A Spatial Database for the Later Stone Age Site 'Dunefield Midden' (Western Cape, South Africa)

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Thesis submitted in fulfilment of the requirements for the award of the Master of Science degree.

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December 2002

ACKNOWLEDGEMENTS

First of all I want to thank everybody I have met in the last 24 years - there is no one who had been more or less important for my life, even if I often thought that this would be the case. All of you who contributed directly to this work will know that I am very thankful for the support you gave me. Once again I realized how important it is to have friends - especially when you are in a foreign country. Thank you for sharing time with me and for enjoying life to its very best.

There are several people who I want to name in detail: Above all John Parkington for being my supervisor and encouraging me to finish archaeology. His openness, calmness and creativity provided the fertile background on which the Dunefield Midden Spatial Database was developed. Also thanks to my parents who never hesitated to encourage me in pursuing my ideas and giving me all the help they could.

In the three years I was studying at the University of Tuebingen (Germany), Nicholas Conard supported me in many ways. He took me to South Africa for surveying in the West Coast National Park and to Egypt to work with Mark Lehner (Oriental Institute of Chicago, USA) at the Pyramids of Giza. He also gave me the opportunity to show and enhance my computer skills working for him in the Archaeology Department as a computer network administrator. I want to thank Mark Lehner for his confidence in my work as a field archaeologist and his understanding that I had to take a break from field work for doing my degree. For the financial support I have to thank the German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD). Without the grant it would have been impossible to come to South Africa to do this degree.

Quite a lot of people were part of the Dunefield Midden Project. Dozens of excavators and analysts provided the data which is represented by the Dunefield Midden Database. Most of them I never personally met, but I want to say thanks to Debbie, Lyndall and Leonard for their work. Without them there would be no complete dataset for the DFM shellfish - they managed the huge task of handling the hundreds of boxes and bringing the datasheets up to date and provided me with the raw data for the shellfish analysis part presented in this thesis.

Many thanks to Stephanie for proof reading parts of this thesis and last but not least I want to thank the people of South Africa for the friendliness, openness and warmth they showed me and made me feel like I am at home.

ABSTRACT

This thesis demonstrates how computer applications can significantly improve data management and data analysis in an archaeological context. A research database for the Later Stone Age site 'Dunefield Midden' (Western Cape, South Africa) was developed integrating a relational database, a Geographical Information System and a statistical analysis software package. Spatial analysis methods are evaluated and applied to the shellfish remains of Dunefield Midden after the data quality has been assessed. The investigation of spatial patterning is focused around the processes of collection, transport, processing and discard of shellfish and from the results, a specific model of shellfish handling behavior at Dunefield Midden is suggested.

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CHAPTER I INTRODUCTION

1 THE DFM SPATIAL DATABASE PROJECT

Background

In 1988, John Parkington (Department of Archaeology, University of Cape Town) began to excavate a series of ephemerally occupied open air Later Stone Age camps at Elands Bay, about 200km north of Cape Town, South Africa (Figure 1 to Figure 3). Although they were identified as several briefly occupied campsites, they are referred to collectively as the 'Dunefield Midden site', in the following abbreviated to 'DFM' (Parkington et al. 1992:63).

Over the last 14 years, the site has been researched intensively with dozens of undergraduate and postgraduate students excavating, mapping and analyzing the material from DFM. The information from an area of over 850 square meters is the basis for this thesis.

The geological setting and the morphology of the site are exceptional: there is very strong evidence that Dunefield Midden represents a series of very short occupations with a minimum degree of over-printing. A large set of 28 C^{14}-dates shows a very tightly calibrated distribution between 1300-1400 AD (Table 1 and Figure 7) and stratigraphic observations point towards a predominantly single layer context. These characteristics result in a very high resolution in time and space.

In 1998 Susan Kent described preliminary results from DFM and emphasized that "Dunefield Midden is one of the best examples of spatial archaeology in southern Africa." (Kent 1998:46) In this sense, the DFM Spatial Database Project provides the means to analyze the exceptionally detailed records of relatively recent hunter-gatherer material remains and might enable archaeologists to resolve urgent questions about the material reflections of human behavior.

Objective

A huge amount of data was gathered over the years but a concrete data management structure did not exist. The exceptional situation at Dunefield Midden and the general interest amongst archaeologists in analyzing spatial patterns, made it necessary to develop a data management system. First attempts to create a database were made by

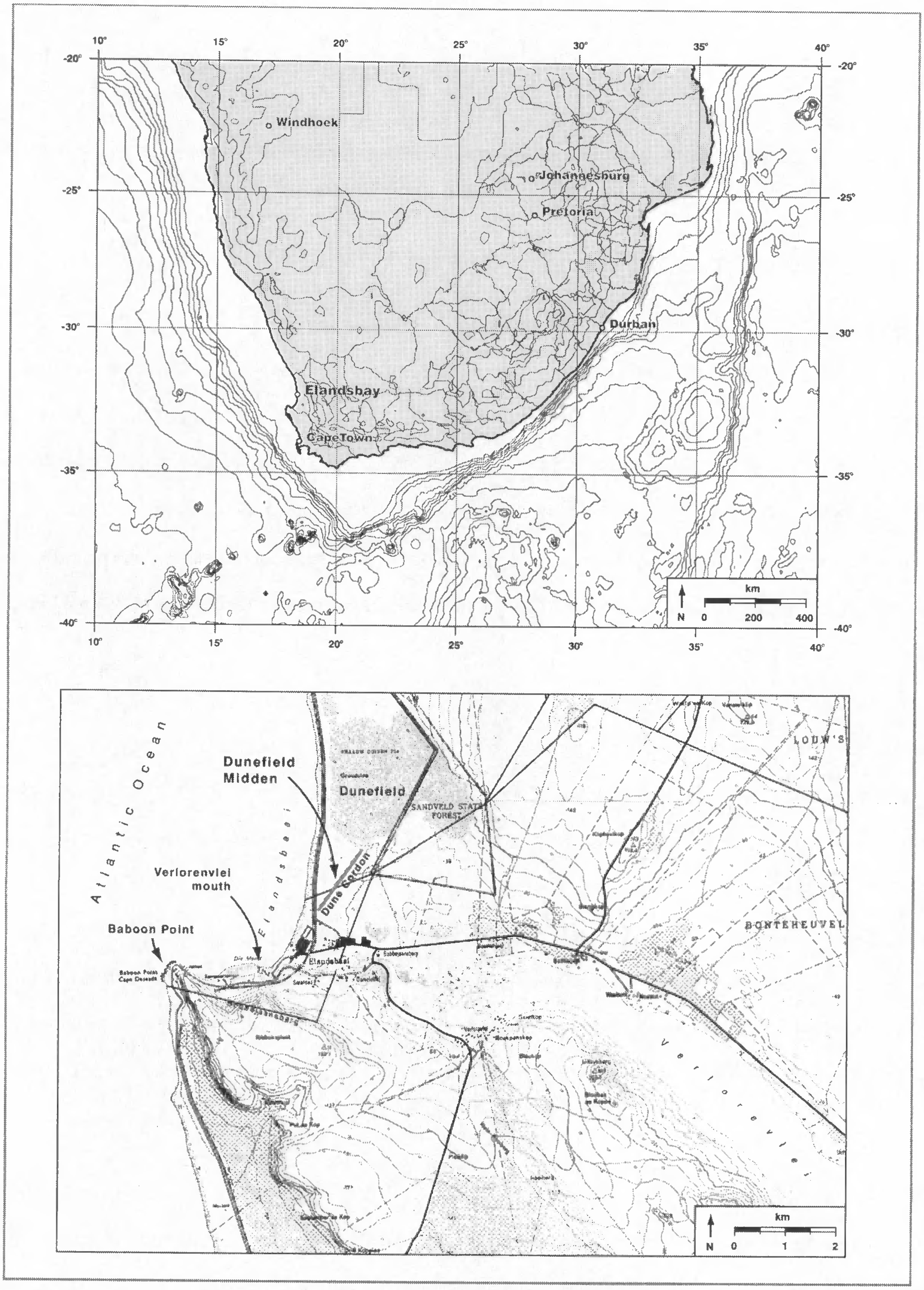


Figure 1: Geographical position of Dunefield Midden.

Figure 2: Baboon Point from the airplane facing SSE (Sinclair et al. 1986:P.D.Morant, October 1980). (Top)

Figure 3: Elandsbaai Dunefield from the airplane facing SE (Sinclair et al. 1986:ECRU 79-08-14). (Bottom)

John Parkington and Larry Bartram in 1997, but were never completed (Parkington and Batram 1997). Then, in the year 2000, it became the task of this project to create an environment where the Dunefield Midden data could be managed and analyzed.

In this sense, the main objective of this thesis is to develop an archaeological research database system being capable of storing all spatial information existing for DFM and to enable extensive spatial analysis using a linked Geographical Information System (GIS). The possibilities of the system are demonstrated with several application examples and interpretations for the emerging patterns are suggested. Intentionally, the interpretation of patterns observed at Dunefield Midden is not put into the focus of this thesis. Instead, an environment for spatial analysis is created and the existence of patterns at DFM is demonstrated and quantified. It will be left for further research to decide if the complex data and the extraordinary high resolution in space and time of Dunefield Midden will enable archaeologists to identify distinct human behaviors.

Unfortunately much of the archaeological material produced by DFM has not yet been analyzed and the data input is not complete. Therefore it was necessary to develop a database that provides easy-to-use data input tools and is capable of future additions and changes. Even with the current dataset, however, it is possible to analyze site and shellfish structure in great detail. By examining the spatial patterns evident in the distribution of finds and features, ideas about the usage of space at DFM can be tested and new ideas can be developed. In future the analysis of a complete dataset might be the key to reconstruct and understand social behavior of Stone Age people living along the western coast of South Africa.

