Temporal and spatial patterns in the distribution of infaunal Polychaetes in Jervis Bay, New South Wales, Australia

Patricia A. HUTCHINGS & Charles A. JACOBY***

* The Australian Museum, P.O. Box A285, Sydney South, NSW 2000 Australia
** Marmion Marine Laboratories, CSIRO Division of Fisheries
P.O. Box 20, North Beach WA 6020 Australia

ABSTRACT

A series of quantitative infaunal samples were taken between February 1989 and July 1991 at 10 sites in Jervis Bay, a protected marine embayment on the south coast of New South Wales. Six sites had muddy/sand sediments and four sites were in beds of the seagrass *Posidonia australis*. Replicate samples were taken at each site in every time period to produce a quantitative baseline with estimates of variability. This baseline can be used to assess future changes in the infaunal assemblages in Jervis Bay. Polychaetes were a major component of the fauna in terms of numbers of individuals and numbers of species. The polychaete fauna was represented by 171 species in 36 families. Assemblage data were analysed using multivariate classifications. Assemblages tended to differ between the two habitats and among some sites within a habitat. These differences remained stable through time. Some species were widely distributed across sites and habitats, and the patterns in assemblage composition were due primarily to the restricted distribution of some rarer species. Density data for the dominant polychaete species were used in analysis of variance in an attempt to assess spatial and temporal patterns in their abundances. Densities of most species varied in a complex manner with spatial patterns being more obvious than temporal ones. Patterns in abundance are difficult to explain or predict because of the limited information available on life histories of these or related species and the absence of similar studies conducted elsewhere.

RÉSUMÉ

Structures temporelles et spatiales de la distribution des Polychètes endogées de la baie de Jervis, Nouvelles Galles du Sud, Australie

Une étude quantitative de l'endofaune de substrat meuble a été réalisée sur la côte Sud du NSW (Australie) à Jervis Bay, une baie peu profonde et protégée de la houle. Dix stations ont été échantillonnées ; quatre au sein de l'herbier de *Posidonia australis* et six en dehors de l'herbier. Les prélévements ont été effectués tous les quatre mois de février 1989 à juillet 1991. Les Polychètes sont, en nombre d'espèces et en nombre d'individus, les organismes les plus abondants de cette endofaune : 36 familles et 171 espèces ont été identifiées. Toutes les données ont été traitées avec le "Pattern Analysis Package". Il en ressort que les replicats d'un même substrat tendent à fusionner, indiquant ainsi la prépondérance du facteur site sur le facteur saison. Une analyse de variance portant sur les principales espèces de Polychètes montre que si les facteurs sites ou saisons sont prépondérants pour la distribution de nombreuses espèces, ils agissent aussi en synergie. Ces modèles de distribution sont

---

HUTCHINGS, P.A. & C.A. JACOBY, 1994. — Temporal and spatial patterns in the distribution of infaunal Polychaetes in Jervis Bay, New South Wales, Australia. *In:* J.-C. DAUVIN, L. LAUBIER & D.J. REISH (Eds), Actes de la 4ème Conférence internationale des Polychètes. *Mém. Mus. natn. Hist. nat.*, **162** : 441-452. Paris ISBN 2-85653-214-4.

discutés en détail en tenant compte des faibles données existant sur le cycle de vie de ces espèces. Les résultats obtenus sont également comparés à ceux fournis par des études similaires réalisées dans d'autre régions du monde, rien de comparable n'ayant été fait en Australie.

INTRODUCTION

Jervis Bay, a temperate marine embayment on the south coast of New South Wales, is highly regarded for its environmental quality and is listed on the Register of the National Estate. The bay is currently used for tourism, commercial and recreational fishing and Department of Defence training exercises. Population growth in the surrounding area is increasing. Concern about the possible impacts of current uses and proposed additional uses led the Department of Defence to fund a three year program of inventory and baseline studies (WARD & JACOBY, 1992). One of these studies aimed to quantify spatial and temporal patterns in the abundances of infauna in the muddy/sand and vegetated sediments around the Bay. This paper discusses the preliminary findings from this study with an emphasis on polychaetes, which were a major component of the infauna and an essential part of any baseline that characterises the existing status of Jervis Bay.

METHODS

Jervis Bay (35°08'S, 150°45'E) is a kidney-shaped marine embayment. It reaches a maximum depth of about 30 m, has a surface area of 102 km^2, and opens onto the continental shelf through a 3.5 km wide entrance. The bay has a relatively small catchment which does not contain a major river but does include several small creeks. Mangroves and saltmarshes line these creeks. The shores of the bay are primarily sandy beaches bounded by creek mouths and shallow rocky reefs. Extensive beds of seagrass *Posidonia australis* occur in the shallow, subtidal areas (above 10 m) in the northern and southern parts of the bay. Beyond the rocky reefs and seagrasses (below 10 m), are characterised by extensive muddy/sand areas.

Four sites were selected in *P. australis* beds (vegetated sites) and six were chosen in deeper, muddy/sand sediments (Fig. 1). Depths at the vegetated sites varied in depth from 2–6 m (Callala Boat Ramp 2 m, Hare Bay 3 m, Green Island 6 m and Hole in the Wall 5 m). Four muddy/sand sites, Hole in the Wall, Montague Roadsted, Green Point and Plantation Point 'shallow', were at 12 m and two sites, Honeymoon Bay and Plantation Point 'deep' were at 20 m.

