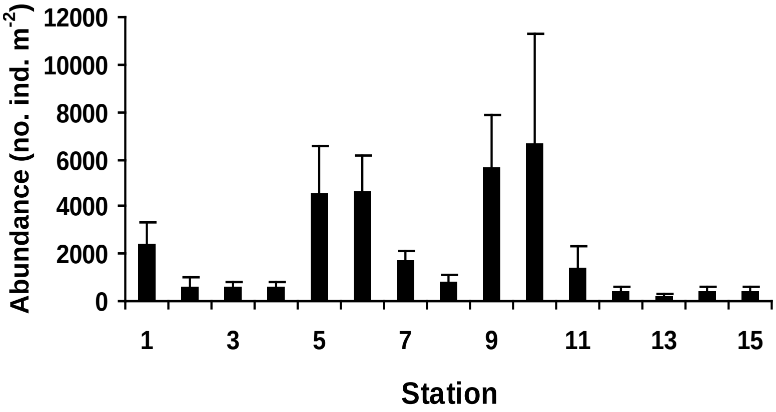

Figure 10. Distribution and abundance of polychaete worms in the Great Berg estuary. Data reflect mean values for seven series of data (collected February 2003 – February 2006) +1SE

Amphipod distribution and variance (Figure 11) reflects the same general pattern shown for the polychaetes. The most abundant amphipods were *Grandidierella lutosa* and *Corophium acherusicum,* with maxima exceeding 16 000 ind. m^{-2} (Station 5 in February 2004) and 84 000 ind. m^{-2} (Station 8 in February 2003 respectively (Figure 11). *C. acherusicum* was also the most abundant of all species on most occasions in the subtidal benthos (Appendix 3.3). *G. lutosa* was consistently more abundant at lower sites, while *C. acherusicum* occurred further upstream (Figure 12). The center of the population of both species occurred nearer the mouth during the wet season when numbers also tended to be lowest.

The sandprawn *Callianassa kraussi* was also relatively common in the lower estuary (Stations 5 - 7) in summer, attaining a maximum abundance 867 ind. m^{-2} and 972 ind. m^{-2} in February 2006 and February 2004 respectively.

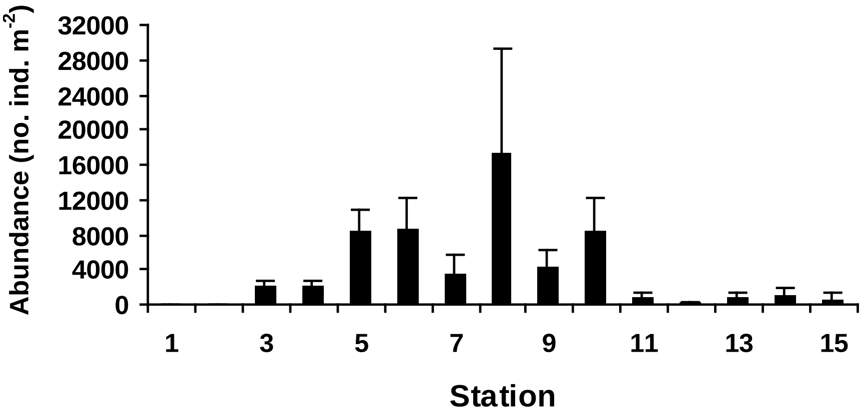

Figure 11. Distribution and abundance of amphipods in the Great Berg estuary. Data reflect mean values for seven series of data (collected February 2003 – February 2006) +1SE

3.4 CLASSIFICATION AND ORDINATION OF BIOTIC ASSEMBLAGES

3.4.1 Macrozooplankton

The zooplankton assemblage of tidal estuaries having full horizontal salinity gradients is grouped into three categories:

- a marine associated fauna (salinity values above ca 28),
- a freshwater-brackish community (salinity values <4) and
- a typical endemic estuarine fauna found at salinity values ranging between 4 and 28.

The marine-associated group is characterized by having a relatively large number of species. The typical estuarine assemblage has fewer species, but numbers of individuals within species tends to be very high compared to the marine group. Freshwater species are also high in number, although in the Great Berg estuary only the transitional fringe was sampled. Bray-Curtis similarity analysis using group average mode on square-root transformed data (Appendix 3.3) clearly showed distinct clusters of sites representing the three major groups noted above for the seven series of samples collected (Figure 12). Group linkages shown by the Bray-Curtis similarity matrix in Figure 13 is also closely reflected by non-metric multi-dimensional scaling (MDS) plots (Figure 14). Whereas similarity analysis provides the level of similarity (%) in the species assemblage between sites, the MDS plots group the sites as a 2-dimensional matrix. The relative distance between sites in an MDS plot is a reflection of the degree of similarity between them, based on the species assemblage. The further the distance between points, the greater the difference in the species assemblage between them. In the later method, low stress levels indicate a high degree of confidence in the relationships between groups (Clarke & Warwick 1994).

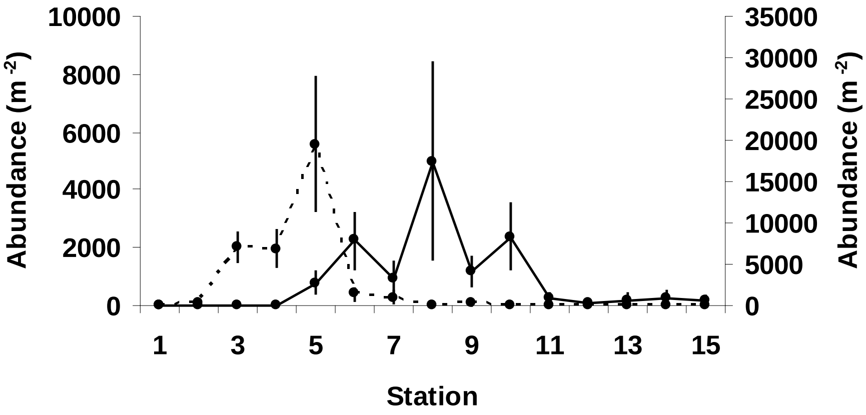

Figure 12. Distribution of the amphipods *Grandidierella lutosa* (dashed line, Y1 axis) and *Corophium acherusicum* (solid line, Y2 axis) at 15 subtidal stations in the Great Berg estuary. Data are mean values for the seven data series ± 1SE.

In Figure 13and Figure 14, the marine associated fauna sometimes extended up to Station 4, linked to the state of the tide and amount of freshwater runoff from the catchment into the estuary. Uppermost sites reflect the brackish water community that penetrates downstream in relation to the amount of freshwater runoff. The typical estuarine community extends over much of the estuary, particularly during summer when runoff is relatively low (extending to Station 15 in April 2005). Between these major groups, transitional communities exist, as indicated in Figure 13 and Figure 14.

Environmental variables (Appendices I - VII) were then linked to the biotic assemblages recorded for each trip (Appendices VIII – XIV) using the PRIMER package BIO-ENV to best explain linkages. Abiotic data is first analyzed on its own. The multivariate pattern is then compared to species data to identify the extent of matching patterns that reflect the degree to which environmental data 'explains' the biotic pattern for each set. A Draftsman Plot was first used to identify environmental variables that were highly correlated. For example, integrated salinity, surface salinity and bottom salinity were usually highly correlated leading to the exclusion of surface and bottom salinity readings from further analysis. A similar process of potential elimination was undertaken for other variables where multilevel readings were taken.

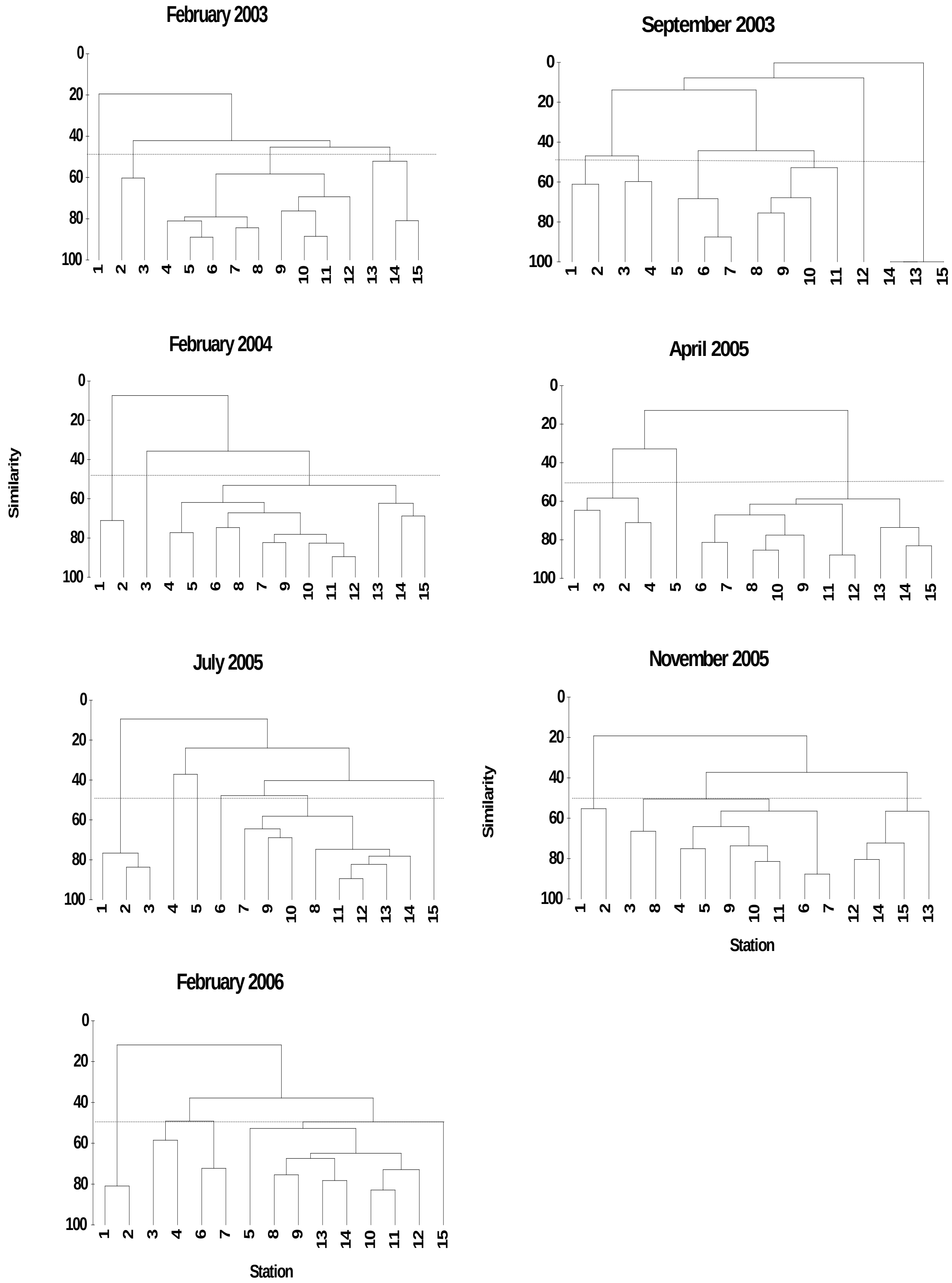

Figure 13. Dendrogram for Bray-Curtis similarity clustering of sites based on zooplankton composition and abundance. Data for seven series, collected between February 2003 and February 2006. The dotted line represents the arbitrary 50% cut-off used to delineate groups within the community.

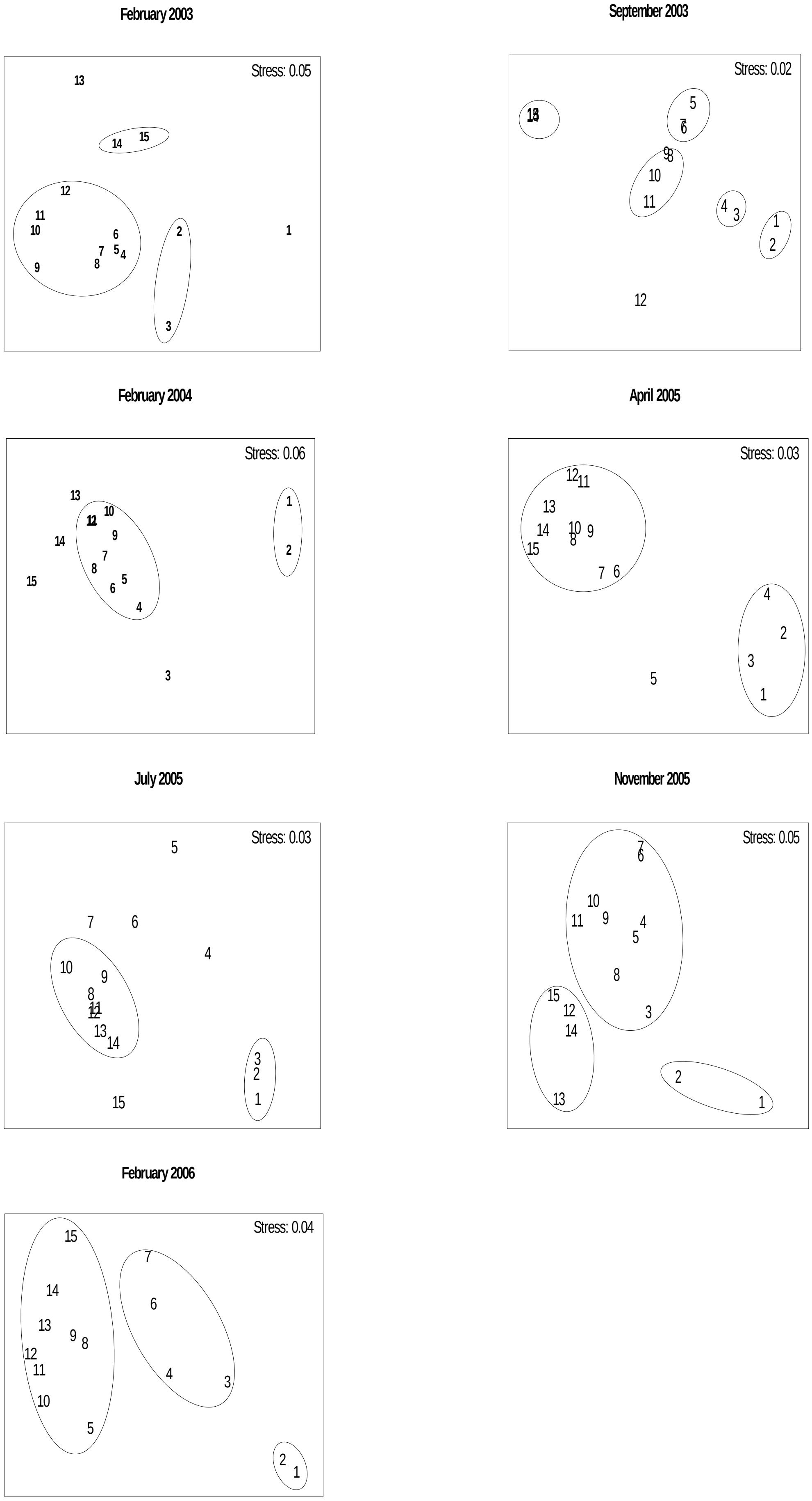

Figure 14. 2-dimentional MDS configuration of zooplankton community structure in the Great Berg estuary, based on the 50% cut-off similarity index shown in Fig 12.

Although up to five variables explained much of the correlation between environmental parameters measured and zooplankton community structure along the estuary (Table 6), salinity consistently emerged as the most important. The contribution of salinity as a factor explaining zooplankton distribution and structure ranged between 67 and 94.1%. Other variables identified usually explained <10% of the correlations as individual entities, although some were probably surrogates of variables not measured, e.g., sediment structure responds to water current velocity. In turn, estuarine zooplankton avoids strong currents in order to reduce being flushed from the estuary.

Table 5. Correlation between the zooplankton species assemblage and environmental variables for each of the seven sampling trips to the Great Berg estuary.

	Variables	**Correlation**	**Comments**
February 2003	Integrated salinity, sediment characteristics	94.2%	Integrated salinity on its own accounted for 80% of the correlation
September 2003	Integrated salinity	94.1%	Salinity highly correlated
February 2004	Integrated salinity, sediment characteristics	77.5%	Integrated salinity on its own accounted for 67.2% of the correlation
April 2005	Integrated salinity, integrated temp, NTU surface, NTU integrated, sediment characteristics	88.5%	Integrated salinity on its own accounted for 80% of the correlation.
July 2005	Integrated salinity, NTU surface, NTU bottom Ch-*a* integrated, % coarse sand	94.5%	Integrated salinity (71.5%), surface & bottom turbidity (15.4%) account for most of the correlation
November 2005	Integrated salinity, sediment organic matter	79.3%	Integrated salinity on its own accounted for 75.7% of the correlation
February 2006	Integrated salinity, NTU integrated, Ch-*a* integrated, sediment characteristics	93.7%	Integrated salinity on its own accounted for 81.1% of the correlation

SIMPER analysis identifies species that primarily account for the assemblage (*a posteriori*) within cluster groups that are typically estuarine or brackish in composition (refer to Figs. 12 & 13). An arbitrary cut-off level of <50% similarity is used to define the major groups. Tables 6 - 12 rank the species in order of numerical dominance up to a cut-off cumulative contribution of 90%. The marine group (lower stations nearer the mouth) is excluded from all comparisons. Typically, estuarine communities are dominated by relatively few species, but numbers are high and this is in contrast to the marine component where the number of species is relatively high, but abundance levels of any species are low (refer to Appendices VIII – XIV).

Table 6. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine and brackish water cluster groups shown for February 2003 in Figure 13 and Figure 14. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 4 – 12					
Pseudodiaptomus hessei	18295.67	28.02	9.35	44.27	44.27
Halicyclops sp.	2582.61	9.70	2.06	15.32	59.59
Acartia longipatella	2185.50	6.80	0.79	10.75	70.34
Gilchristella aerstuaria larvae	163.50	3.56	1.04	5.63	75.97
Rhopalphthalmus terranatalis	11.17	3.10	1.77	4.90	80.87
Corophium acherusicum	48.50	2.73	1.15	4.31	85.18
Mesopodopsis wooldridgei	33.22	2.13	1.12	3.37	88.55
Exosphaeroma hylocoetes	8.78	1.52	0.80	2.40	90.95
Average similarity between stations in the group: 63.29%					
Stations 13 – 15					
Pseudodiaptomus hessei	6599.17	40.93	4.87	58.68	58.68
Daphnia sp.	9740.17	16.50	5.35	23.66	82.34
Gilchristella aestuaria larvae	9.50	8.01	4.47	11.48	93.83
Average similarity between stations in the group: 69.75%					

Table 7. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine and brackish water cluster groups shown for September 2003 in Figure 13 and Figure 14. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 5 – 7					
Pseudodiaptomus hessei	16414.67	36.33	8.30	45.90	45.90
Exosphaeroma hylocoetes	71.67	9.48	7.74	11.98	57.88
Rhopalphthalmus terranatalis	56.67	7.46	4.88	9.42	67.30
Hymenosoma orbiculare	29.33	6.47	4.97	8.18	75.48
Mesopodopsis wooldridgei	6.33	5.59	11.67	7.06	82.54
Melita zeylanica	11.67	5.01	7.63	6.33	88.86
Halicyclops sp.	546.33	4.35	0.58	5.49	94.35
Average similarity between stations in the group: 79.15%					
Stations 8 – 11					
Pseudodiaptomus hessei	1495.75	35.60	13.09	63.10	63.10
Corophium acherusicum	8.00	4.25	3.88	7.54	70.64
Rhopalophthalmus terranatalis	59.50	3.28	0.41	5.82	76.45
Hymenosoma orbiculare	4.30	2.95	0.79	5.23	81.69
Halicyclops sp.	76.25	2.65	0.41	4.69	86.38
Chironomid larvae	0.65	2.37	0.90	4.20	90.58
Average similarity between stations in the group: 56.41%					
Stations 13 – 15					
Chironomid larvae	0.10	100.00		100.00	100.00
Average similarity between stations in the group: 100.00%					

Table 8. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine and brackish water cluster groups shown for February 2004 in Figure 13and Figure 14. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 4 – 12					
Pseudodiaptomus hessei	3290.11	28.38	7.90	44.99	44.90
Rhopalphthalmus terranatalis	64.67	7.01	1.48	11.10	56.09
Halicyclops sp.	109.11	6.15	1.11	9.74	65.84
Acartia longipatella	161.89	4.70	0.80	7.45	73.28
Exosphaeroma hylocoetes	5.89	4.04	1.67	6.40	79.68
Gilchristella aestuaria larvae	7.56	3.43	1.13	5.44	85.12
Mesopodopsis wooldridgei	2.78	2.01	0.83	3.19	88.31
Corophium acherusicum	13.89	1.82	0.57	2.88	91.20
Average similarity between stations in the group: 63.09%					
Stations 13 – 15					
Pseudodiaptomus hessei	1520.00	28.77	21.76	42.55	42.55
Halicyclops sp.	128.33	16.47	22.68	24.36	66.92
Chironomid larvae	10.00	7.19	13.64	10.63	77.55
Daphnia sp.	144.33	6.17	0.58	9.13	86.68
Other insect larvae	13.67	5.84	13.84	8.64	95.32
Average similarity between stations in the group: 67.60%					

