Centre for Environmental Management
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Gladstone Campus

PORT CURTIS MACROBENTHOS MONITORING AND RESEARCH 1995-1997

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GLADSTONE CAMPUS

PORT CURTIS MACROBENTHIC MONITORING AND RESEARCH 1995 -1997

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Foreword

The Gladstone Port Authority, the major organization with responsibility for the health of Gladstone Harbour in particular and Port Curtis in general, has determined, after consultation with the consultants WBM Oceanics Australia and the Queensland Department of Environment, that macrobenthic communities will serve as primary indicators of the health of Gladstone Harbour and Port Curtis.

This report, a second of a series, reports upon this program to December 1997.

Dr Michael Walker
18 February 1998

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1. Introduction

The Gladstone Port Authority (GPA) is committed to ensuring that industrial and urban development within the Gladstone area does not negatively impact upon Port Curtis. GPA together with the Department of Environment conducted the Curtis Coast Study (QDEH, 1994). This study encompassed Port Curtis and adjacent coastline known as the Curtis Coast and provides a baseline inventory of land and marine resources. During the period of this study GPA commissioned the consultants WBM Oceanics, Australia to design **a long term** benthic monitoring program for Port Curtis (WBM, 1993). A sampling design was mutually determined by GPA and WBM which utilised power analysis techniques to predict an appropriate level of replication of sampling necessary to achieve the primary objective of such a monitoring program namely **"to quantitatively assess whether current or future anthropogenic activities significantly impact benthic fauna and the Port Curtis ecosystem"**. WBM Oceanics Australia have undertaken limited time macrobenthic studies within Port Curtis for GPA and the Queensland Department of Environment, (WBM, 1990, 1991).

Macrobenthic invertebrate communities have been shown to be sensitive to environmental stress, especially pollution, and therefore have the potential to detect gross and maybe subtle changes occurring in the aquatic environment (Gray, J.S. *et al*, 1990, Hartley, 1982, Rees, H.L. and Eleftheriou, A., 1989, Steimle, R.S., 1990). Macrobenthic invertebrate communities are sedentary and generally are relatively long lived and thus integrate recent past environmental conditions in terms of species diversity and abundance. They also have an intimate relationship with the sediment where pollutants accumulate and sometimes bioconcentrate.

Macrobenthic communities both those living on the sediment or burrowing into it and greater than 1mm directly interact with biological, physical and chemical components of the marine environment especially the sediment. Macrobenthos thus has considerable potential to detect environmental changes and disturbance and to be an indicator of ecosystem health. Scientific evidence of impacts and or changes in the marine macrobenthic community relies upon detection of statistically significant community changes in treatment/disturbed areas which do not occur in undisturbed/control areas.

The Gladstone Port Authority determined in consultation with the Queensland Department of Environment and the consultants WBM Oceanics Australia, that macrobenthic communities will serve as the primary indicators for the long term monitoring of Gladstone Harbour, (WBM, 1993).

The Gladstone Port Authority in 1995 invited Central Queensland University (CQU), through its developing Centre for Environmental Management (CEM), to instigate long term marine environmental programs for Port Curtis involving initially benthos and later seagrass and mangroves under the direction of Senior Research Fellow/Senior Lecturer, Dr Michael Walker. The macrobenthic program is the cornerstone of marine environmental research and monitoring undertaken by the CQU Centre for Environmental Management. The macrobenthic program in terms of design and implementation follows the program developed by GPA and WBM in 1993. This program has been reported previously (Walker and McNamara, 1997). This report documents the results of this macrobenthic program to the ceasation of November sampling 28 November 1997 and past sample processing to 18 February 1998.

2. Project objectives

The research aims and objectives of the macrobenthic program were defined by GPA and WBM in 1993 as follows **"to quantitatively assess whether current or future anthropogenic activities significantly impact benthic fauna and the Port Curtis ecosystem".**

The current research goal of the Port Curtis marine environmental research program is to **produce scientifically credible protocols, tools and techniques to predict the combined effects of important stressors on the Port Curtis marine ecosystem and its components.**

Anthropogenic stressors which jeopardise/threaten the Port Curtis and Central Queensland marine ecosystem include:

- catchment alteration resulting in changing nutrient and sedimentation loads
- habitat loss and alteration
- planned and unplanned biotic introductions
- pollution from industrial, shipping, agricultural and urban sources.

Research aims include:

- determination of simple and multiple stressor response relationships
- development of spatial and temporal sampling procedures and models
- quantification of variability of multiple stressor effects
- separation of stressor effects from natural variability.

3. Methodology

3.1 Sampling design

The Port Curtis macrobenthic monitoring program was recommended to GPA by WBM to be of a stratified sampling design using two environmental types, treatment/disturbed and control/undisturbed areas. Treatment areas are located in the vicinity of Auckland Point Wharf and Clinton Coal/R G Tanna Wharf (Figure 1). Control areas are located adjacent to Curtis Island and at Grahams Creek in the Narrows (Figure 1). Within each area 4 sampling sites were selected by GPA giving a maximum pooled data set of 8 stations in treatment and control areas.

3.2 Replicates required

Statistical power analysis techniques based on WBM data (WBM, 1993) were used by WBM to predict the number of replicate samples needed per site. Results indicated that a replication of 10 samples per station effectively detects (with a power of >80%) changes of ca 14% in benthic parameters between each of the 4 areas (2 treatment, 2 controls) and between treatment and control areas (WBM, 1993).

3.3 Sampling frequency

Sampling frequency was recommended to be 2 sampling periods per annum ie. late dry season sample, November and a late wet season sample, April (WBM, 1993). Sampling periods are representative of previous benthic surveys within Port Curtis and of periods of maximum and minimum benthic populations respectively (Saenger, P., Moverley, J. and Stephenson, W., 1980).

3.4 Field collection

Samples were collected in the field from a chartered stable platform (MV RUYS) using a $0.1m^2$ van Veen grab (Figure 2) in November 1995, April 1996, November 1996, April 1997 and November 1997. A small portion of sediment was collected from each sample and retained for grain size analysis. Samples were sieved through 1mm sieves and preserved in 5% formalin/seawater for at least 24 hours. Samples were later changed in to 70% ethanol sometimes to which glycerol has been added and stored for future sorting. The field operation of the sampling program is shown (Plate 1).

3.5 Laboratory sorting and classification

Samples were sorted in the laboratory using dissection microscopes and abundances noted. The benthic fauna was identified in the laboratory to family level but was separated and preserved for identification to the species level in the future as required. Line drawings were prepared for all fauna identified. Figures 2 - 7 provide examples of such line drawings.

3.6 Augmentation

The WBM/GPA sampling design regime allowed for future expansion if required. Additional sampling areas can be added over time and compared with existing control blocks. Southern Pacific Petroleum supported an additional area south of Friend Point before the Narrows (stations 17 - 20) from November 1995 and Stuart Energy Development/Suncor from April 1997 (stations 21 - 24) (Figure 1). The location in terms of latitude and longitude are shown (Table 1), as determined by GPS.

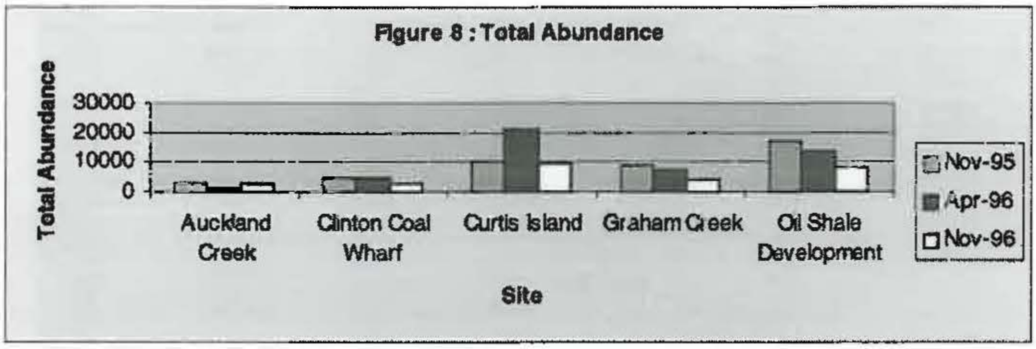
Parallel marine monitoring and research studies are currently undertaken by the Centre for Environmental Management into mangroves, seagrass and mud crabs. Data from these studies in the future will assist greatly in the interpretation of benthic monitoring program results.

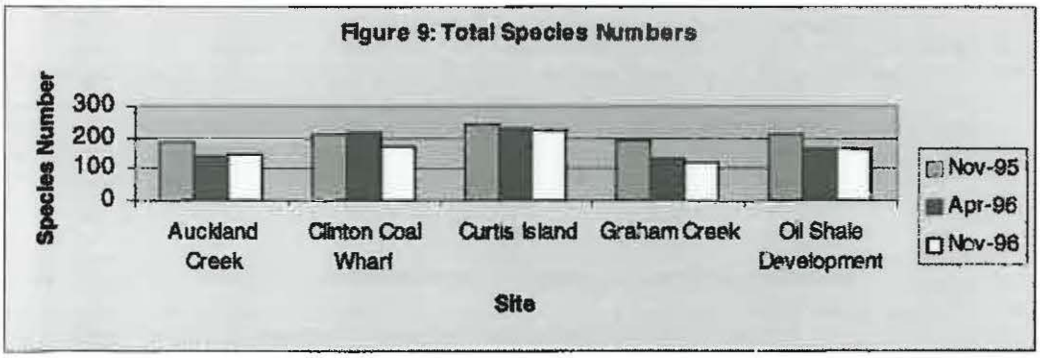
Sampling of seagrasses from within Port Curtis was undertaken during 1997 using the van Veen $0.1m^2$ grab for seagrass seasonal biomass determination. Samples were sieved through 1mm sieves and preserved. The potential thus exists in the future to sort and identify macrobenthos from these preserved samples for incorporation in this program. The sorting and identification process is however extremely labour intensive and therefore costly.

4. Results

Five sampling events have been undertaken since November 1995 (Table 2,3). From these, three sampling events have been processed. It can be seen that Curtis Island has the highest species diversity and abundance while Auckland Creek has the lowest species diversity and abundance (Figures 8-9).

In order to display the breakdown of species/abundance of the major taxa, pi graphs have been constructed for each site. Bar graphs show the change in species diversity and abundance for each site on consecutive sampling occasions.





Figures 10-14 present a taxonomical breakdown for macrobenthic species found at each Port Curtis site. These graphs show dominance by gastropods at all sites with a smaller, but relatively similar number of both polychaete and bivalve species.