Nine sets of infaunal samples were collected at each site between February 1989 and June 1991. Sampling periods were separated by two to five months. At each vegetated site, infauna were collected by SCUBA divers using a hand operated corer (11 cm internal diameter; surface area of 0.01 m^2). Four replicates were collected from each of two plots (2 m x 2 m) separated by about 50 m. At muddy/sand sites, five replicate samples were collected using a Smith-McIntyre grab (sampling area 0.06 m^2). All samples were put into bags made of 1.0 mm mesh, washed, stained with Biebricht Scarlet and fixed in 7 % neutralised formalin. In the laboratory, animals were extracted, identified and counted. The mesh size was selected after consideration of time and funds available for sorting and the main objective of the study, i.e., description of the overal distribution and abundance of the benthic macroinfauna within the bay.

Assemblage data were analysed to assess spatial and temporal patterns in species composition. All data were $\log_{10}(x + 1)$ transformed prior to analyses. Multivariate classifications were based on Bray–Curtis dissimilarity measures (BELBIN, 1989). These measures were classified by hierarchical, polythetic, agglomerative fusion using unweighted pair group arithmetic averaging (UPGMA), with no order or adjacency constraints and a beta coefficient of - 0.01). The results of the fusion were used to construct a dendrogram from which groups of samples were defined on the basis of fusion patterns. In addition, multivariate classifications of species according to their occurrences in samples were conducted using two–step dissimilarity measures in a UPGMA fusion with no constraints on adjacency or order and a beta of – 0.01 (BELBIN, 1989). Species groups were defined from a dendrogram constructed from the results of the classification. The relationships between species groups and site groups were examined using two–way tables.

Spatial and temporal patterns in the distribution of common species were investigated using univariate analyses of variance. The ANOVAs based on data from grab samples had sampling periods and sites as random factors. The ANOVAs based on core samples, also had sampling periods and sites as random factors, as well as, plots as a random factor nested within sites. Prior to conducting the ANOVAs, data were tested for homogeneity of variance using Cochran's test. All data required $\log_{10}(x+1)$ transformation to achieve homoscedasticity. Some data remained heterogeneous, and these data were not analysed.

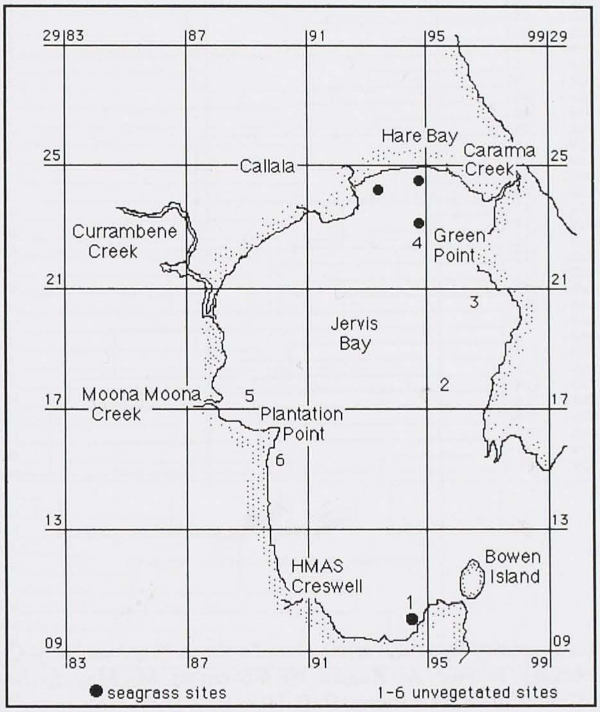

FIG. 1. — Map of Jervis Bay showing location of vegetated and muddy/sand sites. Site 1, Hole in the Wall; Site 2, Honeymoon Bay, Site 3; Montague Roadsted; Site 4, Green Point and Site 5, Plantation Point "shallow"; Site 6, Plantation Point "deep".

RESULTS

Over 630 infaunal species were collected, including 248 crustaceans, 197 molluscs, 171 polychaetes and 15 echinoderms as well as representatives of Nemertea, Sipuncula, Phoronida, Turbellaria and Coelenterata which were not identified to species. A majority of the 171 species of polychaetes (representing 31 families) have previously been recorded from New South Wales waters (HUTCHINGS & MURRAY, 1984).

Analyses were confined to a data set composed of counts of polychaetes, molluscs, and echinoderms from nine sampling periods. To date, crustaceans have been identified only in the first four sets of samples.

A series of classifications were performed. Initially, a multivariate analysis, was performed using 558 replicates as separate samples. The resulting distribution of dissimilarity measures was strongly skewed towards high values which suggests that single replicate samples varied greatly. It is unlikely that single samples adequately represented an assemblage; therefore replicate samples from each combination of site and time periods were summed (i.e., n = 5 for grab samples and n = 8 for core samples) and the analysis was repeated. This classification revealed a strong dissimilarity between core and grab samples, i.e., samples from vegetated and muddy/sand sites. This dissimilarity may have been partly due to biases introduced by the two different types of sampling gear. These biases will be investigated in a separate paper. Subsequent analyses considered samples from vegetated and muddy/sand sites separately.