Thesis structure

This thesis contains seven chapters. The first three are introductory and give an overview of the site of Dunefield Midden, explain the analytical framework and elaborate on the methodology of this project. Chapter four explains in broad terms the integrated Database-GIS-System and demonstrates its basic functions. This is followed by an investigation of the variability of shellfish analyses (chapter five) where the quality of the DFM shellfish data is evaluated. In chapter six the Dunefield Midden Spatial Database is used to identify and quantify spatial patterning in the shellfish remains and a conclusion is drawn in chapter seven.

There are five appendices attached at the end. In the first appendix important data from primary analyses on DFM shellfish is presented while the description of recent shellfish populations at Elandsbay can be found in appendix two. The third appendix discusses the calculation of the spatial autocorrelation statistics used for spatial analysis. The fourth is a detailed documentation of the database structure providing the metadata for the DFM Spatial Database and the fifth presents the tables and figures used to evaluate the shellfish analysis variability experiments.

2 DUNEFIELD MIDDEN

Context

The site 'Dunefield Midden' is situated about half-way between the small village of Elandsbay and an active Dune-field in the north of Elandsbay (Figure 1). In the east, it is bounded by a relict barrier dune dating at least into the mid-Holocene, "that rises about 1km north of Elands Bay village and trends NNE away from the present coastline..." (Miller et al. 1993:39). Today, the shore of the Atlantic Ocean lies about 600m to the west of Dunefield Midden (Parkington et al. 1992:63).

Before the construction of a railway line, sand was regularly transported by southerly winds from the Elandsbay shore to the area of the Dunefield. The barrier dune acted as a boundary for the transport resulting in a small funnel through which the sand was blown northwards (Miller et al. 1993:39). Evidence for this process can clearly be seen at Dunefield Midden as the occupational remains were covered with up to 2m of archaeologically sterile aeolian sands (Parkington et al. 1992:63).

The people living at Dunefield Midden chose an older beach deposit as the base for their activities. It is described by Parkington et al. (1992:63) as a "yellow sand with quartz pebbles that is clearly waterlaid." Miller et al. (1993:39f) analyzed the geology north of Elandsbay village and found that this beach deposit was situated right next to a late-Holocene washover feature (Figure 4) dated to 1230±50 BP (Pta-4477, calibrated: 1310 AD, one sigma range: 1287-1339 AD) and 1560±50 BP (Pta-4298, calibrated: 1014 AD, one sigma range: 972-1043 AD). As an interpretation, Miller et al. (1993:40) suggested that water from the Atlantic Ocean successively washed over a probably older beach surface into an area behind it. As it would be retained there for some time, there is a possibility that the water would have been much closer to the site than it is today if in fact the washover was still active at the time when DFM was occupied (as Pta-4477 might indicate). Sea-level fluctuations, as described in the following chapter (see "Holocene environment" on page 30), can be seen as a crucial factor that created these features.

In can be concluded that two prominent topographical features existed during the occupation of DFM: the remains of an exposed, old beach deposit sloping gently towards the shoreline and a high dune cordon in the east cutting off any visual connection to the interior (Figure 5).

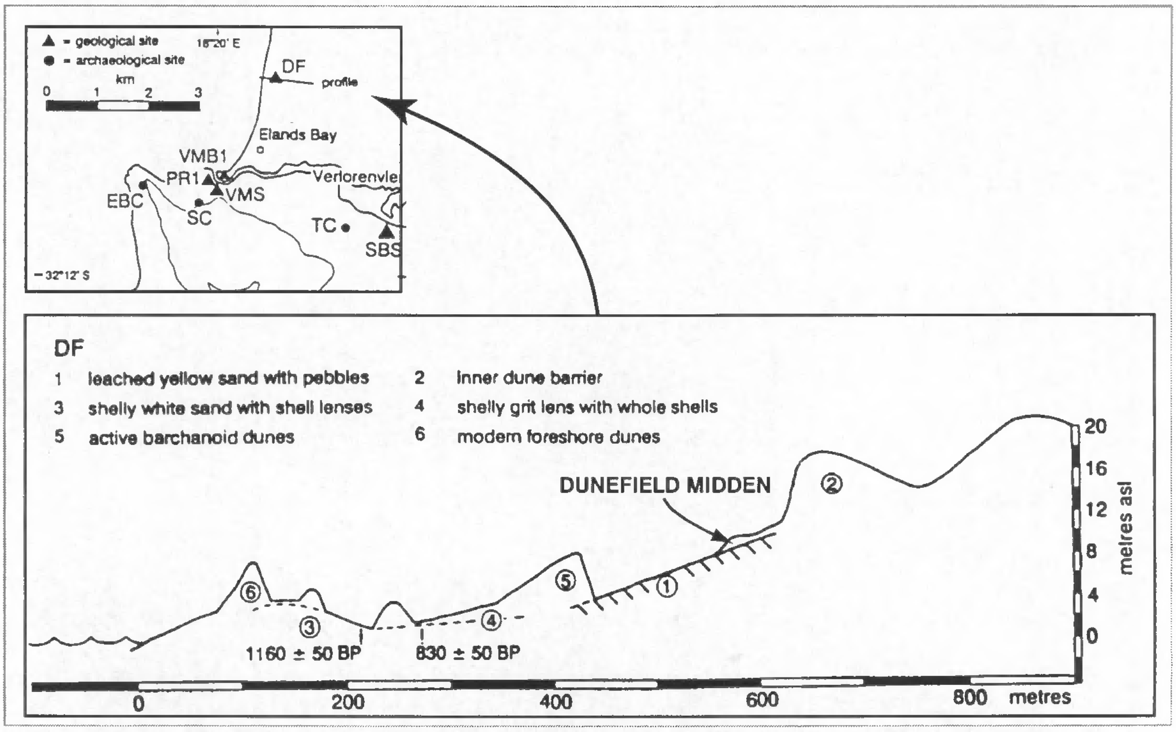


Figure 4: Geological profile of the Dunefield near Elandsbay (changed after Miller et al. 1993:40).

Excavation

During the many years of excavation, a specific strategy was followed, that is (Parkington et al. 1992:63):

> "... to expose as large a continuous area of occupied surface as possible by removing the aeolian overburden in metre squares, mapping as much of the debris as is possible and sieving all removed sand through a very fine (1,5mm mesh) sieve."

This strategy was chosen with a specific methodology and theory in mind: It was assumed that "social issues and processes" of pre-colonial people can be analyzed if two main problems concerning the resolution of archaeological work can be minimized: the problem of palimpsests on archaeological sites and the limited size of exposure of archaeological living floors (Parkington et al. 1992:64). As DFM shows just minimum indications of overlapping traces, a large area was excavated, trying to reach "the boundaries of reasonable scatter" (Parkington et al. 1992:63). It was expected that this site could serve as an almost ideal case for a Stone Age site with both of the previously described problems being minimized. In this sense the excavations "at DFM are an attempt to derive a resolved episode in the history of western Cape settlement." (Parkington et al. 1992:64)

The first excavation took place in 1988 and was followed by regular seasons once or twice a year (except for 1995, 1996 and 2000). The last season was conducted in 2001 with the author participating. Throughout the excavations the