Figure 10 : Macrobenthic Species of Auckland Creek

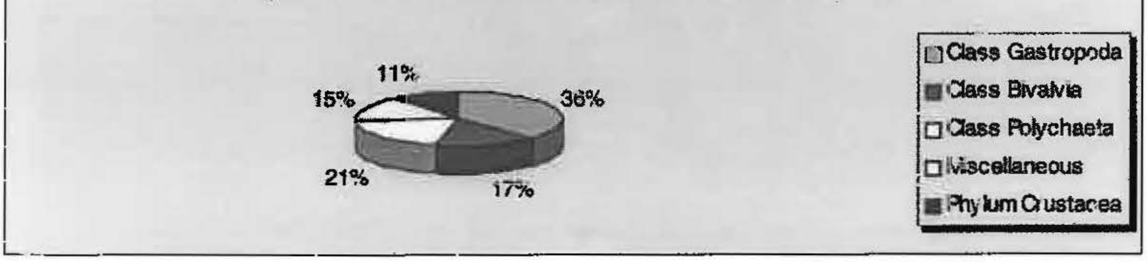


Figure 11: Macrobenthic Species of Clinton Coal Wharf

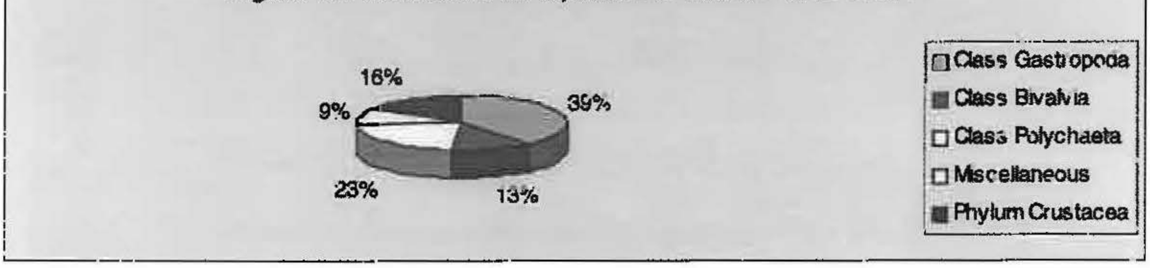


Figure 12: Macrobenthic Species of Curtis Island

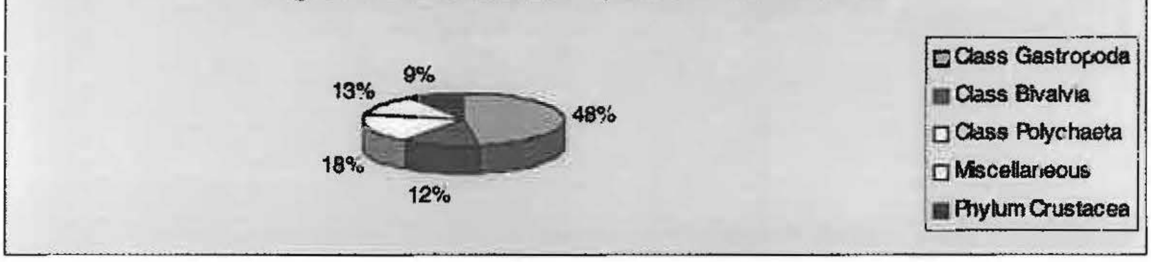


Figure 13: Macrobenthic Species of Graham Creek

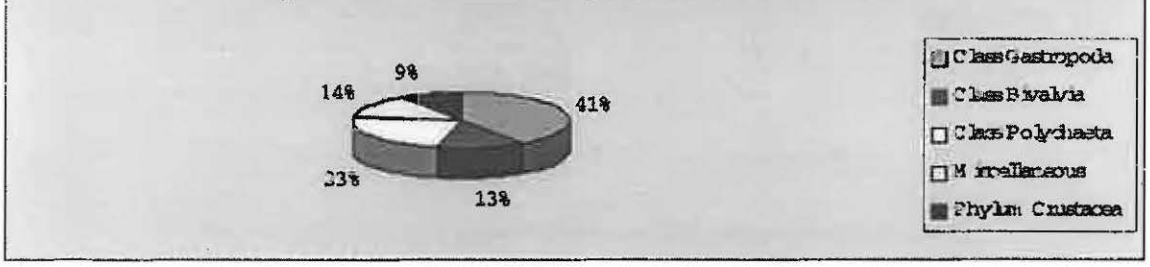
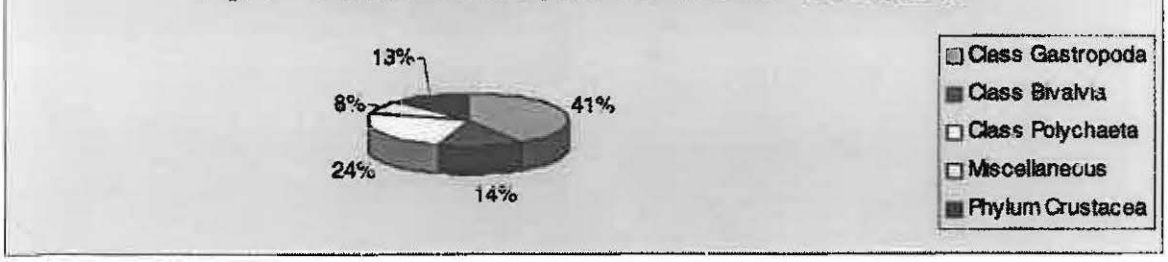


Figure 14: Macrobenthic Species of Oil Shale Development



Figures 15-19 present the abundance of the major taxonomical groups found at each site. The gastropods are also the most abundant of all taxa making up at least ~70% of the total number of macrobenthos found at each site.

Figure 15: Abundance of Macrobenthos of Auckland Creek

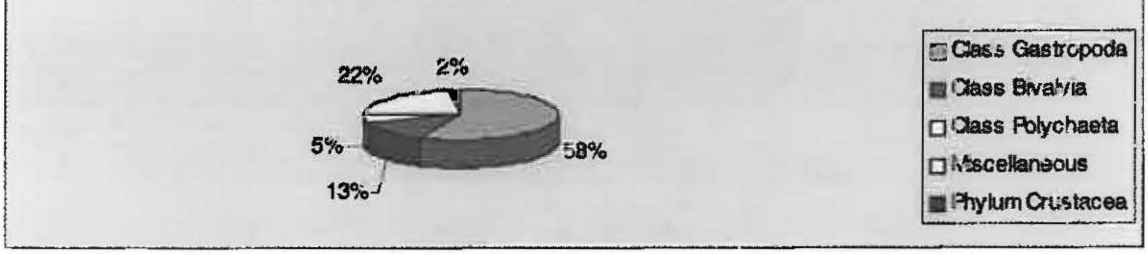


Figure 16: Abundance of Macrobenthos of Clinton Coal Wharf

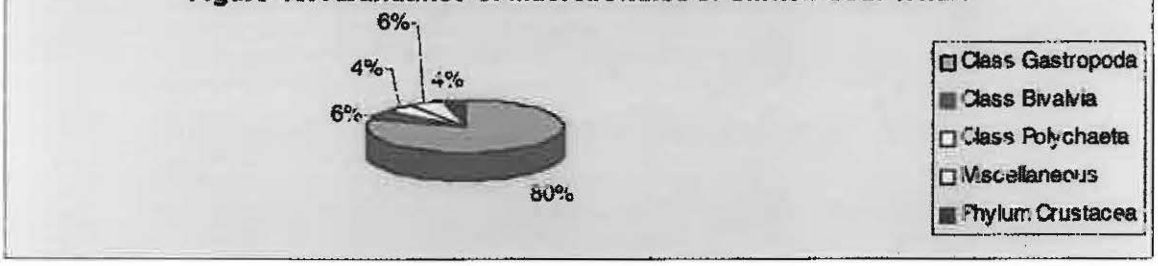


Figure 17: Abundance of Macrobenthos of Curtis Island

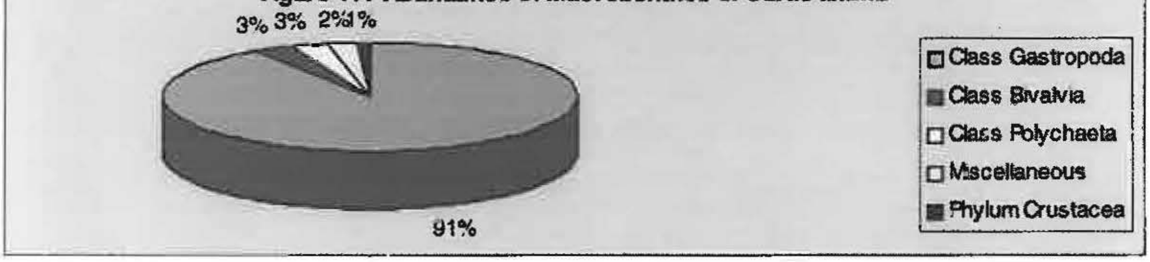
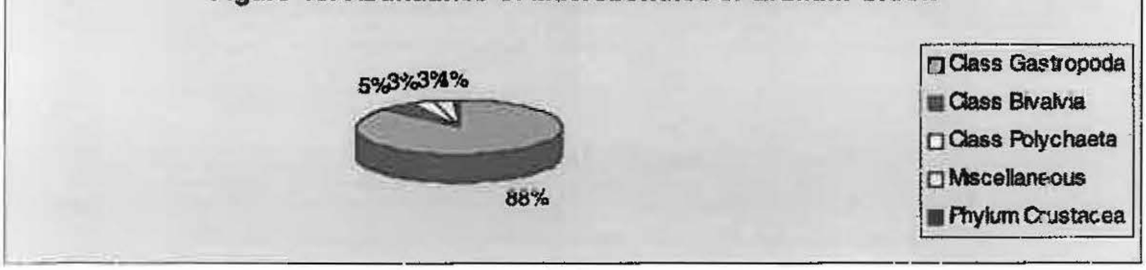
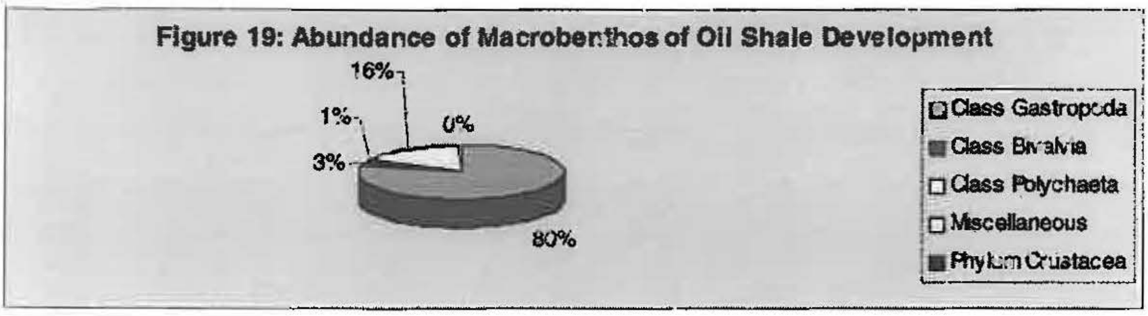
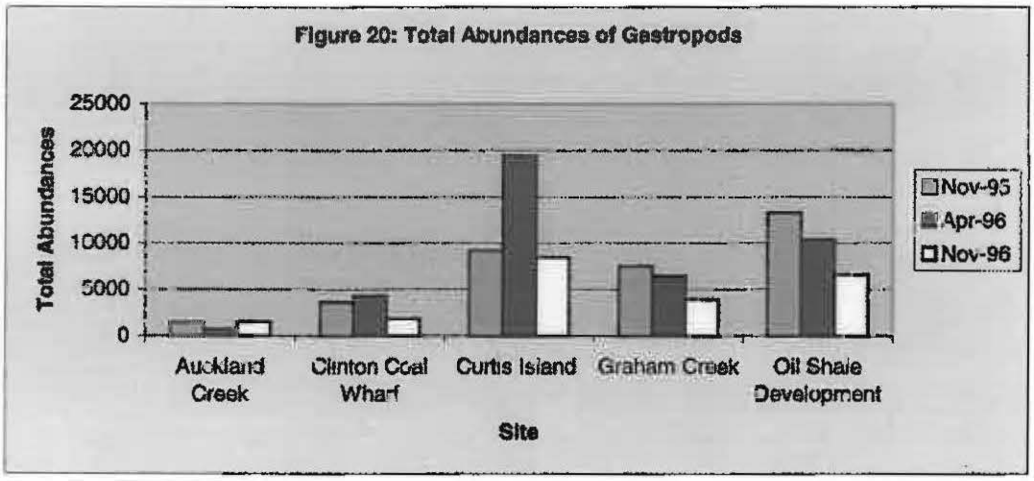


Figure 18: Abundance of Macrobenthos of Graham Creek





Figures 20-24 and 25-29 show the change in macrobenthic abundance and species diversity respectively, at all sites on consecutive sampling occasions.