Table 9. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine cluster group shown for April 2005 in Figure 13 and Figure 14. The brackish water community was not represented on this occasion. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 6 – 15					
Pseudodiaptomus hessei	3880.80	32.47	5.60	56.37	56.37
Rhopalphthalmus terranatalis	71.10	4.75	0.99	8.24	64.62
Melita zeylanica	8.00	4.52	1.8	7.84	72.45
Corophium acherusicum	10.30	4.23	1.16	7.34	79.80
Exosphaeroma hylocoetes	10.90	3.19	0.91	5.53	85.33
Hymenosoma orbiculare larvae	25.90	2.18	0.69	3.78	89.11
Uromunna sheltoni.	32.50	1.74	0.47	3.03	92.13
Average similarity between stations in the group: 57.60%					

Table 10. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine cluster group shown for July 2005 in Figure 13and Figure 14. The brackish water community was only present at one station and it was therefore not possible to perform a SIMPER analysis. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 7 – 14					
Pseudodiaptomus hessei	176.25	26.76	7.17	37.58	37.58
Halicyclops sp.	23.88	15.50	4.52	21.77	59.35
Corophium acherusicum	4.50	10.30	11.86	14.46	73.81
Copepod sp.	50.63	9.49	1.04	13.33	87.14
Melita zeylanica	1.33	4.02	0.93	5.65	92.79
Average similarity between stations in the group: 71.20%					

Table 11. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine and brackish water cluster groups shown for November 2005 in Figs. 12 and 13. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 4 – 7, 9 - 11					
Pseudodiaptomus hessei	21327.43	25.52	7.09	38.54	38.54
Acartia longipatella	2176.29	6.82	0.92	10.30	48.84
Gastropod spat	3858.71	6.49	0.92	9.80	58.64
Gobiid larvae	14.14	4.45	6.13	6,72	65.36
Gilchristella aestuaria larvae	32.29	3.48	1.45	5.26	70.62
Gilchristella aestuaria eggs	39.42	3.00	1.36	4.53	75.15
Melita zeylanica	11.57	2.83	1.51	4.27	79.42
Corophium acherusicum	8.29	2.71	1.47	4.09	83.51
Rhopalphthalmus terranatalis	8.86	1.95	0.90	2.95	86.46
Exosphaeroma hylocoetes	11.29	1.90	0.90	2.87	89.33
Mesopodopsis wooldridgei	7.57	1.70	0.90	2.57	91.89
Average similarity between stations in the group: 66.22%					
Stations 12 – 15					
Pseudodiaptomus hessei	2268.00	32.02	7.06	44.76	44.76
Halicyclops sp.	107.25	13.76	7.22	19.24	63.99
Chironomid larvae	4.75	7.50	8.84	10.48	74.47
Other insect larvae	4.75	7.48	10.60	10.46	84.93
Corophium acherusicum	8.00	7.37	6.71	10.30	95.25
Average similarity between stations in the group: 71.54%					

Table 12. SIMPER analysis of the numerically dominant zooplankton species (ranked) in the estuarine cluster group shown for February 2006 in Figure 13and Figure 14. The brackish water community was not represented on this occasion. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 8 – 15					
Pseudodiaptomus hessei	2939.78	29.21	9.56	51.70	51.70
Halicyclops sp.	140.33	10.01	1.65	17.72	69.42
Rhopalphthalmus terranatalis	58.78	4.72	0.92	8.35	77.77
Corophium acherusicum	35.89	3.63	0.81	6.43	84.20
Gilchristella aestuaria larvae	8.00	2.78	0.83	4.91	89.11
Exosphaeroma hylocoetes	3.56	1.50	0.60	2.65	91.76
Average similarity between stations in the group: 56.49%					

3.4.2 Hyperbenthos

Bray-Curtis similarity analysis on the hyperbenthos (Appendix 3.3) using group average mode on square-root transformed data showed at least seven clusters at the 50% cut-off level (Figure 15), reflecting a high degree of dissimilarity between site groupings on all sampling occasions. At lower resolution (20 -40% similarity level), the three broad categories (marine, estuarine and a brackish water community) were identified, but variability within these broad groups was also high between sampling sessions. High variability in community composition and structure is also reflected in the irregular pattern shown by station sequence along the X-axis on all occasions. This may in part also reflect the presence of few species at many sites. MDS plots performed on the data further emphasized the absence of any distinct pattern (Figure 16). Consequently, no further data analysis is performed on the data.

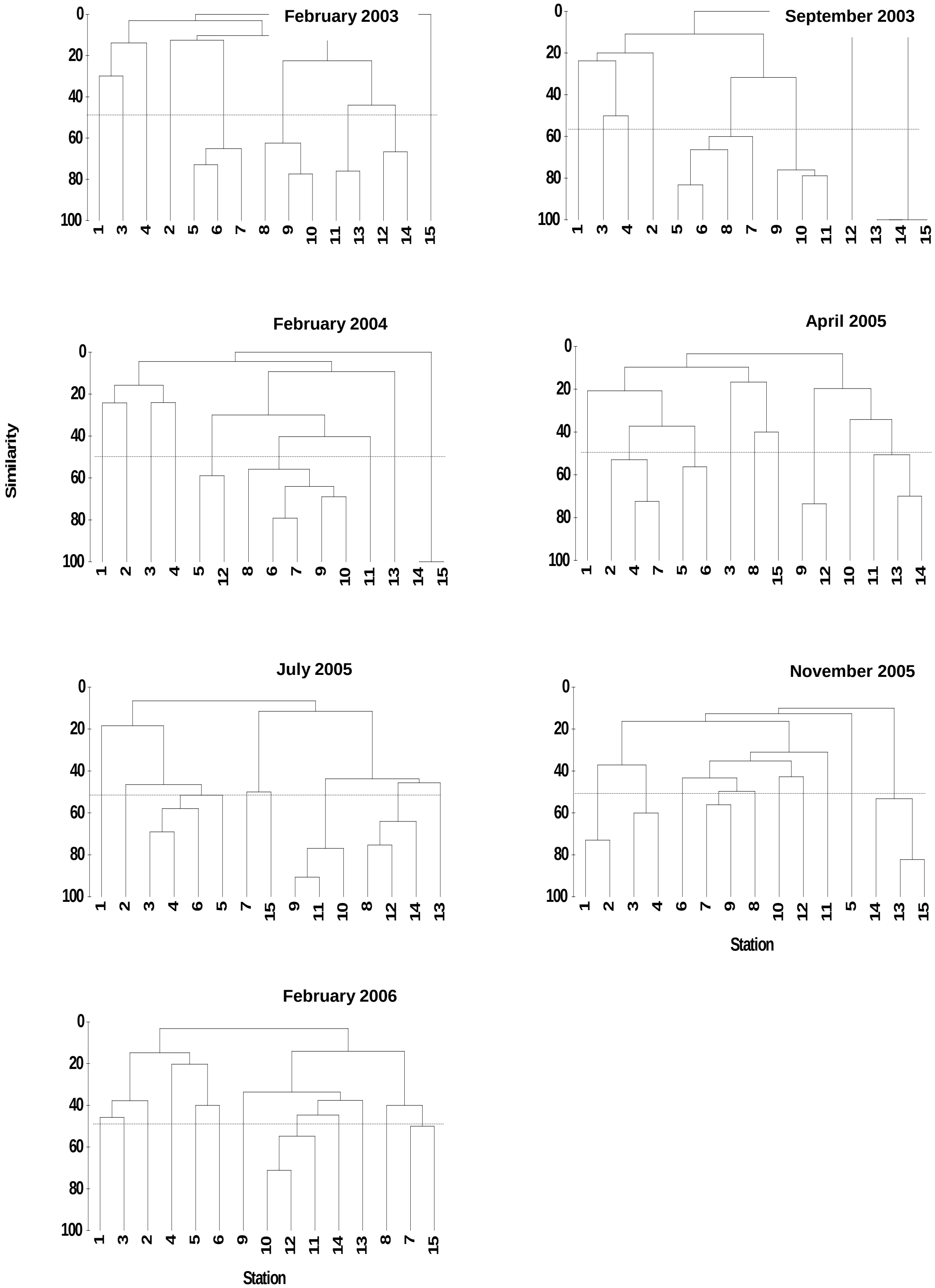

Figure 15. Dendrogram for Bray-Curtis similarity clustering of sites based on hyperbenthos composition and abundance. Data for seven series, collected between February 2003 and February 2006. The dotted line represents the arbitrary 50% cut-off used to delineate groups within the community.

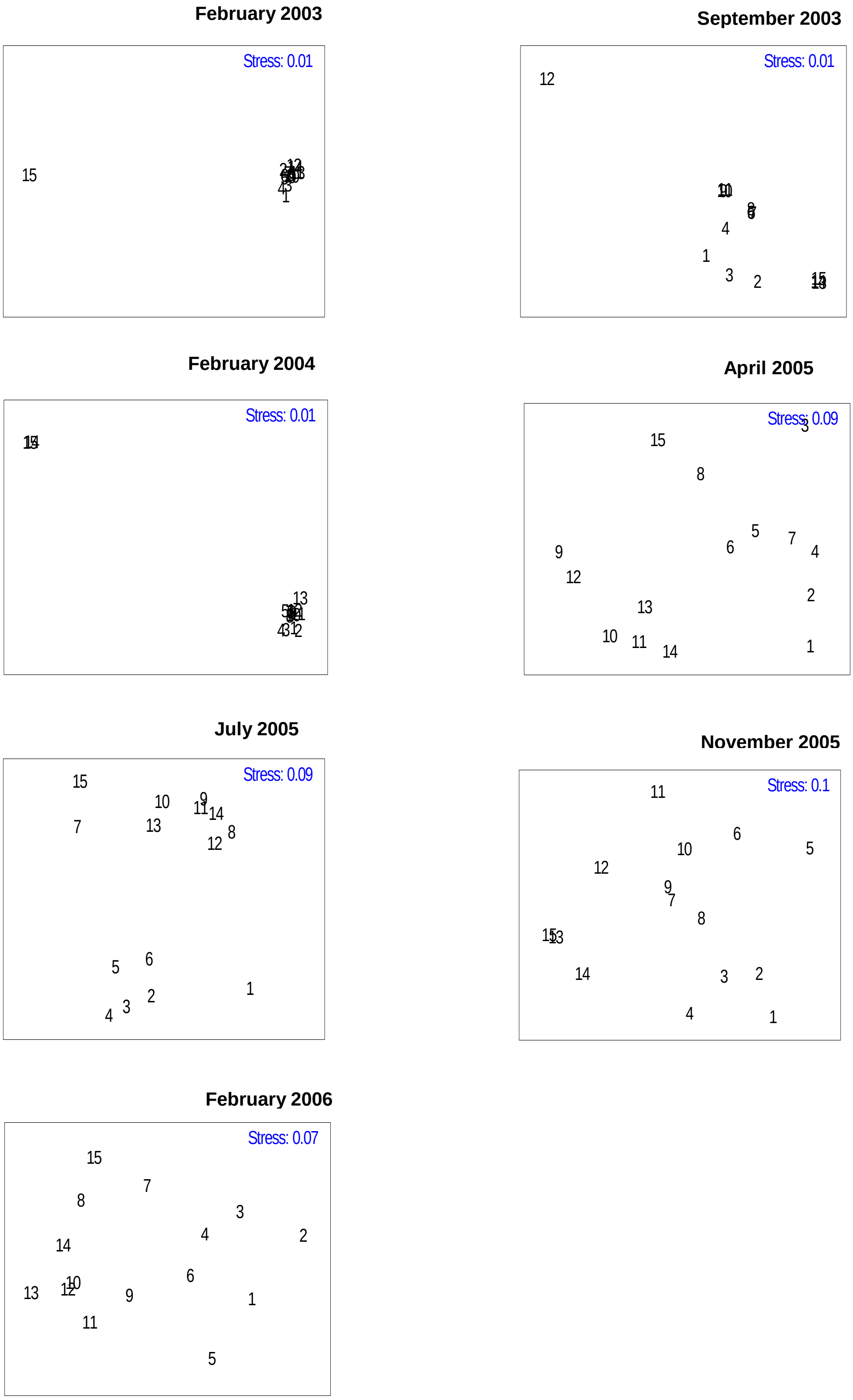

Figure 16. 2-dimentional MDS configuration of hyperbenthic community structure in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006.

3.4.3 Subtidal benthos

Bray-Curtis similarity analysis on the subtidal macrobenthos (Appendix 3.4) using group average mode on square-root transformed data exposed between four (September 2003) and 10 clusters (July 2005) at the 50% cut-off level (Figure 17), reflecting a high degree of dissimilarity between site groupings on most sampling occasions. At lower resolution (20 -40% similarity level), the three broad categories (marine, estuarine and a brackish water community) were identified, but variability within these broad groups was moderately high between sampling sessions. Composition of the community consistently showed a major change upstream of Stations 9 - 11, with <20% similarity to downstream stations. These upper sites represent a brackish water community that also reflected fewer species. MDS plots performed on the data further emphasized the high degree of variability between sites and sampling trips (Figure 18).

Environmental variables (Appendix 3.1) were then linked to the subtidal benthic assemblages recorded for each trip (Appendix 3.4) using the PRIMER package BIO-ENV to best explain linkages. A Draftsman Plot was first used to identify environmental variables that were highly correlated. For example, integrated salinity, surface salinity and bottom salinity were usually highly correlated leading to the exclusion of surface and bottom salinity readings from further analysis. A similar process of potential elimination was undertaken for other variables where multilevel readings were taken.

Although up to three variables explained much of the correlation between environmental parameters measured and the subtidal benthic community composition and structure along the estuary (Table 13), salinity emerged as the most important on most occasions. However, salinity did not show any correlation with the biotic community at times of high river flow (September 2003 and July 2005, Fig. 2). In July 2005, Ch-*a* emerged as an important factor that explained the correlation. No chlorophyll data are available for the initial three sampling trips. Highest correlation between salinity distribution and the community occurred during summer (February 2003, February 2004 and February 2006, exceeding 70% on all three occasions.

SIMPER analysis identifies species that primarily account for the assemblage (*a posteriori*) within cluster groups that are typically estuarine or brackish in composition (refer to Figure 17). An arbitrary cut-off level of <50% similarity is used to define the major groups as indicated in the figure. Table 14-Table 20 rank the species in order of numerical dominance up to a cut-off cumulative contribution of 90%. The marine group associated with stations nearer the mouth usually had a similarity level of <50% between sites due to the rapid transition from marine to a typically estuarine community. These lower sites are excluded from all comparisons. Typically, estuarine communities are dominated by relatively few species compared to the marine component, although abundance levels of individual species are relatively high (refer to Appendix 3.4).

In general, the typical estuarine community supported more species up to a 90% cumulative cut-off level (ca 6 -8 species) compared to the brackish water community (ca 2 -3 species). An increase in salinity at uppermost sites (Figure 2, April 2005 and February 2006) during the dry months led to an increase in the number of euhaline species, with a concomitant decrease in the brackish water assemblage.

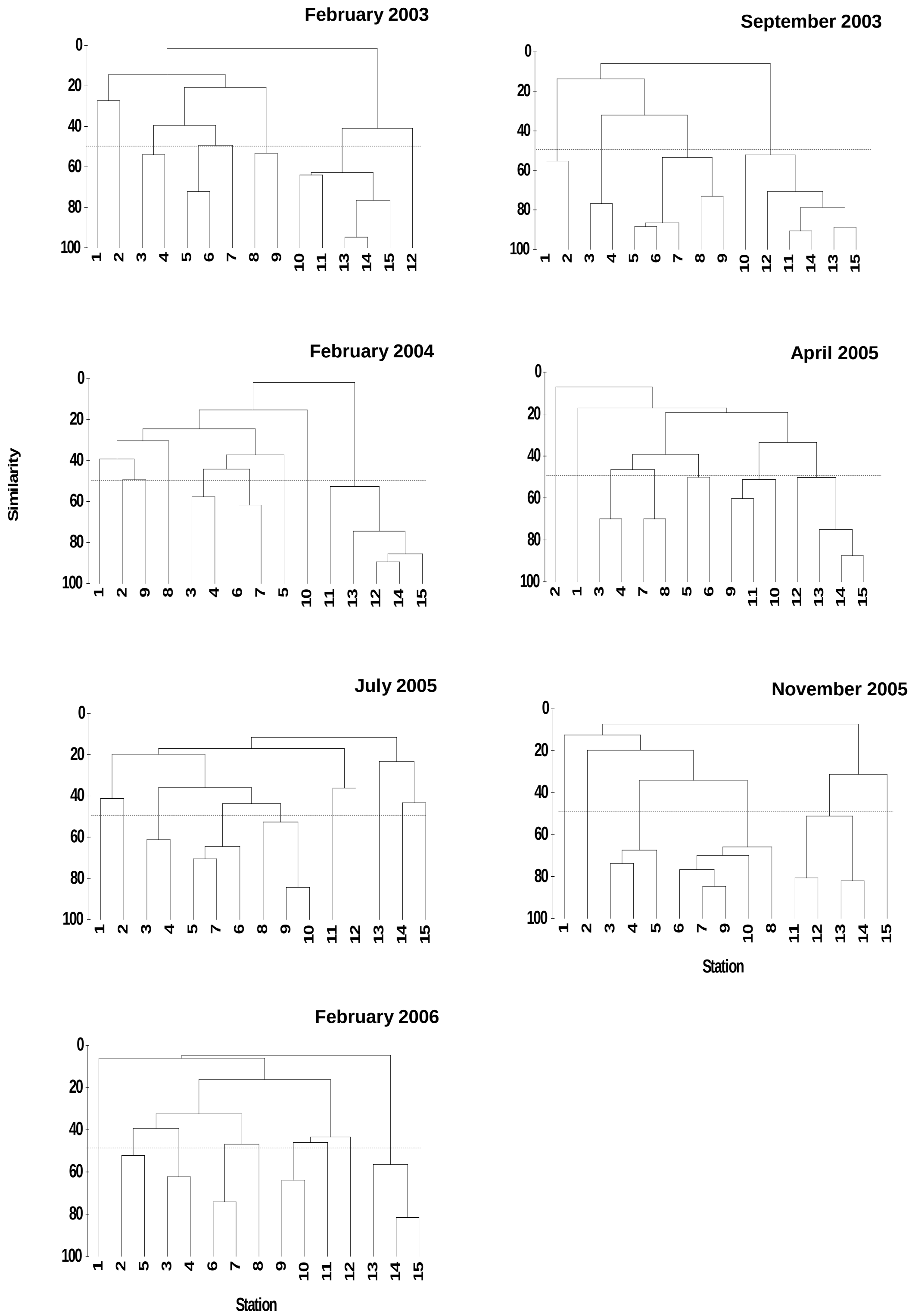

Figure 17. Dendrogram for Bray-Curtis similarity clustering of sites based on subtidal benthic composition and abundance. Data for seven series, collected between February 2003 and February 2006. The dotted line represents the arbitrary 50% cut-off used to delineate groups within the community.

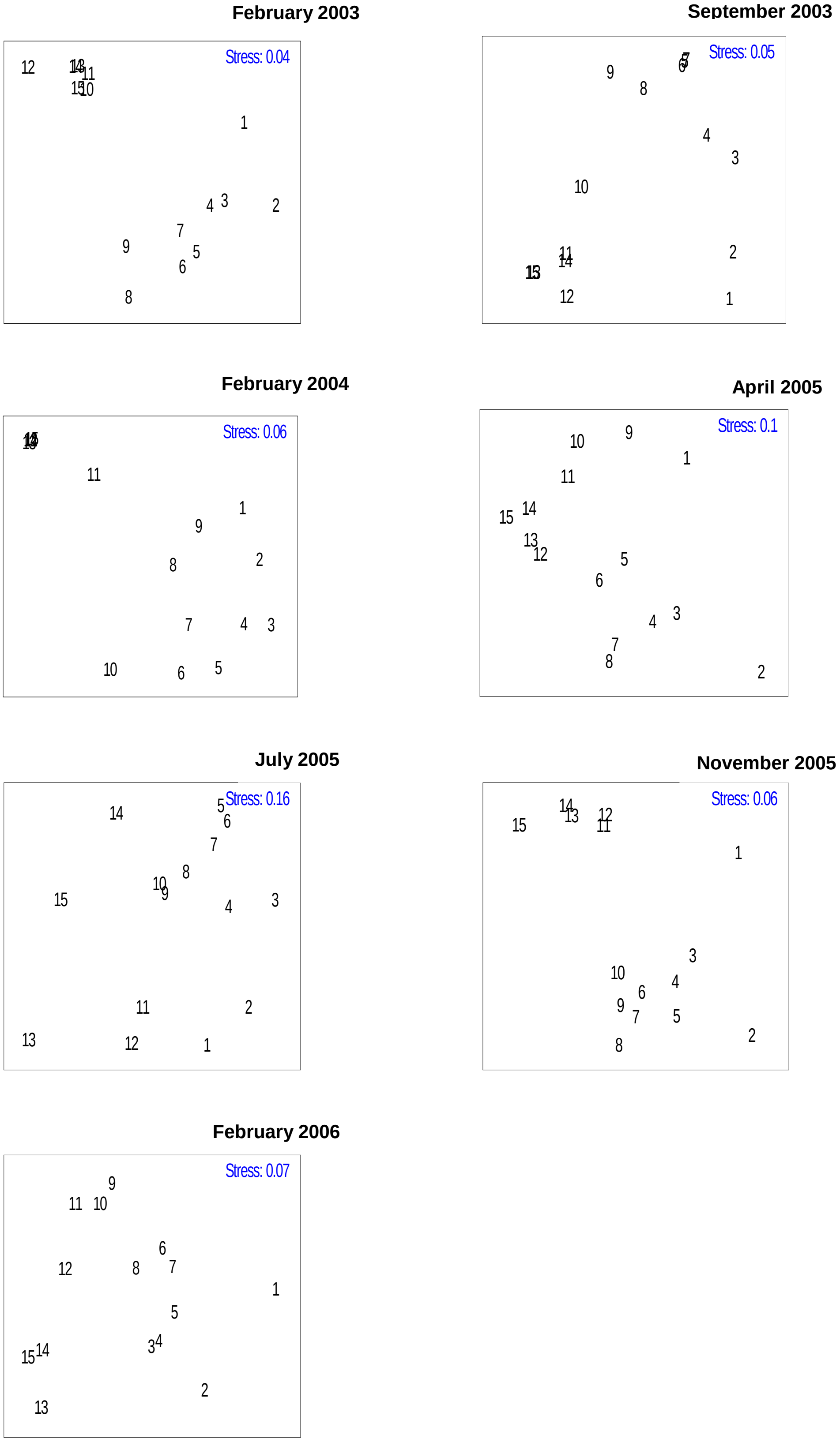

Figure 18. 2-dimentional MDS configuration of subtidal benthic community structure in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006.