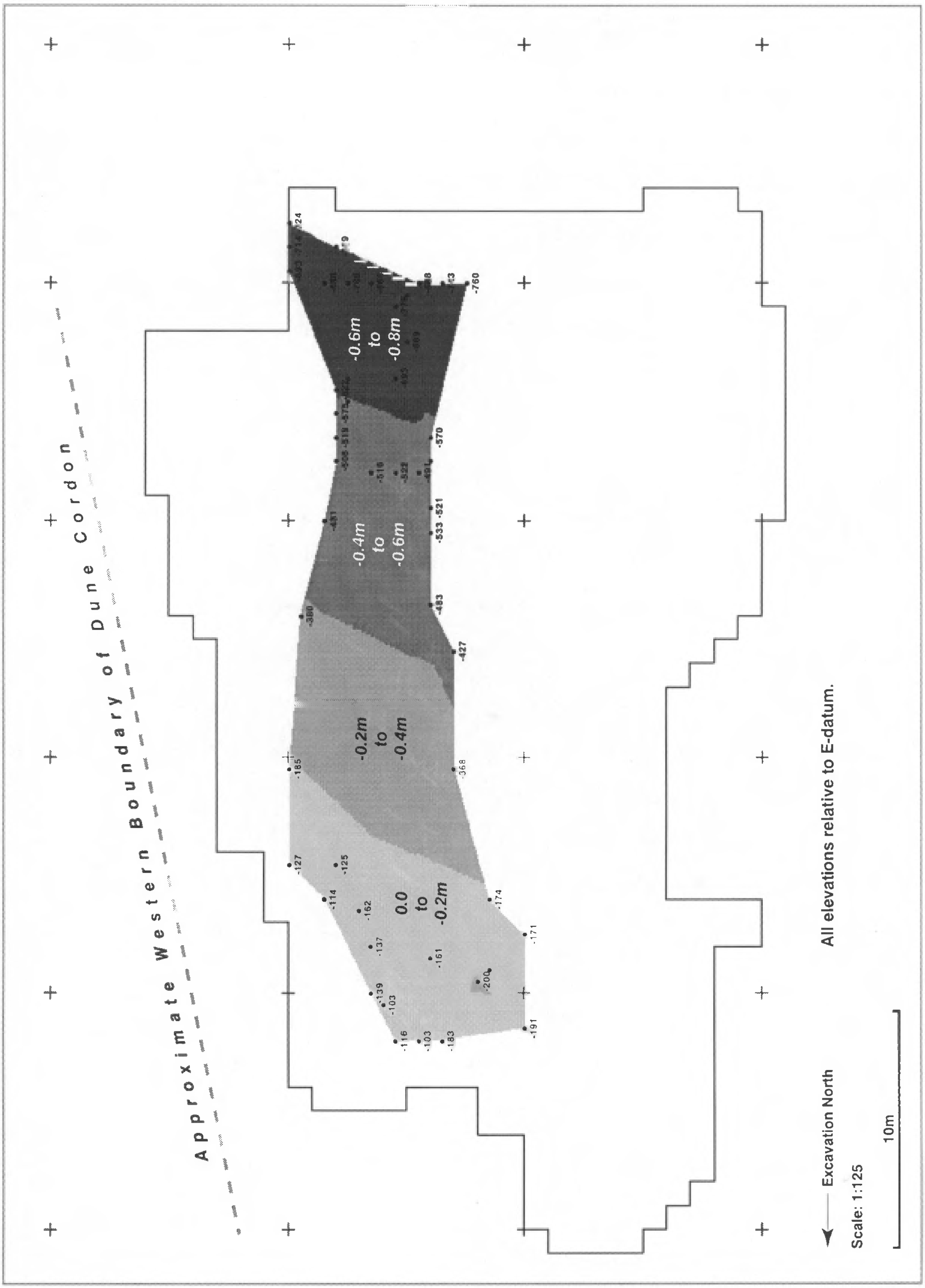


Figure 5: Topography of DFM occupation plane and approximate location of dune cordon.

same grid initially setup in 1988 was used and consists of units and squares, with one unit containing 100 squares. Each unit is named with three letters and the squares are numbered sequentially from 1 too 100. All excavations together, including the latest of 2001, produced a total excavated area of 859 square meters. The excavation border, the location of the units and the numbering of the squares is shown in Figure 6. The exact geographical orientation of 'excavation north' is unknown but believed to be about north-east.

As the occupational remains showed almost no stratigraphy, it was decided to excavate the site as one context defined by its position between the sterile, aeolian sands on top and the yellow, waterlaid sand beneath. In few cases where two or more different contexts could be separated, they were labeled (e.g. 'upper', 'lower') and excavated separately. This particularly concerns the southernmost part of the DFM where at least two separate occupations (called 'dark phase' and 'pale phase') were found.

All features were mapped carefully and the finds retrieved from the excavations were returned for further analysis to the laboratories in Cape Town (for details see "Archaeological material" on page 10). Most of the finds were plotted in situ and have absolute x- and y-coordinates. This excludes shell that was never plotted and is thus only provenanced to meter square as it is also the case with the finds retrieved through sieving.

Post-occupational disturbances seem to be slight. It is believed that the site was covered quickly by aeolian sand as the preservation of bones is generally good. Carnivore-gnawing was shown to have altered the assemblage (Stynder 1994) and micro-mammalian bones were largely brought in by other animals (Matthews 1992). Vertical movement of finds (especially shells) was observed frequently. Although most of the occupational debris is found on the waterlaid yellow sand, finds and especially shell were found for several centimeters down into the old beach deposit. This can be interpreted to be due to the trampling effect described by Gifford-Gonzalez et al. (1985): Finds move vertically through sandy sediments when trampled on and the resulting distribution shows a decrease in relative numbers with increasing depth while following a normal curve (Gifford-Gonzalez et al. 1985:815f). These migrations may happen in scales of 3-8cm (Gifford-Gonzalez et al. 1985:803) and observations from Dunefield Midden were largely within this range.

Although it is impossible to prove the contemporaneity of the whole site, the C^{14}-dates taken from various places indicate that most of the occupation happened in a very short time period around 1300-1400 AD (average 1353 ± 53 AD). The large set of 28 C^{14}-dates is reproduced in Table 1 and Figure 7 illustrates graphically the distribution (samples sorted from left to right by calibrated date). All dates were cross-checked with the Quadru internet database

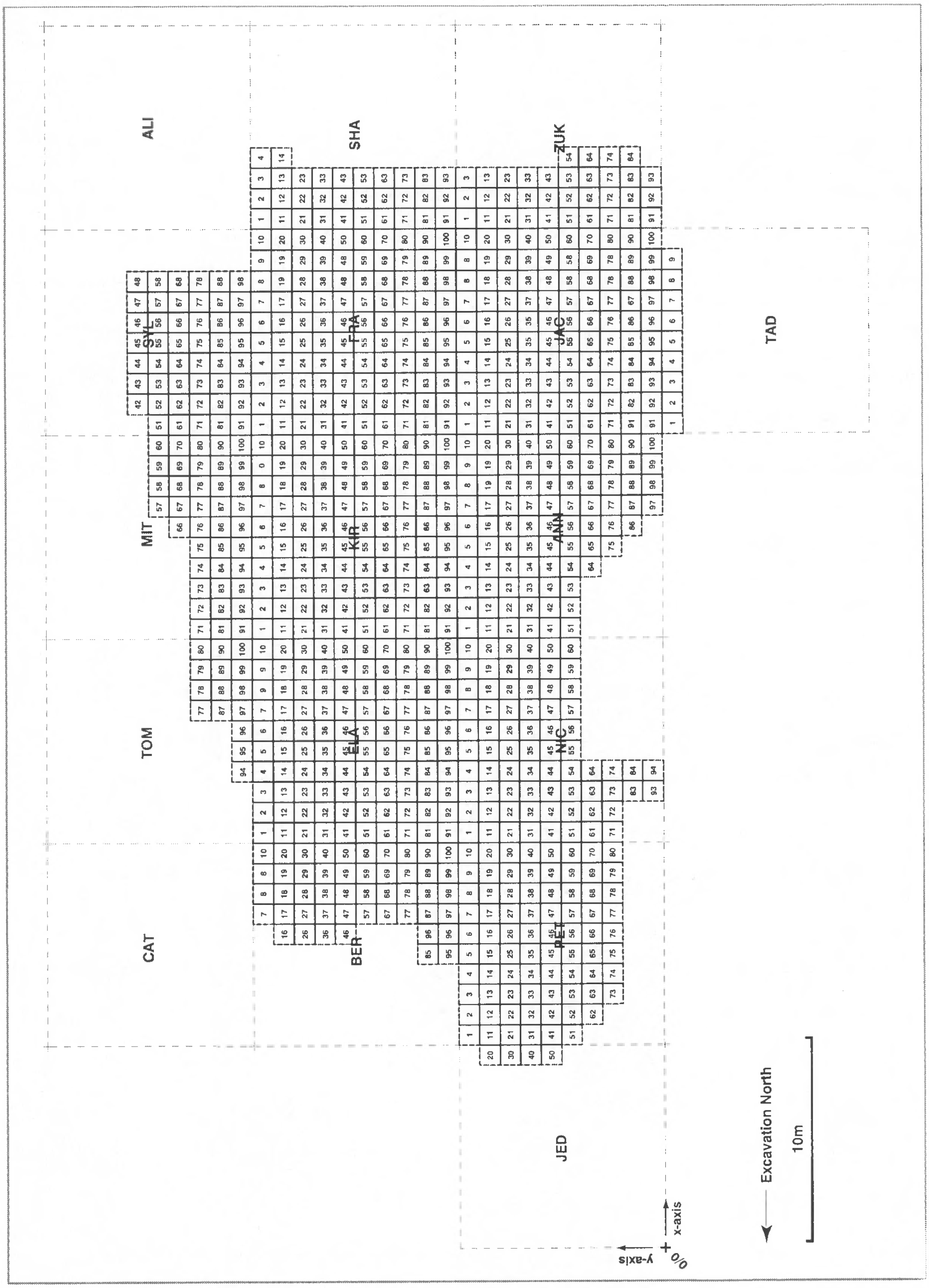


Figure 6: The Dunefield Midden excavation grid.

(www.quadru.co.za, 27-09-2002) and were calibrated with the Pretoria Radiocarbon Calibration Program CAL4H using the following calibration datasets:

- for marine samples: WC93 (South African West Coast marine calibration curve)
- for terrestrial samples: SH98 (Southern hemisphere calibration data)

Samples for C^{14}-dating were taken from shell and from charcoal and their spatial distribution on the site can be seen in Figure 8 and Figure 9. Dates from shell are indicated separately from charcoal dates as they are independent evidence for different processes happening at DFM. The charcoal was sampled only from clear features, often in situ hearths, that may be found inside living areas; the shells of shellfish on the other hand were sampled from different dump areas, usually situated in the periphery of the living areas. Although it is tempting, an interpretation of the spatial distribution of the C^{14}-dates to obtain a relative chronology of specific events is very difficult, as most of the dates overlap on the one sigma range. Possible patterns cannot be proven due to the insufficient resolution of C^{14}-dating.

Archaeological material

The main archaeological sources from DFM are finds and features. All of the features had an ashy matrix and were interpreted to be the remains of in situ fire places or dumps of ash and charcoal from nearby fire places. No structures indicating housing, shelters or windbreaks were found. Several of the features were situated in small pits in the yellow, pebble rich sand. This is taken as a strong indicator that they represent in situ hearths. Other features were thin and scattered on and within other debris (such as bones, shell and lithics) and are interpreted to be secondary dumps from hearths. As these ashy deposits are reflecting different processes on site, the use of space is reflected by them. Feature categories were generated by Parkington and Fisher (Parkington et al. In prep.) and the results are shown in the section "Feature Map".