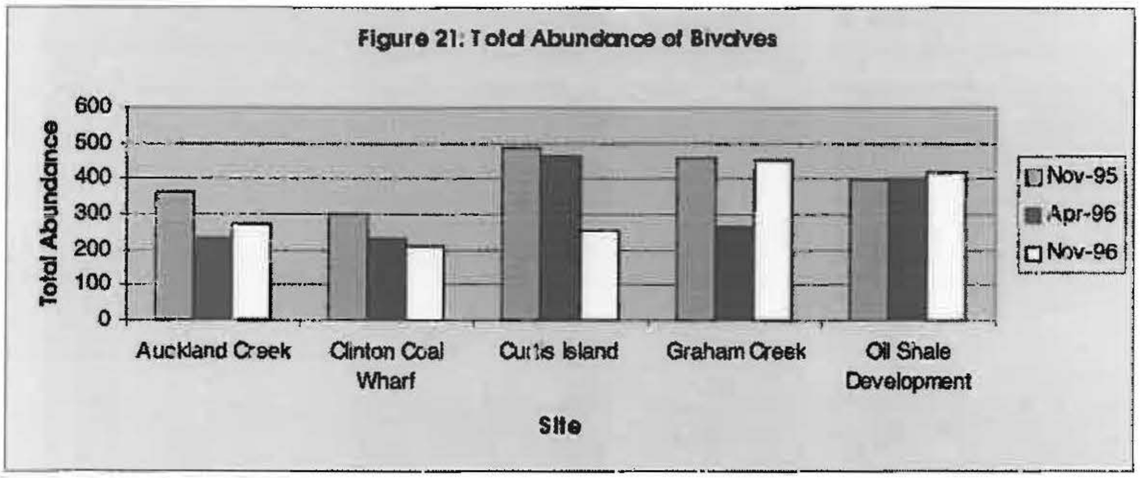


Figure 22: Total Abundance of Polychaetes

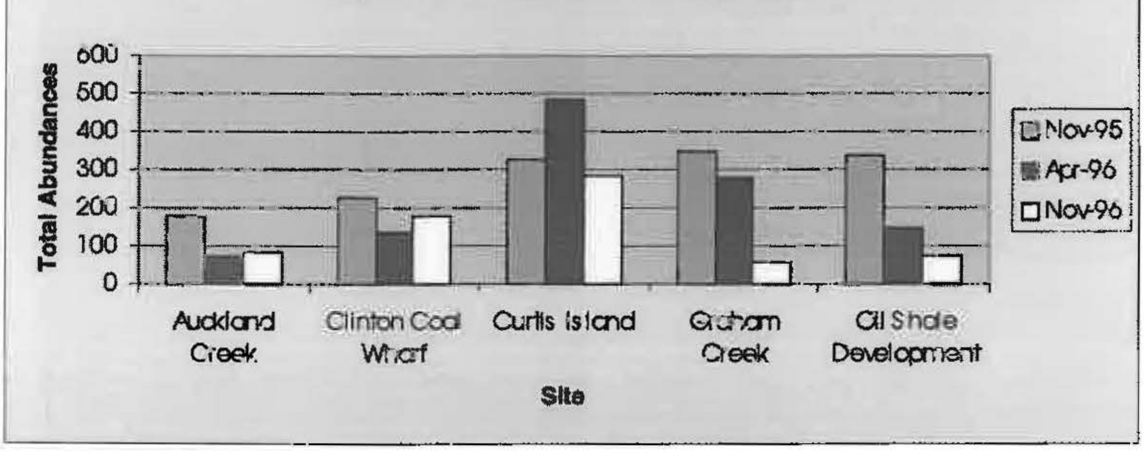


Figure 23: Total Abundance of Crustaceans

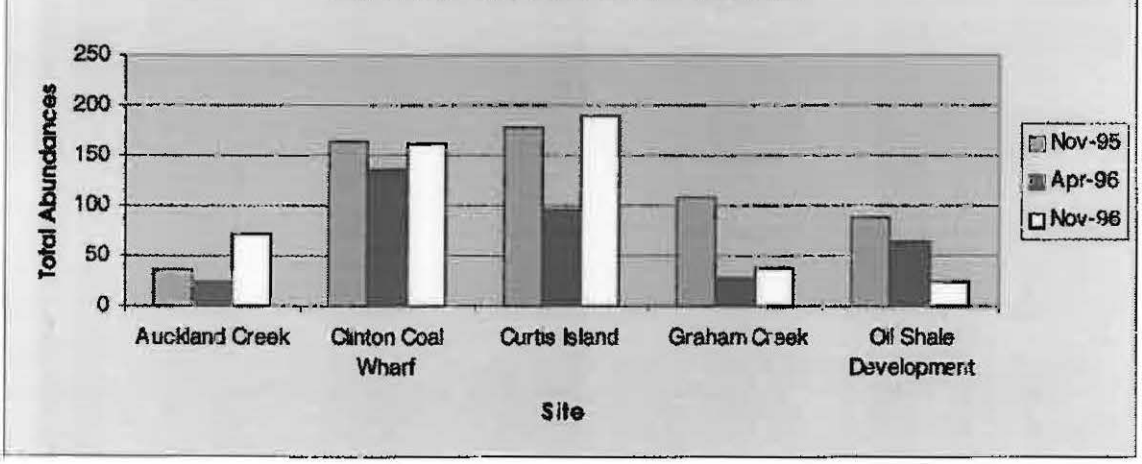
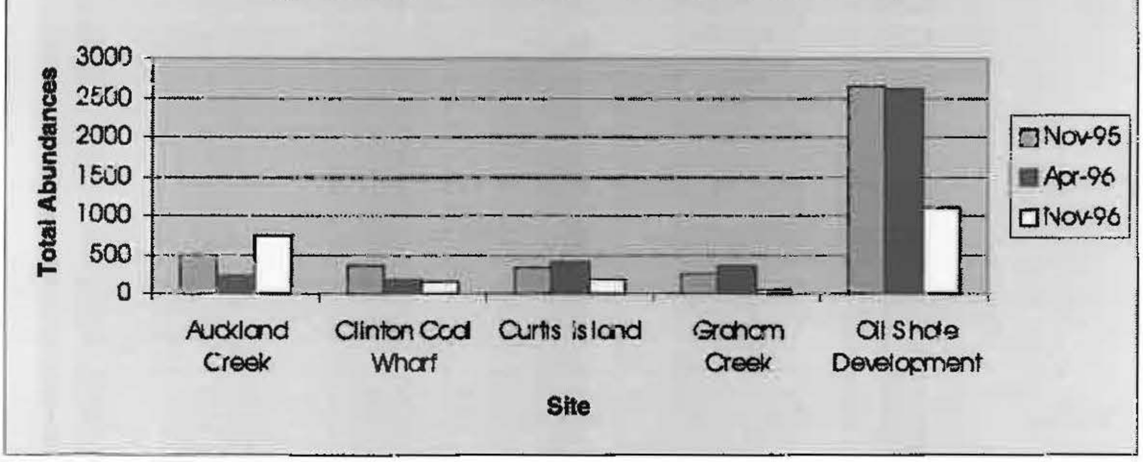


Figure 24: Total Abundance of Miscellaneous Taxa



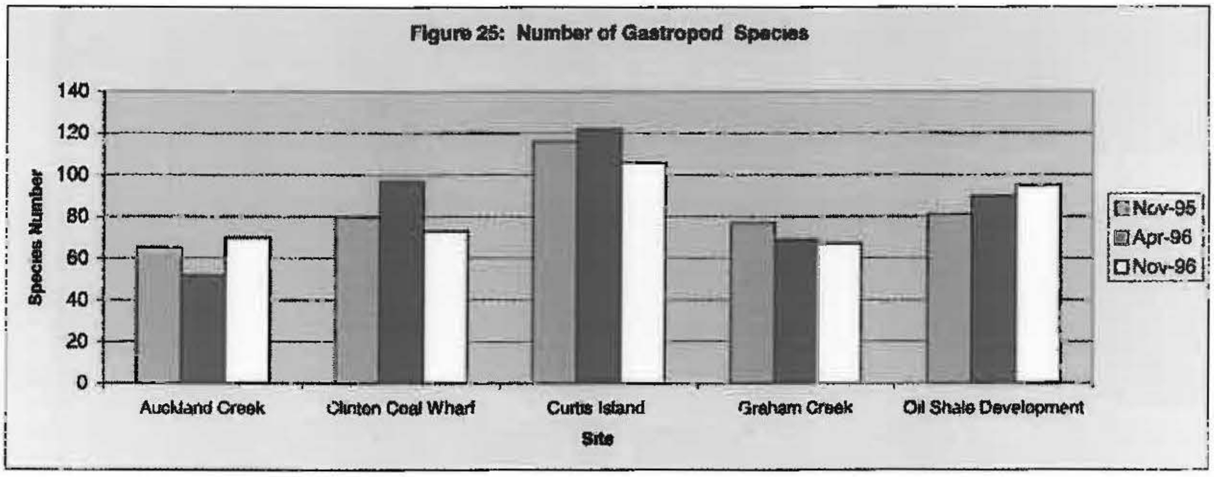


Figure 25: Number of Gastropod Species
140
120
100
80
60
40
20
0
Species Number
Auckland Creek
Clinton Coal Wharf
Curtis Island
Graham Creek
Oil Shale Development
Site
Nov-95
Apr-96
Nov-96

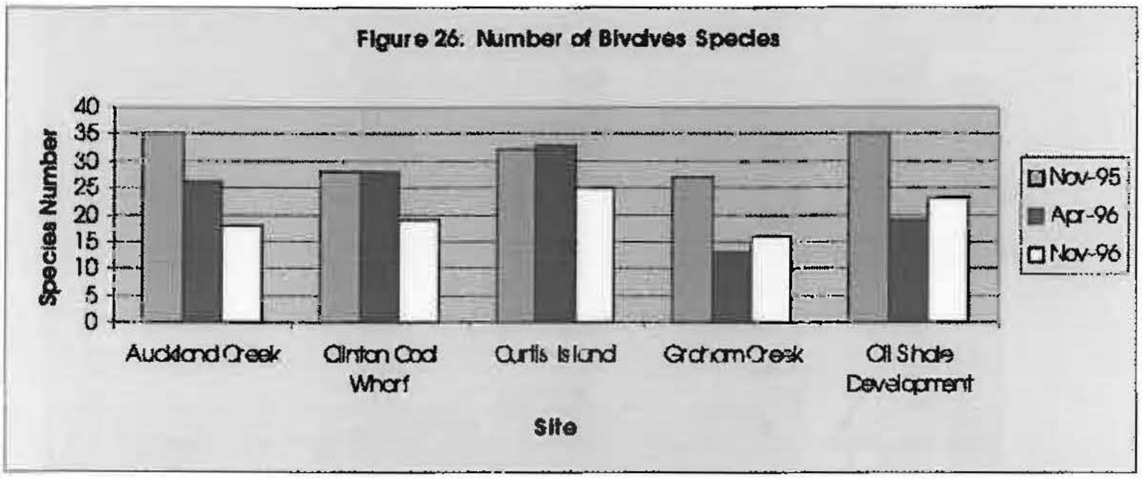


Figure 26: Number of Bivalves Species
40
35
30
25
20
15
10
5
0
Species Number
Auckland Creek
Clinton Coal Wharf
Curtis Island
Graham Creek
Oil Shale Development
Site
Nov-95
Apr-96
Nov-96