Table 13. Correlation between the subtidal benthic species assemblage and environmental variables for each of the seven sampling trips to the Great Berg estuary.

	Variables	Correlation	Comments
February 2003	Integrated salinity	70.8%	Integrated temperature, percentage sand, and salinity correlates at the 69.8% level.
September 2003	Integrated temperature, Integrated O2 saturation	72.0%	Correlation with salinity relatively low (<40%).
February 2004	Integrated salinity	80.2%	Correlation with salinity high
April 2005	Integrated salinity, Integrated temperature, Integrated O_2 (mg/l),	71.2%	Salinity on its own correlates at the 55.1% level. Salinity, temperature, oxygen and coarse sand correlate at the70.7% level
July 2005	Integrated Ch-*a*, Integrated temperature Sediment (percentage coarse sand and mud)	69.2%	Integrated Ch-*a* on its own accounts for 56.3% of the correlation
November 2005	Integrated salinity, Integrated pH	75.0%	Integrated salinity on its own accounted for 68.7% of the correlation
February 2006	Integrated salinity, Integrated temperature, Integrated NTU	80.7%	Integrated salinity on its own accounted for 74.8% of the correlation

Table 14. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for February 2003 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	**Av. Abund.**	**Av. Sim.**	**Sim/SD**	**Contrib%**	**Cum %**
Stations 5 – 9					
Corophium acherusicum	16152.17	12.92	1.81	33.96	33.96
Ceratonereis keiskama	345.83	7.43	1.31	19.52	53.49
Anthurid sp.	330.56	4.93	1.14	12.96	66.45
Desdemona ornata	2397.22	4.13	0.73	10.87	77.31
Boccardia sp.	98.61	2.76	0.78	7.27	84.58
Melita zeylanica	12.50	1.92	0.78	5.05	89.64
Callianassa kraussi	187.50	1.37	0.47	3.61	93.24
Average similarity between stations in the group: 38.03%					
Stations 11 – 14					
Oligochaete sp.	148.44	46.79	7.73	70.91	70.91
Chironomid larvae	50.52	19.20	0.87	29.09	100.00
Average similarity between stations in the group: 69.75%					

In general, a similar species assemblage dominated the euhaline and brackish water communities on all sampling occasions. The crustaceans *Corophium acherusicum, Grandidierella lutosa* and *Apseudes digitalis* were on average the most important contributors to the euhaline assemblage during low and high river runoff periods, contributing on average 48% and 43% respectively. The polychaete worms *Ceratonereis keiskama*, *Boccardia* sp and *Desdemona ornata* contributed on average about 29-30% to total abundance during high and low runoff periods (Table 14-Table 20). The brackish water community when present in samples was represented by Chironomid larvae and polychaete worms

Table 15. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for September 2003 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	**Av. Abund.**	**Av. Sim.**	**Sim/SD**	**Contrib%**	**Cum %**
Stations 5 – 8					
Corophium acherusicum	7014.93	21.77	18.43	27.58	27.58
Ceratonereis keiskama	575.17	11.81	7.42	14.96	42.54
Anthurid sp.	1681.60	10.80	2.50	13.68	56.22
Desdemona ornata	1342.53	9.90	2.71	12.54	68.76
Boccardia sp.	238.02	6.83	5.57	8.66	77.42
Prionospio bocki	144.44	6.38	5.01	8.09	85.51
Chironomid larvae	23.78	4.22	3.83	5.34	90.85
Average similarity between stations in the group: 78.93%					
Stations 13 – 15					
Chironomid larvae	303.70	75.04	10.35	100.00	100.00
Average similarity between stations in the group: 75.04%					

Table 16. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for February 2004 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	**Av. Abund.**	**Av. Sim.**	**Sim/SD**	**Contrib%**	**Cum %**
Stations 4 – 12					
Ceratonereis keiskama	1244.74	11.81	1.27	38.39	38.39
Desdemona ornata	1798.61	3.92	0.56	12.72	51.11
Corophium acherusicum	2805.95	3.78	0.89	12.25	63.36
Anthurid sp.	1187.30	2.94	0.55	9.52	72.89
Boccardia sp.	1006.65	2.44	0.59	7.90	80.79
Capitella capitata	1254.66	1.98	0.37	6.41	87.19
Grandidierella lutosa	2356.45	1.06	0.39	3.44	90.63
Average similarity between stations in the group: 30.83%					
Stations 14 – 15					
Oligochaete sp.	94.44	60.97	-	65.50	65.50
Chironomid larvae	8.33	32.11	-	34.50	100.00
Average similarity between stations in the group: 93.08%					

Table 17. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for April 2005 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	**Av. Abund.**	**Av. Sim.**	**Sim/SD**	**Contrib%**	**Cum %**
Stations 2, 4 – 7					
Anthurid sp.	2227.78	9.39	1.11	21.23	21.23
Grandidierella lutosa	2551.12	7.63	2.43	17.26	38.49
Corophium acherusicum	4907.78	5.17	0.99	11.70	50.19
Callianassa kraussi	88.89	5.08	1.04	11.48	61.67
Ceratonereis keiskama	291.11	4.35	1.07	9.85	71.52
Prionospio sexoculata	215.56	3.60	1.09	8.15	79.67
Exosphaeroma hylocoetes.	121.11	3.48	1.14	7.87	87.54
Desdemona ornata.	158.89	1.36	0.59	3.08	90.62
Average similarity between stations in the group: 44.22% up to here					
Stations 11, 13 – 14					
Corophium acherusicum	4566.67	28.99	8.05	44.81	44.81
Oligochaete sp.	731.48	16.22	9.30	25.07	69.88
Chironomid larvae	588.89	6.85	0.58	10.59	80.47
Ceratonereis keiskama	1350.00	5.55	0.58	8.57	89.04
Capitella capitata	718.52	4.74	o.58	7.33	96.37
Average similarity between stations in the group: 64.70%					

Table 18. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for July 2005 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	**Av. Abund.**	**Av. Sim.**	**Sim/SD**	**Contrib %**	**Cum %**
Stations 3 – 6					
Grandidierella lutosa	1748.61	11.26	3.34	23.93	23.93
Anthurid sp.	1611.11	9.19	3.47	19.53	43.46
Prionospio sexoculata	*313.89*	*7.32*	*2.14*	*15.56*	*59.01*
Desdemona ornata	*1697.22*	*7.32*	*2.91*	*15.56*	*74.57*
Corophium acherusicum	7002.78	5.54	0.59	11.77	86.34
Ceratonereis keiskama	144.44	2.82	1.58	5.99	92.33
Average similarity between stations in the group: 47.05%					
Stations 8, 12 & 14					
Corophium acherusicum	8.7.41	13.57	0.58	56.99	56.99
Ceratonereis keiskama	277.78	6.84	0.58	28.74	85.74
Oligochaete sp.	5.56	2.42	0.58	10.18	95.92
Average similarity between stations in the group: 23.80%					

Table 19. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine and brackish water cluster groups shown for November 2005 in Figure 17. Groups represent sites >50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund.	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 3 – 6					
Corophium acherusicum	18570.14	21.07	16.29	27.80	27.80
Anthurid sp.	3259.95	14.19	22.23	18.72	46.52
Desdemona ornata	*13.77.78*	*10.81*	*13.84*	*14.26*	*60.78*
Grandidierella lutosa	222.92	6.96	16.43	9.18	69.97
Ceratonereis keiskama	147.45	6.57	16.94	8.67	78.64
Hymenosoma orbiculare	*149.31*	*5.84*	*4.33*	*7.71*	*86.35*
Boccardia sp.	235.19	2.76	0.58	3.64	89.98
Prionospio bocki	149.07	2.12	0.58	2.80	92.78
Average similarity between stations in the group: 75.78%					
Stations 13 - 15					
Chironomid larvae	564.81	35.11	2.96	55.98	55.98
Oligochaete sp.	237.04	27.61	7.08	44.02	100.00
Average similarity between stations in the group: 62.72%					

Table 20. SIMPER analysis of the numerically dominant subtidal benthic species (ranked) in the estuarine cluster group shown for February 2006 in Figure 17. The group represents sites >50% similarity. Except for sites 7 and 15, no other clusters exceeded 50% similarity. Columns represent average numerical abundance within a cluster, average similarity between sites, Similarity Standard deviation, Contribution of each species to total numerical abundance and the cumulative contribution (up to the 90% cut-off value).

Species	Av. Abund	Av. Sim.	Sim/SD	Contrib%	Cum %
Stations 3 – 6					
Corophium acherusicum	1514.81	34.21	5.53	61.12	61.12
Ceratonereis keiskama	87.04	13.62	1.88	24.33	85.46
Capitella capitata	*524.07*	*8.14*	*0.58*	*14.54*	*100.00*
Average similarity between stations in the group: 55.97%					

3.4.3.1 Diversity measures

Three diversity indices were measured: Total number of individuals (N), Margalef's species richness (d) and Pielou's evenness index. The maximum number of individuals in the zooplankton was generally recorded in the middle estuary and was linked to the distribution of *Pseudodiaptomus hessei*, although peak in abundance shifted downstream at times of strong freshwater inflow (e.g. September 2003 and July 2005, Figure 19). When abundance of *P. hessei* was relatively low, patterns were mostly associated with species in the high salinity lower estuary (e.g. *Acartia longipatella* and *Paracalanus* sp., Appendix 3.2). Species richness was generally maximal in the lower estuary (Figure 20), while Pielou's eveness index (

Figure 21) peaked in the lower and upper estuary where no species dominated the community in terms of abundance.

No diversity trends were apparent for the hyperbenthos and no diversity plots are provided for this group.

Diversity indices for the subtidal benthic community followed similar patterns (

Figure 22 & Figure 23), except for Pielou's eveness index (Figure 24) that reflected a variable pattern. This was probably linked to the variable ranking of the amphipods (*Grandidierella lutosa* and *Corophium acherusicum*), polychaete worms (*Ceratonereis keiskama* and *Desdemona ornata*) and the species of anthurid isopod that dominate different reaches of the estuary (Table 14-Table 20).

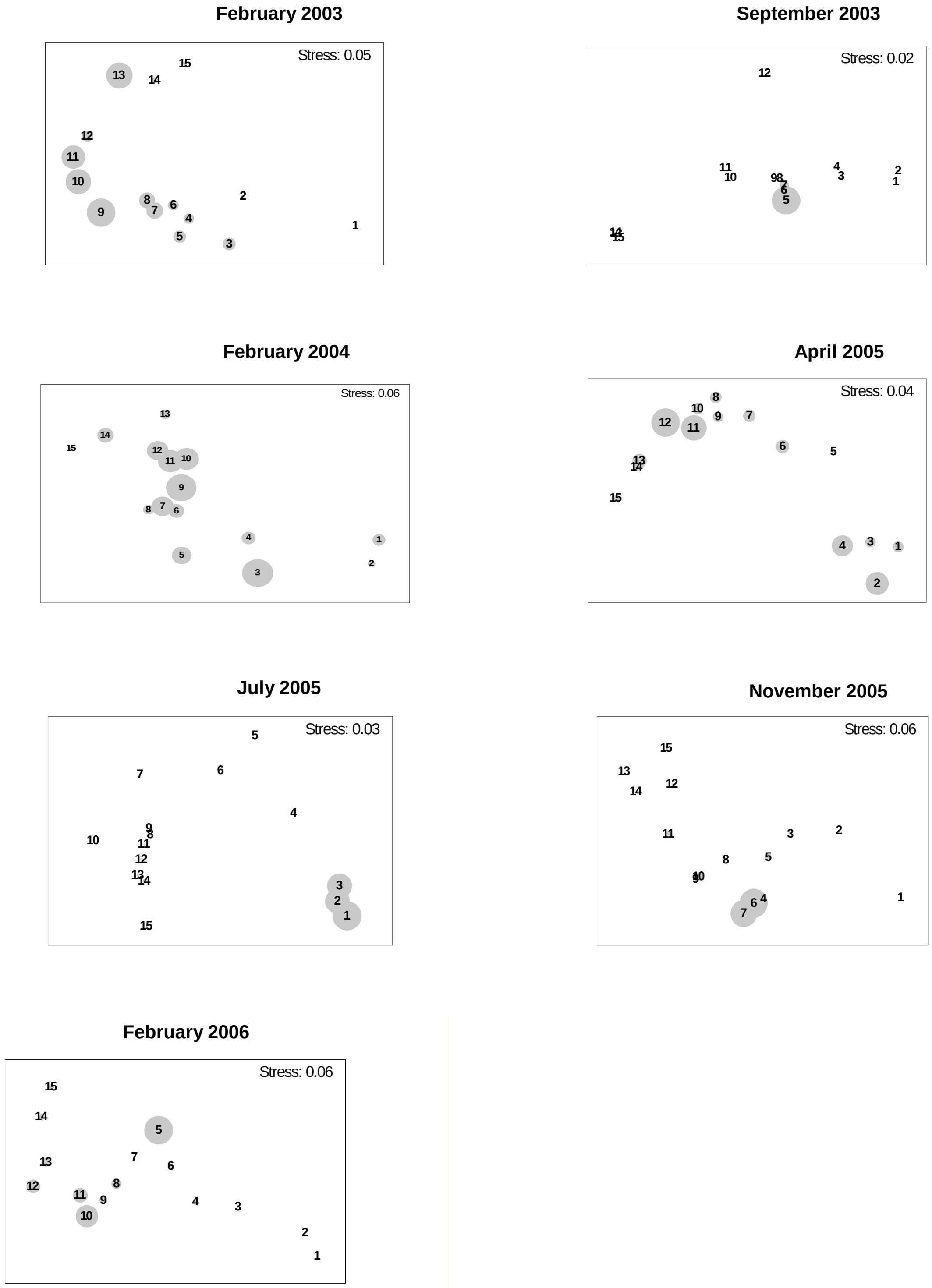

Figure 19. Total number of individuals of all species (N) for the zooplankton at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

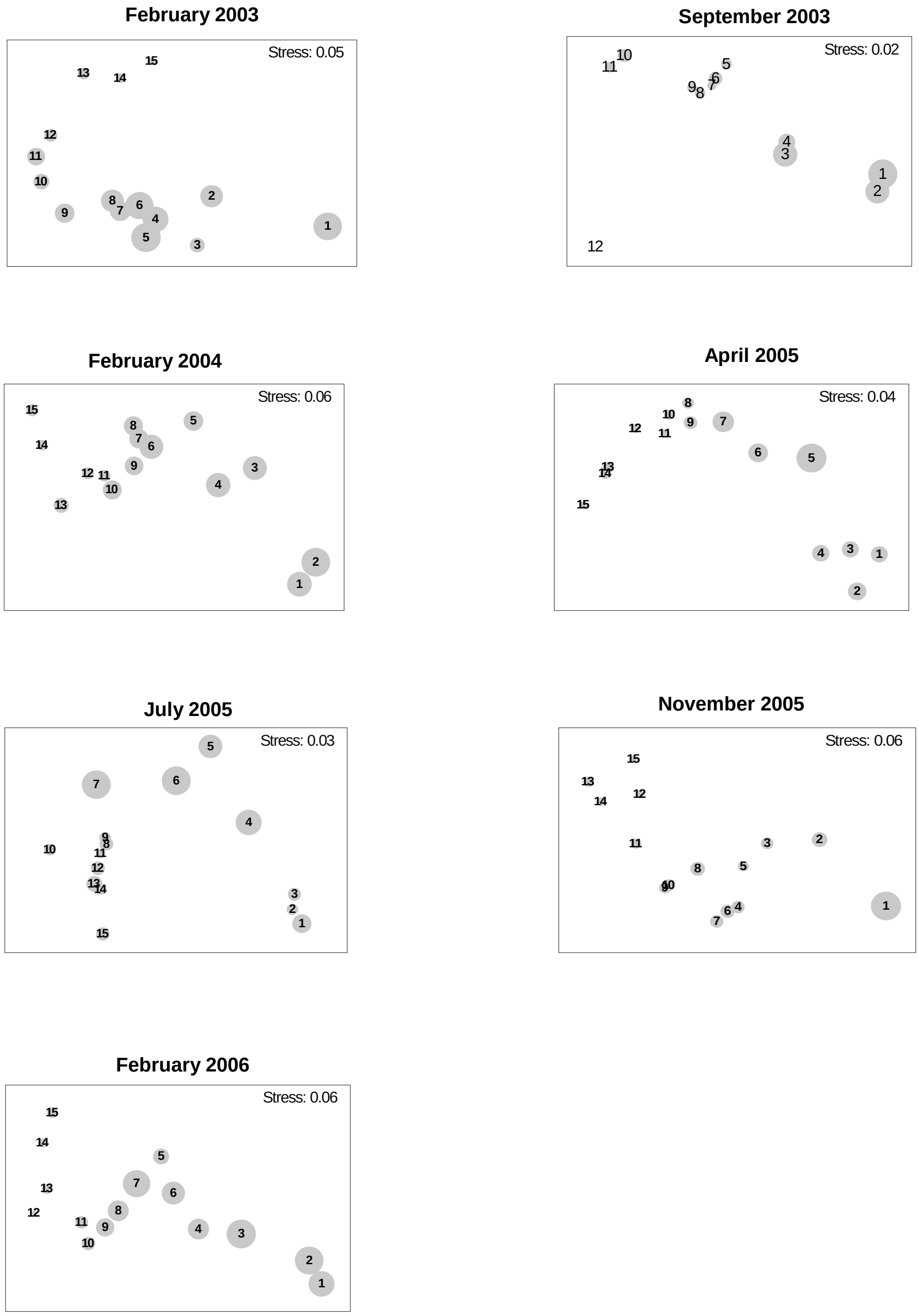

Figure 20. Margalef's index (d) of species richness for the zooplankton at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