The finds were scattered in different densities across the site. Associations with different features indicate that work was done in the vicinity of them. Most of the finds, however, were found in high densities in what is interpreted as refuse dump areas. Living areas are believed to have been cleaned several times with the material being dumped not far away. As Dunefield Midden is a shell midden, shells dominate the finds by specimen counts, ranging in the 100-thousands. Bones and lithics are very frequent with tens of thousands whilst ostrich eggshell pieces, ostrich eggshell beads and ceramics are present in much reduced frequencies of a few hundred each (see "Datasets" on page 87 for details).

It was noted earlier that the data management of the excavation has been rather unstructured. No central organization was established to track the finds that were analyzed and no continuous work on the material retrieved from fol-

Unit	Sq.	Material	Source	Reference	C14-Date	Calib-Date*	+1 StDev	-1 StDev	+2 StDev	-2 StDev
-	-	shell	n/a	Pta-4801	1350±70	1230	1287	1160	1319	1054
BER	8	shell	n/a	Pta-5415	1290±40	1282	1301	1248	1319	1213
ELA	10	charcoal	hearth	Pta-4799	710±45	1296	1383	1284	1400	1270
ELA	10	shell	n/a	Pta-6734	1210±50	1319	1383	1297	1415	1268
ELA	43	charcoal	char. & ash pit	Pta-6721	690±50	1301	1393	1288	1409	1274
ELA	43	charcoal	hearth	Pta-4802	680±50	1304	1397	1291	1412	1277
ELA	86	shell	n/a	Pta-5031	1240±40	1306	1325	1287	1383	1259
FRA	6	shell	crusted feature	Pta-6735	1200±20	1325	1339	1315	1383	1306
FRA	26	shell	n/a, lower	Pta-6737	1210±60	1319	1392	1292	1426	1248
FRA	30	charcoal	roasting pit	Pta-5062	640±40	1346	1406	1304	1417	1293
FRA	52	shell	n/a	Pta-6736	1180±40	1339	1398	1315	1421	1297
FRA	76	shell	n/a	Pta-5405	1190±40	1331	1392	1310	1415	1292
FRA	80	shell	shellmidden	Pta-4482	1200±50	1325	1392	1301	1421	1276
FRA	96	shell	n/a	Pta-6738	1210±40	1319	1356	1301	1404	1282
JAC	7	charcoal	whale barnacle	Pta-6337	640±20	1346	1400	1312	1406	1304
JAC	10	charcoal	hearth	Pta-5280	650±50	1352	1406	1298	1421	1285
JAC	13	shell	n/a	Pta-5419	1170±35	1356	1401	1322	1421	1306
JAC	60	charcoal	hearth	Pta-7894	640±40	1346	1406	1304	1417	1293
KIR	26	charcoal	n/a	Pta-7897	630±35	1397	1407	1310	1417	1298
KIR	50	shell	n/a	Pta-5071	1140±40	1398	1421	1339	1441	1315
KIR	72	charcoal	hearth	Pta-5276	620±50	1400	1414	1308	1430	1293
NIC	30	shell	n/a	Pta-5070	1130±40	1404	1426	1356	1446	1319
PET	27	charcoal	roasting pit	Pta-5277	600±40	1406	1417	1322	1430	1304
PET	27	charcoal	n/a	Pta-7889	590±50	1409	1424	1322	1440	1301
PET	42	charcoal	ashy dump	Pta-5061	580±50	1412	1427	1397	1443	1304
SHA	33	charcoal	ash patch	Pta-4807	510±40	1433	1447	1421	1469	1409
SHA	62	charcoal	hearth	Pta-6730	570±50	1414	1430	1400	1447	1308
SYL	66	shell	n/a	Pta-6732	1030±60	1456	1491	1426	1537	1392

* Dates calibrated with Pretoria Radiocarbon Calibration Program CAL4H. Calibration dataset for marine samples: WC93 (South African West Coast marine calibration curve). Calibration dataset for terrestrial samples: SH98 (Southern hemisphere calibration data).

Table 1: Dunefield Midden C^{14}-dates.

low-up excavations was established. The result was that information has to be searched for, completeness of analyzed data cannot be guaranteed and some parts of the assemblage have not been analyzed at all (especially the

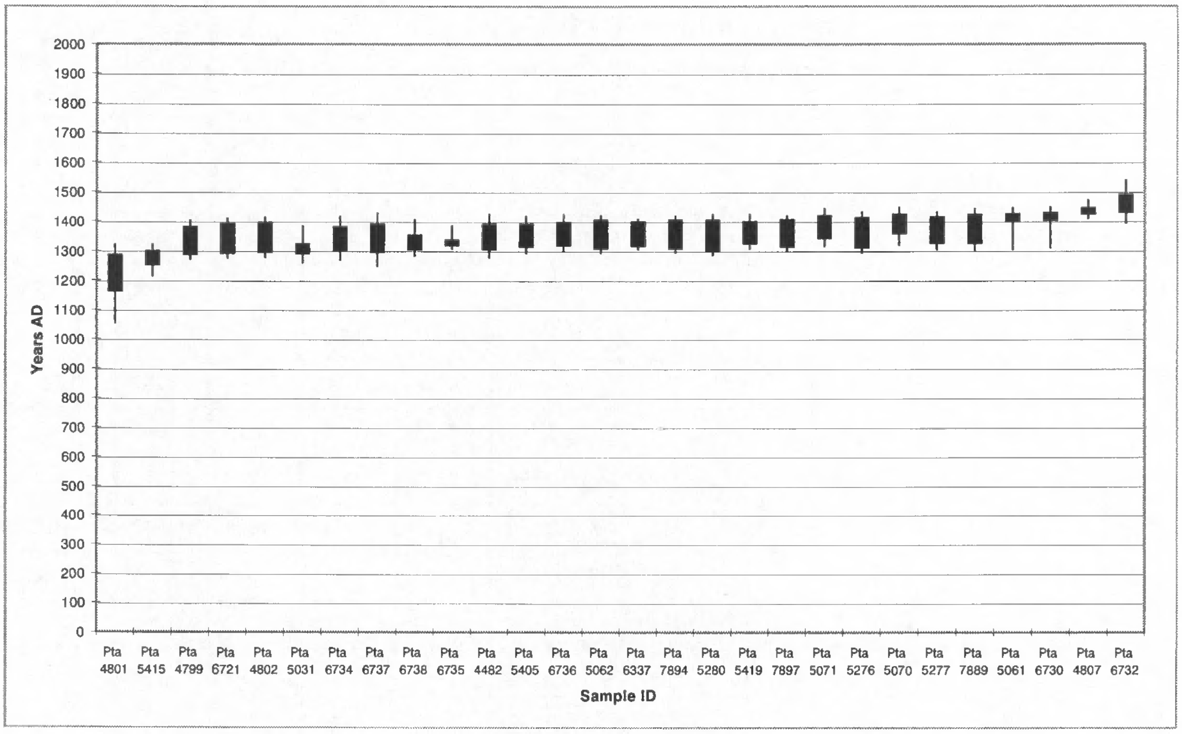


Figure 7: Calibrated C^{14}-dates for Dunefield Midden (with one and two standard deviations).

more recent excavations). Some of these issues were taken on by the development of Dunefield Midden Spatial Database.

Feature Map

In 2000, Koenig and Fisher created a digital feature map of DFM using AutoCAD 2000 (Figure 10). The survey of field notes and drawings was done in 1998 and 1999 by Fisher and Parkington. They established eight different types of features and three confidence levels, representing the "... confidence that the feature in question has been correctly identified/assigned as to a feature type" (Koenig & Fischer 2000:1). Table 2 shows the categories applied by Fisher and Parkington including their confidence levels and counts.

During excavations, archaeologists need to decide upon the dimensions and the limits of features in order to be able to record them. In many contexts with a sandy matrix (such as DFM) it is difficult to exactly pin down the position of the border of a feature as the materials (e.g. sand and ash/charcoal) easily mix with each other. In this sense, the size and shape of the features on the feature map are the best approximations that could be made from DFM field notes and drawings. Not in every case do they reflect the original shapes of the features 600-700 years ago. However, as their spatial locations are correct and their contents are known, spatial analysis of finds and features in reference to them is possible.

Literature review

Dunefield Midden was subject to a number of Honours and Master theses and several articles (Table 3 and Table 4). This section is intended to give a brief overview about some of the results related to the spatial analysis of finds and features.

In 1989 Nilssen investigated the distribution of pottery and eland bones and their refits of the early excavations (Nilssen 1989). The sherds were found to reflect the general scatters of cultural material, with concentrations close to hearths. This was interpreted as the result of food preparation activities carried out in the immediate vicinity of the hearths (Nilssen 1989:30). On the other hand, the eland bones were identified to be distributed differently than pottery and other cultural material: very few bones were found between the hearths and the dump and most of them were scattered in an arc-like zone at the southern end of DFM (Nilssen 1989:47). The skeletal parts seemed to show a pattern with ribs being more strongly represented adjacent to hearths and others in processing or dumping areas (Nilssen 1989:49). Refittings indicated that parts of the same original pieces were scattered over most areas of the site suggesting contemporaneity. This excluded the northern part of DFM as no pieces from there could be conjoined with others from the southern parts (Nilssen 1989).