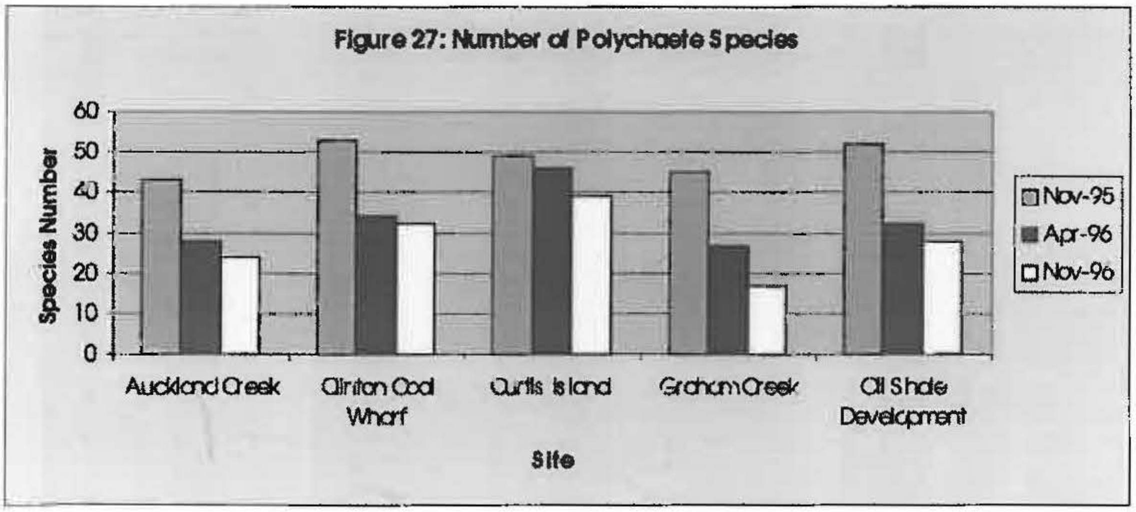
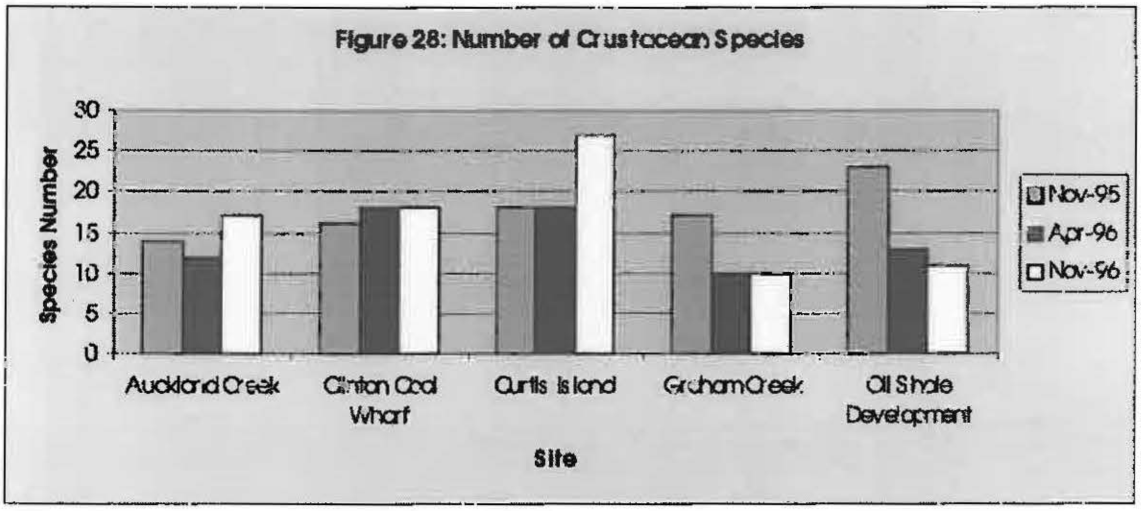
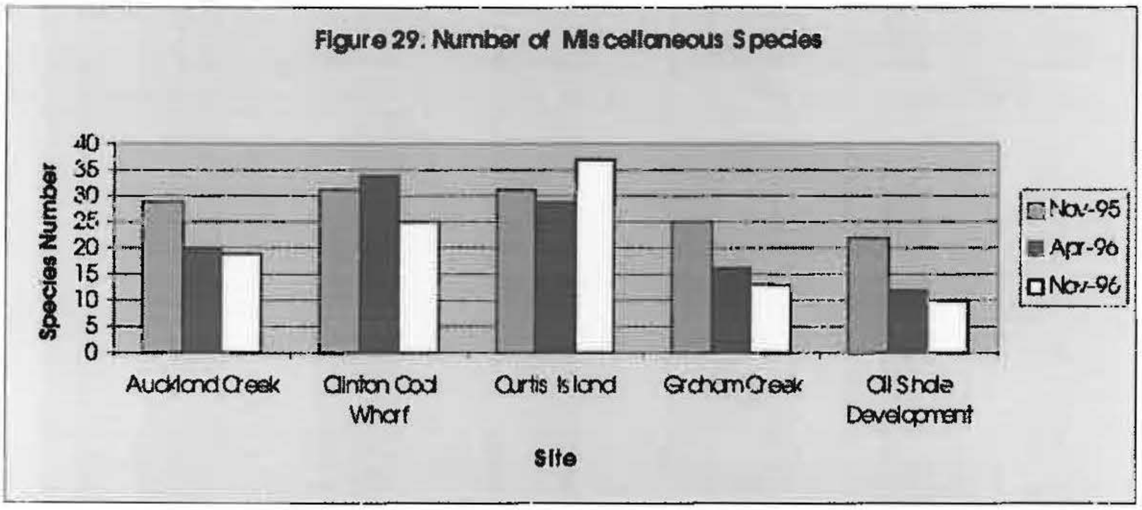


Figure 27: Number of Polychaete Species
60
50
40
30
20
10
0
Species Number
Auckland Creek
Clinton Coal Wharf
Curtis Island
Graham Creek
Oil Shale Development
Site
Nov-95
Apr-96
Nov-96





Major points that can be surmised from these graphs are:

- the abundance of macrobenthos is mostly greater at Curtis Island, Graham Creek, and Oil Shale Development sites than at Auckland Point and Clinton Coal Wharf. These sites represent areas some distance away from urban and industrial influences (Figures 20-24).
- the post wet season represents the minimum populations (April), while the pre wet season (November) represents the maximum populations. This is especially obvious in Graham Creek, Auckland Creek and Clinton Coal Wharf for most major taxa (Figures 21, 23-24).
- Each site seems to support similar species diversity, with only abundance showing distinct differences.

5. Discussion

5.1 General features

Curtis Island, Graham Creek and the Oil Shale Development sites have larger macrobenthic populations than Auckland Creek and Clinton Coal wharf sites. Curtis Island and Graham Creek have been designated as control sites as they represent areas of reasonable distance from urban and industrial influences having similar depths and sediment types. Oil Shale Development Site is located relatively close to QCL and the newly developed Stuart Energy Development Site. No change in macrobenthic populations is observed in this site. Auckland Creek and Clinton Coal Wharf sites are potentially affected by nearby industrial operations, shipping activities, urban development and other activities. Although the species diversity of all sites appears to be similar in number (Figure 9), the overall abundance of these animals is lower in these two sites (Figure 8) to the other sites elsewhere.

Macrobenthic abundances are potentially affected by reduced salinity, oxygen and physical scouring of the sediment that is associated with natural seasonal variation and anthropogenic influences. Each of these will be discussed in terms of how they relate to species diversity and abundance at each site.

Distinct trends in the macrobenthic populations (in terms of their abundance) exist from post wet (April) and pre wet (November) samples. Figures 21, 23-24 indicate that the abundance of macrobenthic taxa falls following the wet season at Auckland Creek, Clinton Coal Wharf and Graham Creek sites. All three areas have a single common factor that is absent at Curtis Island and Oil Shale sites. This is a nearby Creek or river with associated catchment that collects and discharges freshwater during each wet season to these areas thereby reducing the salinity of the environment altering the oxygen demand and availability, scouring the sediment surface and removing unknown quantities of sediment and resident fauna. Oil Shale and Curtis Island sites are not associated with nearby creeks and rivers and therefore the salinity, oxygen do not fluctuate as much and physical scouring is not as harsh in these areas. At this point in this research project it is still unclear as to how much the seasonal variation plays in altering macrobenthic populations, both in terms of abundance and species suite. The present available time series of data is in practical terms inadequate for examination of this matter. This seasonal feature was, however, described for the Calliope River by Saenger *et al* (1980).

Industrial and urban influences also have the potential to alter macrobenthic communities at Auckland Creek and Clinton and Oil Shale sites. Results do illustrate that the species suite is affected by these factors. However, the abundance of species found at these sites is lower than that where sites are spatially separated from anthropogenic factors.

A slight decline in species number at some sites (Figures 27,29) may be due to an increase in taxonomic processes and enhanced ability to identify species found at each site, in year 2 of the program compared to year 1 of the program. This could equally apply the other way ie increased identification expertise leading to a separation of species previously lumped together. This feature must be considered as a potential influence on results. However, abundance of organisms is not at risk of being affected by such identification problems.

Methodology and statistical analysis of results are currently being investigated. It is envisaged that considerable work in this area will occur over the next year and will be reported early in 1999. Sediment analyses have also recently been commenced with the purchase of appropriate equipment, and will play an important role in relating macrobenthic communities to sediment type for all sites and areas.

Gastropods dominate all species suites in terms of their diversity and abundance at all sites. This is probably due to their suitability to a variety of sediment types because of their grazing nature and the nature of the sediment. Other taxa may be more sediment specific eg. Polychaetes in soft muddy substrate and miscellaneous taxa such as anthozoans and echinoderms preferring rocky sediments. Anthropogenic influences and salinity/ oxygen changes may also less adversely affect gastropods.

Due to further development at Auckland Point Wharf one of the sample stations is no longer possible to use Station 1, off Clinton Wharf and suitable areas to replace it are being investigated. Station 7, located in the shipping channel is becoming increasingly difficult to effectively sample due to the absence of soft and/or sandy sediment. Grab samples usually consist of large rocks that prevent the jaws closing and thus much of the sample is lost on the way back up to the boat. The replacement of these two stations is currently being considered.

5.2 Research considerations

The primary objective of the Port Curtis macrobenthic monitoring program is to "quantitatively assess whether current or future anthropogenic activities significantly impact benthic fauna and the Port Curtis ecosystem".

General objectives of environmental monitoring are to recognise environmental pollution problems as early as possible, to analyse the type, source and path of contamination and effects, and to develop recommendations for solving the problems before serious effects become manifest (Wagner and Klein, 1995).

Sampling is the first stage in environmental monitoring and analysis. Environmental sampling methodology is well developed and standardised. It is well described for the Australian/Asian area (English *et al*, 1994). The measurement and prediction of effects of pollutants to individual organisms, suites of organisms or ecosystems is, however, still very much in the research area.

Land based and freshwater aquatic systems are better understood than marine systems. Marine environmental monitoring is therefore a research activity rather than a predictable routine data gathering exercise. This is especially the case for the Australian subtropical and tropical area for the coastal and estuarine marine faunas are poorly documented and understood and have mostly been considered from a fisheries perspective.

The present marine macrobenthic program is the cornerstone of a broader Port Curtis marine ecosystem program which involves relating nutrient flows, fauna exchange and contamination effects through the sediments of mangrove, seagrass and benthic systems. In the future it is hoped to incorporate salt flat systems into this study. Contamination from industrial, agricultural and urban sources occurs by deliberate or accidental discharge into water or air. The Centre for Environmental Management is presently working with the Gladstone Industry Area Network (GAIN) and the Gladstone Port Authority to develop a 3D hydrodynamic model for Port Curtis Management/Strategic Planning. The planned research is to be supervised by Dr Jurek Piorwitz, a coastal engineer, faculty of Engineering and a member of the Centre for Land and Water Resources Management. The model once developed will be useful in prediction of pollutant movement (path) within Port Curtis and will allow further research seeking effects. New industry to the Gladstone area eg Stuart Oil Shale Development, and potential new industry eg Calliope Metals proposed to discharge new metal and hydrocarbon contaminants into Port Curtis. Macrobenthic sampling sites have been selected to research the effects of such contaminants on benthic communities.

The current research program and its continuance also researches the effects of harbour dredging on the Port Curtis ecosystem. Data from the current program was utilized by GPA and DoE to justify dredge spoil disposal ex Fisherman's Landing into Port Curtis. This spoil will be redredged from the sea bottom and utilised as landfill during the next large scale harbour dredging program at Fisherman's Landing. The effects of harbour dredging and dredge spoil disposal are largely undocumented and not understood and urgently in need of research. It is anticipated that this current research program, will make a major scientific contribution in this area.

Research data from the current program and research facilities will in 1998 assist two postgraduate research students. Peter Campbell is in the process of enrolling in a Masters program entitled "Statistical analysis of a macrobenthic monitoring program - any hope of detection of anthropogenic change?" Peter has commenced some manipulation of the past macrobenthic data.

Alison Reardon is in the process of enrolling in a PhD program entitled "A study of marine core sediments in the Rockhampton/Gladstone region using abrasive stripping voltammetry".

Dr Michael Walker routinely gives talks and lectures on the program to industry, fishermen, school, community and environmental groups. He was elected chairman of the Gladstone Region Marine Resources Advisory Committee (GRMRAC) in July 1997. GRMRAC advises the Great Barrier Reef Marine Park Authority and other government bodies on marine resources and their management for the Gladstone region and acts as an information interface between these bodies and the community. This association assists and ensures that environmental research and monitoring results are incorporated into environmental management outcomes.

The current program is peer reviewed in that it is reviewed annually by qualified environmental officers employed by GPA, SPP and QDoE. The program meets the requirements of Queensland Government Environmental Licences which are reviewed annually by them. The design and methodology used in the program was determined by WBM Oceanics Australia in consultation with the GPA, DoE and involved input and advice from statisticians and other scientific researchers (eg University of Queensland and Griffith University)(WBM, 1993).

Research outcomes of this current and continuing macrobenthic program will be/have been as follows:

- Reports prepared annually along with sampling data for GPA and SPP for submission with their applications to the Queensland Department of Environment for environmental licences. 1997 report presented February 1997, 1998 report presented February 1998.

- Talks and lectures prepared and presented in 1997 to

    - Central Queensland Fisheries Zonal Advisory Committee
    - Queensland Deep Draught Club
    - Gladstone Region Marine Resources Advisory Committee (GRMRAC)
    - Hon. Peter Beattie and Jim Elder Leader and Deputy Leader Queensland State Labour Party
    - Queensland DPI Fisheries Branch (Executive)
    - Gladstone Schools and Industry Science Group
    - Candidates for Deputy Vice Chancellor's position (CQU)
    - West Committee in Higher Education
    - Gladstone Industry Area Network (GAIN) Environmental Officers
    - CQU Engineering Planning Committee
    - Central Queensland Chemical Institute
    - CQU Faculty of Engineering
    - GRMRAC, GBRMPA Survey Sub Committee
    - Bangladesh University Delegation
    - Gladstone Area Science Summer School
    - Toolooa State High School
    - CQU Environmental Management Residential School
    - Port Curtis Catchment Working Group
    - Tannum Primary School Students
    - CQU Open Day Gladstone Campus
    - Gladstone Area Combined Rotary Clubs
    - New Research Opportunities Working Group, Faculty of Arts, Health and Sciences
    - CQU Steps program
    - Saiki City - Education Authorities - Gladstone Sister City
    - Star of the Sea Primary School

1998 is predicted to be a busy year for community based lectures as it is the International Year of the Ocean.