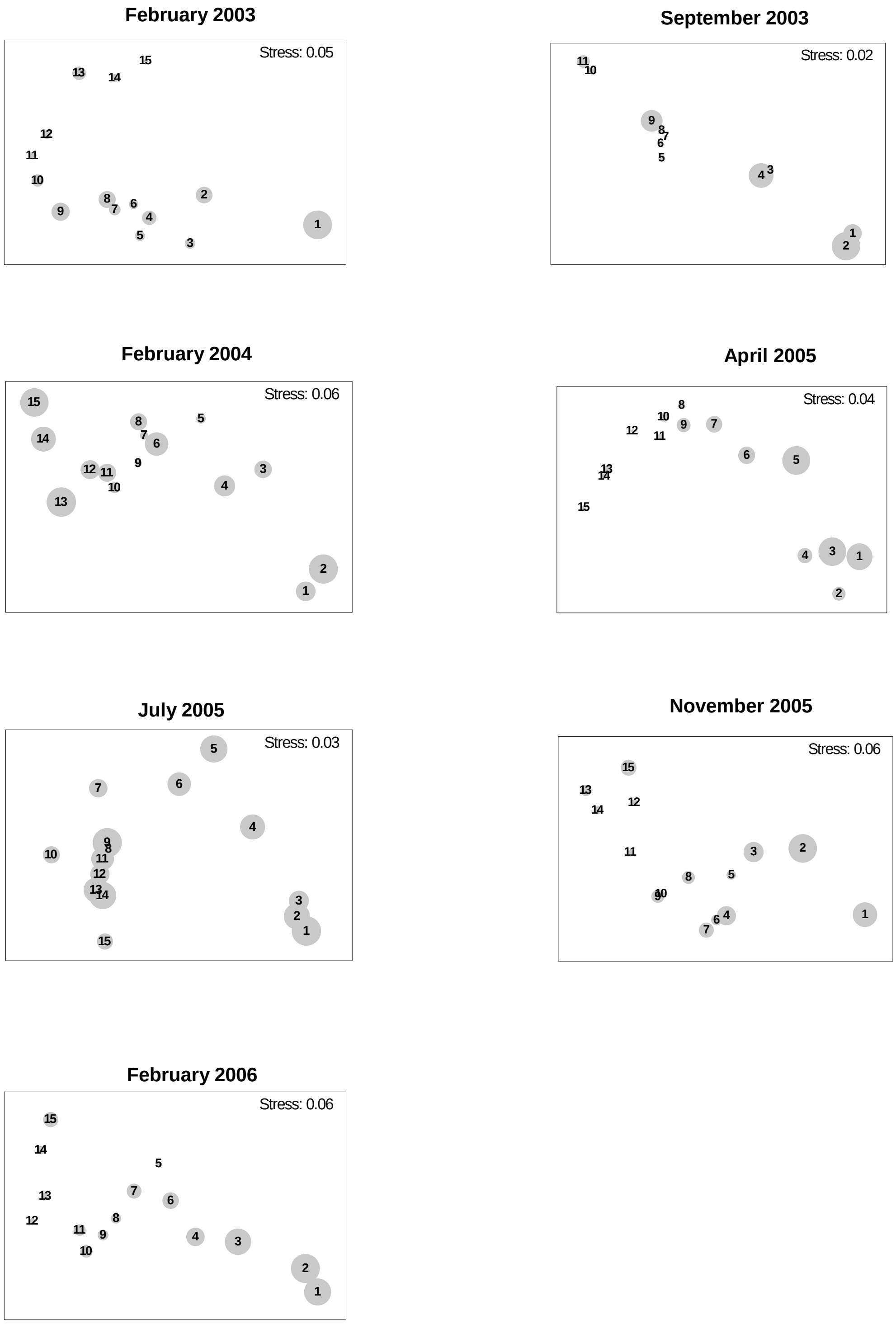

Figure 21. Pielou's eveness index (J') for the zooplankton at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

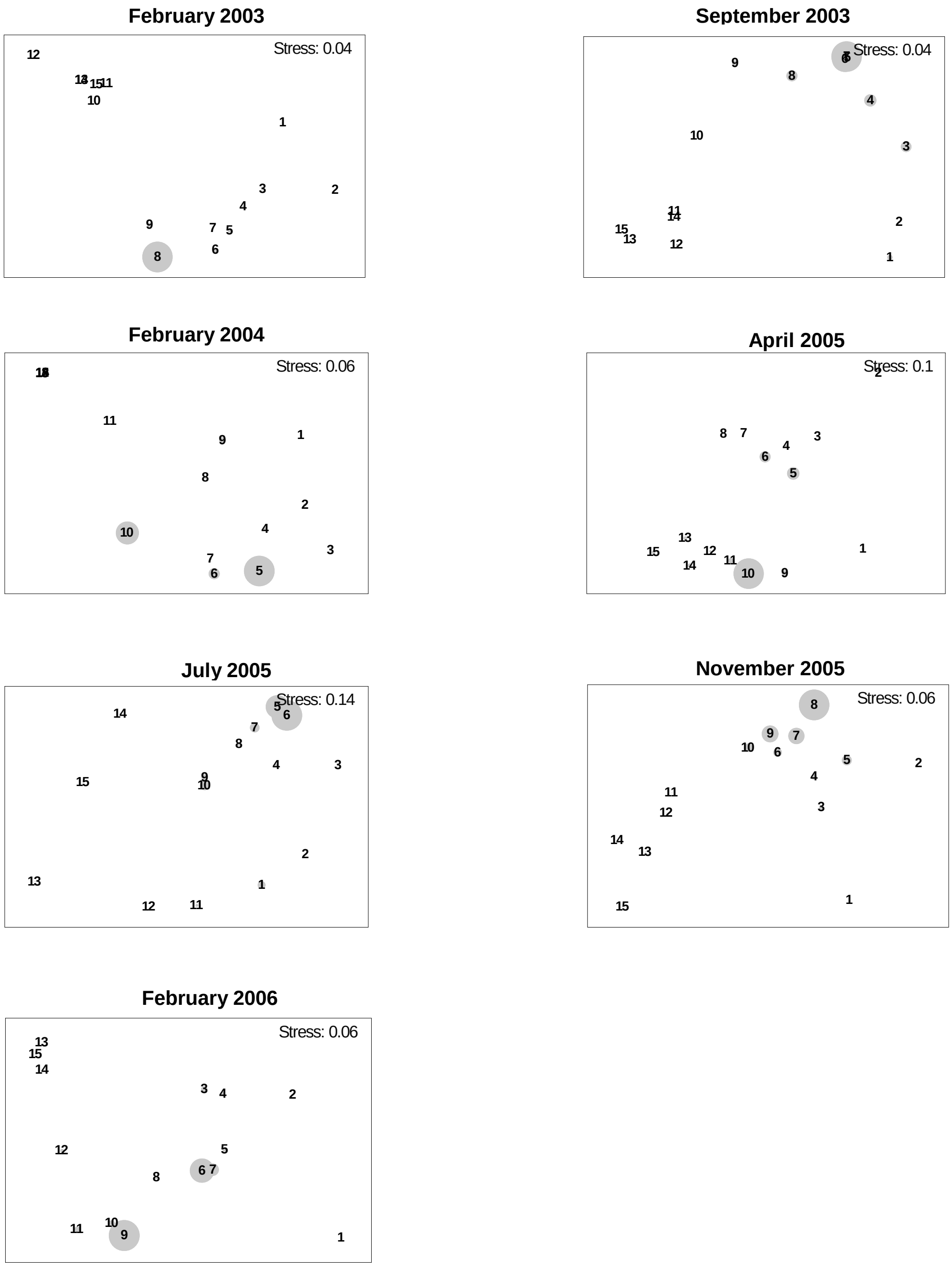

Figure 22. Total number of individuals of all species (N) for the subtidal benthos at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

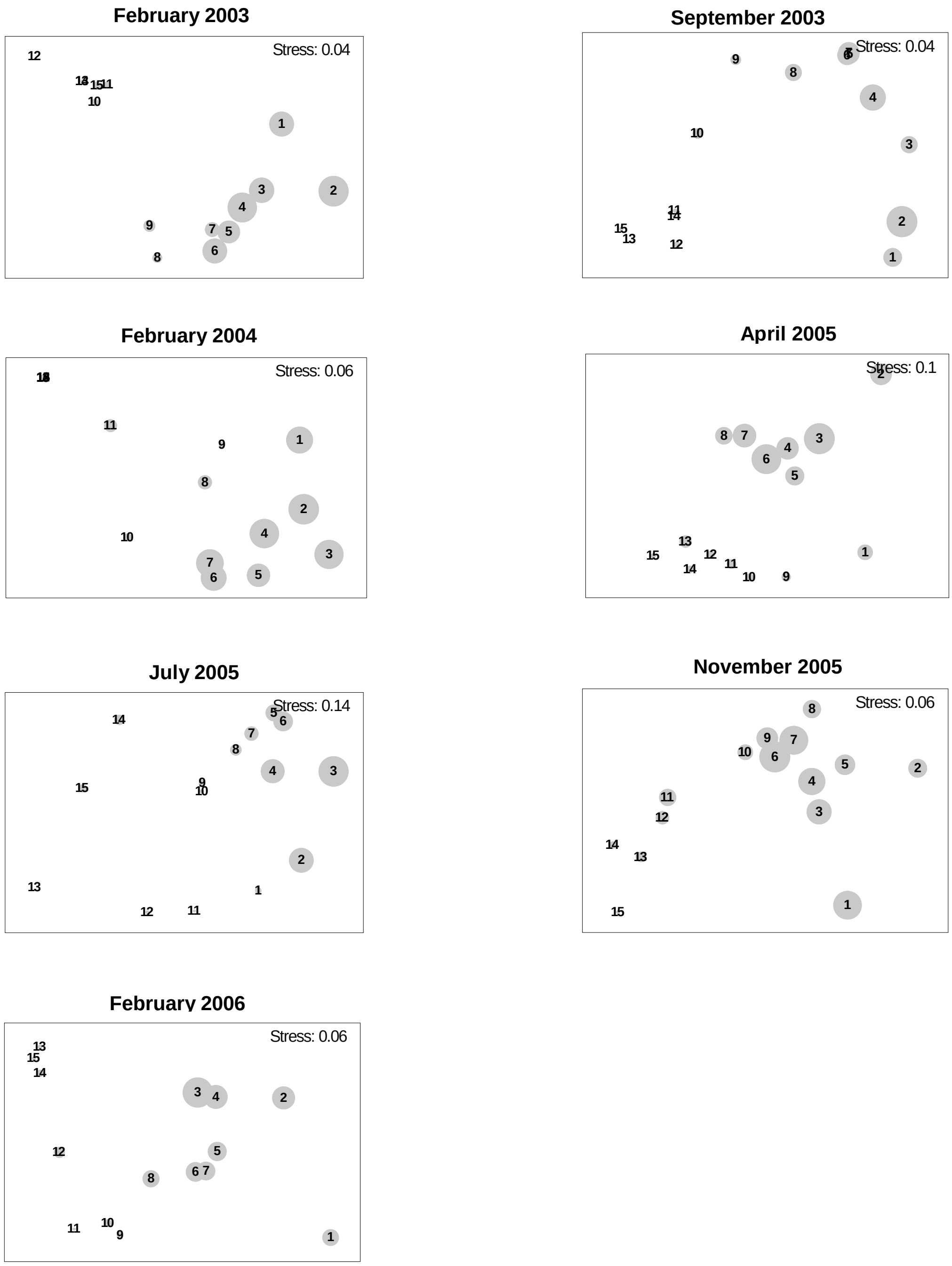

Figure 23. Margalef's index (d) of species richness in the subtidal benthos at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

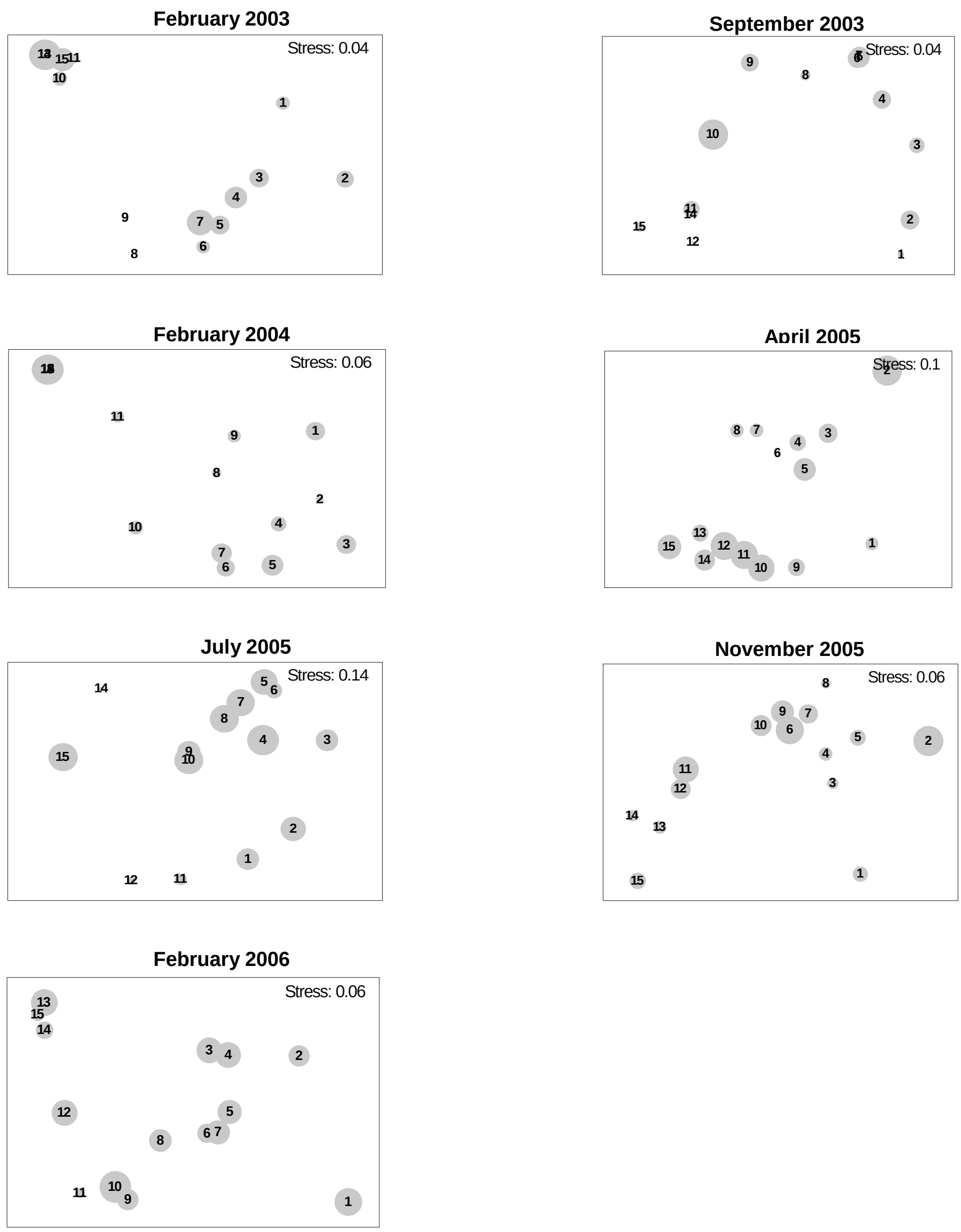

Figure 24. Pielou's eveness index (J') for the subtidal benthos at 15 stations in the Great Berg estuary. Data for seven series, collected between February 2003 and February 2006. Circle size is a relative measure between sites.

3.4.3.2 Intertidal benthic community

Intertidal benthic species composition and abundance recorded in September 2003 and February 2006 is given in Appendix 3.5. On the latter occasion, saltpans were not sampled. Sixteen and twelve taxa were identified on the two occasions. Polychaetes and amphipods clearly dominated from a numerical viewpoint (Figure 25). Only insect larvae (chironomids) were recovered in samples collected in two of the freshwater pans (FP1 – FP2, Appendix 3.5).

The polychaetes *Ceratonereis erythraeensis*, *Boccardia* sp. and *Capitella capitata* were the most common species in September 2003 at Stations KH1 – KH3 (82% of total abundance). *C. erythraeensis* and *C. capitata* were most abundant at KH3 (Figure 26), while *Boccardia* sp. attained maximum abundance at KH1. Only one polychaete species (*Namalycasatis* sp.) was recorded at KH4. The latter site was instead characterized by relatively high numbers of amphipods (*Melita zeylanica* and a species of *Talorchestia*) and the isopod *Exosphaeroma hylocoetes*.

In February 2006, *C. erythraeensis* and *C. capitata* were the only polychaetes present in samples (67%). On this occasion, the amphipod *Grandidierella lutosa* contributed 30% to total abundance, compared to 11% in September 2003. Abundance levels *C. erythraeensis*, *C. capitata* and *Grandidierella lutosa* were significantly higher compared to September 2003, with the latter species attaining a density exceeding 15000 ind.m^{-2} at KH3 (Figure 26).

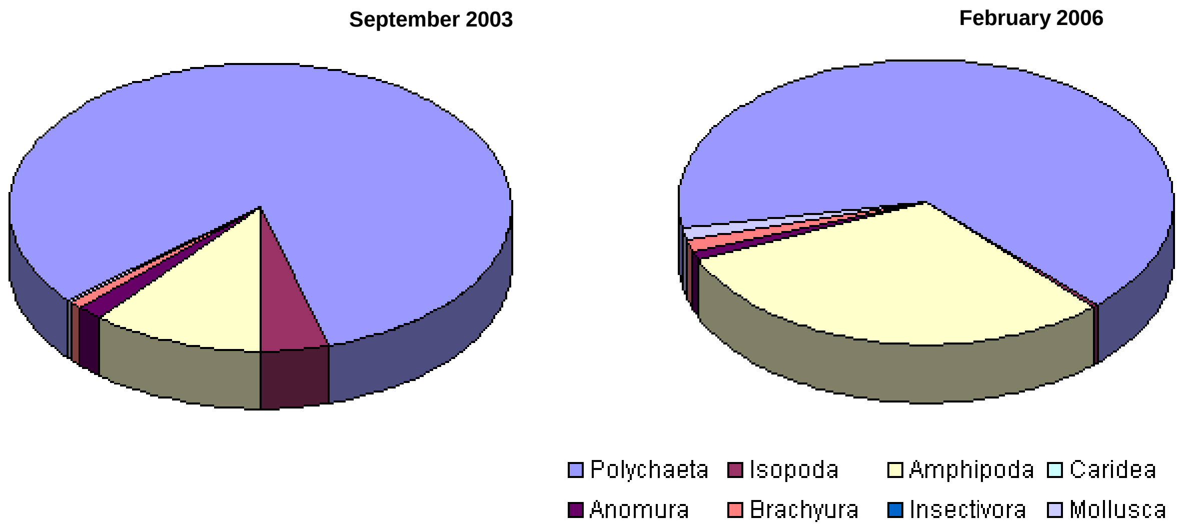

Figure 25. Pie-diagram showing the numerical dominance of polychaetes and amphipods in the intertidal benthos (Sites KH1 to KH4) of the Great Berg estuary, September 2003 and November 2006.

Bray-Curtis similarity analysis of intertidal sites using group average mode on square-root transformed data (Appendix 3.5) showed three clusters in September 2003 and two clusters in February 2006 at the 50% cut-off level (Figure 27). In September 2003, composition of the community showed a high degree of dissimilarity between Floodplain pan sites (FP1 - FP4) and the downstream sites (KH1 to KH4). Station KH4 also showed little similarity to KH1, KH2 and KH3, separating at about the 10% level. In February 2006, there was greater similarity between sites.

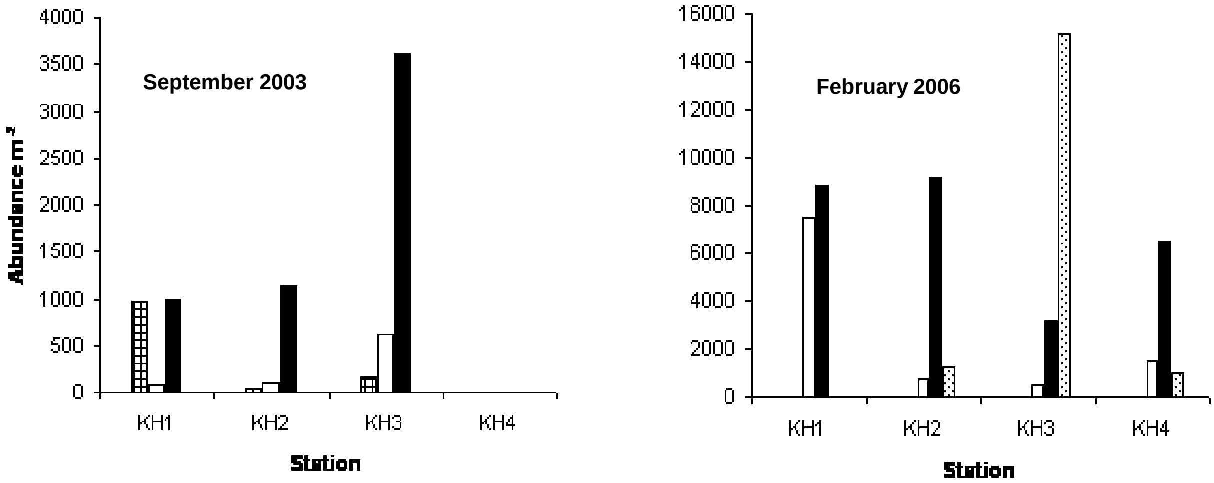

Figure 26. Abundance of *Ceratonereis erythraeensis* (solid bars), *Capitella capitata* (open bars), *Boccardia* sp. (squared bars) and Grandidierella lutosa (stippled bars) at intertidal sites (K1 to K4) in the Great Berg estuary, September 2003 and February 2006.

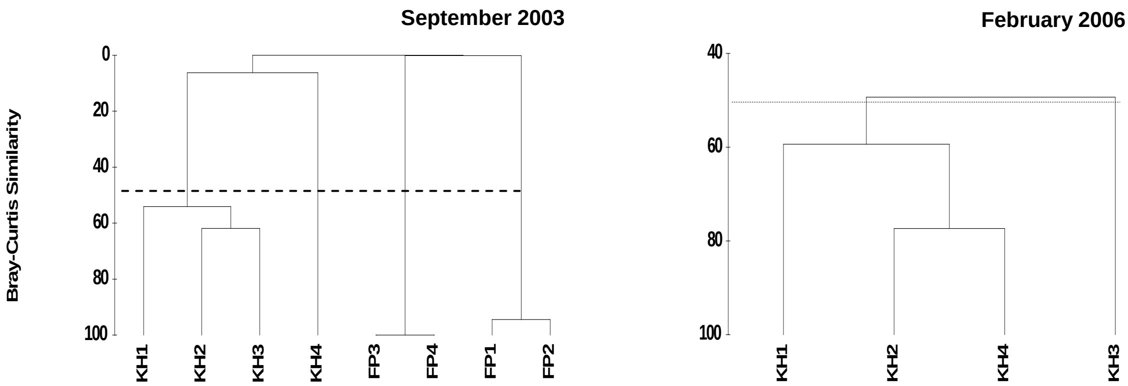

Figure 27. Dendrogram for Bray-Curtis similarity clustering of intertidal sites based on composition and abundance. Data for the Great Berg estuary, September 2003 and February 2006. The dotted line represents the 50% cut-off line.