Three years later, Reeler (1992) used a GIS to create distribution maps and to analyze spatial characteristics of finds and features. As a statistical method 'spatial autocorrelation' was applied to quantify spatial patterning. Ethnographic and ethnoarchaeological material was taken to compare them to the results of the spatial analysis and to aid the interpretation of the data (Reeler 1992:ix). Assessments concerning the type of site, the length of occupation, the number of people involved and "... the nature of the behaviors which caused the spatial patterning evident on site" (Reeler 1992:ix) were made. An analysis of the site structure revealed that it "... is immediately apparent ... that this site differs in detail from the ethnoarchaeological examples cited, as well as differing markedly from the 'classic' notion of a hunter-gatherer campsite" (Reeler 1992:136). Reeler estimated the length of occupation and the number of people living at DFM concluding that "... the site was a base camp occupied by between ten and twenty-five people for a month to a month and a half" (Reeler 1992:ix).

In 1995 Jakavula refitted several find categories from Dunefield Midden and used a GIS for mapping numerical information (such as find densities) and visualizing spatial distributions and relationships of features and finds. On basis of the distribution of shellfish, two dumps were distinguished: a northern and a southern one (Jakavula 1995:69). Whale barnacles were shown to form a very defined scatter around one of the roasting pits. This was interpreted as a reflection of a specific event of processing whale meat (Jakavula 1995:72). The distribution of refits from stone catego-

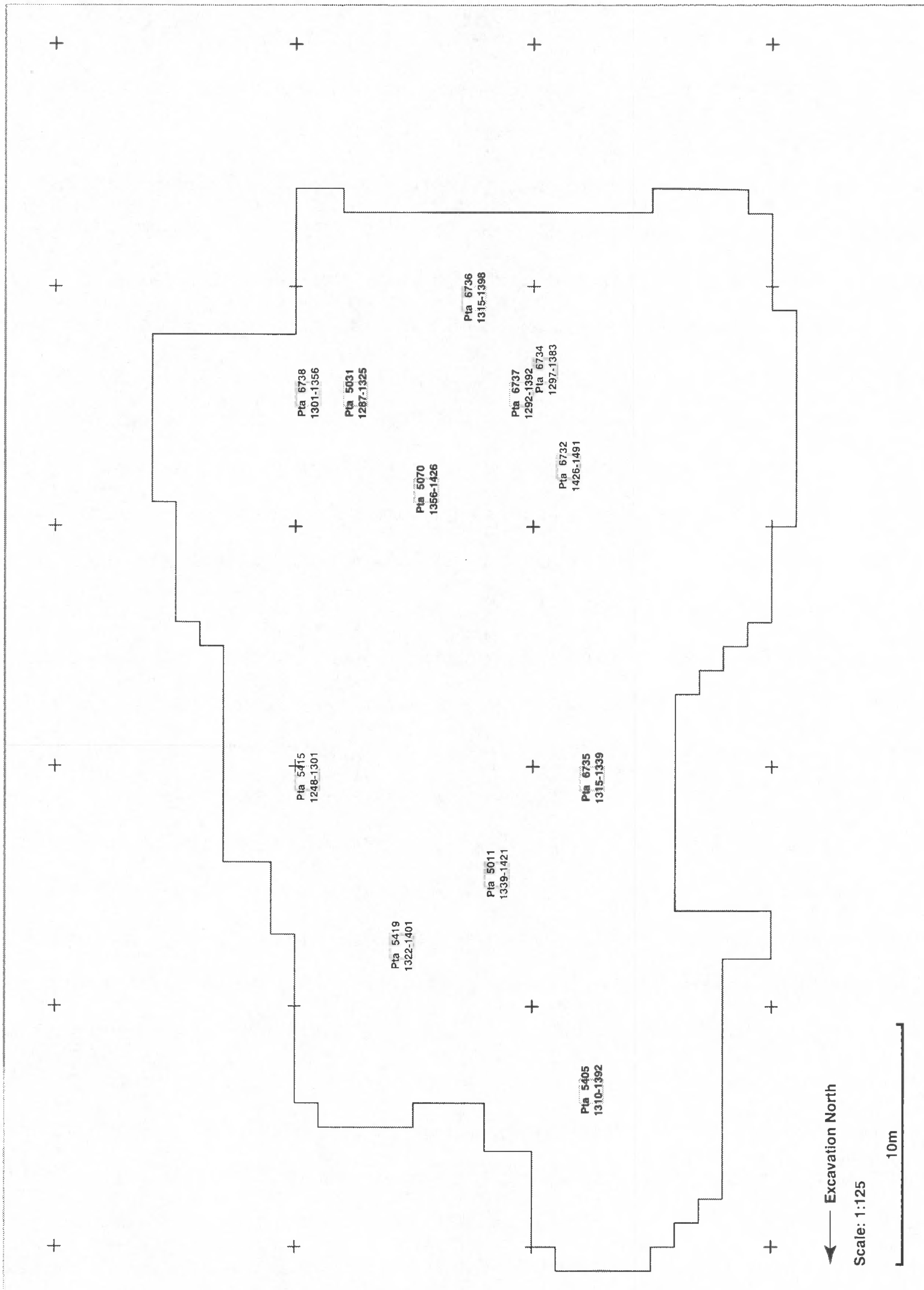


Figure 8: Location of calibrated C^{14}-dates from shell samples at Dunefield Midden (dates in one sigma range).

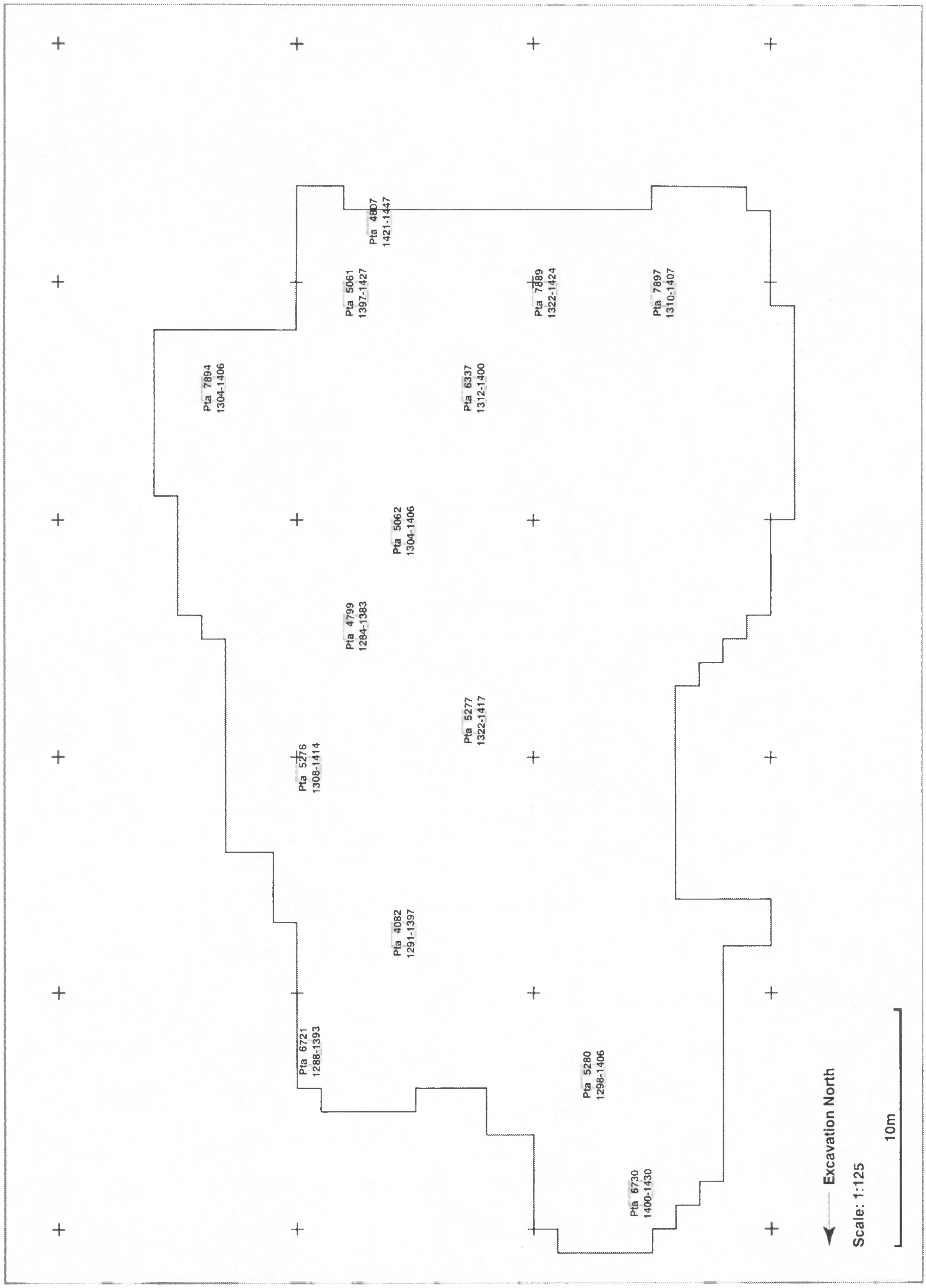


Figure 9: Location of calibrated C^{14}-dates from charcoal samples at Dunefield Midden (dates in one sigma range).