- Paper prepared and to be presented at International Conference "Marine Benthos Dynamics: Environmental and Fisheries Impacts, 5 -7 October, 1998, Crete".

- Postgraduate students enrolled/enrolling in Masters and PhD programs entitled:
    - "Statistical analysis of a macrobenthic monitoring program - any hope of detection of anthropogenic change?"
    - "A study of marine core sediments in the Rockhampton/Gladstone region using abrasive stripping voltammetry".

- Data from 1995, 1996 and 1997 sampling program evaluated as justification for harbour dredging and spoil disposal at Fisherman's Landing. Dredge site sampled prior to dredging. Site to be revisited in the future.

- It is planned ultimately to have all data available on a GIS accessible to industry, government and others.

5.3 Collection and processing of samples

The collection of samples at sea is a lengthy process taking a combination of underway operational (sample collection at sea), standby hours (sample sorting hours) in port taken over a varying number of days depending upon weather and suitable tides during daylight hours. It is only possible to sample benthos at slack water associated with either the high or the low tide. Sorting of samples can only be undertaken under calm conditions during daylight hours in port.

Table 2 presents a summary of the sampling times. This table shows the increasing number of sampling stations with time and the inclusion of some sampling to determine seagrass biomass.

Processing of samples in the laboratory ie sorting, identification and data entry is a lengthy time consuming task. The current program has developed rapidly over three years. The first two years collection of samples was well ahead of the processing and a considerable backlog of samples developed. The new Environmental Management Building (EMB) was completed in 1997. The EMB included facilities for the marine environmental research group which moved into the EMB March/April 1997. Facilities prior to this time were extremely limited. The good facilities in the EMB, which includes a dedicated laboratory for the current marine environmental research programs, enabled some expansion in terms of casual sorting staff in 1997 resulting in a clearing of some of the backlog of samples unprocessed. It is anticipated that by April 1998 processing of all previously collected macrobenthic samples 1240 samples will have achieved, a considerable task. Processing progress of samples to 18 February 1998 is shown (Table 4).

5.4 Data entry and analyses

Entering of data as a word processing document from a sampling event at each station occurs on completion of sorting of the 10 samples from that station. This process is also a lengthy time consuming process. Data to date has only been presented in graphical and tabular form.

Investigation is currently being undertaken into the choice of an appropriate index (ices) of ecosystem health or ecosystem pollution which incorporates species diversity, species abundance and species dominance. A low diversity and high population level for an organism usually denotes major stress conditions which eliminate many species and promote a few. A high diversity and little dominance of species in number is usually an indicator of relative environmental stability. Superficially this generally appears to be the case throughout Port Curtis with some anthropogenic effects at Auckland Point, Clinton Coal Wharf and Graham Creek. A knowledge of the normal community makes the task of looking and defining change easier. Certainly Port Curtis generally couldn't be assumed to be a normal ecosystem in 1995, 1996 or 1997. Thus one must attempt to compare with similar 'pristine' control areas elsewhere or the work of others (Saenger *et al*, 1980) and (WBM, 1990, 1991). At small space/time scales reductionist predictions must fail in principle for we cannot measure the initial system state exactly (Rosen, 1978) and at least some dynamic changes will be grossly sensitive to the initial state that is chaotic (Gleick, 1987).

It is hoped that comparisons with Saenger *et al* (1980) and WBM (1990, 1991) will be possible. These workers treated their data in different ways and used different indices.

The treatment of benthic data is clearly still in the research domain as indeed is identification of the macrobenthic fauna, presently of the order of 600 species have been identified to family level. There is presently disagreement as to whether identification to family level is adequate to detect environmental change (QLD Museum *pers. com.* P. Mather (Knott), 1995). The location of Port Curtis on the edge of tropical and subtropical Indo-west Pacific fauna is likely to yield many new marine species from within the macrobenthic collection. Considerable research work and effort is required in the future. This effort is likely to yield many research papers and make a significant contribution to the understanding of these marine faunas.

The types of benthic population parameters proposed by WBM, (WBM, 1993) to be assessed during the program were:

- benthic abundance (number of animals)
- benthic diversity (absolute number of families)
- community composition and change
- rates of change/recovery in populations over time.

A new research student Peter Campbell is currently enrolling in a research masters program jointly supervised by Kevin Tickle and Michael Walker. He is to work with the current macrobenthic data set. His topic is currently entitled "Statistical analysis of a macrobenthic monitoring program - any hope of detection of anthropogenic change?" This situation is of benefit to both the student and the program and is an exciting development.

In terms of data analysis the methodology to be pursued during 1998 is summarized as follows:

- to group the 24 stations to reveal any important zones;
- in order to do this faunistic records at each station must be compared with those at every other station by means of a co-efficient of similarity or dissimilarity;
- 2 co-efficients have been selected for use and comparison

Jaccards co-efficient based on the presence or absence of each species at each station and stored in a station by station matrix.
Czekanowski's co-efficient which includes measures of abundance.
Measure 1: the number of samples from each station in which the species was recorded.
Measure 2: the log transformed abundance, the natural log of total number of each specimens of each species found at each station regardless of whether the specimens were all found in one sample or were spread through the samples.

$$Yij = \log e\ (Xij + 1)$$

Xij is the number of specimens of the i^{th} species at the j^{th} station and Yij is the log-transformed abundance.

Meaningful summaries should be able to be obtained from the matrix of co-efficients. Either principal component analysis or a dendrogram will be used.

Clearly this analysis task will take considerable time. It is planned to present a research paper on the results to the international conference "Marine Benthos Dynamics: Environmental and Fisheries Impacts, 5 -7 October, 1998, Crete".

5.5 Sediment analysis and the relationship between the sediment and macrobenthic fauna

Benthic communities, vary with bottom type in terms of diversity and abundance. The benthic environment is predominantly determined by current, wave energy and sediment. The coarse particles are generally found in tidal and shipping channels and mouths of tidal creeks and inlets. Larger material predominates in high energy locations while in low energy locations silt, clay and organic matter will be present and acrete with time. Clay particles are small and provide a large surface area onto which organic material binds. As the percentage of clay in the sediment increases so does the amount of organic material from the water. Contaminants/pollutants in the water bind to the clay and organic matter. In the case of some metals they may bioaccumulate and bioconcentrate in seagrass and enter the organic chain when seagrass leaves break free and decompose. Decomposition of organic matter requires oxygen. Where the amount of organic material is high overlying water can become depleted of oxygen. Thus it is possible in seabed areas of high organic matter, high temperature and little water circulation that oxygen may be depleted to a point that the sediment becomes anaerobic and H_2S becomes abundant.

The macrobenthic program to date has devoted no attention to sediment in terms of its analysis for its components - gravel, sand, silt, clay etc nor to its organic content. The necessary funding, staff and equipment has not been available. This is currently being addressed. Sediment samples have been collected routinely since the inception of the program in November 1995. Analysis of the large backlog of collected sediment samples has recently begun. An appropriate analysis protocol has been developed and is currently being refined. It is hoped that with future sampling events to incorporate the determination of organic content for each sampling station.

The distribution of infaunal and some other benthic invertebrates is determined by the sediment. There are close relationships between infaunal feeding habitats, organic content and the mechanical nature of the substrate.

Muddy sediments usually are soft, have little overlying water circulation, and have high organic content within and on the bottom. This habitat favours filter feeders which feed on the organic matter present. Filter feeders which rely upon constantly suspended food in the water can not live in muddy areas devoid of circulation. Fauna which live in such an environment usually burrow into the mud as defense from predators. Maintenance of burrows in extremely muddy silty areas is often difficult as burrows collapse. The more sand present in muddy sediments the easier the maintenance of burrows.

Sandy sediments usually occur in areas with more current and generally are less rich in organic material than muddy sediments. Such sediments support filter feeders which feed on suspended material in the water. The more pronounced the current the more potential food availability. Sand if its too hard makes burrowing difficult or impossible and if too soft burrows collapse.

In areas where the current is very strong sediment transport occurs routinely and benthic invertebrates have trouble maintaining their position. These areas are usually gravelly, shelly or rocky and often unfavourable to filter feeders.

Generally muddy, sandy sediments or sediments composed of a mixture of clay, silt and sand support the greatest diversities of macrobenthic invertebrates.

Shipping movements either large ships (ocean going type), service or recreational vessels all have the capacity to alter and have altered bottom sediments. The natural sediments of Port Curtis ie sediments prior to major port development, were well described historically in 'Sediments and sedimentary processes in Gladstone Harbour, Queensland' (Conaghan, 1966).

It is planned, as more time becomes available, to analyse collected macrobenthic data to build up a profile of how the distribution and abundance of Port Curtis macrobenthic fauna relates to composition of the sediment. This work will be related to other marine environmental monitoring programs involving seagrass and mangroves. These plants are a major source of the organic detritus upon which the macrobenthic fauna depends.

6. Program budget

The funding allocated to the program by GPA was $89 700 for year 1, $58840 for year 2 (1996/97) and $91041 for year 3 (1997/98). Southern Pacific Petroleum (SPP) joined the program with a contribution of $20000 for year 1, $20000 for year 2 and $21550 for year 3. Year 3 saw the introduction of a new sampling site for SPP and the program at Flying Fox Creek/Boat Harbour.

The proposed program budget for 1998/99 is presented in full (Table 5) and in summary (Table 6).

During the later half of 1997 casual research workers without scientific backgrounds were engaged on an hourly basis to extract macrobenthos from sieved field samples. This process is time consuming, requires the use of microscopes and is thus hard on the eyes. It cannot be undertaken for continuous prolonged periods. The same situation applied to scientific identification and drawing of each macrobenthic species. Employing of such casual workers speeds up the laboratory process and during 1997 allowed some of the backlog of previously collected macrobenthic samples to be reduced. It is hoped that the backlog of previous samples will be cleared during 1998, this will allow a cost reduction in the program of the order of 20% for years beyond 1998/99.

Casual assistance is utilised to assist in the field sampling of macrobenthos. A lengthy process taking between 6 - 12 days depending upon tides and vessel availability. Field sampling involves at least 4 personnel.

No processing of samples collected for sediment analyses occurred prior to 1998 because of equipment unavailability. Equipment is now available and laboratory protocols developed. Funds are sought for 1998/99 for casual assistance to process samples and for an extra oven and sieve to speed up the process. The backlog of samples will be cleared by 1999/2000 allowing cost savings in subsequent years and the correlation of previous results with sediment size and texture.

Funding is sought in 1998/99 for attendance and paper presentation at the International Conference Marine Benthos, The Environment and Fisheries to be held in Crete, October 1998. Attendance at this conference will both promote the work and allow contacts to be made with similar programs elsewhere in the world.

Funds were sought in 1997/98 for an extra microscope and video equipment to speed up the sample sorting and identification process. Because of the flows of funds in 1997/98 it was not possible to make commitments to purchase these items. Funding is sought for these in 1998/99.

7. Acknowledgements

Gladstone Port Services are thanked for the provision of the MV Ruys for marine sampling. Central Queensland University provided the laboratory and administrative facilities. In particular the CQU Head of the Gladstone campus, Mr Rex Metcalfe and his administrative support staff Sue Oakey and Gerda Whiteley are thanked for their administrative support in the conduct of the macrobenthic program as are the staff of the Faculty of Applied Science and the Dean of Arts, Heath Science and Science Associate Professor Errol Payne, administrative staff in Finance and personnel at CQU Rockhampton campus.