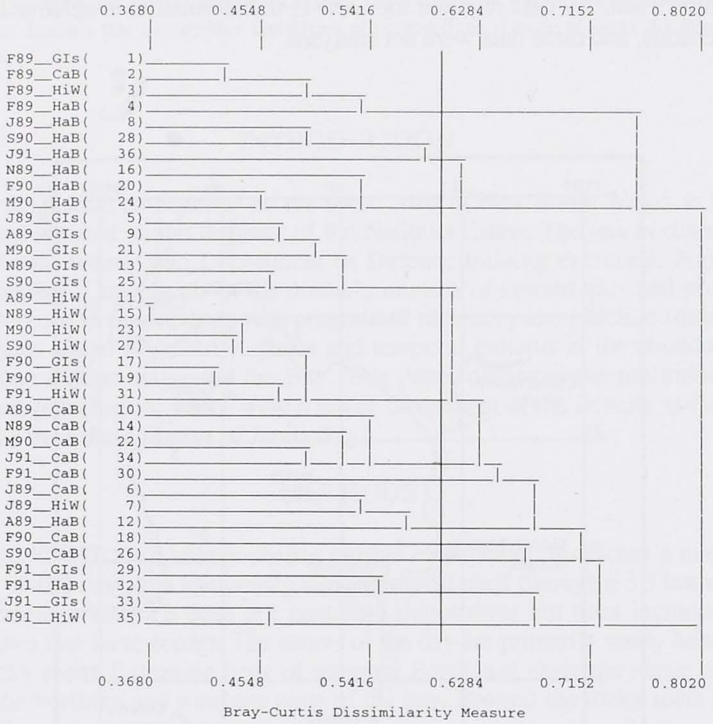

FIG. 2. — The results of the fusion generated by multivariate classifications based on Bray–Curtis dissimilarity measures, for the vegetated core sites. F= February, J= June, A= August, N= November, M= May, S= September, 89 = 1989, 90 = 1990, 91 = 1991, GIs–Green Island, CaB–Callala Boat Ramp, HaB–Hare Bay, HiW–Hole in the Wall.

Separate classifications based on data from grab and cores revealed that species composition differed primarily among sites and was reasonably stable among sampling times (Figs 2 & 3). Exceptions were the February 1989 core samples which had relatively unique species composition regardless of their site of origin (Fig. 2). The grab samples from shallow (12 m) muddy/sand sites (Hole in the Wall, Green Point and Montague Roadsted) tended to group together (Fig. 3). All the samples from Plantation Point deep (20 m) and most of the samples from Honeymoon Bay (20 m), formed distinct groups (Fig. 3). The overall species composition of these two sets of samples were clearly different from those found in the samples taken at the other muddy/sand sites (Fig. 3).

The distribution of species which led to differentiation of site groups were determined by examining two-way tables. These tables showed that many species were abundant at all sites. Site groups were most clearly characterised by a few rare species with restricted distributions.

Assemblage composition did not show change dramatically through time, but the abundances of individual species may have varied between sampling periods. Univariate ANOVAs provided a means of assessing these variations. More than 25 % of the species recorded from the 558 samples were represented by less than 10 individuals, but some polychaete species were present in sufficient samples for detailed analyses of their distribution among sites and through time. Following Cochran's tests, data for three species from core samples and five from grab samples were examined using ANOVAs.

Analyses of variance indicated that the densities varied among combinations of sampling time and site. The exceptions were *Eunice australis* and *Owenia fusiformis* from vegetated sites. Their densities varied significantly only with time. Our knowledge of the reproductive biology of these common species, or their relatives, is limited, and this makes predictions or interpretations of temporal patterns in abundances difficult. Some preliminary comments can be made.