Feature type	*Confidence levels*	*Counts*
Hearth	high	28
	medium	10
	low	2
Ashy Patch	high	48
	low	1
Crusted Feature	high	6
	medium	5
Roasting Platform	high	1
Ash Dump	high	3
	medium	1
Roasting Pit	high	2
	medium	1
Charcoal-&-Ash Pit	high	3
Mongoose Burial	high	3
TOTAL		*114*

Table 2: Feature types, their confidence levels and counts found on the DFM feature map (after Koenig & Fisher 2000:1).

ries (anvils, hammerstones, fire-cracked stones and manuports) was seen to confirm the distinction of two different dumps as the latter two categories cluster in the southern part of the site. Mean refitment distances are found to be relatively high and might have been a result of site formation processes (Jakavula 1995:94f). Ostrich eggshell were shown to be arranged in seven clusters mostly in dump areas with pieces conjoining mainly in the northern part of DFM (Jakavula 1995:100). The distribution of ceramics refits was once again seen to provide evidence for the two separate dumps and showed about nine clusters mostly associated with ashy patches (Jakavula 1995:108).

Orton (1998) designed a lithics classification system for DFM and presented distribution maps of these stone categories. He conducted an analysis of spatial patterns and explored patterns of manufacture. The lithics assemblage was seen to reflect "...two occupation periods of very different age as indicated by the presence of rounded and non-rounded artefacts" (Orton 1998:i). Orton's work emphasized that there is a good correspondence in the distribution of hearth features and utilized flakes. This was interpreted as activity areas associated with the domestic hearths supporting the nuclear family theory (Orton 1998:149). The amount of stone artefacts present at DFM and results of previous research "... seems to point towards a series of relatively short stays at the site..." (Orton 1998:149).

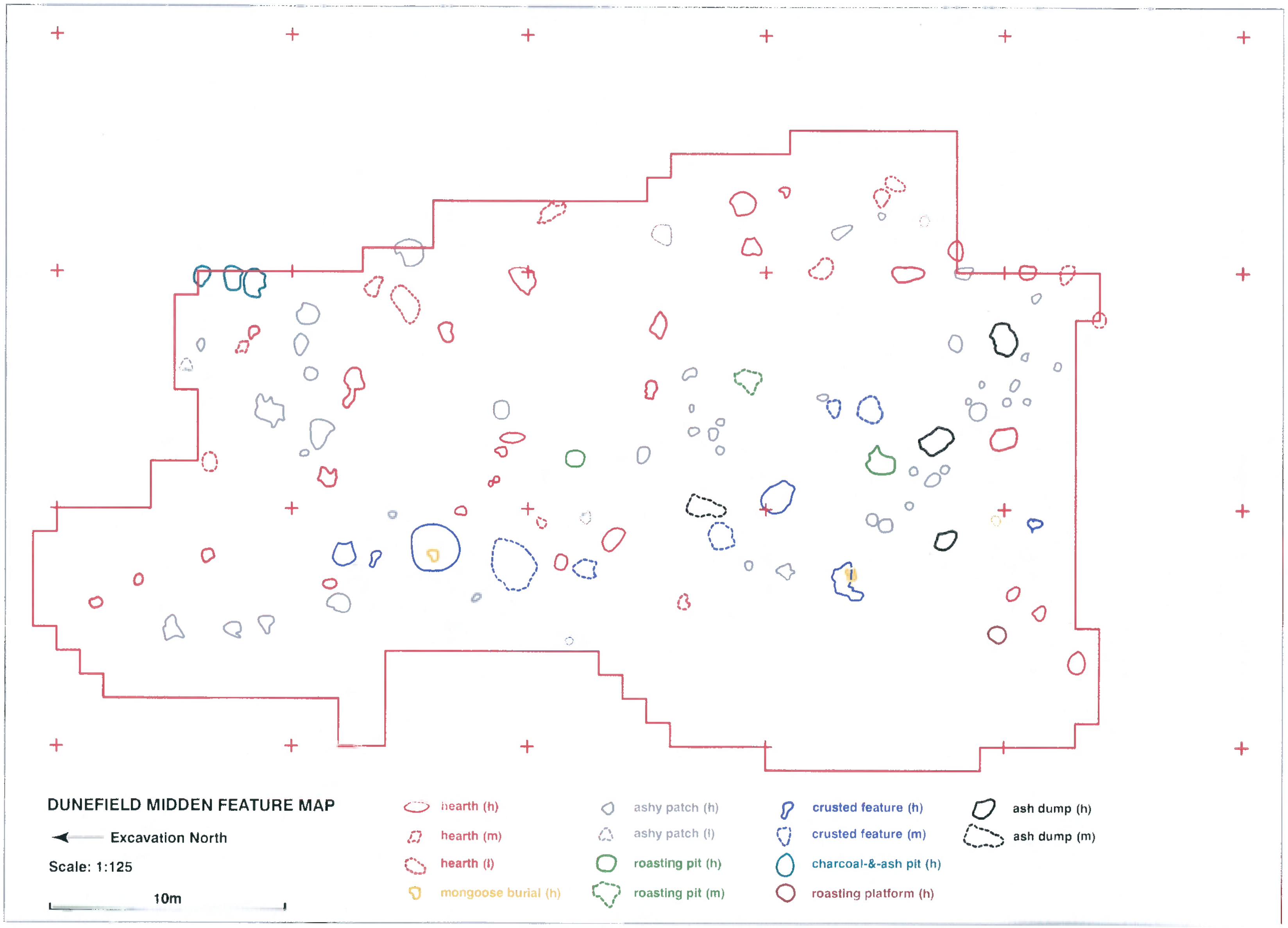


Figure 10: DFM feature map (after Koenig & Fisher).

Year	Type	Title	Author
1989	Honours	An Economic and Spatial Analysis of a Camp/Domestic Site at Eland's Bay.	Siegruhn, B.
1989	Honours	Refitting Pottery and Eland Body Parts as a Way of Reconstructing Hunter-Gatherer Behaviour: An example from the Later Stone Age at Verlorenvlei.	Nilssen, P.-J.
1990	Honours	Home is where the Hearth is: an interpretation of hearth associated activity areas and domestic organisation at the Dunefield's Midden site, Eland's Bay.	Henshilwood, C.S.
1990	Honours	Spatial Patterning in the Stone Artefacts from Dunefield Midden.	Vermeulen, C.
1992	Master	Spatial patterns and Behaviour at Dunefield Midden.	Reeler, C.
1992	Honours	An Analysis of the Microfauna from Dunefield Midden, Eland's Bay.	Matthews, T.
1994	Honours	Has Carnivore Gnawing significantly altered the seal bone assemblage from Dunefield Midden?: An investigation into the effects that small carnivore gnawing has on archaeological faunal assemblages.	Stynder, D.D.
1995	Honours	"More Than Lines on a Map?": Refitting Dunefield Midden.	Jakavula, Z.
1998	Honours	Patterns in Stone Understanding the lithic assemblage of Western Cape Later Stone Age campsite.	Orton, J.D.J.

Table 3: Overview of Honours and Master theses on DFM.

Year	Title	Author(s)	Journal
1992	Making sense of space at Dunefield Midden Campsite, Western Cape, South Africa.	Parkington, J., Nilssen, O., Reeler, C., Henshilwood, C.	South African Field Archaeology
1994	Chew Marks and Cut Marks on Animal Bones from the Kasteelberg B and Dune Field Midden Later Stone Age Sites, Western Cape Province, South Africa.	Cruz-Uribe, K. & Klein, R.G.	Journal of Archaeological Science
1995	Seal bones as indicators of the timing and duration of hunter-gatherer coastal visits.	Woodborne, S., Hart, K., Parkington, J.	Journal of Archaeological Science
2002	Patterns in Stone: The Lithic Assemblage from Dunefield Midden, Western Cape, South Africa.	Orton, J.	South African Archaeological Bulletin
In prep.	"The Fires are Constant, The Shelters are Whims": a feature map of Later Stone Age campsites from the western Cape, South Africa.	Parkington, J., Fisher, J.W., Tonner, T.W.W.	In prep.

Table 4: Overview of articles on DFM.

Early results of investigations into spatial patterning were published by Parkington et al. (1992). The site was divided into two main areas: a dump consisting mainly of shell mixed with ash and bones in the western part and a domestic area to the east of it represented by hearth features and associated assemblages (Parkington et al. 1992:65f). The mean sizes of limpets per square were described to be spatially patterned and interpreted as reflecting a decrease in collected shell size with increasing days of occupation (Parkington et al. 1992:67). Other patterns were mentioned briefly but their significance and concrete distribution were only described vaguely as this represented an early stage of analyses (Parkington et al. 1992:68f).

This brief literature review shows that work on Dunefield Midden was largely focused on the spatial analysis of site structure. Reeler's (1992) and Jakavula's (1995) approach to the DFM data is in many ways very similar to that of this project as Reeler applied spatial analysis techniques to quantify archaeological patterning and Jakavula showed the advantages of using a GIS for the visualization of finds and features and their relationships. There is, however, a substantial difference to the work presented in this thesis which is the strong focus on developing a *research database*. It is not anticipated in this thesis to resolve social behaviour at DFM - the aim is to create a tool that will enable further research to analyze all numerical Dunefield Midden information in great detail and to identify and quantify distinct spatial patterning. Other obvious differences are technological and quantitative: Technologically, the power of computer hardware and software has increased exponentially over the last seven to ten years providing an environment suitable for complex databasing and spatial analysis. Quantitatively, there is a significantly larger data basis available upon which analysis can be performed, specifically a complete record for the shellfish category.

Data quality

The observations stored in the Dunefield Midden Spatial Database reflect the accumulated results from analyses conducted by many different people. It has to be considered that there is information missing or even wrong information included. Additionally it is unclear how good the data quality of each analysis is, as this was not evaluated by the analysts themselves.