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Table 1

GPS markings for GPA and Oil Shale Sites

STATION 1:	23° 50'01.7" E 151 ° 15'48.5" S	**STATION 13:**	23° 44'38.0" E 151 ° 10'14.6" S
STATION 2:	23° 49'52.8" E 151 ° 15'10.2" S	**STATION 14:**	23° 44'17.2" E 151 ° 09'54.0" S
STATION 3:	23° 49'29.4" E 151 ° 15'46.9" S	**STATION 15:**	23° 44'34.0" E 151 ° 10'22.2" S
STATION 4:	23° 49'36.7" E 151 ° 15'49.3" S	**STATION 16:**	23° 44'29.4" E 151 ° 11'07.9" S
STATION 5:	23° 49'16.4" E 151 ° 14'31.1" S	**STATION 17:**	23° 46'19.4" E 151 °09'51.7" S
STATION 6:	23° 48'55.7" E 151 ° 14'11.6" S	**STATION 18:**	23° 46'03.8" E 151 °09'41.8" S
STATION 7:	23° 48'31.5" E 151 ° 14'32.2" S	**STATION 19:**	23° 46'07.4" E 151 °10'12.0" S
STATION 8:	23° 49'13.4" E 151 ° 15'01.5" S	**STATION 20:**	23° 46'17.2" E 151 °10'06.7" S
STATION 9:	23° 47'44.8" E 151 ° 13'57.9" S	**STATION 21:**	23° 49'08.0" E 151 °11'50.0" S
STATION 10:	23° 47'41.3" E 151 °14'16.8" S	**STATION 22:**	23° 46'16.0" E 151 °11'19.0" S
STATION 11:	23° 47'45" E 151 ° 14'38.5" S	**STATION 23:**	23° 48'55.0" E 151 °11'05.0" S
STATION 12:	23° 47'49.5" E 151 ° 16'09.3" S	**STATION 24:**	23° 48'30.0" E 151 °10'30.0" S

Table 2

Port Curtis Macrobenthic Sampling Events 1995 - 1997

Date	Station sampled	Samples collected	Date	Station sampled	Samples collected
26.11.95	11,12,14,16	35	15.4.97	1,2	20
10.11.95	1	4	15.4.97	4	10
17.11.95	1	6	16.4.97	15,16	20
18.11.95	2	10	17.4.97	9,10	20
19.11.95	3	10	18.4.97	7,8	20
20.11.95	4,6	20	18.4.97	5,6,3	30
21.11.95	7,8	20	19.4.97	17,18	20
22.11.95	5,9	20	19.4.97	13,14	20
23.11.95	10	10	20.4.97	19,20	20
24.11.95	13,14	15	22.4.97	21,22	20
25.11.95	15	10	22.4.97	11,12	20
2.4.96	1	11	23.4.97	23,24	20
2.4.96	2	11	22.10.97	WI 1,3	20
3.4.96	3	11	29.10.97	WI 2,4	20
3.4.96	4	2	3.11.97	Sth End 1,2	20
4.4.96	6	11	12.11.97	Sth End 3,4	20
4.4.96	5	11	14.11.97	1,2	20
5.4.96	4	9	14.11.97	5,6	20
5.4.96	13	11	19.11.97	3,4	20
6.4.96	14,15	17	21.11.97	17,18	20
8.4.96	14,16	16	24.11.97	15,16	20
8.4.96	9,10	22	25.11.97	19,20	20
9.4.96	7,8	22	26.11.97	21,22	20
9.4.96	11,12	22	26.11.97	13,14	20
4.11.96	1	2	27.11.97	9,10	20
6.11.96	2,3	22	27.11.97	7,8	20
6.11.96	1,4	20	28.11.97	23,24	20
7.11.96	5,8	22	28.11.97	11,12	20
7.11.96	6,7	22	10.12.97	25,26	20
8.11.96	9,10	22	10.12.97	27,28	20
9.11.96	17,18	22			
9.11.96	11,12	22			
11.11.96	13,16	22			
11.11.96	14,15	22			
12.11.96	QCL	22			
13.11.96	BSL Wharf	24			

Table 3

No. Hours Operating and Standby for Macrobenthic Sampling Events in Port Curtis and Time Taken to Complete Sampling - 1995 -1997

Sample	No. of Stations	No. of Hours			Days
		Operational	Standby	Total	
*Nov 95	16			35	11
Apr-96	16	24	12'45"		7
Nov-96	20 + BSL	23'30"	20		8
Apr-97	24	25'30"	21'45		8
Nov-97	28	37'15"	32'15"		12

& South End and Wiggins Island Seagrass and further stations

* In November 1995 Boat charges were made without delineation into standby and operational/underway hours.

Table 4

Port Curtis Macrobenthic Stations Completed To 18 February 1998 in terms of sorting and classification

Station No.	Nov-95	Apr-96	Nov-96	Apr-97	Nov-97
1	x	x	x	x	
2	x	x	x	x	
3	x	x	x	x	
4	x	x	x	x	
5	x	x	x	x	
6	x	x	x	x	
7	x	x	x	x	
8	x	x	x	x	
9	x	x	x	x	
10	x	x	x	x	
11	x	x	x	x	
12	x	x	x	x	
13	x	x	x	x	
14	x	x	x	x	
15	x	x	x	x	
16	x	x	x		
17	x	x	x		
18	x	x	x		
19	x	x	x		
20	x	x	x		
21					
22					
23					
24					
25					
26					
27					
28					

Table 5

Macrobenthic Program Budget 1998/99

Personnel			
Research worker 3.3			
Sorting and field program supervision		28500	
Casual assistance sample collection April and November		18000	
Casual assistance sample sorting all year		33460	
Casual assistance sediment processing		5000	
Secretarial data entry and report production		5000	
Project supervision Dr Michael Walker		10000	
10% on costs (superannuation, insurance) all positions		10026	
			110285
Travel			
Vehicle mileage	1500		
Interstate travel visit museums			
Sydney and Brisbane fares and accommodation		2000	
International conference Marine Benthos The Environment and Fisheries, Crete October 1998		3500	
			7000
Other expenses			
Boat charter and operating expenses		6200	
Sampling gear, consumables, chemicals, bottles and library material		3500	
Ropes, sorting gear, laboratory facilities - power and container hire		250	
Photography (sample recording and report production)		1200	
			11150
Capital Items			
*Microscope and video equipment to speed up the sorting process		6288	
Sartorius electronic balance 110g capacity x 0.1 mg resolution SAR BP 110S		2000	
Drying oven MEMM VLE 500 180L		2500	
Extra set of Endocott sorting sieves		650	
Replacement of original van Veen grab		950	
			11888
			$140323

*budgetting for 1997/98 not utilised as funding did not flow in as required during the 1997/98 financial year.

Table 6

Macrobenthic Program Budget Summary and Funding Source 1998/99

Personnel	110285
Travel	7000
Other Expenses	11150
Capital Items	11888
	$140323

Funding sought from Southern Pacific Petroleum and Suncor 2 areas out of 6.	$4000
Funding sought from Gladstone Port Authority.	$100323
Combined Total Funding Sought	**$140323**

Note 1998/99 sees the first full year of a 6[th] sampling area to be funded by SPP/CPM and Suncor. The cost of this program should be reduced by about 20% in 1999/2000 as the backlog of unprocessed samples will be cleared.

Figure 1

Macrobenthic sampling areas within Port Curtis, Central Queensland

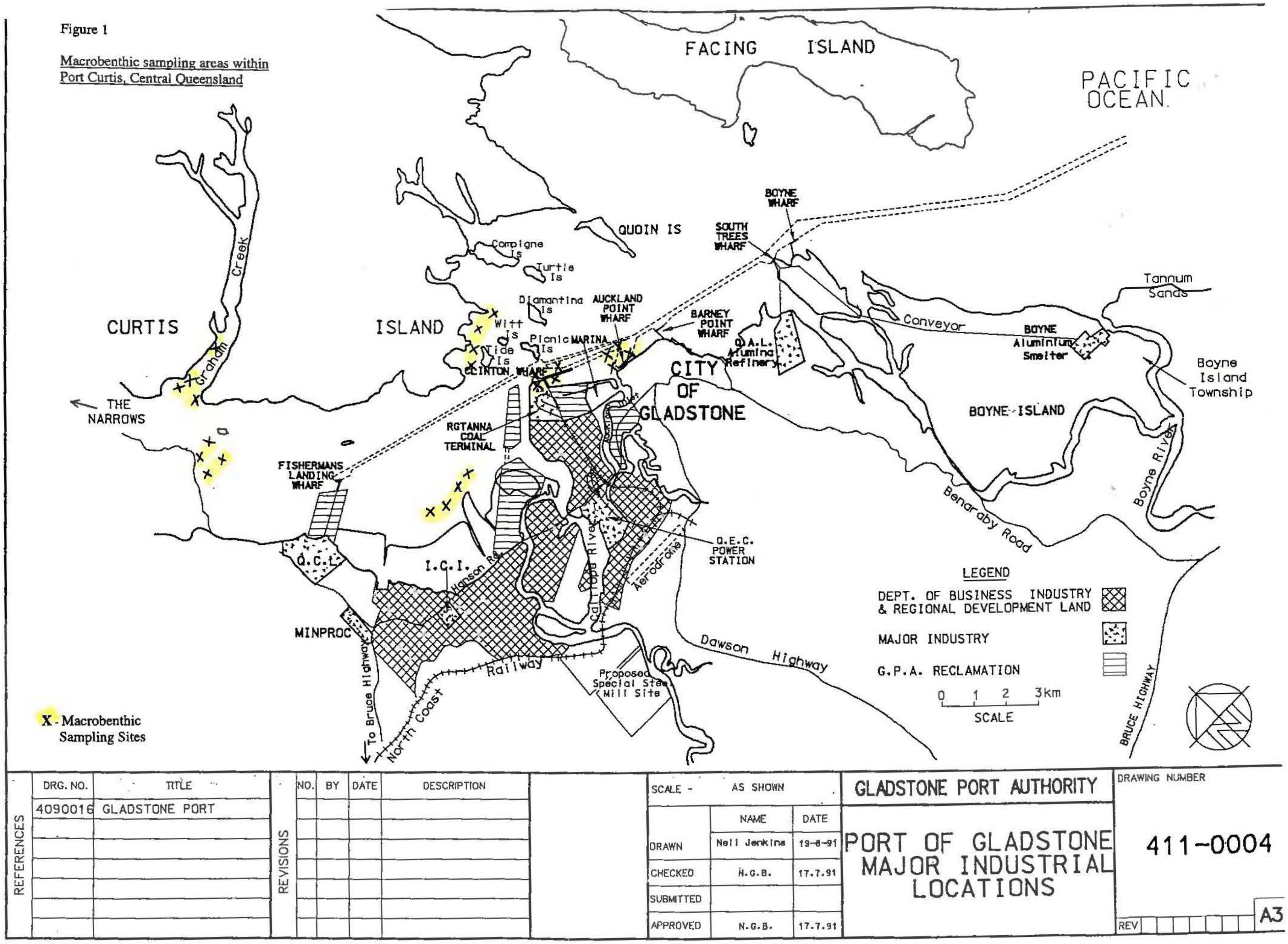
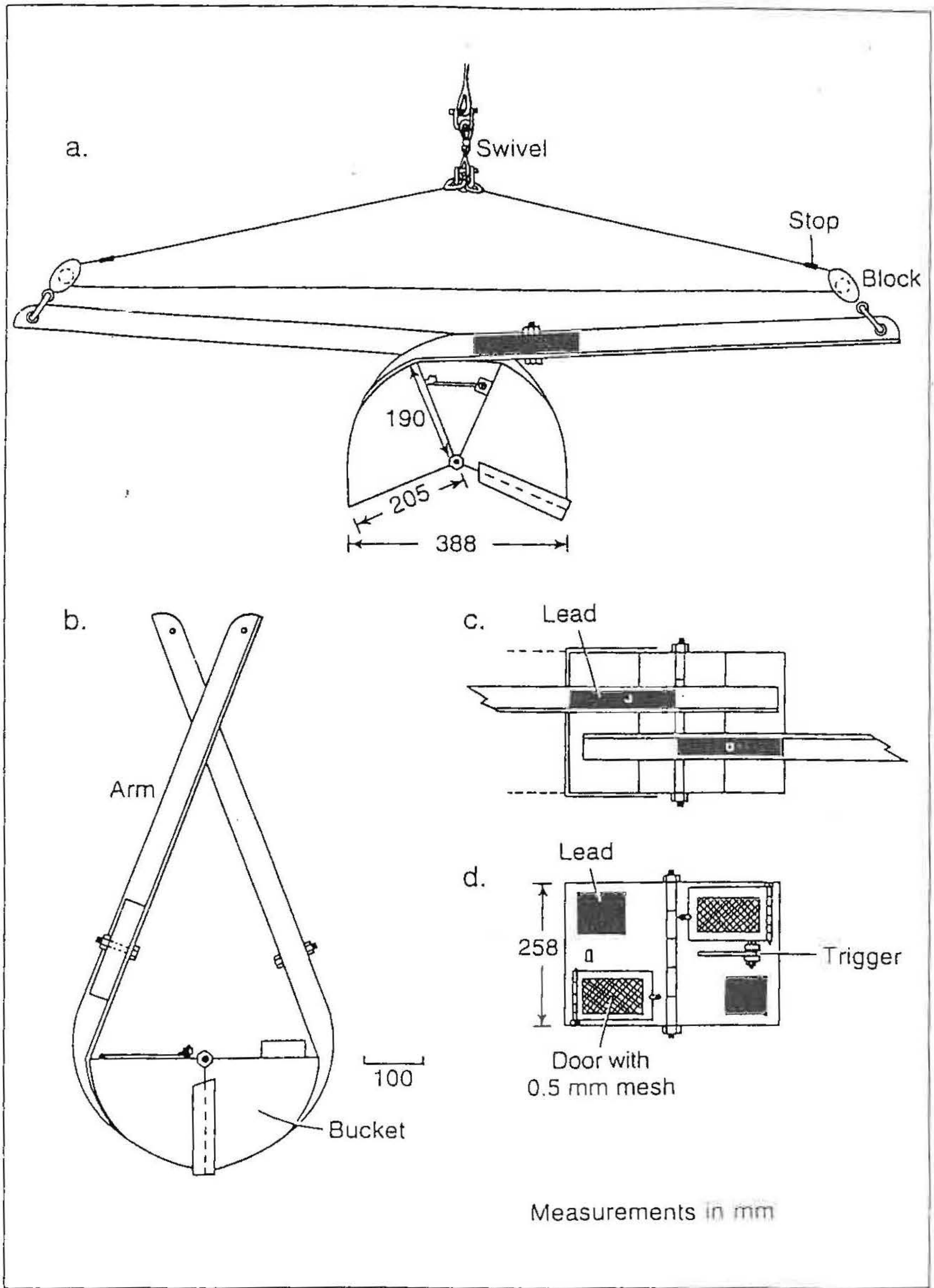