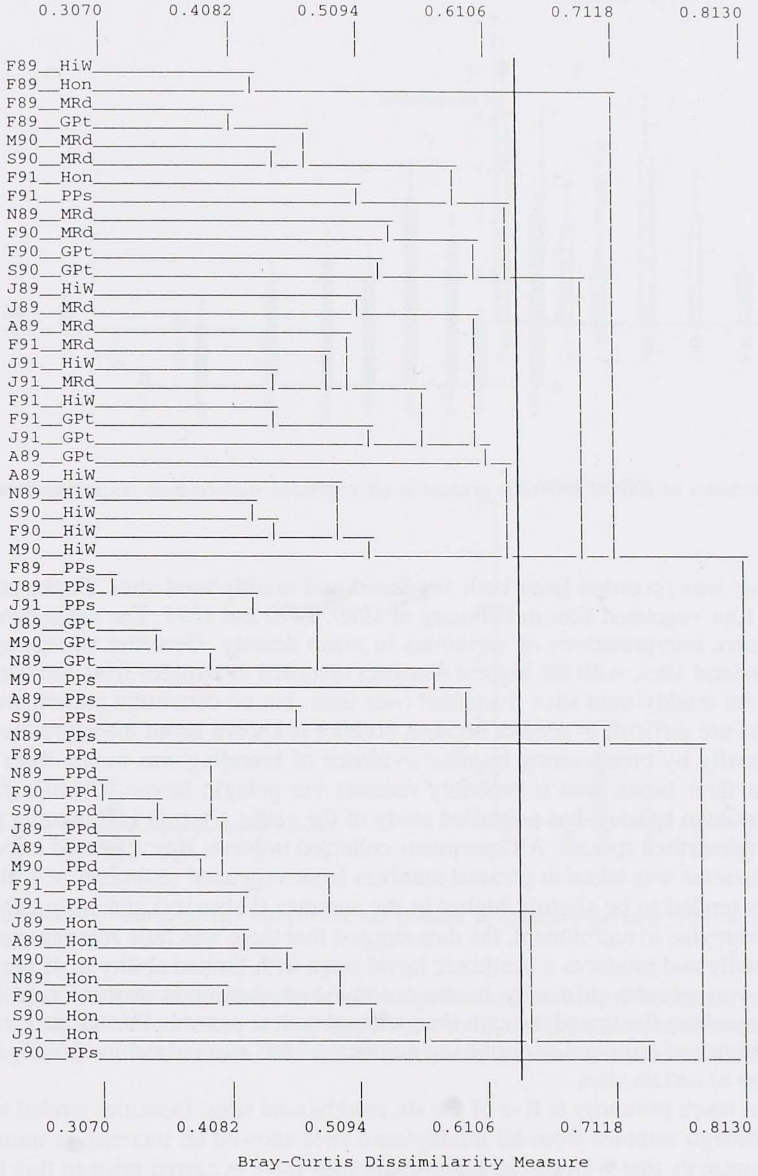

FIG. 3. — The results of the fusion generated by multivariate classifications based on Bray–Curtis dissimilarity measures, for the muddy/sand grab sites. F= February, J= June, A= August, N= November, M= May, S= September, 89 = 1989, 90 = 1990, 91 = 1991, HiW–Hole in the Wall, Hon–Honeymoon Bay, MRd–Montague Roadsted, GPt–Green Point, PPs–Plantation Point "shallow", PPd–Plantation Point "deep".

Eunice australis was taken primarily in core samples. All four sites had relatively high numbers in the summer (February) and spring (November) of 1989, but the overal mean density of *Eunice* was always low (Fig. 4). This makes interpretations of temporal patterns difficult. *Eunice australis* probably breeds annually after reaching maturity in its second year. It is almost certainly a broadcaster and recruits by pelagic larvae. The life–span of this species is greater than one year, which may explain why some individuals were always present in the vegetated core samples although numbers varied over time. If increases in numbers were due to recruitment, it appeared to be poor in 1991.

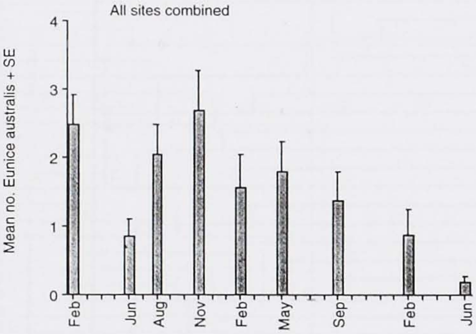

FIG. 4. — The mean numbers of *Eunice australis* present at all vegetated sites on nine occasions between February 1989 and June 1991.

Owenia fusiformis was recorded from both vegetated and muddy/sand sites. Peaks numbers of individuals were observed at all four vegetated sites in February of 1989, 1990 and 1991. The mean densities of *Owenia* were low, which complicates interpretations of variations in mean density. Densities of this species were higher in samples from muddy/sand sites, with the highest densities recorded in samples from the deeper sites. Numbers of *Owenia* taken from the muddy/sand sites fluctuated over time, but no consistent pattern were evident. Temporal patterns in abundance are difficult to predict because nothing is known about the reproduction of this species. It probably breeds annually by broadcasting because evidence of brooding was never observed when individuals were extracted from their tubes, and it probably recruits via pelagic larvae. *Owenia fusiformis* is currently regarded as a cosmopolitan species, but a detailed study of the genus *Owenia* in Australia may disprove this and reveal one or more undescribed species. All specimens collected in Jervis Bay appeared to belong to one species.

Notomastus chrysosetus was taken in greatest numbers from vegetated sediments at Hole in the Wall (Fig. 5). At this site, numbers tended to be slightly higher in the summer (February) and spring (November) of the first year. If these peaks were due to recruitment, the data suggest that there was little recruitment in 1991. This species probably breeds annually and produces a benthonic larval stage with limited ability to disperse.

Magelona sp.1 was present primarily in the muddy/sand sediments at the 'deep' and 'shallow' sites at Plantation Point. Its numbers fluctuated through time without a clear pattern. Further research is needed to clarify the biological significance of temporal variations in numbers of this species and to identify the factors that appear to limit its distribution to certain sites.

Nephtys inornata was taken primarily at five of the six muddy/sand sites. Densities tended to vary with time in an unpatterned way, although samples from all muddy/sand sites showed an increase in numbers during February 1991 (Fig. 6). This suggests that widespread recruitment may have occurred prior to this time. There was some evidence that recruitment had occurred in the summer during the two previous years, but only at some sites (Fig. 6). *Nephtys* is almost certainly an annual breeder with mass spawning giving rise to pelagic larvae. Our data suggest that levels of successful recruitment varied among years and locations.

Augeneria verdis was found primarily in the muddy/sand sediments with numbers varying inconsistently over time (Fig. 7). Honeymoon Bay always had the lowest number of individuals present (Fig. 7). Although studies have not been undertaken on the reproductive strategies employed by this species or related ones, we suspect that it breeds annually by broadcasting and recruits via pelagic larvae.

Mediomastus n.sp., was referred to as *Mediomastus californiensis* in earlier reports (CSIRO, 1991) and by HUTCHINGS & MURRAY (1984) but it is a new species of *Mediomastus,* which is being described by WARREN *et al.* (in press). *Mediomastus* n.sp. occurred predominantly at the six muddy/sand sites (Fig. 8). During at least one sampling period, mean densities were above 10 at all sites, except Plantation Point 'shallow'. Densities of this species increased in February or May 1990 at all sites except Plantation Point 'shallow' (Fig. 8). Recruitment may have occurred at this time. We suspect that this small species (5–10 mm in length) breeds annually, produces few gametes and does not survive spawning. Judging from the protracted period of increased numbers, the breeding season may be fairly extended. In addition, it may have been several weeks after settlement before new recruits would have been sampled by our techniques, and this may explain why the increase in numbers were spread over several months.