An exception is the shellfish category that provided the core of the spatial analysis of this thesis. As it was analyzed by more than a dozen people over the last 14 years, two aspects were seen to be relevant for an investigation: intra-group and inter-group variability of shellfish analysis. The former was expected to contribute to a closer understanding how a number of people working as a group on the same material at the same time and location show differences in the identification and the measurements of shells. The latter was expected to give an estimate of how big these differences are between groups that have worked at different times on the same material. As the groups were generally supervised by one central analyst, the variability between the groups should resemble differences in the instructions given by the supervisor to his crew. For the results of these investigations see "Variability of DFM shellfish analysis" on page 109.

CHAPTER II ANALYTICAL FRAMEWORK

1 THE FINAL LATER STONE AGE IN SOUTH AFRICA

Introduction

It was mentioned in the previous chapter that the objective of this thesis is to show how computer technology can be used in an archaeological context to analyze spatial information. Thus it is mainly concerned with the application of computer techniques for analyzing material culture. Dunefield Midden, dating to the final Later Stone Age (LSA), acts as a specific case where this kind of computer system is developed and it is thus important to give a brief introduction to the appropriate temporal context of this site. No details about the final LSA are of deeper relevance for the core of this thesis and any issues directly concerned with the interpretation of the examples that are given later in the analysis part will attain special attention in the relevant sections.

The beginning of the Later Stone Age in South Africa is defined by changes in the material culture. Differences to the preceding Middle Stone Age are mainly characterized by the use of specific techniques of flaking stone and polishing bone. Deacon and Deacon (1999:109f) see this time period as a "technological unity in the way that tools were made" and a "functional unity in that similar tasks were done in similar ways with similar tools, regardless of who the people were and where they lived". These changes were technological innovations and with them came, as Deacon and Deacon (1999:109) note, a massive increase of rock art, painted and engraved stones, the deliberate burial of the dead in formal graves, smaller stone tools, bows and arrows, bored stones used as digging-stick weights, grooved stones, decorative items like beads and pendants of shell and ostrich eggshell, decorated ostrich eggshell flasks, tortoiseshell bowls, polished bone tools, fishing equipment and, within the last 2000 years, earthenware pottery. The most important Later Stone Age sites found in the Western and Eastern Cape are shown on Figure 11.

The stone assemblage of the final LSA can be summarized as follows (Deacon and Deacon 1999:119):

> "Two kinds of assemblages may be found, with or with out pottery: (a) with informal stone artefacts on coarse-grained rocks made by, or contemporary with, Khoekhoe stock farmers; or (b) with pottery and stone tools on fine-grained rocks such as indurated shale, chalcedony, quartz or silcrete, which may have long scrapers with backed bladelets (Smithfield) or small scrapers with some backed bladelets

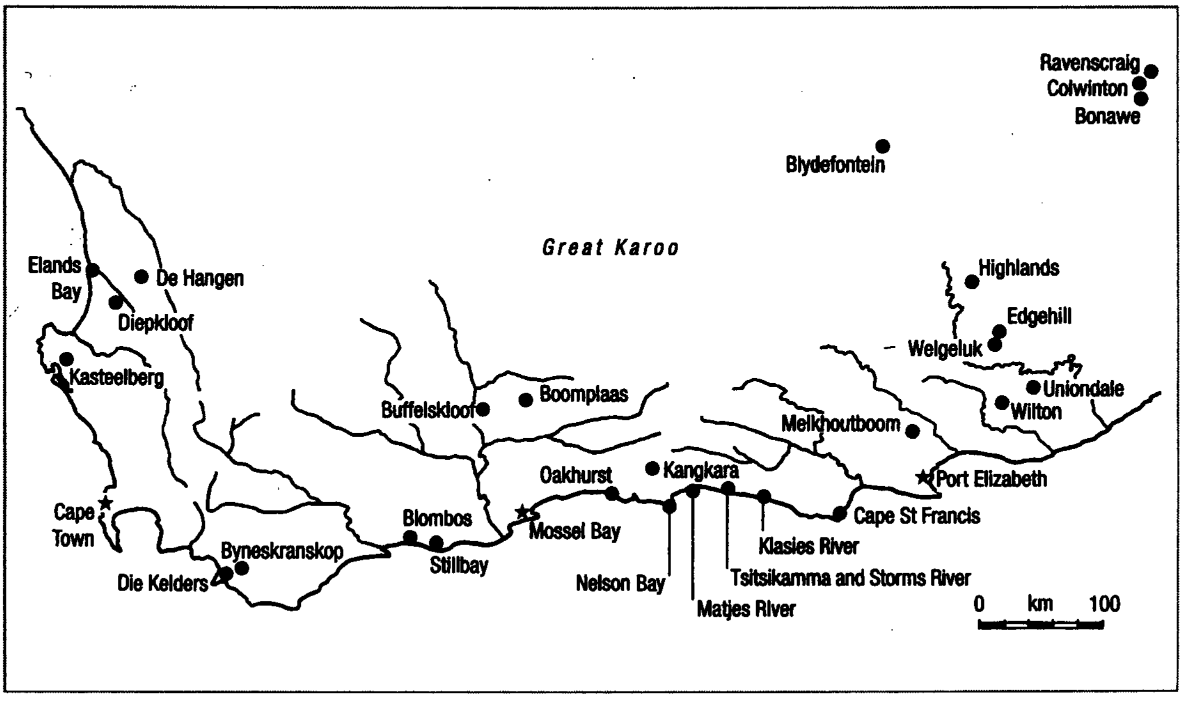


Figure 11: LSA sites in the Western and Eastern Cape of South Africa (Deacon and Deacon 1999).

> but rare segments (Interior Wilton or Post-Wilton). Adzes tend to be more common in these assemblages than in the preceding time period."

It is generally accepted that especially the final Later Stone Age can be seen as closely connected to the history of the Khoisan, the aboriginal inhabitants of southern Africa. This has important implications for archaeology as there are rich ethnographical records (Lloyd and Bleek records: Lloyd 1911; Bleek 1923, 1928, 1931, 1932, 1933, 1935, 1936; Lewis-Williams 2000) that can give hints for the interpretation of the archaeological remains of their close ancestors.

Pastoralism in the final LSA

Hunting and gathering was the dominant subsistence strategy throughout the Later Stone Age. In its final phase, signs of changes in the material culture can be seen that finally lead to the extinction of hunting and gathering in the Western Cape. Many of these changes are closely related to the advent of pastoralism in this part of South Africa.

Occupational remains from Dunefield Midden can leave no doubt that the inhabitants were Stone Age people - no signs of metal but earthenware pottery was found (Parkington, pers. comm.). This is an important fact as the site is only 600 to 700 years old and thus dates into a time when pastoralists were living in the Western Cape *side by side* with hunter-gatherers and just before southern Africa was colonized by Europeans. These facts make this time period an interesting and difficult part of archaeological research: central issues about how and when pastoralism arrived in the Western Cape and how the new subsistence strategy interacted with the traditional, are currently under discussion. Again, the importance of this research is acknowledged but is not of general importance for the aims of this project. Nevertheless, to create a rough framework, two opposing theories shall be discussed briefly: the advent of pastoralism in form of a donor society (Smith 1998) and in form of the diffusion of a new subsistence strategy (Sadr in prep.).

The important material indicators for the introduction of pastoralism to the Western Cape are pottery and the bones of domesticates. Pottery can be found associated with archaeological layers dating up to 2000 BP (calibrated: 50 AD) (Sealy and Yates 1994:164). The introduction of stock in the Western Cape was reported by Sealy and Yates (1994:62f) to be relatively late, suggesting that the arrival did not take place earlier than 1630 BP (calibrated: 440 AD). However, new dates from Blombos seem to confirm the original theory that pottery and stock came as a package to southern Africa as early as 1960 BP (calibrated: 80 AD) (Smith 1998:153).

In his work, Smith suggests two models that may explain the way how pastoralism was introduced to the Western Cape (1998:154):

> "(1) The introduction of stock to an aboriginal hunting population and the spread of animals by exchange similar to that of beads, i.e., reciprocal social connections ..."
>
> "(2) A truly pastoral donor society, which is difficult to identify archaeologically."

Even though evidence for the second model is agreed to be "difficult to identify", Smith favours it over the first model arguing mainly with evidence from his site 'Kasteelberg' (Klein et al. 1989, Sadr and Smith 1991, Smith et al. 1991). The main issue which does not allow the model to be proven is thought to be the lack of archaeological data due to a focus on the excavation of 'the wrong' sites:

> "This putative donor pastoral society may be difficult to identify, since its archaeological signature could be masked by the more dominant Iron Age sites on which research has been focused."

This is challenged by a different view by Sadr (in prep.). He analyzed the evidence for a donor society as early as 2000 BP (uncalibrated) and concludes that the original interpretations have to be revised (Sadr in prep.):

> "Kasteelberg seemed to vindicate the majority opinion that the prehistoric pastoralists has indeed migrated south and that there was a long sequence of Khoekhoe pastoralism at the Cape." ... "Recent excavations have shown that only in the late first millennium was a relatively intensive form of small stock pastoralism practiced ...".

As there is no clear evidence for the existence for prehistoric Khoekhoe living in the Western Cape, Sadr interpreted the subsistence strategy seen in the LSA sites from this time period as 'hunters with sheep'. Indeed, as the bone assemblage from Dunefield Midden shows, there were hunter-gatherers that possessed sheep. How they were obtained and if they were kept permanently is unclear.

These two opposing approaches provide the framework in which archaeological work has been and will be conducted in the final LSA of Western Cape in South Africa. So far, there is no agreement on answers to any of the questions and more research has done before the complex processes that led to the introduction of pastoralism and its interactions with hunter-gatherers can be understood.