Figure 2

van Veen Grab



after English *et al*, 1994

P. CRUSTACEA
C. MALACOSTRACA
O. AMPHIPODA
St 12 (3)
9.11.96

Figure 3

BCMA 1/9
1996

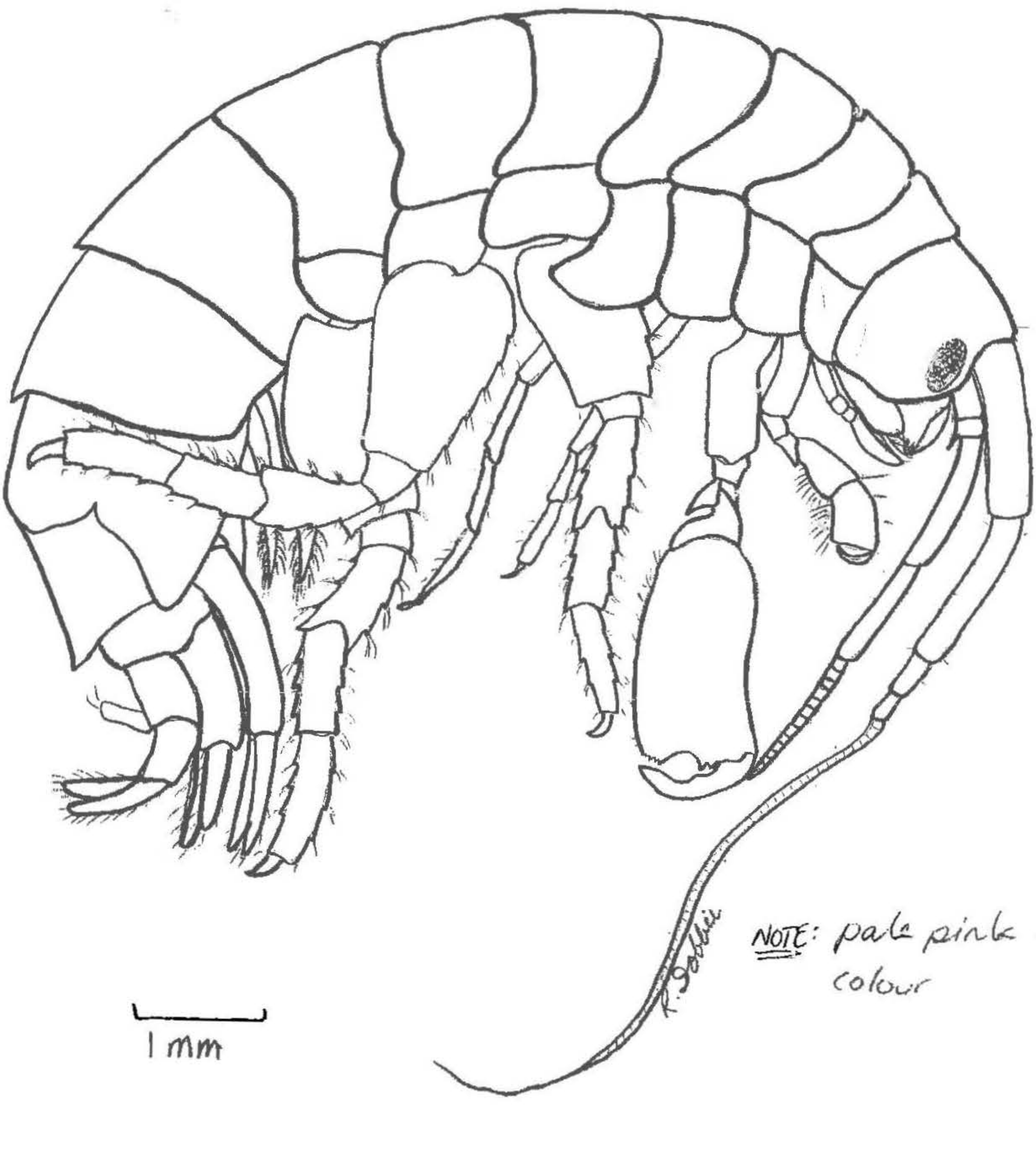
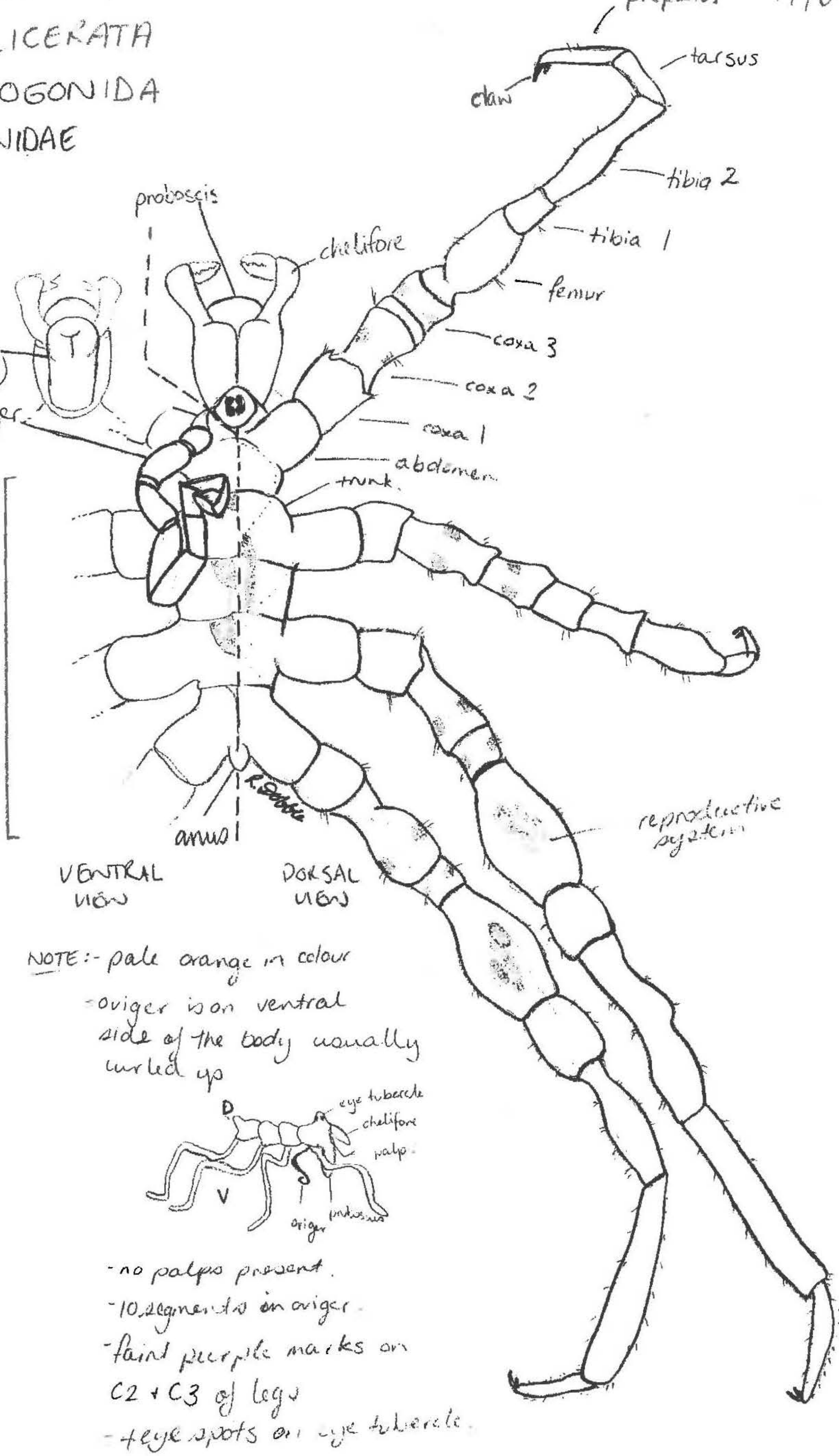


Figure 4

BAP 1/1
1996

P. ARTHROPODA
S.P. CHELICERATA
C. PYCNOGONIDA
F. PALLENIDAE

St9 (2)
NOV '95



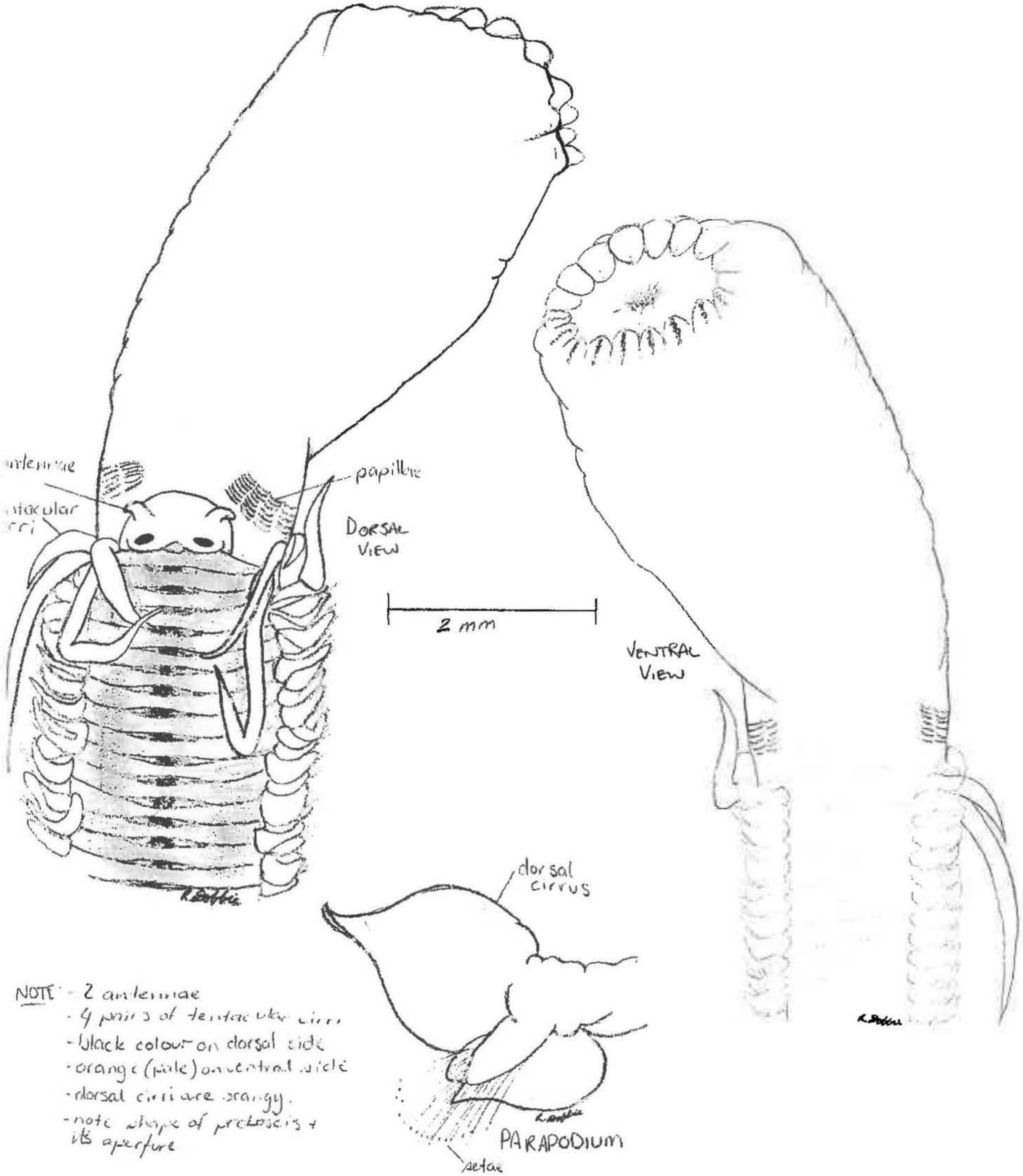
NOTE:- pale orange in colour
- oviger is on ventral side of the body usually curled up

- no palps present.
- 10 segments in oviger.
- faint purple marks on C2 + C3 of legs
- 4 eye spots on eye tubercle.