4 DISCUSSION

Estuaries are dependent on marine and freshwater links in order to function optimally. A salinity gradient becomes established that typically ranges from freshwater at the tidal head (near-zero salt content) to seawater at the mouth (salt concentration around 35 parts per thousand or 35 ppt). However, a number of factors operating over different time scales lead to temporal variations in the horizontal salinity profile. For example:

the ebb and flow of the tides operate over time scales of a few hours,

seasonal changes in evaporation and rainfall operate over time scales of months, and

shifts between wet and dry cycles operate over time scales of years.

Vertical differences in salinity are also common. The volume of freshwater inflow, the degree of tidal mixing and the topography of the estuary structure the vertical salinity profile. Tide-generated currents also have a major influence on sediment characteristics and the type of organisms found along the estuary. Where strong currents prevail, the substratum will be coarse (sand or gravel). Finer particles (e.g. silt) settle where waters are calm and the currents weak.

The variable nature of estuarine habitats, especially defined by fluctuating salinity and substratum type, make estuaries a stressful and rigorous environment in which to live. Estuarine organisms must cope with problems unlike those of plants and animals living in purely marine or fresh waters. It is therefore not surprising that in general, estuaries are environments inhabited by far fewer species compared to other marine ecosystems, but they rank among the most productive environments on earth. This is only possible if estuaries maintain functional links with both rivers and the sea. Very few organisms are able to tolerate the full salinity range found in estuaries and are broadly separated into three groups:

A marine component is the largest in terms of the number of species and includes two subgroups:

- Stenohaline marine animals are typical marine forms that either are unable to tolerate, or barely able to tolerate salinity changes. This component is restricted to the tidal inlet region where salinity remains close to that of seawater. These animals are often the same as those found in the marine nearshore.
- Euryhaline marine animals can tolerate varying degrees of salinity reduction below 30 ppt and can penetrate some distance up-estuary. Many can tolerate salinity values down to about 15 ppt, with a few hardy species tolerating levels down to 3 ppt.

A brackish water or true estuarine component comprises those species that are found in the middle reaches of estuaries where salinity varies between 5 ppt and 20 ppt. This category includes endemic species.

A third component is derived from freshwater, with species usually restricted to a zone where salinity does not exceed 5 ppt in the upper reaches.

The Great Berg Estuary is classified as a river-dominated system where sediment dispersal occurs seaward of the river mouth. Only two other South African estuaries are characterized by having offshore mud deposit centres, namely the Orange or Gariep and the Thukela (Cooper 2001). Besides the Great Berg, numerous other examples of river-dominated estuaries occur in South Africa. In all of them, river flow is critical to the maintenance of an outlet channel and the impact of impoundments is especially notable in these systems (Cooper 2001). River dominance in the Great Berg is clearly apparent in the present study with horizontal salinity distribution in the estuary following seasonal changes in river flow. In summer, salinity penetrated relatively far upstream compared to winter. Exceptionally high salinity values were recorded at Stations 1 and 2 (>60 ppt in bottom waters) in February 2003, possibly due to breaching of saltpan levees following heavy rains at the time, but this was not substantiated. These conditions were of short duration and had disappeared a few days later when further measurements were taken (Strydom, pers. com.). The general estuarine salinity regime between summer and winter therefore follows a pattern described by Slinger & Tajaard (1994), with salinity measurements in January or February at Kersfontein showing comparable values to those reported by other authors (Table 21). These values naturally vary between years, depending on rainfall pattern and volume of fresh water flowing in to the estuary. (See also report by Schumann 2007 – BRBMPR Vol. 3, Chapter 3).

All three major groups linked to the salinity gradient and described above were identified in the Great Berg Estuary. Marine associated invertebrates did not penetrate far up the estuary and were rapidly replaced by euryhaline forms. The latter group are highly tolerant of salinity fluctuations and only hardy species survive. This would partly explain the relatively low number of species recorded in the zooplankton and benthos as species number is partly controlled by physical characteristics (de Villiers et al. 1999). Day (1964) previously noted that the composition of the fauna of South African estuaries is more dependent on the physical characteristics of an estuary (depth, condition of the mouth, salinity regime, nature of the bottom sediments etc) than on geographical location.

Table 21. Salinity readings documented by different authors at Kersfontein (40 – 45 km from the mouth) during low-flow periods (January or February). (S) surface and (B) bottom reading.

Date	Salinity	Source	Comments
1979	9	Day (1981)	No details provided
1990	1-2	Slinger & Taljaard (1994)	Well mixed water column
1993	0	Bennett (1994)	No details provided
2003	(S) 6.7 (B) 13.8	Wooldridge (this study)	Stratified water column
2004	(S) 0 (B) 0	Wooldridge (this study)	Well mixed water column
2006	(S) 1.6 (B) 1.7	(Wooldridge (this study)	Well mixed water column

However, the relatively low number of species recorded in samples from the Great Berg may also be linked to the biogeographical location of the estuary. Although it is possible to compare west and east coast estuaries directly, it is more realistic to group all surveyed estuaries within a specific region and then to compare results with data from other biogeographical regions of South Africa (Day 1974). Based on this approach, Day (1974) noted that South coast estuaries supported the richest number of intertidal macrofaunal species and the west coast estuaries the least (Table 22).

Table 22 clearly shows the paucity of species from west coast estuaries. Included in this relatively small sample are data from Milnerton estuary (Millard & Scott 1954) and the Orange River estuary (Brown 1959), supplemented by unpublished data from the Great Berg and Olifants estuaries (Day 1974). Such low species richness was ascribed to the inability of species to tolerate sharp water temperature changes near the mouth during tidal ebb and flow. This is particularly true at times of upwelling in summer when upwelled water reduces water temperatures in the lower estuary considerably (Day 1974). However, de Villiers et al. (1999) point out that such temperature changes are also experienced in south coast estuaries. Three of the estuaries in Day's (1974) analysis are river-dominated systems (Orange, Great Berg and Olifants) and this must also influence the species assemblage present. In effect, the low species number reflected in the table may be more of a response to river dominance rather than the temperature effect as suggested by Day (1974). This suggests that the number of species may increase if river dominance decreases in these west coast systems.

Table 22. Summary of the combined totals of intertidal macrofaunal species (main groups only) identified from all estuaries sampled by Day (!974) and his co-workers. Data for the Morrumbene estuary in Mozambique provided for further comparison (Data extracted from Table 8, Day 1974).

	Morrumbene Estuary	KZN-Transkei estuaries	Southern Cape estuaries	Atlantic coast estuaries
Number of species	378	237	357	59

Invertebrates recorded in the Great Berg may generally be described as typical estuarine species tolerant of wide variation in the physico-chemical environment. This is born out by BIO-ENV analysis that showed salinity and temperature to best explain the correlation between biological data at the community level (Table 5 and Table 13- zooplankton and subtidal benthos) and the environmental variables measured. In addition, sediment characteristics and chlorophyll-*a* values were also important parameters that explained distribution and abundance of the subtidal benthos. Salinity is often described as the major factor determining distribution patterns of estuarine benthic fauna (e.g. Day 1964, Carricker 1967, Hill 1981, Wolf 1983 among others), although sediment is also known to be a major factor in structuring communities (Day 1964, Holland, Shaughnessy & Hiegel 1987, Teske & Wooldridge 2003). Clearly, factors that structure invertebrate communities are inter-related in complex ways, with the relative importance of any particular factor linked to the magnitude of river domination, degree of sediment change and other drivers along the estuary.

The number of species recorded in the estuary for all three invertebrate groups generally reflected fewer species during high flow periods (September 2003 and July 2005) compared to summer when freshwater runoff was relatively low (Table 23). However, the summer pattern is augmented by breeding activity of benthic forms that supplement the zooplankton and hyperbenthos since their larvae are temporarily planktonic.

Table 23. The range in the number of species recorded during the low flow period (summer) and high flow (winter) for the zooplankton, hyperbenthos and subtidal benthic communities in the Great Berg estuary.

	Summer	**Winter**
Zooplankton	**30-32**	**25-27**
Hyperbenthos	**15-21**	**13-14**
Subtidal benthos	**20-32**	**21-23**

Low water temperatures characterize the cool temperate biogeographical province on the west coast. In the Great Berg estuary, colder water in summer dominates the lower estuary where marine influence is high. Water temperatures increased from ca 15 to >25^{o}C upstream, with temperatures rising relatively steeply up to Station 5. Summer water temperatures in the middle and upper reaches are more influenced by the river flowing across the hot interior of the country and not the colder marine water. These data therefore support Day (1974) who concluded that summer temperatures in the upper reaches of west coast estuaries are not much different from estuarine water temperatures on the east coast. However, water temperatures at least in the lower estuary fall sharply at times of upwelling (Day 1974). During winter, water temperatures in the estuary are influenced by colder inflowing river water and cold marine water, such that temperatures may be maximal in the middle-upper estuarine reaches. Figure 28 illustrates estuarine water temperatures from four estuaries around the South African coast, extending from the cool temperate zone (Olifants and Great Berg estuaries), around the south-east coast (Keiskamma estuary) and in to the transitional zone between the warm temperate and subtropical provinces (Mngazana estuary). All are permanently open systems and illustrate the relatively close similarity in upper estuarine water temperatures in summer. Lower reaches illustrate cooler marine influence, particularly on the west coast. In winter, water temperatures in the four estuaries reflect little variation along the lengths of each estuary and all range between 14.5 and 19^{0}C.

The composition of the euryhaline community is similar to community composition found in estuaries on the south and east coasts of South Africa. Day (1974) noted that none of the benthic species recorded in Atlantic coast estuaries is restricted to the Atlantic coast. Polychaetes such as *Capitella capitata* and *Glycera tridactyla*; crustaceans and molluscs such as *Hymenosoma orbiculare*, *Palaemon perengueyi*, *Upogebia africana*, *Melita zeylanica* and *Nassaria kraussiana* even extend in to Mozambique. The present study on the estuarine zooplankton, hyperbenthos and subtidal benthos supports the notion that most species are not unique to the west coast, although non-benthic marine species that temporarily move in to the lower estuary on flood tides do not all follow this pattern. Elevated summer water temperatures in the middle-upper estuarine reaches and the relatively narrow range between the estuaries in winter may in part explain the similarity between these euryhaline communities, although recent work by Peter Teske and Isabelle Papadopoulos using DNA techniques may alter distribution patterns for some species that are currently perceived to be ubiquitous around the coast.

Although the number of species appears relatively low in the Great Berg estuary, total abundance of some euryhaline species is very high. The estuarine invertebrate fauna (zooplankton, hyperbenthos and benthic subtidal components) reflects the expected pattern where strong marine influence in the lower estuary leads to high species number and low dominance or high eveness near the mouth. The converse holds true for the euryhaline fauna that reflects low species number and high dominance or low eveness (see section 8.2.4). Dominant euryhaline forms in the zooplankton were *Pseudodiaptomus hessei* and mysid shrimps (*Mesopodopsis wooldridgei* and *Rhopalophthalmus terranatalis*); in the hyperenthos mysid shrimps dominated while in the benthos, polychaete worms (e.g. *Ceratonereis keiskama*) and amphipods (*Corophium acherusicum*) attained very high population abundance levels. The upper reaches of the Great Berg estuary had a relatively depauperate fauna, probably due to fluctuating salinity values that respond to variable freshwater inflow volumes over different time scales (tidal and seasonal particularly). A brackish water faunal community therefore does not have sufficient time to establish itself at the fixed sampling stations. Should future freshwater abstraction levels reduce intra- and interannual variability in salinity distribution along the estuary, faunal communities will follow a trajectory towards increased species richness and lower dominance in an upstream direction. In extreme cases, estuarine communities change significantly in response to a reducing supply of freshwater as documented in the next section.

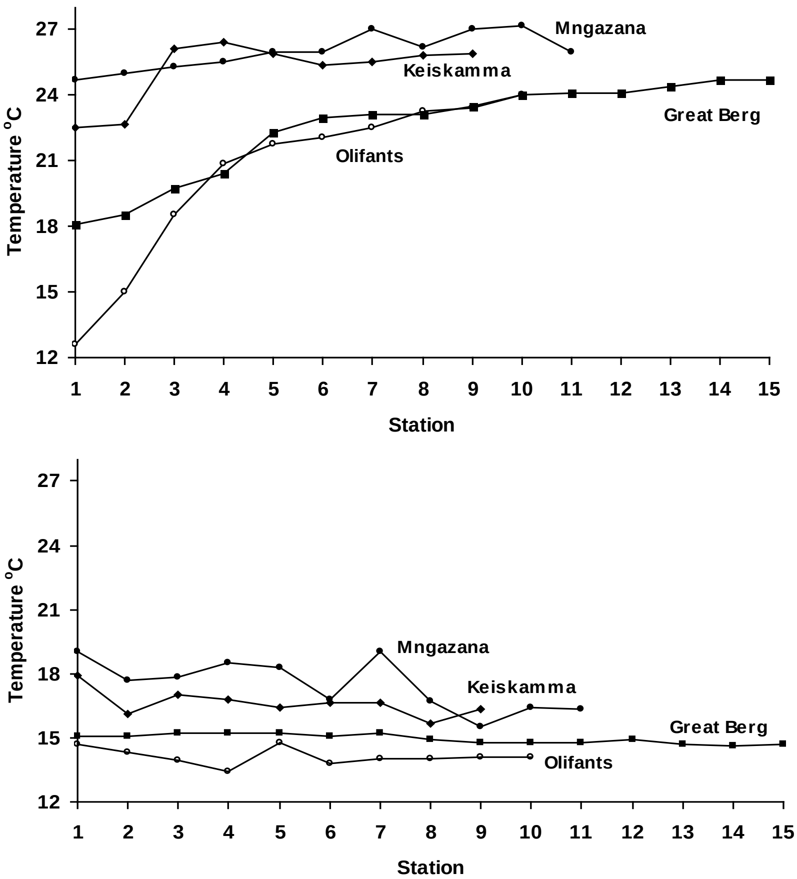

Figure 28. A comparison of summer (A) and winter (B) water temperatures between four permanently open estuaries around the South African coast. The Olifants and Great Berg are located in the cool temperate region, the Keiskamma is located in the warm temperate province and Mngazana occurs further east in the transition zone between the warm temperate and subtropical provinces. Data are extracted from January-February (summer) and June-July data (winter). Data are integrated for the water column at each station along the length of each estuary.

Many of the dominant zooplankton species in the Great Berg estuary also dominate in south and east coast estuaries. The copepod *Pseudodiaptomus hessei* is endemic to estuaries and is widespread around southern Africa (Wooldridge 1999). It attains high population densities, especially under conditions of relatively high freshwater inflow. In the Gamtoos estuary, maximum abundance was attained in regions of the estuary where salinity ranged between 10 and 25 ppt. In the Great Berg, maximum abundance occurred at salinity values between 20 and 26 ppt relatively high up in the estuary. *P. hessei* is described as a pioneer species (Wooldridge & Melville-Smith 1979), responding to flooding or strong freshwater discharges through marked increases in population density. Although population recovery is extremely rapid, a decline in density may be equally abrupt. This was shown in numerous other estuarine studies (Wooldridge 1999) that leads to high variability in density over time. Such a pattern is typical for the species. The relative abundance of *P. hessei* in South African estuaries that experience contrasting inputs of freshwater is shown in Table 24. Data reflect the population response (measured as numbers m^{-3}) to freshwater rich conditions and freshwater starved conditions. Salinity *per se* does not explain the high variability, but correlative evidence suggests that freshwater pulsing leads to nutrient enrichment, increased phytoplankton biomass and hence a greater food supply for the developing zooplankton community. Because of its ability to colonize ‘new estuarine’ water, the initial absence of predators would also exacerbate the rapid recovery of the population. Predators include numerous other species of zooplankton such as mysid shrimps, crab larvae and larvae of the round herring (*Gilchristella aestuaria*).

Table 24. Maximum abundance levels (number m^{-3}) recorded for the copepod *Pseudodiaptomus hessei* from different southern African estuaries. Estuaries with strong inflow of freshwater have strong horizontal salinity gradients (Group 1); estuaries with low or no freshwater inflow have weak or reverse horizontal salinity gradients (Group 2). The salinity range shown refers to values recorded at all sampling stations along each estuary.

Estuary	Salinity range (ppt)	Max. abundance recorded to-date	Reference
Group 1			
Sundays	7-35	33 500	Wooldridge & Bailey (1982)
Great Fish	0-35	91 500	Unpublished records
Keiskamma	0-35	117 000	Unpublished records
Great Berg	7-34	52 000	This study
Olifants	0–34	41 000	Unpublished records
Group 2			
Gqutywa	35-40	12 250	Unpublished records
Kariega	25-36	4 800	Unpublished records
Kromme	31-42	6 000	Wooldridge 1999

Salinity distribution (linked to the volume of freshwater inflow) was identified as the single most important factor explaining zooplankton community patterns in the Great Berg estuary (Table 5). A marine associated fauna dominated the zooplankton up to ca 2-3 km chainage (Station 2-3) where salinity remains above ca 30. A brackish water assemblage distinguishes the upper zooplankton community where salinity does not exceed 3 – 5 (Chainage 38-40 km). Between these extremes, a typical estuarine community develops. Although the number of species is typically low, abundance and biomass attain very high levels. The community is euryhaline and because of high biomass, provides a major linkage between primary producers and secondary consumers in the water column.

Although three communities typify the zooplankton, boundaries are not fixed as previously described. Under conditions of low freshwater inflow, salinity values increase generally that may lead to a concomitant upstream shift of the euryhaline community as the brackish zone recedes (Table 10, April 2005). By contrast, high riverine inflow leads to flushing of the zooplankton from the estuary. At the species level, *Pseudodiaptomus hesse*i was identified as the single most important copepod in the estuary from a numerical point of view on all sampling occasions. This follows the typical pattern shown for many other South African estuaries. The species is extremely euryhaline and is described as a pioneer species. It is interesting to note that no correlation was found between salinity distribution and population abundance, although strong correlations exist between salinity and species at the community level. Similar descriptions probably also apply to species at population and community levels in the subtidal benthos, but research is still ongoing.

5 CONCLUSIONS

Invertebrates identified from the Great Berg estuary are not unique to the west coast of South Africa. However, the number of species present in the estuary may be low compared to communities on the south and east coasts, at least for intertidal organisms. Insufficient information is currently available to test biogeographical trends for other groups (zooplankton, hyperbenthos and subtidal benthos) in the Great Berg, but the causal factors driving observed patterns are sometimes difficult to isolate. For example:

- Because of river dominance, salinity values are reduced to relatively low levels most of the time. Consequently, a species-rich invertebrate community does not establish itself in the lower estuary. However, an incursive marine zooplankton component enters the lower estuary on the flood tide. Species are again flushed out on the ebb tide.
- Although biogeographical patterns relating to intertidal organisms suggest that Atlantic coast estuaries have fewer species compared to south and east coast estuaries, the effects of river dominance on community composition may exacerbate this pattern. River dominated systems on the east and south coasts also have relatively few species (e.g. Thukela and Breede estuaries). Only two other major estuaries occur on the west coast (Orange and Olifants) and both are river dominated. The larger west coast estuaries are therefore characterized as river dominated systems and can be expected to have relatively low species richness.
- Sampling approach may lead to an underestimate of composition and abundance of species. For example, techniques used by different researchers have varied over time. The use of different types of sampling gear (corers, sleds, nets), or different mesh sizes to separate animals from water or sediment will provide different answers. Smaller animals are often more abundant, but these may pass through a relatively coarse net or sieve.
- The number of species in each of the three groups investigated (zooplankton, hyperbenthos and subtidal benthos) was lower in winter compared to summer. This may be partly explained by increased river runoff (some species may not tolerate reduced salinity levels that result), although species richness may be augmented in summer by seasonal breeding patterns of benthic species whose larvae or juveniles exhibit different lifestyles compared to adults.

Crustaceans dominated three of the four groups investigated (zooplankton, hyperbenthos and subtidal benthos). Major groups representing the zooplankton were copepods, mysids and fish larvae (particularly larvae of *Gilchristella aestuaria*). Crab larvae and mysids were particularly abundant in the hyperbenthos. The subtidal benthos was numerically dominated by amphipods in both summer and winter. However, the pattern changed along the estuary. Amphipods were more prevalent in the middle estuary and polychaetes nearer the mouth. The intertidal benthos was dominated by polychaetes.

Species numerically dominating communities in the Great Berg are also dominant species in estuaries on the south and east coast of South Africa. In the Great Berg, maximum population densities of zooplanktonic, hyperbenthic and subtidal benthic species were mostly present in the middle estuary (Stations 7 – 11).