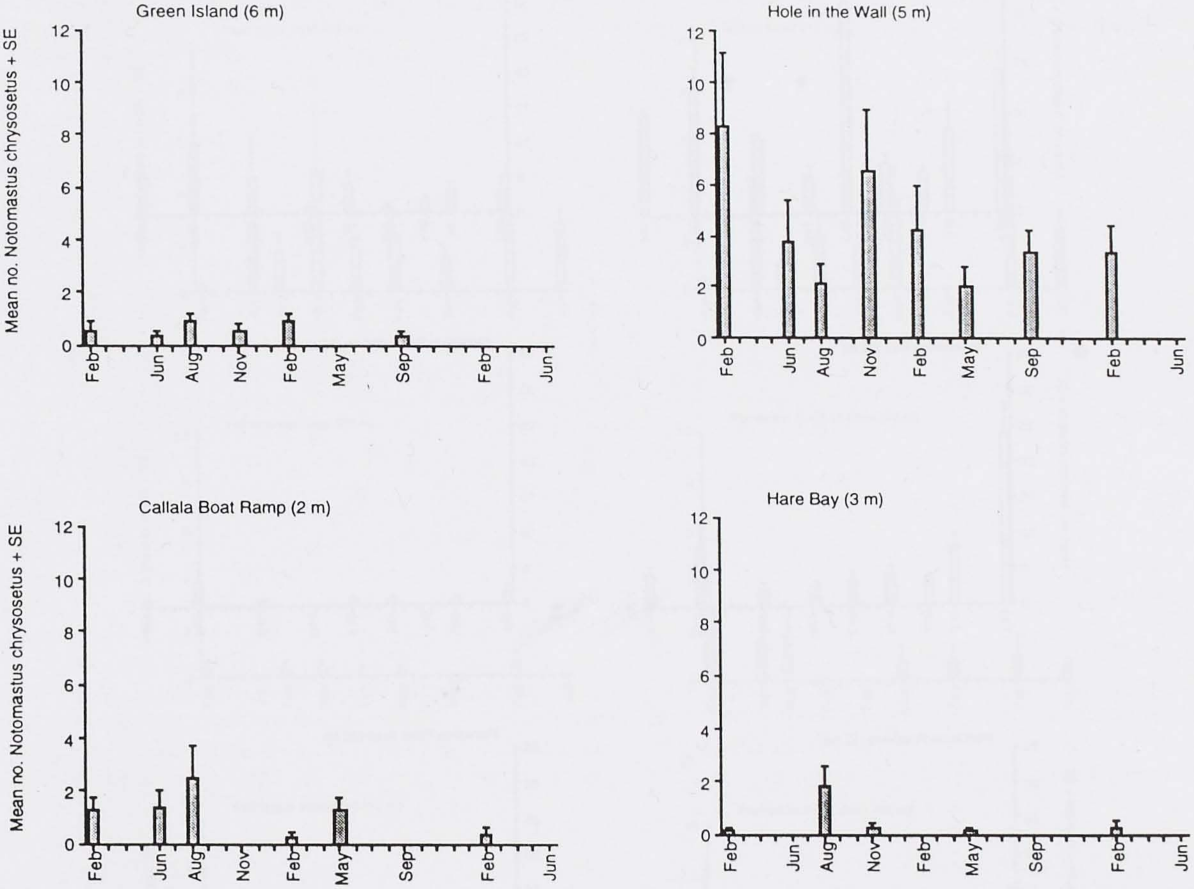

FIG. 5. — The mean numbers of *Notomastus chrysosetosus* present at all the vegetated sites on nine occasions between February 1989 and June 1991.

DISCUSSION

Both types of analyses indicated that the densities of polychaetes and other infauna varied in a more consistent manner among sites than among sampling times. The species composition of the infauna from muddy/sand sediments appeared to vary between the two depths that were sampled. Multivariate analyses indicated that differentiation among sites at different depths was due mainly to the distributions of less abundant species, and *Owenia fusiformis* also followed this trend. Although the results are not reported here, a tendency for species composition to vary among sites and remain similar at a site through time was also seen when data for molluscs and echinoderms were included in the analyses.

It appeared that many species occurred in both vegetated and muddy/sand sites, but muddy/sand sites generally yielded more species. This trend may be partly due to the different sampling techniques employed in the different habitats.