ANNELIDA
POLYCHAETA
PHYLLODOCIDAE
irrodoce sp (possibly)

Figure 5

BAPP 1/4
1996

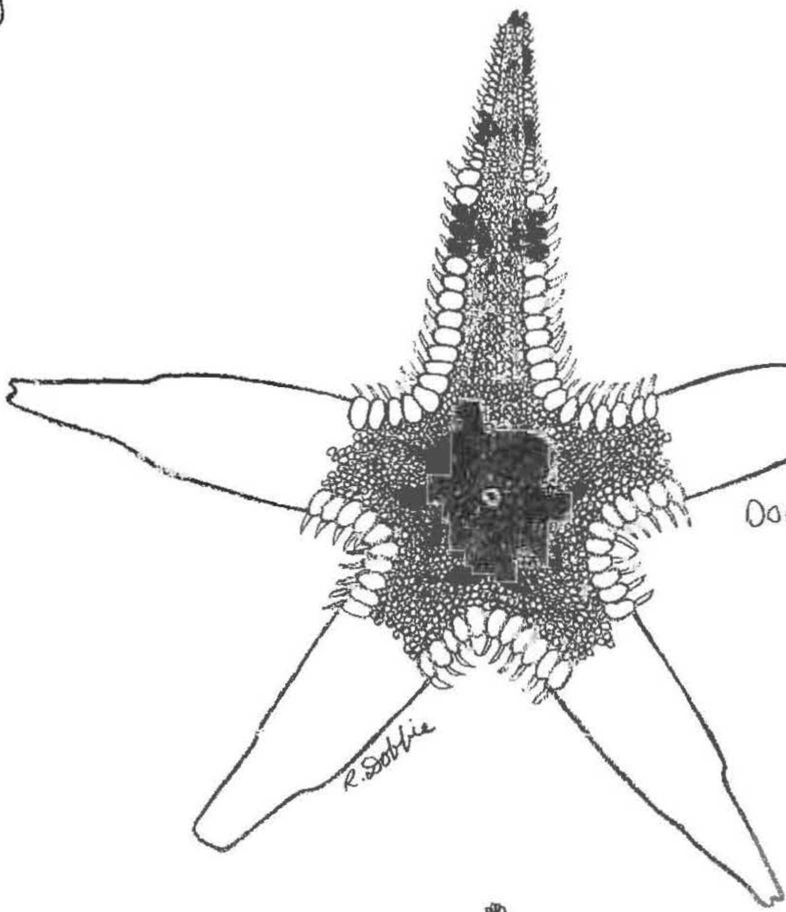


NOTE: - 2 antennae
- 4 pairs of tentacular cirri
- black colour on dorsal side
- orange (pale) on ventral side
- dorsal cirri are orangy.
- note shape of proboscis + its aperture

ECHINODERMATA
ASTEROIDEA
ASTEROPECTINIDAE
St 12 (2)
9 11 96

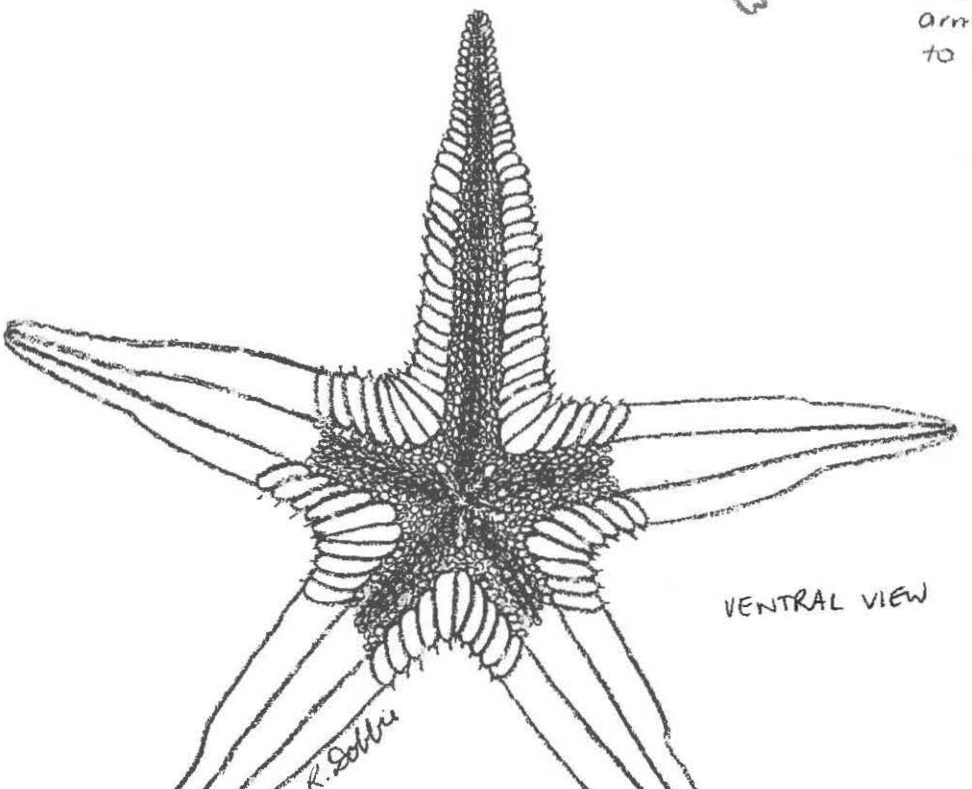
Figure 6

BEAA 1/3
1996



DORSAL VIEW

NOTE - ventral surface is cream in colour with white ends
- dorsal surface is beige with brown/grey mark (distinctive)
- size ranges from an arm length of 5cm to 12cm.



VENTRAL VIEW

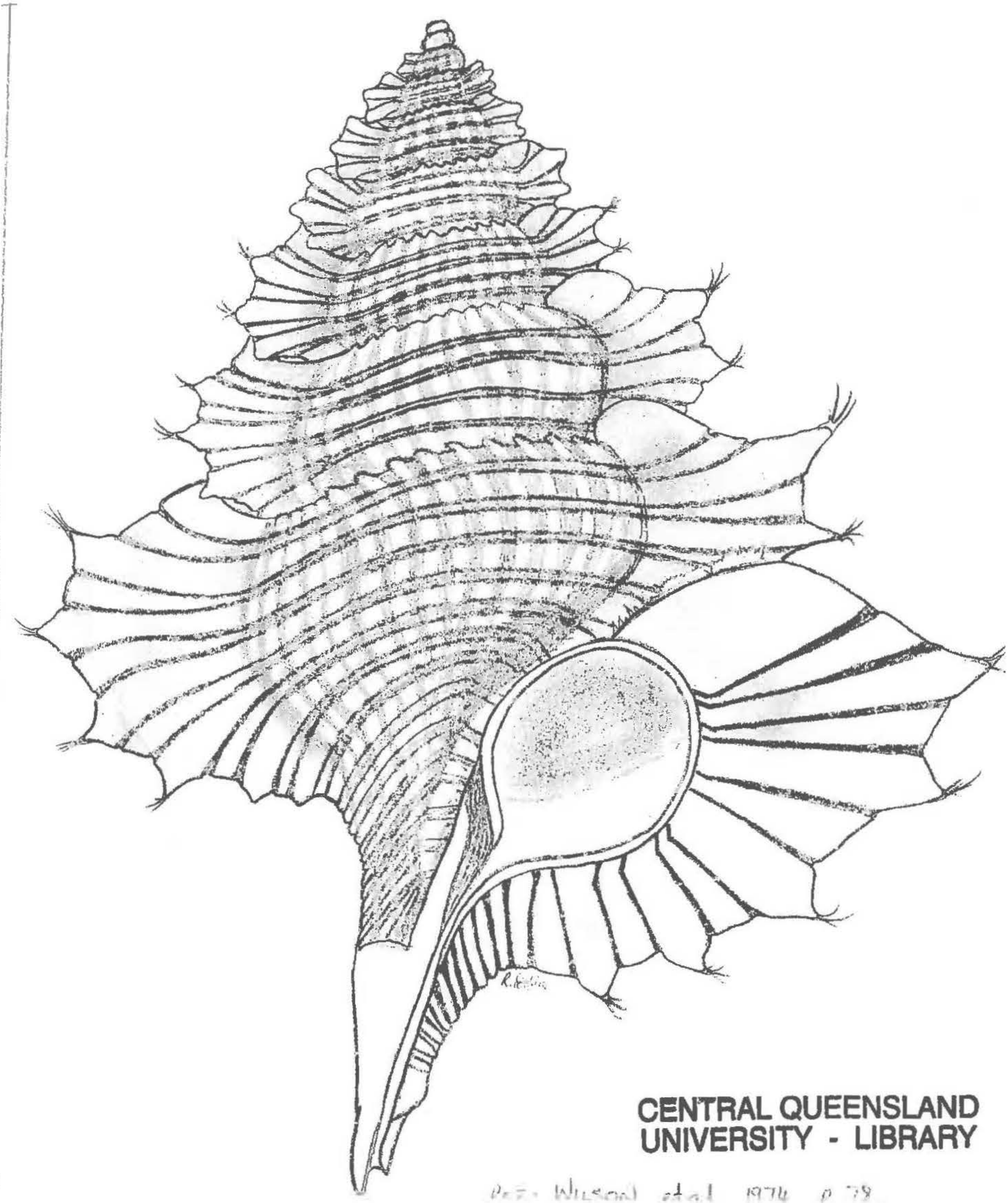
arm length ranges from

5cm → 12 cm

Figure 7

MOLLUSCA
GASTROPODA
CYMATIIDAE
Gyrineum jacundum

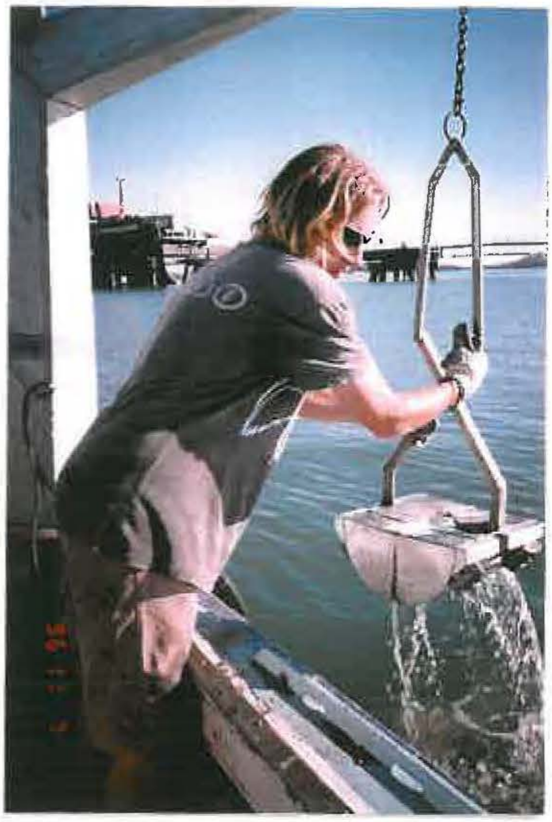
BMGCGj 1996 1/1
(was BMGCAP 1996 1/1)



3.0

Ref: Wilson et al. 1974 p. 78

Plate 1



Photographs of the field based operation from collection to sorting.