Water temperature distribution and its influence on estuarine communities remains an unknown factor. Water temperatures in the middle and upper estuary were relatively high in summer, due to warming of river water as if flowed across the landscape. Little variation existed along the length of the estuary in winter. It is possible that the general similarity between invertebrate community composition in the Great Berg and those in south and east coast estuaries may be partly linked to estuarine water temperatures.

Increased freshwater abstraction has the potential to increase marine dominance in the Great Berg estuary. Canalization and regular dredging of the estuary mouth will maintain a strong link with the marine environment, exacerbating tidal penetration up the estuary. Increased marine dominance is likely to lead to a change in invertebrate community structure, causing an upstream shift towards a more marine associated fauna. The level of marine penetration upstream will determine the extent of change in the fauna. In addition, increased marine dominance upstream may lead to lower water temperatures in summer and this could also influence community structure and estuarine processes.

The subtidal benthic community was an important component of the invertebrate fauna of the Great Berg estuary. This group has received comparatively less attention from estuarine researchers to date and little comparative data exists. Levels of amphipod abundance in the middle estuary for example, are considered very high and they are likely to play an important role in estuarine processes. The subtidal benthic community is unique, having a different assemblage of species not found in other communities above the substratum.

Dominant species in all groups (zooplankton, hyperbenthos and subtidal benthos) are highly tolerant of fluctuations in the physico-chemical environment, having a range of adaptations that aid survival, including avoidance mechanisms that reduce the possibility of being flushed from the estuary.

6 MONITORING RECOMMENDATIONS

Invertebrates form an important part of the estuarine ecosystem, particularly in their contribution to sustaining populations of predatory fish and birds. However, there is little historic information on abundance and diversity of invertebrates in the Berge estuary and the brief snapshot of their dynamics in this three-year baseline study does not provide a very firm baseline against which future changes can be assessed. Collection and processing of invertebrate samples is also time consuming and hence cannot realistically be undertaken as frequently as with other faunal components. Thus, it is recommended that detailed surveys such as those undertaken for this study are repeated at approximately five-yearly intervals. These surveys should include all components of the invertebrate fauna including intertidal and subtidal benthos, hyperbenthos, and zooplankton, to be sampled at at least 10 stations extending up the length of the estuary.

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APPENDIX 3.1 Estuary Invertebrate Data – Abiotic

Appendix I. **Abiotic measurements recorded in February 2003 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum.**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Salinity (integrated)	34.0	33.9	33.4	32.9	31.1	29.6	29.2	27.3	26.7	24.4	22.5	20.0	18.1	14.3	10.2
Salinity (surface)	34.0	33.9	33.4	32.7	30.7	29.6	28.9	27.2	26.6	23.7	20.1	19.4	16.9	10.6	6.7
Salinity (bottom)	34.0	33.9	33.4	33.0	31.4	29.6	29.5	27.3	26.8	24.8	25.4	20.7	18.8	15.9	13.8
Temperature (integrated ^oC)	18.1	18.5	19.7	20.4	22.3	23.0	23.1	23.1	23.5	24.0	24.1	24.1	24.4	24.7	24.7
Temperature (surface ^oC)	18.1	18.5	19.6	20.9	22.4	23.0	23.3	23.1	23.6	23.9	24.0	24.1	24.3	24.4	24.7
Temperature (bottom ^oC)	18.2	18.5	19.7	20.2	22.1	22.9	22.7	23.1	23.4	24.0	24.2	24.1	24.6	24.8	24.7
Conductivity (integrated)	44.8	45.1	45.6	45.8	45.2	43.9	43.4	40.8	40.5	37.6	35.1	31.4	29.0	23.5	17.0
Conductivity (surface)	44.8	45.1	45.6	45.9	44.9	43.9	43.2	40.8	40.4	36.5	31.6	30.6	27.2	17.8	11.7
Conductivity (bottom)	44.9	45.1	45.6	45.7	45.4	43.8	43.4	40.9	40.5	38.2	39.4	32.5	30.0	26.0	22.7
Depth (m)	2.5	3.5	2.5	3.0	2.5	3.0	3.0	2.0	3.5	2.0	3.5	2.5	2.5	4.0	3.0
pH (integrated)	7.4	7.4	7.4	7.4	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.6	7.6	7.6	7.7
Sediment - % mud (<0.065 mm)	36.9	10.2	5.7	9.3	10.0	7.6	5.4	14.6	16.3	76.7	77.4	82.6	9.9	0.6	2.1
Sediment - % sand (0.125 - 0.355 mm)	15.6	56.3	19.9	10.8	34.0	53.3	38.2	34.4	45.9	2.2	11.2	4.0	27.4	18.2	22.5
Sediment - % sand (0.355 - 1.00 mm)	9.1	20.9	44.6	13.8	24.3	9.4	41.4	12.7	20.9	2.4	2.6	0.8	51.7	74.4	65.9
Sediment organic matter (%)	4.8	1.8	1.7	2.4	1.7	2.6	2.5	2.1	2.8	14.1	5.6	6.4	1.8	0.6	0.9

Appendix II. Abiotic measurements recorded in September 2003 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Salinity (integrated)	55.6	38.8	19.1	4.1	1.9	1.3	1.1	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9
Salinity (surface)	42.9	19.3	10.4	4.1	1.9	1.3	1.1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Salinity (bottom)	65.1	61.1	25.1	4.2	1.9	1.3	1.1	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9
Temperature (integrated oC)	15.9	16	16.4	16.6	17	17	17	17	16.8	16.8	17	17.8	17.4	17.4	17.6
Temperature (surface oC)	16.7	16.9	16.9	16.6	17	17	17	17	17.1	17.4	18.1	18.5	18.2	17.4	17.8
Temperature (bottom oC)	15.4	15.4	16	16.5	17	16	16	16	16.3	16.3	16.4	16.4	17	17.3	17.3
Conductivity (integrated)	65.6	48	25.4	6.2	3	2.8	1.8	1.5	1.5	1.4	1.4	1.5	1.6	1.6	1.5
Conductivity (surface)	53.5	26.1	14.9	6.2	3	2.1	1.8	1.6	1.5	1.4	1.4	1.5	1.6	1.6	1.5
Conductivity (bottom)	74.7	70.8	32.5	6.3	3	2.1	1.9	1.5	1.5	1.4	1.4	1.5	1.5	1.5	1.5
Oxygen (integrated mg/l)	4.1	4.1	5	7.2	7.4	7.2	7.1	7.5	7.9	7.8	8.2	8.2	8.9	8.3	9.1
Oxygen (surface mg/l)	4.6	5.5	6.1	7.2	6.9	6.9	6.9	7.3	8	7.9	8.9	8.8	9.8	7.7	9.3
Oxygen (bottom mg/l)	3.7	2.7	3.4	7.2	7.3	7.3	7.1	7.4	7.7	7.7	7.2	7.8	8.4	8.7	8.8
Oxygen (% saturation integrated)	59.1	51.5	54.4	76	74.6	74	73	77	82.1	82.5	85.2	84.5	92.5	86.1	95.8
Oxygen (% saturation surface)	62	63.5	66	76	72.3	70	72	76	83.2	81.2	92.4	91.2	97.3	79.2	96.5
Oxygen (% saturation bottom)	57.1	39.4	40.5	76	76.6	75	73	76	79.4	78.8	74.5	81.4	87.3	90.1	92.3
Depth (m)	1.5	2	2.8	1.5	1	4.5	3	3.5	2.3	3	2.2	2	1.3	2.3	1.5
pH (integrated)	7.9	7.9	7.8	7.8	7.9	7.8	7.8	7.8	7.8	7.9	8.1	8.5	8.2	8.2	8.2
Sediment organic matter (%)	6.6	1.8	1.6	1.3	1.5	1.1	1.1	3	4.7	7.8	3.5	7.6	3.3	1.8	4.7

Appendix III. Abiotic measurements recorded in February 2004 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Salinity (integrated)	34.1	33.3	32.4	31.9	29.9	27.1	23.5	19.1	14.0	15.3	11.1	7.3	1.7	0.0	0.0
Salinity (surface)	34.1	33.3	32.4	31.9	29.9	26.7	21.0	16.0	12.1	10.9	7.4	5.1	0.7	0.0	0.0
Salinity (bottom)	34.1	33.3	32.4	31.9	30.1	28.1	24.8	23.4	18.0	18.6	16.7	13.2	4.4	0.0	0.0
Temperature (integrated oC)	19.5	20.8	22.5	23.4	23.5	24.0	24.1	24.2	24.4	24.3	24.6	24.3	24.4	24.1	24.1
Temperature (surface oC)	19.5	20.8	22.5	23.4	23.5	24.0	24.1	24.2	24.4	24.4	25.1	24.3	24.6	24.5	24.1
Temperature (bottom oC)	19.0	20.8	22.5	23.4	23.4	24.1	24.1	24.2	24.4	24.2	24.3	24.5	24.5	23.9	23.9
Oxygen (integrated mg/l)	5.8	5.7	5.4	6.4	5.6	5.9									
Oxygen (bottom mg/l)	5.2	5.2	5.3	6.1	5.1	5.9									
Oxygen (% saturation integrated)	62.8	62.8	59.8	76.8	67.3	70.1									
Oxygen (% saturation bottom)	56.4	56.4	58.9	73.9	62.8	69.7									
Depth (m)	1.4	1.4	2.6	1.8	2.0	2.5	3.0	4.0	2.6	3.6	3.0	2.0	1.5	2.0	1.9
pH (integrated)	8.2	8.0	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.9	7.9	7.7	7.6	7.9	8.1
Sediment - % mud (<0.065 mm)	29.5	5.2	8.6	21.0	4.1	7.6	4.5	38.4	43.8	43.9	69.6	80.1	7.7	17.9	11.7
Sediment - % sand (0.125 - 0.355 mm)	28.6	15.2	16.1	18.6	41.6	3.3	43.0	3.2	15.7	4.3	11.4	2.8	84.9	70.0	26.3
Sediment - % sand (0.355 - 1.00 mm)	17.3	13.0	51.9	42.9	32.8	0.0	41.9	1.0	3.6	0.4	2.5	0.0	9.2	10.8	51.5
Sediment organic matter (%)	6.7	2.3	1.8	1.2	1.3	1.9	1.5	0.5	4.8	4.3	7.0	6.1	1.3	1.7	1.5

Appendix IV. Abiotic measurements recorded in April 2005 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Salinity (integrated)	35.3	35.2	35.1	34.5	34.4	32.7	30.5	26.2	22.9	20.1	15.6	11.7	3.0	0.9	0.9
Salinity (surface)	35.2	35.2	35.1	34.5	34.4	32.6	30.1	26.0	21.6	17.7	10.8	7.0	1.8	0.9	0.9
Salinity (bottom)	35.3	35.2	35.1	34.5	34.4	32.7	30.9	26.4	24.0	22.4	19.3	18.2	4.6	0.9	0.9
Temperature (integrated °C)	15.8	16.4	16.7	17.1	17.6	18.3	18.7	19.0	18.9	19.2	19.0	19.2	18.2	18.3	18.2
Temperature (surface °C)	15.8	16.4	16.3	17.1	17.6	18.3	18.9	19.2	19.2	19.3	18.1	19.3	18.3	18.4	18.2
Temperature (bottom °C)	15.8	16.4	16.7	17.1	17.6	18.3	18.6	18.9	18.8	19.9	19.2	19.5	18.2	18.2	18.1
Oxygen (integrated mg/l)	2.8	2.8	2.4	3.9	4.4	5.1	5.7	5.7	6.0	6.2	6.7	6.3	7.2	7.5	7.5
Oxygen (bottom mg/l)	2.7	2.7	2.3	3.9	4.3	4.8	5.4	5.4	5.5	4.5	4.8	4.1	6.1	7.4	7.4
Oxygen (% saturation integrated)	34.8	35.9	30.1	49.2	56.0	65.3	72.7	71.3	74.1	76.0	80.2	73.1	77.8	80.7	79.6
Oxygen (% saturation bottom)	33.7	33.8	29.2	49.2	55.4	62.2	69.0	67.5	67.6	56.5	58.1	49.6	66.6	78.4	78.7
NTU (integrated)	21.5	18.3	19.0	6.9	9.1	4.1	0.9	0.0	2.5	5.9	18.4	65.7	127.0	126.8	107.0
NTU (surface)	22.0	13.2	7.1	5.2	8.9	2.3	0.2	0.0	0.0	1.5	30.5	74.0	99.4	118.9	99.4
NTU (bottom)	22.2	32.8	69.8	10.0	11.5	11.5	4.0	0.0	11.1	21.1	14.2	58.4	172.2	144.1	116.0
Depth (m)	1.0	3.0	3.6	1.5	3.0	5.0	3.5	5.0	3.0	3.4	2.5	2.8	1.5	2.4	2.4
pH (integrated)	7.0	7.1	7.1	7.2	7.2	7.3	7.1	7.0	7.0	7.1	7.1	7.0	7.1	7.1	7.0
Chlorophyll *a* (mg/l integrated)	2.0	1.6	1.5	1.9	2.1	3.7	4.7	5.0	8.4	11.5	23.4	22.7	17.9	13.4	14.4
Chlorophyll a (mg/l maximum)	2.2	2.3	1.9	2.1	2.4	7.2	9.3	5.4	10.6	20.0	33.9	34.1	19.1	14.7	15.1
Sediment - % mud (<0.065 mm)	92.3	5.9	7.0	12.9	13.4	8.2	6.9	17.8	35.9	79.4	90.9	6.4	37.5	23.9	9.0
Sediment - % sand (0.125 - 0.355 m	1.3	7.2	24.7	24.9	31.3	47.6	44.4	55.9	31.5	5.9	2.7	37.9	33.2	52.4	5.5
Sediment - % sand (0.355 - 1.00 mn	0.0	47.4	45.4	55.8	19.3	32.8	35.2	19.2	3.6	1.4	1.2	44.2	4.2	22.6	61.8
Sediment organic matter (%)	3	0.3	0.3	0.6	0.6	0.5	0.4	0.5	1.2	2.5	2.8	3.8	0.6	0.4	0.2

Appendix V. Abiotic measurements recorded in July 2005 at 15 stations in the Great Although the number of species appears relatively low in the Great Berg estuary, total abundance of some estuarine species is very high.Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Salinity (integrated)	27.0	17.4	12.3	8.1	3.4	2.4	1.9	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Salinity (surface)	26.1	17.2	12.3	8.1	1.1	2.1	1.9	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Salinity (bottom)	29.3	18.1	12.3	8.1	3.9	2.9	1.9	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Temperature (integrated °C)	15.1	15.1	15.2	15.2	15.2	15.1	15.2	14.9	14.8	14.8	14.8	14.9	14.7	14.6	14.7
Temperature (surface °C)	15.2	15.1	15.2	15.2	15.2	15.1	15.2	14.9	14.8	14.8	14.8	15.0	14.7	14.6	14.7
Temperature (bottom °C)	14.9	15.1	15.2	15.2	15.1	15.1	15.2	14.9	14.8	14.8	14.8	14.8	14.7	14.6	14.7
Oxygen (integrated mg/l)	8.5	9.5													
Oxygen (bottom mg/l)	7.7	9.1													
Oxygen (% saturation integrated)	100.1	104.6													
Oxygen (% saturation bottom)	91.9	102.3													
NTU (integrated)	81.6	49.8	42.6	38.3	65.7	84.9	93.0	72.5	65.9	67.3	108.1	133.0	108.9	149.8	161.0
NTU (surface)	47.7	36.8	30.8	36.2	54.7	79.1	94.1	70.0	64.2	67.6	102.5	125.9	105.9	134.8	155.0
NTU (bottom)	145.7	67.8	50.1	39.5	101.3	92.2	96.5	75.0	72.3	67.7	114.5	138.9	113.1	164.0	168.9
Depth (m)	1.0	3.0	4.0	1.0	3.0	4.0	3.5	4.6	3.7	3.7	2.8	3.0	2.0	3.0	3.0
pH (integrated)	9.9	9.9	9.9	9.9	9.9	9.7	8.7	8.7	8.2	8.1	8.0	8.0	7.9	7.9	7.9
Chlorophyll *a* (mg/l integrated)	4.0	2.6	3.1	3.3	4.3	5.3	6.0	5.7	5.2	5.7	8.4	7.7	8.4	10.3	11.0
Chlorophyll a (mg/l maximum)	7.2	3.1	3.4	3.8	5.1	5.6	9.0	10.1	5.0	6.2	10.0	9.0	8.4	10.8	11.3
Sediment - % mud (<0.065 mm)	57.7	8.3	5.4	22.0	13.8	2.9	3.8	11.5	46.4	24.2	82.6	57.2	0.7	31.3	0.6
Sediment - % sand (0.125 - 0.355 mm)	5.3	46.6	22.9	11.9	42.5	37.2	44.2	44.8	24.9	14.4	4.2	6.7	18.5	11.8	12.2
Sediment - % sand (0.355 - 1.00 mm)	1.5	8.6	44.3	8.9	13.5	43.8	41.8	18.3	4.1	0.2	0.3	0.3	74.7	23.4	80.3
Sediment organic matter (%)	1.9	0.6	0.3	1	0.6	0.6	0.4	0.5	1.3	3.8	2.8	1.7	1.8	0.1	0.1

Appendix VI. Abiotic measurements recorded in November 2005 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Salinity (integrated)	32.9	33.5	32.4	33.4	26.8	21.0	20.7	16.6	10.8	6.1	2.5	0.5	0.4	0.4	0.4
Salinity (surface)	32.9	33.5	32.4	33.4	26.8	21.0	18.5	16.9	10.4	6.1	2.0	0.5	0.4	0.4	0.4
Salinity (bottom)	32.9	33.5	32.4	33.4	26.8	21.0	23.7	16.9	11.3	6.2	3.5	0.5	0.4	0.4	0.4
Temperature (integrated °C)	18.0	16.3	18.3	16.4	21.4	22.4	22.3	23.4	23.3	22.9	22.9	23.0	23.4	23.1	23.3
Temperature (surface °C)	18.1	16.3	18.3	16.4	21.4	22.4	22.2	23.4	23.3	23.0	23.7	23.5	23.7	23.2	23.7
Temperature (bottom °C)	17.9	16.3	18.3	16.4	21.6	22.4	22.3	23.2	23.2	22.8	22.1	22.7	23.2	23.1	23.1
Oxygen (integrated mg/l)								8.3	8.3	9.1	10.0	9.3	4.1	3.9	5.3
Oxygen (bottom mg/l)								8.2	8.1	8.8	8.3	8.7	4.1	3.9	3.9
Oxygen (% saturation integrated)								106.8	104.2	110.1	118.0	108.1	47.8	45.9	64.0
Oxygen (% saturation bottom)								106.0	101.3	105.6	103.0	100.2	47.4	46.0	46.3
NTU (integrated)								36.6	23.8	78.9	128.4	257.6	297.0	268.0	168.8
NTU (surface)								20.0	26.0	57.1	129.0	225.0	271.2	214.9	8.0
NTU (bottom)								60.2	22.2	121.0	127.1	356.2	309.9	342.2	245.2
Depth (m)	1.5	2.0	1.0	2.0	3.5	1.5	2.0	4.0	2.0	4.0	3.0	3.0	1.0	2.0	3.0
pH (integrated)	8.2	8.0	8.0	7.7	7.6	7.5	7.5	7.5	7.5	7.4	7.4	7.3	7.2	7.1	7.1
Chlorophyll *a* (mg/l integrated)	0.3	0.5	0.4	0.4	0.4	0.4	1.0				8.1				6.1
Chlorophyll a (mg/l maximum)	0.3	0.7	0.4	0.5	0.5	0.5	1.7				8.1				8.6
Sediment - % mud (<0.065 mm)	21.1	13.0	15.4	6.4	6.4	28.1	20.2	8.2	28.7	15.5	50.3	80.3	11.2	14.6	21.0
Sediment - % sand (0.125 - 0.355 mm)	24.2	40.6	5.8	10.3	58.5	11.0	40.2	68.6	45.7	60.6	26.3	8.2	71.3	60.5	56.4
Sediment - % sand (0.355 - 1.00 mm)	0.5	44.4	0.1	2.0	0.4	0.2	0.4	17.5	0.5	3.9	0.7	0.3	9.2	24.4	0.2
Sediment organic matter (%)	2.3	0.6	2.8	1.5	1	3.1	2	0.6	2.7	1.1	3.9	3.4	0.9	1.1	2.7

Appendix VII. Abiotic measurements recorded in February 2006 at 15 stations in the Great Berg estuary. Integrated values are the mean for all readings in the water column. Surface readings refer to the top 15 cm of the water column; bottom readings reflect conditions just above the substratum