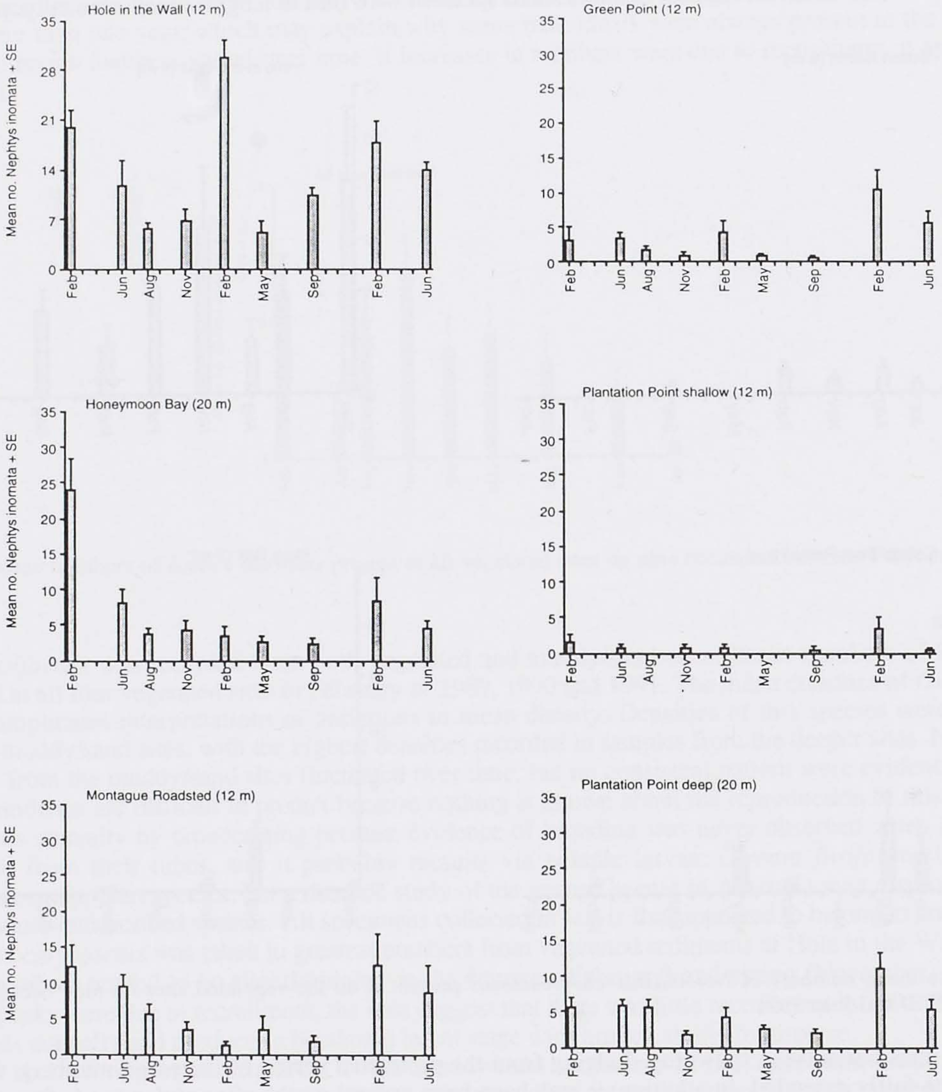

FIG. 6. — The mean numbers of *Nephtys inornata* present at each of the muddy/sand sites on nine occasions between February 1989 and June 1991.

The majority of polychaete species were not sufficiently numerous or common for analyses of their distributions over time. Of the 171 species, only seven were common enough for univariate analyses. Temporal variation in densities of common species would be due to a combination of recruitment and mortality of older individuals. The available data do not provide strong evidence for consistent patterns in these events either within or among years. Evidence of temporal patterns in mortality could be obtained by examining the size classes represented in the samples. All material has been retained for future examinations. Direct evidence of recruitment was not expected because recruits of most species are too small to have been retained by the 1.0 mm mesh employed during this study. The mesh size used was the most appropriate for determining the overall distribution and abundance of infauna, the primary goal of this study. Two hypotheses suggested by the results of this study are: (1) polychaete recruitment is not equal at sites separated by a few kilometres and (2) many species of polychaetes recruit annually but the intensity varies among years.