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Salinity (integrated)	36.8	36.0	35.8	35.5	34.5	33.1	31.4	26.1	22.8	19.6	16.2	13.4	8.4	4.5	1.6
Salinity (surface)	36.6	35.9	35.7	35.4	34.4	32.9	30.6	25.0	21.6	18.1	15.0	12.2	8.3	4.1	1.6
Salinity (bottom)	36.8	36.0	35.8	35.5	34.6	33.4	32.7	27.8	24.2	22.2	17.8	15.4	8.5	5.3	1.7
Temperature (integrated ^{o}C)	18.8	21.0	21.7	22.4	22.7	23.4	23.7	24.3	24.3	24.3	24.7	24.7	24.5	25.1	25.1
Temperature (surface ^{o}C)	18.8	21.0	21.8	22.4	22.8	23.4	24.1	24.6	24.1	24.1	24.5	24.3	24.6	25.1	25.1
Temperature (bottom ^{o}C)	18.8	20.9	21.7	22.4	22.6	23.5	23.2	24.0	24.5	24.9	24.9	25.4	24.3	25.1	25.1
Oxygen (integrated mg/l)	8.6	7.6	7.5	7.7	6.9	6.8	6.9	7.0	7.2	7.1	6.8	5.6	6.6	6.0	6.4
Oxygen (bottom mg/l)	7.9	7.0	7.3	7.5	6.6	6.4	6.3	6.2	6.5	5.7	6.0	2.2	6.3	5.3	6.1
Oxygen (% saturation integrated)	115.5	106.4	105.1	109.9	98.4	97.7	98.0	97.3	97.9	94.6	90.3	73.7	83.5	74.3	78.0
Oxygen (% saturation bottom)	105.7	96.3	102.7	106.7	92.9	92.8	88.6	85.7	89.3	78.0	80.3	34.4	79.6	66.3	75.1
NTU (integrated)	9.2	0.1	2.9	4.5	2.5	3.7	34.6	7.3	4.6	8.9	15.3	23.0	68.1	111.9	159.5
NTU (surface)	0.1	0.1	0.1	2.1	1.2	2.1	2.0	6.0	3.0	0.1	6.1	32.0	57.2	93.0	125.3
NTU (bottom)	36.5	0.1	17.4	13.4	6.9	4.1	194.8	53.1	14.6	48.1	59.9	17.2	90.3	148.6	278.1
Depth (m)	2.0	2.5	3.7	2.0	3.0	4.9	4.0	6.5	3.0	3.5	3.0	3.5	2.0	3.0	3.0
Chlorophyll *a* (mg/l integrated)	3.0	2.9	2.9	3.1	8.5	10.6	11.4	11.5	10.8	8.1	5.4	5.7	14.1	12.8	20.4
Chlorophyll a (mg/l maximum)	6.8	3.7	3.3	4.0	8.9	12.0	13.3	12.5	14.8	11.4	5.7	7.5	14.8	13.4	23.9
Sediment - % mud (<0.065 mm)	45.4	1.7	5.2	1.7	7.5	2.5	6.0	18.5	18.5	67.8	70.5	95.9	70.3	6.0	12.1
Sediment - % sand (0.125 - 0.355 mm)	11.4	30.7	30.6	8.4	40.3	46.7	37.7	45.9	49.1	20.8	12.6	1.4	19.0	30.4	38.4
Sediment - % sand (0.355 - 1.00 mm)	3.8	59.3	37.0	63.8	34.4	24.9	44.1	8.3	2.9	0.1	0.6	0.1	0.1	59.5	46.2
Sediment organic matter (%)	5.1	0.8	1.2	0.6	1.2	1.1	0.6	2.7	2.7	7.3	7.1	6.3	5.8	1.6	1.4

APPENDIX 3.2 Estuary Invertebrate Data – Zooplankton

Appendix VIII. Composition and abundance (numbers m^{-3}) of zooplankton collected February 2003 at 15 stations in the Great Berg estuary.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Copepoda															
Acartia longipatella	0	671	15108	4238	3147	1961	3814	5967	544	0	0	0	0	0	0
Copepod parasitic sp. 1	580	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepod parasitic sp. 2	0	0	0	0	0	0	0	0	544	307	24	122	0	0	0
Copepod spp.	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	28647	494	80
Halicyclops sp.	0	37	0	103	3	93	426	1146	13151	4845	2682	796	136	16	0
Labidocera sp.	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	460	2607	2300	9290	13579	12143	18662	14394	24198	29009	29603	13786	7421	7585	4792
Mysidacea															
Mesopodopsis wooldridgei	73	4	5	3	3	4	6	42	222	20	0	0	0	0	0
Rhopalophthalmus terranatalis	0	0	0	5	3	13	14	8	32	20	7	0	0	0	0
Cumacea															
Cumacean spp	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exosphaeroma hylecoetes	17	4	3	8	43	16	8	3	3	0	0	0	0	0	0
Munna sheltoni	0	0	0	0	18	34	1	0	0	8	4	0	0	0	0
Paridotea ungulata	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	2	18	1	1	0	1	3	192	65	157	11	0	0
Grandidierella lutosa	0	0	0	3	3	0	0	1	0	0	0	0	0	0	0
Melita zeylanica	0	0	3	3	5	5	1	0	6	8	0	0	0	0	0
Neomacrodeutopus sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia africana postlarvae	0	0	0	0	18	2	4	0	0	0	0	0	0	0	0
Brachyura															
Chiromantes eulimine larvae	0	0	0	86	0	0	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare larvae	48	199	156	40	25	11	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0
Zoea larvae	0	0	0	0	8	16	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	20	6	4	3	0
Chironomid larvae	0	0	0	0	0	0	0	3	0	0	24	6	7	0	0
Pisces															
Gilchristella aestuaria eggs	0	0	3	31	0	0	0	16	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	16	4	332	682	284	125	30	11	7	11
Gobiid larvae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0

Appendix IX. Composition and abundance (numbers m^{-3}) of zooplankton collected September 2003 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cnidaria															
Cubomedusae	0.3	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Copepoda															
Acartia longipatella	0	53	65	1039	0	0	0	0	0	0	0	0	0	0	0
Copepod parasitic sp. 1	0	0	0	0	0	0	0	0	0	43	15	0	0	0	0
Copepod spp.	206	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euterpina acutifrons	72	85	0	0	0	0	0	0	0	0	0	0	0	0	0
Halicyclops sp.	0	0	0	0	1373	266	0	0	262	43	0	0	0	0	0
Labidocera sp.	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Oithona spp	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0
Paracalanus sp	1284	1553	4188	1746	0	0	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	0	0	86	624	29412	9894	9938	2484	1310	1563	626	18	0	0	0
Saphiriella sp.	24	200	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea															
Mysidopsis major	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0
Mesopodopsis wooldridgei	79	712	2	3	7	7	5	5	0	0	0	0	0	0	0
Rhopalophthalmus terranatalis	2	0	2	3	14	25	131	119	119	0	0	0	0	0	0
Cumacea															
Cumacean spp	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0.5	0.3	20	4	113	39	63	5	6	0	0	0	0	0	0
Amphipoda															
Afrochiltonia capensis	0	0	0	0	0	0	0	0	0	0.2	6	0	0	0	0
Corophium acherusicum	0	0	0.1	0	7	3	0.1	0.1	0.2	0.7	31	0	0	0	0
Grandidierella lutosa	0.3	1	3	0	13	5	0	0	0	0	0	0	0	0	0
Lysianassa ceratina	0.4	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	2	3	3	9	27	3	5	0	0	0.2	6	0	0	0	0
Paramoera capensis	2	7	0	0.5	0	0	0	0	0	0	0	0	0	0	0
Talorchestia sp.	0	43	0	0	0	0.1	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	30	13	0	12	0	0	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	2	7	29	6	47	36	5	11	6	0.2	0	0	0	0	0
Chaetognatha															
Sagitta sp	2	43	63	0	0	0	0	0	0	0	0	0	0	0	0
Insectivora															
Chironomid larvae	0	0	0	0	0	0	0	0.2	0	0.4	2	0	0	0	0

Appendix X. Composition and abundance (numbers m^{-3}) of zooplankton collected February 2004 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polychaeta															
Polychaete larvae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda															
Acartia longipatella	0	0	4665	275	218	779	120	33	32	0	0	0	0	0	0
Copepod parasitic sp. 1	0	47	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepod spp.	289	64	0	0	0	0	0	0	0	26	0	0	8	0	0
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	335	98
Halicyclops sp.	0	0	0	0	0	72	32	40	33	52	320	433	162	152	71
Pseudodiaptomus hessei	0	0	821	2041	3295	1886	3786	1695	5349	4173	4014	3372	1461	2449	650
Saphiriella sp.	1900	987	149	148	0	0	0	0	0	0	0	0	0	0	0
Mysidacea															
Mesopodopsis wooldridgei	34	2	1	0	0	2	2	0	4	2	2	13	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	1	23	31	124	80	108	157	58	1	0	0
Cumacea															
Cumacean spp	1	17	2	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe truncata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	4	10	1	10	12	10	1	7	4	8	1	0	0	0	0
Paridotea ungulata	10	17	1	6	1	1	0	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	0	0	2	0	0	32	2	0	0	0	0	1
Amphipoda															
Corophium acherusicum	0	0	0.5	2	0	0	0	0	9	56	42	16	184	16	0
Grandidierella lutosa	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	1	2	1	2	4	1	0	0	0	0	0	0
Paramoera capensis	2	1	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Decapoda															
Decapod larvae	5	10	0	6	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi post larvae	1	1	1	0	0.3	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1	20	15	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia africana postlarvae	0	0	0	6	0.5	2	3	9	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	53	78	25	5	1	3	0	0	2	0	0	0	0	0	0
Hymenosoma orbiculare	0	0	0	0	0	0.5	0.5	2	0	1	0	0	0	0	0
Zoea larvae	0	47	51	23	19	0	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0	37	3	1
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	0	23	4	3
Pisces															
Gilchristella aestuaria larvae	0	0	0	0	0	2	6	4	9	30	6	11	12	0	0
Gobiid larvae	1	0	0	4	0	0	0	2	0	2	0	0	0	0	0
Pipefish juv.	0.1	0	0.3	3	0	0	0.5	0	0	0	0	0	0	0	0

Appendix XI. Composition and abundance (numbers m^{-3}) of zooplankton collected April 2005 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Copepoda															
Acartia longipatella	0	0	0	0	155	546	527	73	100	0	0	0	0	0	0
Copepod spp.	302	407	184	1199	0	0	0	0	55	0	0	0	0	0	0
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Halicyclops sp.	0	0	0	0	0	0	0	0	0	0	0	0	274	43	14
Harpacticoid sp.	130	153	117	0	155	113	133	0	0	0	0	0	0	0	0
Oithona spp	0	167	0	0	0	88	0	0	0	0	0	0	0	0	0
Oncaea sp.	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paracalanus sp	898	5908	1138	4768	155	45	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	0	0	37	29	271	3019	2697	3286	2646	2985	7444	8562	3933	2273	1963
Saphiriella sp.	141	28	382	205	77	0	0	0	0	0	0	0	0	0	0
Mysidacea															
Mysidopsis major	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesopodopsis wooldridgei	89	198	1243	76	1	2	0	0	0	0	0	3	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0	2	25	6	250	81	267	78	2	0	0
Cumacea															
Cumacean spp	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp.	0	6	0	0	1	0	0.1	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0	0	2	16	25	16	5	28	14	17	4	0	0	0
Paridotea ungulata	0	0	0.1	2	1	5	0.2	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	0	0	0	60	101	11	152	0	0	0	1	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0	0	2	0	11	2	10	14	43	19	2
Grandidierella lutosa	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	2	1	6	10	4	3	2	7	43	3	2	0
Paramoera capensis	1	6	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon perengueyi	0.1	0.1	0.1	2	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa krauss i juvs	0	0	0	0	0.1	0	0.6	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	1655	122	50	48	0.1	95	133	4	11	9	7	0	0	0	0
Hymenosoma orbiculare	0	0.1	0	0	0.1	0	1	0.2	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	1	26	23	2
Pisces															
Gobiid larvae	6	0	0	4	0.1	35	1	0	0	0	7	0	2	0.1	0
Pipefish juv.	0.1	0	0	0.1	0.1	1	0	0	0	0	0	0	0	0	0

Appendix XII. Composition and abundance (numbers m^{-3}) of zooplankton collected July 2005 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Copepoda															
Copepod spp.	615	522	192	32	1	6	0	14	29	0	29	30	74	229	127
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1
Halicyclops sp.	0	0	0	0	0	0	3	12	8	21	29	33	62	23	10
Oithona spp	738	202	168	0	0	0	0	0	0	0	0	0	0	0	0
Paracalanus sp	1135	222	675	183	0	0	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	0	0	0	15	5	66	49	344	62	78	201	268	203	205	0
Mysidacea															
Mesopodopsis wooldridgei	1490	2462	2803	21	0	0	0	0	0	0	0	0	0	0	0
Rhopalophthalmus terranatalis	61	20	31	14	0	0.1	0.1	0	0	0	0	0	0	0	0
Cumacea															
Cumacean spp	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0	3	13	19	3	0.1	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0	1	2	4	2	1	3	4	7	13	5
Grandidierella lutosa	0	0	0	3	0	4	0.2	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	2	0.5	1	4	0.5	2	0	2	2	0.1	0	0
Decapoda															
Decapod larvae	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi post larvae	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi juvs	0	0	0	1	0	0	0.2	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	586	503	81	3	2	11	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	0.1	0.2	0.1	1	1	4	2	3	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0.1	0	3	2	2	1
Chironomid larvae	0	0	0	0	0	0	2	0.1	0	0.1	0	4	1	7	5
Pisces															
Anguilla sp.	0.1	0.1	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Gobiid larvae	5	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0
Pipefish juv.	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XIII. Composition and abundance (numbers m^{-3}) of zooplankton collected November 2005 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polychaeta															
Polychaete larvae	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda															
Acartia longipatella	0	38	535	1612	1653	5804	5118	496	1047	0	0	0	0	0	0
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	25	85	0
Halicyclops sp.	0	0	0	0	0	0	0	1	215	481	717	136	20	57	216
Harpacticoid sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	621
Oithona spp	31	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Paracalanus sp	511	463	209	0	0	0	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	0	571	2355	7776	11674	50667	37001	3823	10169	17849	14156	2727	520	2386	3439
Saphiriella sp.	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mysidacea															
Mesopodopsis wooldridgei	6	0	0	4	0	7	8	4	15	19	0	0	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0	7	8	5	10	12	25	0	0	0	0
Cumacea															
Cumacean spp	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	8	28	30	21	22	23	8	7	0	5	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	6	0	27	7	5	4	4	9	6	18	4	2	8
Grandidierella lutosa	0	28	58	229	6	15	4	0	0	0	0	0	0	0	0
Melita zeylanica	11	28	24	21	9	16	23	2	0	9	3	0	0	0	0
Paramoera capensis	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi post larvae	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1 larvae	240	38	0	0	0	0	0	0	0	0	0	0	0	0	0
Callianassa kraussi juvs	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	129	92	25	25	28	13	8	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	11	19	1	0	6	7	0	0	0.2	4	6	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	6	3	4	4	8
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	3	8	4	4	3
Mollusca															
Bivalve spat	36	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Gastropod spat	0	0	0	2603	0	5998	16507	385	798	1105	0	0	0	23	0
Pisces															
Gilchristella aestuaria eggs	8	19	134	131	86	26	25	33	4	4	0	8	0	0	0
Gilchristella aestuaria larvae	3	0	0	16	0	10	45	5	105	31	19	3	2	0	0
Gobiid larvae	14	0	0	21	14	10	16	2	8	9	21	0	0	0	0
Pipefish juv.	0.2	0	0	1	0	0.2	0	0	0	0	0	0	0	0	0

Appendix XIV. Composition and abundance (numbers m^{-3}) of zooplankton collected February 2006 at 15 stations in the Great Berg estuary

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Copepoda															
Acartia longipatella	0	0	147	99	102	112	44	771	433	0	37	0	0	0	0
Copepod spp.	124	252	140	121	0	0	0	0	0	0	0	0	0	0	0
Daphnia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	62	934
Halicyclops sp.	0	0	0	0	262	112	115	41	0	0	0	0	39	62	163
Oithona spp	166	310	0	0	0	0	0	0	0	0	0	0	0	0	0
Paracalanus sp	166	191	666	0	0	0	0	0	0	0	0	0	0	0	0
Pseudodiaptomus hessei	0	0	446	2698	26055	1637	861	8265	6313	16446	11152	12514	7702	4954	3629
Saphiriella sp.	387	443	446	1450	166	112	0	0	0	0	0	0	0	0	0
Mysidacea															
Mysidopsis major	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesopodopsis wooldridgei	0	0	4	0	0	0	0	0	4	0	9	0	14	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0	21	22	29	62	205	154	209	101	0	0
Cumacea															
Cumacean spp	9	6	7	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp.	5	7	19	0	0	4	2	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	6	10	98	256	6	10	24	20	35	0	0	0	0	0
Paridotea ungulata	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	3	0	66	0	307	14	38	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	4	1	18	0	4	40	406	4529	2421	16	509	251	3
Grandidierella lutosa	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0
Melita zeylanica	0	6	0	17	258	10	4	6	9	27	12	0	0	0	0
Paramoera capensis	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon perengueyi	2	6	2	0	0.4	2	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1 larvae	3	64	8	37	0	0	0	0	0	0	0	0	0	0	0
Callianassa kraussi juvs	0	0	0	0	0	0	4	20	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	31	89	0	0	0	0	0	61	0	10	0	0	0	0	0
Hymenosoma orbiculare	3	7	19	49	326	24	20	2	11	9	3	0	0	0	0
Zoea larvae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6
Pisces															
Gilchristella aestuaria eggs	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
*Gilchristella aestuaria l*arvae	0	0	0	0	0	0	4	8	54	18	17	171	6	2	2
Gobiid larvae	3	2	4	1	1	2	4	29	4	27	3	0	0	0	0
Pipefish juv.	0	0	0.2	1	0	0	0.2	0	0	0	0	0	0	0	0

APPENDIX 3.3 Estuary Invertebrate Data – Hyperbenthos

Appendix XV. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected February 2003 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	0	703.5	1	0.1	1	3.5	2	6.5	37.5	49.5	0	0	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0.5	0	0	0.5	7.5	17	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Paridotea ungulata	0.4	0	1	0.5	0	0	0	0	0	0	0	0	0	0	0
Sphaeromid sp	0.1	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0.5	0	0.5	2	7	1.5	3	0	0	0	0
Grandidierella lignorum	0	0	0	0	1	0	0	0	0	3	1	0	0	0	0
Melita zeylanica	0	0	1	5	0.5	0.1	0.5	1	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi	10.5	0	1	4	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Chiromantes eulimine larvae	0	2.5	0	0	344	176.5	65	5	0	0	0	0	0	0	0
Hymenosoma orbiculare larvae	0	0	0	564.5	3.5	0	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0
Zoea larvae	0	0	0	68.5	0	0	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5
Pisces															
Brown goby	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0
Gilchristella aestuaria eggs	0	0	0	0	0	0	0	6.5	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	0	0.5	103	251	74.5	12	0.5	13	3	0
Gobiid larvae	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pipe fish	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0

Appendix XVI. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected September 2003 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	256.5	3.5	1	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalophthalmus terranatalis	53.5	0.1	8.5	12	0.1	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	4	0.4	0.4	0.1	0.5	11	20	14.5	0	0	0	0
Cyathura estuaria	0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
Grandidierella lutosa	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	0.1	0	0.1	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi	4.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0.1	0.1	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0
Pisces															
Caffrogobius nudiceps	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullet juv	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0
Syngnathus temminkii	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psammogobius knysnaensis	0.1	0	0	0.1	0.1	0.1	0.1	0.3	0	0.3	0.7	0	0	0	0
Solea bleekeri	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0

Appendix XVII. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected February 2004 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Gastrosaccus brevifissura	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Mesopodopsis wooldridgei	3	0.1	0	0	0	0	0	0	0	4	6	1	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	3	48	25	31	53	28	427	3	0	0	0
Cumacea															
Cumacean spp	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0.1	0.1	0	0	0	0	1	3	0	0	0	0	0	0
Paridotea ungulata	0.6	0.1	0	0.4	0	0	0	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0
Melita zeylanica	0	0	0.1	0	0	0.3	0.1	9	0	0	0	0	0	0	0
Decapoda															
Decapod larvae	1	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi	0	0	0.2	7	0	0	0	0	0	0	0	0	0	0	0
Palaemon peringueyi larvae	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0	0	0	0.5	0	0	0.1	0.1	0	0	0	0	0	0	0
Insectivora															
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisces															
Caffrogobius nudiceps	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	0	0	0	1	2	2	0.5	1	0	0
Syngnathus temminkii	0	0	0.2	0.2	0.5	0	0	0	0	0	0	0	0	0	0

Appendix XVIII. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected April 2005 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	230	1	0	0	0	0	0	0.1	0	0	0.5	0	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0.1	0	0	0.1	137	14	8	329	2	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0	0	0	0.1	0	0	0	0	3	0	0	0	0	0
Paridotea ungulata	3	1	0.1	0.1	0.1	0	0.1	0.1	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	0	0	0	0	0	0	115	1	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0	0.4	0	0.1	0	13	79	4	15	20	0.1
Grandidierella lutosa	5	0	0.1	0	0.1	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	1	0.3	0	0	0	5	0	0	0	0	0
Caridea															
Palaemon peringueyi	1	2	0	2	0.3	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare larvae	9	32	0	6	1	1	5	0	0	0	0	0	0	0	0
Hymenosoma orbiculare	0	0	0	0	0	0	0	0	0	1	0.1	0	0	0	0
Insectivora															
Chironomid larvae	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pisces															
Gilchristella aestuaria larvae	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
Gobiid larvae	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Syngnathus temminkii	0	0.1	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0