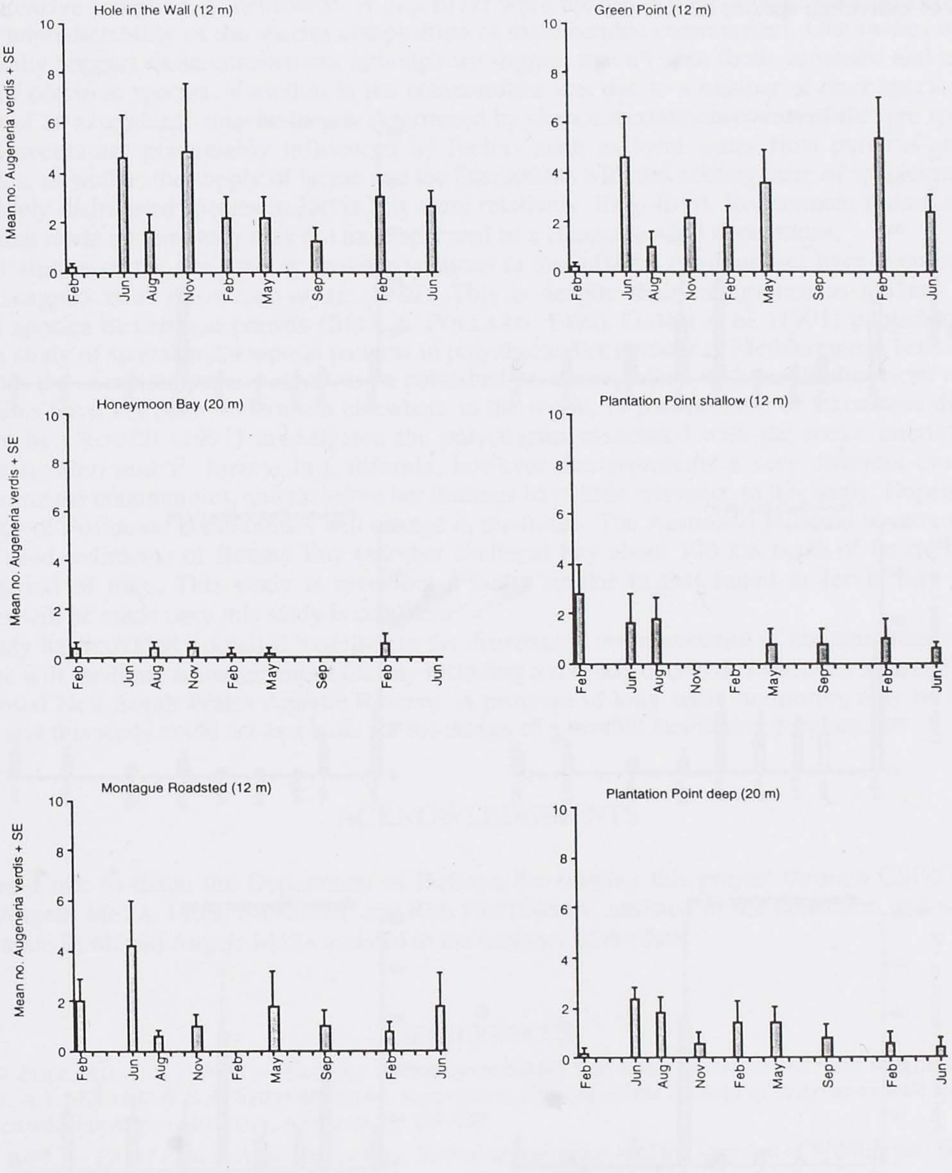

FIG. 7. — The mean numbers of *Augeneria verdis* present at all muddy/sand sites on nine occasions between February 1989 and June 1991.

Multivariate analyses also indicated that the polychaete fauna differed between vegetated and muddy/sand sites. Samples from vegetated sites contained a subset of the suite of species which occurred in the muddy/sand sites.

The study also highlights the need for more information on the reproductive strategies of these common species in Jervis Bay. In all cases we have put forward our opinion of their reproductive strategies on the basis of what is known for related species and, in some cases, information on egg sizes observed for these species either in individuals from Jervis Bay or elsewhere in southern Australia.

All the common species in Jervis Bay have been found in vegetated and muddy/sand sediments throughout southern Australia (HUTCHINGS & MURRAY, 1984). Although the number of quantitative studies conducted in southern Australia has increased considerably over the past 20 years no other studies have examined changes in the densities of individual species over time.

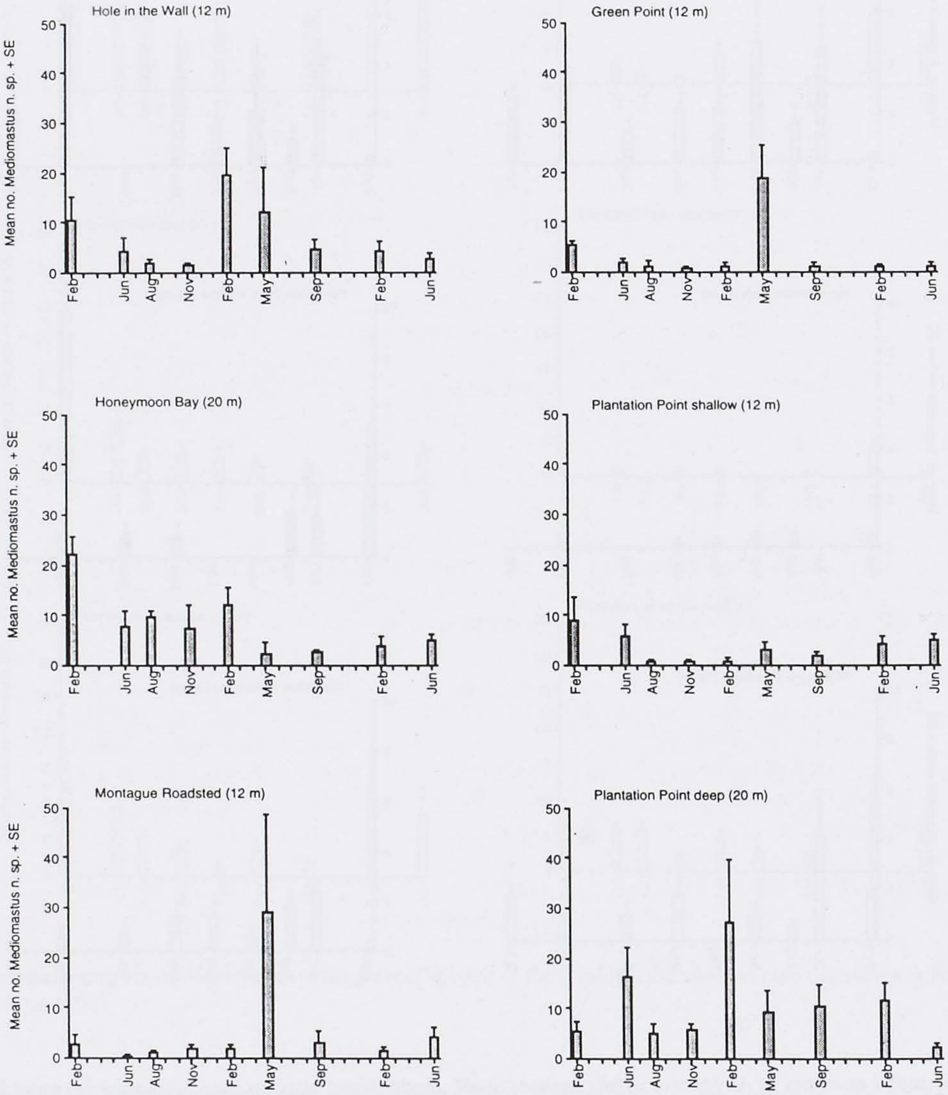

FIG. 8. — The mean numbers of *Mediomastus n.sp.* present at all the muddy/sand sites on nine occasions between February 1989 and June 1991.