Appendix XIX. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected July 2005 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	0	2	0.1	0.3	0	0	0.1	0	0	0	0	0	0	0	0
Rhopalophthalmus terranatalis	189	11	4	2	5	2	0	0	0	0	0	0	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0	0.4	0.2	1	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0.4	0	0.4	0	0	0.1	0	0	0.3	0	0
Cyathura estuaria	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grandidierella lutosa	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	1	0	0	0.1	0	0	0	0.1	0	0	0
Caridea															
Palaemon peringueyi larvae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0.1	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0.1	0.3	0	0
Chironomid larvae	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0
Pisces															
Anguilla sp.	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psammogobius knysnaensis	0	0.3	0	0	0	0	0	0	0.1	0.1	0.1	0	0	0	0

Appendix XX. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected November 2005 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	17	14	1	0	0	0	0	0	1	2	0	0	0	0	0
Rhopalophthalmus terranatalis	0	0	0	0	0	0	2	0	5	2	104	5	0	0	0
Isopoda															
Exosphaeroma hylecoetes	0	0.1	2	1	0	3	0	1	3	0	0	0	0	0	0
Paridotea ungulata	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Amaryllis sp.	1	0.3	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Corophium acherusicum	0	0	0	0	0	0	1	0	5	0.2	0	2	2	3	0.4
Grandidierella lutosa	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	2	2	0	0	3	1	0	0	0	0	0.1	2	0.1
Caridea															
Palaemon peringueyi	0	0	0.5	0.2	0.1	0	0	0	0	0	0	0	0	0	0
Anomura															
Upogebia africana stage 1	9	43	15	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	3	2	2	2	0	0	3	3	2	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	0	0.4	7	0.4
Chironomid larvae	0	0	0	0	0	0	0	0	1	0	0	0.1	0.4	5	0.4
Pisces															
Gilchristella aestuaria eggs	0	0	0	0	0	6	3	1	2	0	0	1	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	0	1	3	14	2	25	1	0.1	0.1	0.1
Gobiid larvae	0	2	1	0	1	7	36	1	9	3	35	0	0	0	0
Syngnathus temminkii	0	0	0	0	0	0.2	0.3	0	0	0	0	0	0	0	0
Psammogobius knysnaensis	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0

Appendix XXI. **Composition and abundance (numbers m^{-3}) of hyperbenthic organisms, collected February 2006 at 15 stations in the Great Berg estuary**

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mysidacea															
Mesopodopsis wooldridgei	0	0	0	0	0	0	0	0	0	0.1	0.5	1	15	0.1	0
Rhopalophthalmus terranatalis	0	0	0	0	0	0	0	0.1	2	2	4	7	2	0	0
Cumacea															
Iphinoe sp.	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Uromunna sheltoni	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	0	0	0	0.1	2	6	52	2	0	0.5	0
Cyathura estuaria	0.1	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Melita zeylanica	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi	0.1	0.1	0.3	20	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0.1	0	0	0.4	0.1	0.4	0	0	0.3	0	1	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	1	0	0.3	0.1
Chironomid larvae	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.1	0
Pisces															
Caffrogobius nudiceps	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0
Gilchristella aestuaria larvae	0	0	0	0	0	0	0.1	0.1	0	3	14	3	1	2	0.1
Gobiid larvae	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0
Syngnathus temminkii	0	0	0.1	0.2	0	0.4	0.1	0	0.2	0	0	0	0	0	0

APPENDIX 3.4 Estuary Invertebrate Data – Benthos

Appendix XXII. Composition and abundance (numbers m-2) of benthic organisms collected February 2003 at 15 stations in the Great Berg estuary

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Polychaeta															
Boccardia sp.	0	0	0	8.3	308.3	158.3	0	100	25	0	0	0	0	0	0
Capitella capitata	2183.3	16.7	12.5	466.7	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis erythraeensis	583.3	16.7	75	333.3	0	0	133.3	0	0	0	0	0	0	0	0
Ceratonereis keiskama	0	0	12.5	308.3	500	775	325	300	175	0	0	0	0	0	0
Chaetopterid sp.	0	8.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Desdemona ornata	0	0	0	83.3	4033.3	9875	441.7	0	33.3	0	0	0	0	0	0
Oligochaete sp.	0	0	0	0	0	0	0	0	0	150	400	25	100	68.8	66.7
Orbinia angrapequensis	16.7	50	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamilla reniformis	0	0	1300	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio bocki (?)	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0
Prionospio pinnata	0	0	0	0	0	58.3	0	0	0	0	0	0	0	0	0
Prionospio sp. 1	0	8.3	0	16.7	8.3	100	0	0	0	0	0	0	0	0	0
Prionospio sexoculata	0	8.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Spionid sp.	0	0	0	0	0	83.3	0	0	0	0	0	0	0	0	0
Cumacea															
Cumacean sp. 1	8.3	8.3	12.5	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp. 1	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	0	875	275	741.7	758.3	450	25	8.3	0	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	12.5	0	0	0	0	33.3	0	0	0	0	0	0	0
Paridotea ungulata	33.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Amphipod sp. 1	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipod sp 2.	0	0	0	0	41.7	0	0	0	0	0	0	0	0	0	0
Corophium acherusicum	8.3	0	62.5	25	133.3	1300	533.3	84183.3	10750	16.7	0	0	0	0	0
Grandidierella chelata	0	8.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Grandidierella lignorum	0	0	0	0	0	8.3	0	8.3	0	0	0	0	0	0	0
Grandidierella lutosa	108.3	75	2437.5	1150	341.7	0	0	0	0	0	0	0	0	0	0
Lysianassa sp.	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neomicrodeutopus sp.	0	0	512.5	225	108.3	41.7	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	0	466.7	225	33.3	666.7	433.3	25	0	0	0	0	0	0	0	0
Upogebia africana	41.7	0	12.5	8.3	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	8.3	16.7	0	8.3	0	8.3	0	100	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	37.5	0	58.3	41.7	16.7	0	0	0	0	0	0	0	8.3
Insectivora															
Chironomid larvae	0	0	0	0	0	0	0	0	16.7	8.3	31.3	0	83.3	87.5	25

Appendix XXIII. Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected September 2003 at 15 stations in the Great Berg estuary

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Polychaeta															
Boccardia sp.	0	0	0	33.3	583.3	233.3	116.7	18.8	77.8	0	0	0	0	0	0
Capitella capitata	2211	522.2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis erythraeensis	38.9	0	33.3	94.4	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis keiskama	0	0	0	211.1	544.4	783.3	416.7	556.3	727.8	138.9	0	0	0	0	0
Desdemona ornata	0	77.8	27.8	66.7	1461.1	1061.1	2816.7	31.3	0	0	0	0	0	0	0
Glycera tridactyla	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaete sp.	0	0	0	0	0	0	0	12.5	5.6	211.1	316.7	838.9	250	388.9	272.2
Prionospio bocki	16.7	38.9	222.2	44.4	133.3	372.2	22.2	50	0	0	0	0	0	0	0
Prionospio sexoculata	0	44.4	0	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	0	1178	1250	2388.9	1572.2	2727.8	37.5	0	0	0	0	0	0	0
Cyathura estuaria	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	0	16.7	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	111.1	6727.8	8377.8	8516.7	4437.5	1744	100	0	0	0	0	0
Grandidierella lutosa	5.6	11.1	3494	3594.4	16.7	77.8	83.3	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	0	0	5.6	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	0	0	0	0	16.7	22.2	5.6	0	0	0	0	0	0	0	0
Upogebia africana	16.7	16.7	16.7	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	55.6	16.7	27.8	27.8	44.4	105.6	27.8	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	11.1	0	0	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0	11.1
Chironomid larvae	5.6	16.7	22.2	333.3	5.6	27.8	5.6	56.3	16.7	11.1	33.3	5.6	0	11.1	0
Mollusca															
Bivalve spat	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisces															
Solea bleekeri	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XXIV. Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected February 2004 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polychaeta															
Boccardia sp.	0	0	0	12.5	6706.3	77.8	62.5	200	0	0	0	0	0	0	0
Capitella capitata	450	2466.7	200	531.3	2593.8	0	0	50	6138.9	0	0	0	0	0	0
Ceratonereis keiskama	222.2	5.6	0	25	4306.3	450	562.5	1988.9	1038.9	366.7	38.9	0	0	0	0
Desdemona ornata	0	194.4	66.7	0	806.3	5750	306.3	0	0	5727.8	0	0	0	0	0
Dorvillea sp.	0	0	0	31.3	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla	5.6	0	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaete sp.	0	0	0	0	0	0	0	0	0	0	505.6	133.3	155.6	116.7	72.2
Orbinia angrapequensis	16.7	44.4	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio sexoculata	0	0	0	0	875	50	25	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	27.8	855.6	2212.5	2743.8	4300	1256.3	11.1	0	0	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	6.3	0	105.6	25	5.6	33.3	19472.2	22.2	0	0	0	0
Grandidierella lutosa	0	16.7	372.2	818.8	16043.8	388.9	62.5	0	0	0	0	0	0	0	0
Melita zeylanica	0	11.1	0	6.3	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	0	11.1	0	37.5	43.8	972.2	81.3	0	0	0	0	0	0	0	0
Upogebia africana	394.4	0	61.1	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	5.6	5.6	5.6	0	12.5	11.1	0	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	6.3	12.5	44.4	12.5	0	0	0	0	0	0	0	0
Insectivora															
Chironomid larvae	0	0	0	0	0	0	0	0	0	5.6	11.1	22.2	111.1	5.6	11.1
Mollusca															
Bivalve spat	5.6	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XXV. Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected April 2005 at 15 stations in the Great Berg estuary

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Polychaeta															
Boccardia sp.	0	0	0	16.7	505.6	0	0	5.6	472.2	1705.6	0	0	0	0	0
Capitella capitata	3022.2	0	127.8	266.7	27.8	11.1	0	0	8055.6	16150	1927.8	227.8	0	227.8	0
Ceratonereis erythraeensis	0	22.2	27.8	0	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis keiskama	44.4	0	16.7	22.2	894.4	266.7	272.2	216.7	2561.1	14166.7	3533.3	683.3	516.7	0	0
Desdemona ornata	0	0	144.4	0	661.1	127.8	5.6	0	0	0	0	0	0	0	0
Oligochaete sp.	0	0	22.2	0	0	0	61.1	0	0	2266.7	566.7	0	288.9	1338.9	1688.9
Orbinia angrapequensis	0	0	16.7	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio bocki	0	0	0	0	0	16.7	0	5.6	227.8	0	283.3	0	16.7	0	0
Prionospio sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	5.6	0	0
Prionospio sexoculata	455.6	16.7	500	55.6	983.3	22.2	0	0	0	0	0	0	0	0	0
Cumacea															
Iphinoe sp. 1	0	11.1	11.1	0	22.2	5.6	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	0	1077.8	2261.1	4983.3	1411.1	2483.3	1216.7	0	0	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	5.6	44.4	483.3	50	27.8	0	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	0	0	5.6	5.6	11.1	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	55.6	5333.3	19055.6	94.4	77.8	38.9	25783.3	3227.8	600	4772.2	5700	4405.6
Grandidierella lutosa	0	27.8	1777.8	2272.2	10372.2	66.7	16.7	0	0	0	0	0	0	0	0
Melita zeylanica	227.8	0	0	0	0	455.6	0	0	0	0	0	0	0	0	0
Paramoera capensis	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caridea															
Palaemon peringueyi	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	0	50	66.7	55.6	0	27.8	311.1	33.3	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0	0	0	0	0	5.6	5.6	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	5.6	0	11.1	0	0	0	0	0	0	0	0	0
Insectivora															
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	1822.2	1055.6	711.1	411.1
Mollusca															
Bivalve spat	0	5.6	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	27.8	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XXVI.	Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected July 2005 at 15 stations in the Great Berg estuary														
Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Polychaeta															
Boccardia sp.	0	0	0	5.6	50	0	0	0	111.1	0	0	0	0	0	0
Capitella capitata	5322.2	355.6	11.1	5.6	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis keiskama	283.3	11.1	5.6	177.8	88.9	305.6	366.7	661.1	1138.9	3061.1	2155.6	172.2	0	0	0
Desdemona ornata	0	55.6	133.3	200	5233.3	1222.2	1000	22.2	0	0	0	0	0	0	0
Glycera tridactyla	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercierella enigmatica	0	0	0	0	0	55.6	0	0	0	0	0	0	0	22.2	0
Oligochaete sp.	861.1	16.7	0	0	0	0	0	0	0	0	0	5.6	172.2	11.1	27.8
Prionospio sexoculata	344.4	250	222.2	600	244.4	188.9	27.8	27.8	222.2	172.2	0	0	0	0	0
Cumacea															
Iphinoe sp. 1	0	11.1	5.6	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	0	161.1	555.6	4266.7	1461.1	4005.6	1244.4	0	0	0	0	0	5.6	0
Exosphaeroma hylecoetes	0	0	5.6	0	5.6	11.1	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	111.1	6800	21100	1522.2	1083.3	4005.6	4938.9	0	0	0	1338.9	72.2
Grandidierella lutosa	0	0	738.9	283.3	4255.6	1716.7	1572.2	72.2	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	0	1666.7	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	0	0	11.1	0	0	0	5.6	0	0	0	0	0	0	0	0
Upogebia africana	0	38.9	11.1	0	0	0	0	0	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	0	0	5.6	33.3	50	22.2	0	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	5.6	0	5.6	0	0	0	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	0	16.7	0	0	0	0	0	0	0	0	0	0
Chironomid larvae	0	5.6	5.6	55.6	0	5.6	5.6	0	0	0	111.1	0	0	5.6	5.6
Mollusca															
Bivalve spat	0	5.6	5.6	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XXVII.	Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected November 2005 at 15 stations in the Great Berg estuary														
Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Polychaeta															
Boccardia sp.	0	0	0	28.6	0	538.9	350	0	355.6	0	22.2	0	5.6	0	0
Capitella capitata	611.1	0	161.1	14.3	0	222.2	262.5	0	0	0	0	0	0	0	0
Ceratonereis erythraeensis	11.1	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratonereis keiskama	38.9	0	0	50	38.9	94.4	181.3	88.9	172.2	83.3	11.1	27.8	16.7	0	0
Desdemona ornata	0	0	5.6	0	0	494.4	788.9	850	2494.4	333.3	0	0	0	0	0
Glycera tridactyla	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaete sp.	0	0	0	0	0	0	0	0	0	0	0	0	77.8	38.9	594.4
Orbinia angrapequensis	22.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio bocki	0	0	50	28.6	27.8	488.9	325	0	122.2	61.1	5.6	5.6	0	0	0
Prionospio sexoculata	5.6	0	44.4	7.1	11.1	94.4	0	0	0	0	0	0	0	0	0
Cumacea															
Iphinoe sp. 1	16.7	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	22.2	266.7	928.6	3466.7	2172.2	3418.8	2027.8	4333.3	1733.3	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	11.1	7.1	5.6	0	81.3	194.4	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	142.9	0	4705.6	12743.8	31750	11216.7	6805.6	33.3	5.6	0	11.1	0
Grandidierella lutosa	0	211.1	4183.3	4750	7538.9	516.7	218.8	111.1	338.9	0	0	0	0	0	0
Melita zeylanica	0	0	0	0	0	0	0	27.8	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	5.6	255.6	0	0	94.4	0	31.3	22.2	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	5.6	55.6	27.8	21.4	111.1	172.2	181.3	227.8	38.9	50	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	0	11.1	5.6	6.3	0	11.1	0	0	0	0	0	0
Insectivora															
Insect larvae	0	0	0	7.1	0	33.3	0	0	0	0	0	0	0	0	0
Chironomid larvae	0	0	27.8	0	0	61.1	6.3	0	127.8	433.3	183.3	177.8	894.4	755.6	44.4
Mollusca															
Bivalve spat	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix XXVIII. Composition and abundance (numbers m^{-2}) of subtidal benthic organisms collected February 2006 at 15 stations in the Great Berg estuary

Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Polychaeta															
Boccardia sp.	0	0	11.1	16.7	5.6	544.4	16.7	0	1344.4	561.1	0	0	0	0	0
Capitella capitata	0	0	188.9	516.7	0	0	0	0	12983.3	1122.2	0	450	0	0	0
Ceratonereis erythraeensis	16.7	0	0	177.8	0	0	0	22.2	0	0	0	0	0	0	0
Ceratonereis keiskama	0	0	0	0	194.4	488.9	422.2	477.8	944.4	133.3	122.2	5.6	0	0	0
Desdemona ornata	0	0	544.4	44.4	0	7472.2	2455.6	0	0	0	0	0	0	0	0
Glycera tridactyla	0	16.7	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephthys capensis	0	5.6	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaete sp.	0	0	94.4	0	0	0	0	0	0	0	0	583.3	27.8	322.2	233.3
Orbinia angrapequensis	83.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio bocki	0	0	0	0	0	0	111.1	0	0	0	0	0	0	0	0
Prionospio sexoculata	0	0	22.2	0	0	5.6	0	0	0	0	0	0	0	0	0
Cumacea															
Cumacean sp. 1	0	11.1	155.6	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe sp. 1	0	0	155.6	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda															
Anthurid sp.	0	5.6	938.9	744.4	361.1	3816.7	2461.1	705.6	0	0	0	0	0	0	0
Uromunna sheltoni	0	0	0	11.1	0	0	0	0	0	0	0	0	0	0	0
Amphipoda															
Corophium acherusicum	0	0	0	0	11.1	572.2	205.6	238.9	1638.9	1244.4	2605.6	694.4	0	5.6	0
Grandidierella lutosa	0	283.3	1116.7	694.4	394.4	11.1	0	0	0	0	0	0	0	0	0
Melita zeylanica	0	0	0	33.3	0	0	0	0	0	0	0	0	0	0	0
Paramoera capensis	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anomura															
Callianassa kraussi	11.1	155.6	38.9	50	866.7	305.6	883.3	5.6	0	0	0	0	0	0	0
Brachyura															
Hymenosoma orbiculare	5.6	16.7	61.1	27.8	5.6	11.1	50	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	11.1	11.1	0	16.7	22.2	11.1	22.2	0	0	0	0	0	0	0
Insectivora															
Chironomid larvae	0	0	5.6	0	0	0	0	5.6	0	0	0	5.6	111.1	61.1	16.7

APPENDIX 3.5 Estuary Invertebrate Data – Intertidal Benthos

Appendix XXIX. Composition and abundance (numbers m^{-2}) of intertidal benthic organisms collected September 2003 at seven stations in the Great Berg estuary.

Station	KH1	KH2	KH3	KH4	FP1	FP2	FP3	FP4
Polychaeta								
Boccardia sp.	960	40	160	0	0	0	0	0
Capitella capitata	80	100	620	0	0	0	0	0
Ceratonereis erythraeensis	980	1140	3600	0	0	0	0	0
Ceratonereis keiskama	0	20	60	0	0	0	0	0
Namalycasatis sp.	0	0	0	336	0	0	0	0
Isopoda								
Anthurid sp.	20	60	0	0	0	0	0	0
Exosphaeroma hylecoetes	0	0	0	336	0	0	0	0
Amphipoda								
Corophium acherusicum	20	0	0	0	0	0	0	0
Grandidierella chelata	60	0	0	0	0	0	0	0
Grandidierella lutosa	400	160	20	0	0	0	0	0
Melita zeylanica	0	20	0	120	0	0	0	0
Talorchestia sp.	60	0	0	264	0	0	0	0
Anomura								
Upogebia africana	0	80	80	0	0	0	0	0
Brachyura								
Hymenosoma orbiculare	0	0	40	24	0	0	0	0
Insectivora								
Chironomid larvae	0	0	0	0	240	192	0	0
Mollusca								
Hydrobia sp.	0	40	0	0	0	0	0	0

Appendix XXX. Composition and abundance (numbers m^{-2}) of intertidal benthic organisms collected February 2006 at four stations in the Great Berg estuary.

Station	KH1	KH2	KH3	KH4
Polychaeta				
Capitella capitata	7520.0	720.0	520.0	1464.0
Ceratonereis erythraeensis	8820.0	9160.0	3200.0	6504.0
Isopoda				
Cyathura estuaria	20.0	0.0	0.0	0.0
Exosphaeroma hylocoetes	0.0	0.0	140.0	0.0
Paridotea ungulata	0.0	0.0	80.0	0.0
Amphipoda				
Grandidierella lutosa	0.0	1280.0	15140.0	960.0
Caridea				
Palaemon peringueyi	40.0	0.0	0.0	0.0
Anomura				
Upogebia africana	0.0	620.0	60.0	0.0
Brachyura				
Hymenosoma orbiculare	0.0	620.0	80.0	0.0
Thaumastoplax spiralis	0.0	0.0	20.0	0.0
Insectivora				
Insect larvae	40.0	0.0	0.0	0.0
Mollusca				
Bivalve spat	820.0	0.0	0.0	0.0