STEPHENSON *et al.* (1974, 1977) sampled the benthos of Moreton Bay, in southern Queensland on a regular basis over many years and they found that changes in the composition of the fauna between years was more important than seasonal changes, and that sporadic floods were a major force structuring these communities. In a subsequent study STEPHENSON (1980) found that the benthic community changed over time with the frequency of change varying between sites. A 3 year cycle was typical at inshore sites and 5.5 year cycles were found at the more oceanic sites. Changes in density of individual species were not examined in detail. After more than a decade of intensive sampling, STEPHENSON *et al.* (1977) were unable to predict community structure and they stressed the unpredictability of the species composition of these benthic communities. Our studies in Jervis Bay would generally support these conclusions, although we suggest that all sites (both vegetated and muddy/sand) had a core of common species. Variation in the communities was due to a number of rarer species. The exact composition of an assemblage may be largely determined by chance recruitment events of the rare species. These recruitment events are presumably influenced by factors such as local water flow patterns and sediment characteristics, as well as the supply of larvae and the interactions with the existing suite of species at a particular site. The widely distributed species in Jervis Bay were relatively long–lived. Recruitment failure in one of the three years that made up this study may not have appeared as a change in adult populations.

No other studies of the temporal or spatial variations in the infaunal communities have been undertaken in Australian seagrass beds (HOWARD *et al.*, 1989). This is despite their importance as nursery habitats for commercial species of fish and prawns (BELL & POLLARD, 1989). GAMBI *et al.* (1991) published an abstract describing a study of spatial and temporal patterns in polychaete distributions in Mediterranean beds of *Posidonia oceanica*, but the complete paper has yet to be published so a comparison with our findings can not be made. Similar studies have not been undertaken elsewhere in the world, in part because of taxonomic difficulties. A recent study by CROUCH (1991) investigated the polychaetes associated with the rocky intertidal surfgrass *Phyllosadix scouleri* and *P. torreyi* in California, however this represents a very different environment to *Posidonia australis* communities, and therefore her findings have little relevance to this study. Hopefully this lack of knowledge of *Posidonia* communities will change in the future. The Australian Museum is currently sampling the muddy/sand sediments of Botany Bay (another sheltered bay about 100 km north of Jervis Bay) over an extended period of time. This study is revealing a fauna similar to that found in Jervis Bay and detailed comparisons will be made once this study is completed.

This study has provided a detailed baseline for the distribution and abundance of macroinfauna in Jervis Bay. The baseline will facilitate management of the bay including a recently declared Australian Marine National Park and a proposed New South Wales Aquatic Reserve. A program of long–term monitoring may be introduced in Jervis Bay, and this study could act as a basis for the design of a benthic monitoring program.

ACKNOWLEDGMENTS

We should like to thank the Department of Defence for funding this project through CSIRO Division of Fisheries. Angela MEZA, Fiona McKILLUP and Rob PATTERSON, assisted in the collection and sorting of this material. Cassie ROSE and Angela MEZA assisted in the analyses of the data.

REFERENCES

BELL, J.D & POLLARD, D.A., 1989. — Ecology of fish assemblages and fisheries associated with seagrasses. *In*: A.W.D. LARKUM, A.J. McCOMB & S.A. SHEPHERD (eds), *Seagrasses: Treatise on the Biology of Seagrasses with special reference to the Australasian Region.* Elsevier, Amsterdam : 565-609.

BELBIN, L., 1989. — *PATN Pattern Analysis Package. Technical Reference.* CSIRO Division of Wildlife and Ecology, 222 pp.

CROUCH, C.A., 1991. — Infaunal polychaetes of a rocky intertidal surfgrass bed in southern California. *Bull. mar. Sci.*, **48** :386–394.

CSIRO.,1991. — *Jervis Bay Baseline Studies, Progress Report, December 1991.* CSIRO Division of Fisheries, Jervis Bay.

GAMBI, M.C., GIANGRANDE, A., MARTINELLI, M & CHESSA, L.A., 1991. — Polychaetes of the Mediterranean seagrass *Posidonia oceanica*: Spatio–temporal distribution and feeding guilds analysis. *Bull. mar. Sci.*, **48**(2) : 596 p.

HOWARD, R.K., EDGAR, G.H. & HUTCHINGS, P.A.,1989. — Faunal assemblages of seagrass beds. *In*: A.W.D. LARKUM, A.J. McCOMB & S.A. SHEPHERD (eds), *Seagrasses: Treatise on the Biology of Seagrasses with special reference to the Australasian Region*. Elsevier, Amsterdam : 536-582.

HUTCHINGS, P.A. & MURRAY, A., 1984. — Taxonomy of polychaetes from the Hawkesbury River and the southern estuaries of New South Wales. *Rec. Aust. Mus.*, **36** (suppl.3) : 1–119.

STEPHENSON, W., 1980. — Time patterns of macrobenthic species in Moreton Bay. *Aust. J. Ecol.*, **5** : 245–262.

STEPHENSON, W., COOK, S.D & RAPHAEL, Y.I., 1977. — The effects of a major flood on the macrobenthos of Bramble Bay, Queensland. *Mem. Qd. Mus.*, **18** :98–119.

STEPHENSON, W., WILLIAMS, W.T. & COOK, S.D., 1974. — The benthic fauna of soft bottoms, southern Moreton Bay. *Mem. Qd. Mus.*, **17** :73–123.

WARD, T.J. & JACOBY, C.A., 1992. — A strategy for assessment and management of marine ecosystems: baseline and monitoring studies in Jervis Bay, a temperate Australian embayment. *Mar. Poll. Bull.*, **25** : 163–171.

WARREN, L.M., HUTCHINGS, P.A & DOYLE, S. (in press). — A revision of the genus *Mediomastus* Hartman, 1947 (Polychaeta: Capitellidae). *Rec. Aust. Mus.*