2 THE VERLORENVLEI AND ELANDSBAY AREA

Introduction

Dunefield Midden belongs geographically to the Verlorenvlei area, a closed coastal estuarine-lake, river and reed-swamp system situated approximately 180km north of Cape Town (Meadows et al. 1996:82). The climatic conditions and thus the environment during the occupation of DFM (about 600 to 700 years ago) were most likely similar to those we can observe today, except that the human presence in the last century modified the landscape by building streets, railway tracks, introducing alien fauna and flora, etc. This had an considerable influence in changing parts of the eco-system, the geography and geology of the area.

The Verlorenvlei is part of the Cape Ecozone which compromises the southernmost part of the subcontinent, and includes the mountains and valleys of the Cape Fold Belt together with the adjacent coastal lowlands. In prehistoric times in had acted as an attractive human habitat and Parkington et al. concluded (1988:24):

> "... a combination of modern and historic observations suggest that the prehistoric landscape at the vlei mouth must have been an attractive area for hunter-gatherers...". "Fresh water is abundant in the coastal lake to within 4km of the shore, beyond which salinity levels are high...". "Shelter and shade, in the form of caves and overhangs are widely available in locations ranging from the exposed coast to the more protected lower reaches of the vlei."

Geography and geology

The Verlorenvlei is aligned in northwest/southeast direction, at 45° to the predominantly north-south coastline, covering an area of about $10km^2$ with a mean depth of 2,5m and a maximum depth of 5m (Figure 12 to Figure 15). Only a narrow 2,5km long channel connects the lake to the ocean at Elandsbay and the input of sea-water into the system occurs very occasionally under extreme conditions of storm and tide. The Verlorenvlei River catchment area is bounded by the Swartberg and the Olifantsrivierberge in the east and by the Piketberg in the south, including the Eendekuil basin in between the two mountain ranges (Sinclair et al. 1986:1&14).

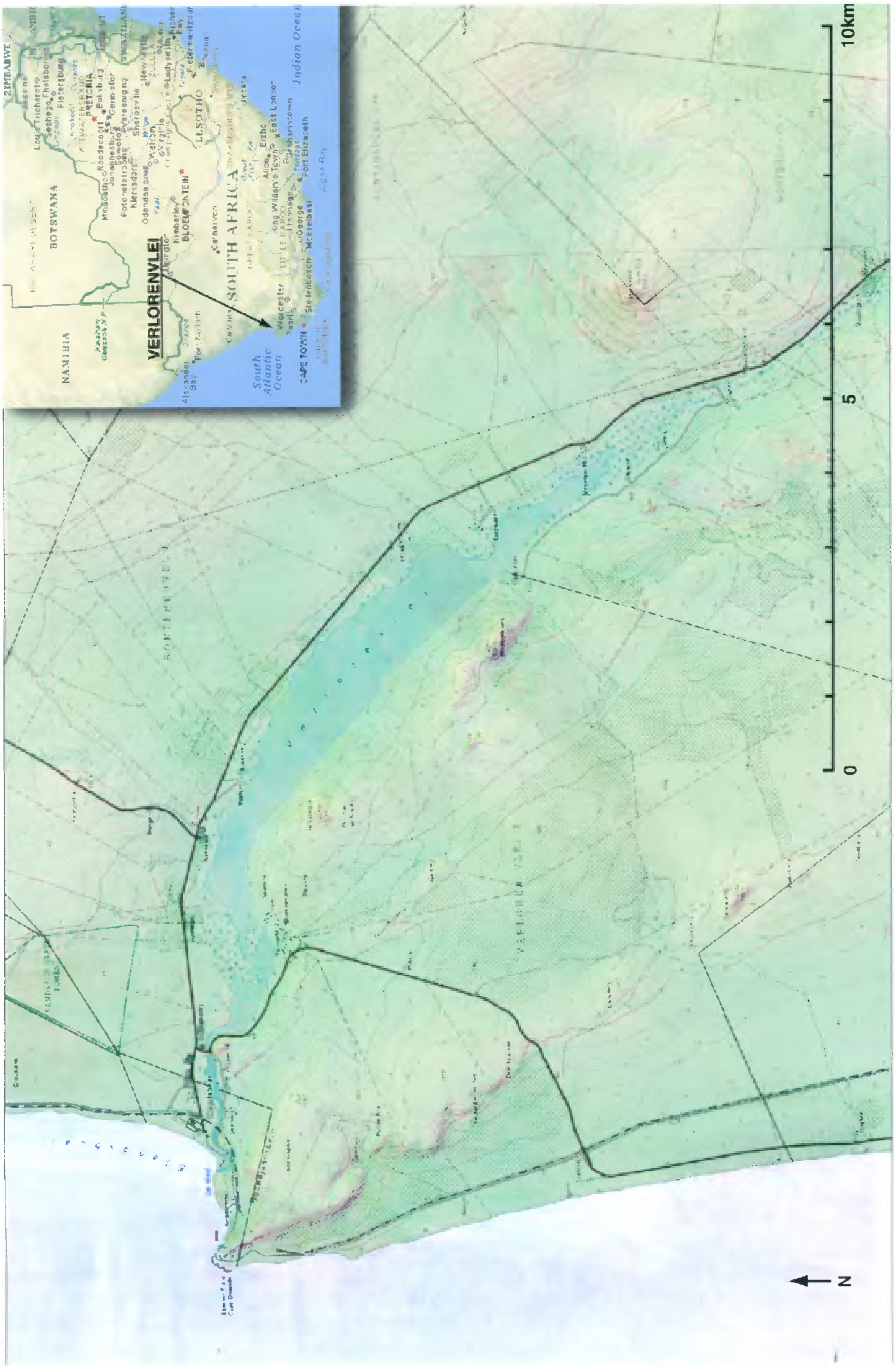


Figure 12: Location and topographical map of the Verlorenvlei and Elandsbay.

Figure 13: Satellite photograph of the Verlorenvlei and Elandsbay (Landsat 7).

Figure 14: The Verlorenvlei from the airplane facing WNW (Sinclair et al. 1986:ECRU 79-04-17). (Top)

Figure 15: The Verlorenvlei from the airplane facing ESE (Sinclair et al. 1986:ECRU 79-08-14). (Bottom)

In the catchment area three major geological deposits can be identified on the surface: Tertiary to Recent sands (40%), Table Mountain Group (30%) and fine-grained rocks of the Malmesbury Group (30%). The coastal lowlands are dominated by Tertiary to Recent sands and thus soils are characterized by littoral sands with low amounts of weatherable minerals, a low silt/clay ratio and low water-retaining capacity (Sinclair et al. 1986:16&20).

The Atlantic shoreline at Elandsbay is clearly described by Parkington et al. (1988:23): The basic geometry is characterized by two factors, the longshore drift and the morphology of the underlying bedrock. The former is responsible for the transport of sediments laterally to the coastline and the latter acts as the reference surface on which any sediment movement and the sedimentation itself is taking place. "As a result of this geometry a long sweeping sandy beach extends some 12 km north of the vlei mouth as far as the next rocky outcrop, whilst a tightly curved rocky shore lies immediately south...", "ending in a high and exposed point, Baboon point." (Parkington et al. 1988:23). This pattern is repeated several times north and south of Elandsbay along the western coast. A small version is a located just south of Baboon point, represented by a 2km long beach and a rocky spur that is known as Mussel Point (Parkington et al. 1988:23).

Concerning the habitat of marine shellfish colonies, the "almost horizontal platform of sandstone bedrock which outcrops in the intertidal areas in Elands Bay and at Mussel Point" is of great importance (Parkington et al. 1988:23f). As this platform gave humans easy access to the shellfish colonies during low tides, they were the foci for shellfish gathering practices of the prehistoric people living in the immediate surroundings of this region.

Climate

As in most parts of the Western Cape Province, the Verlorenvlei catchment area is situated in the winter rainfall area and is classified as Mediterranean although the annual rainfall indicates a typical semi-arid to sub-arid climate (Meadows et al. 1996:82). More than 80% of the less than 300mm precipitation per year occurs between April and September. Lake level fluctuations are considerable and lead to an overflow into the Atlantic Ocean in late winter. Strong evaporation during the dry summer months on the other hand result in very low levels in March or April. Fog might play an important role as a source of moisture for plants that are exposed to the prevailing onshore wind. Following this argument, less than 300mm of annual rainfall might not be fully representative of the total amount of water being available for the biotic environment (Sinclair et al. 1986:23&25). The mean annual air temperature is approximately 18°C and shows a range of about 8°C (Heydorn and Tinley 1980:23).

These figures draw a climatic picture that doesn't seem to be very favorable for human occupation. However, when compared to the surrounding areas, especially the interior to the northeast and southeast, the Verlorenvlei provides an exceptional rich biotic environment.

Fauna and Flora

The fauna and flora of the Verlorenvlei is comparatively rich for the Western Cape of South Africa. Situated between the interior and the coast, it shares characteristics of both of these areas.

Six groups of fauna from the Verlorenvlei are listed by Sinclair et al. (1986): zooplankton, invertebrates, fish, amphibians and reptiles, birds and mammals. Concerning Dunefield Midden information about the last four groups are of interest. Unfortunately there is no recent information concerning the mammalian fauna of the Verlorenvlei area (Sinclair et al. 1986:52ff).

Three indigenous fish species can be identified: Cape kurper (*Sandelia capensis*), Cape galaxias (*Galaxias zebratus*) and Berg River redfin (*Barbus burgi*). When access is given to the vlei when the mouth is open (mainly in the rain season in winter), marine fish may enter. Four species have been reported: white steenbras (*Lithognathus lithognatus*), southern mullet (*Liza richardsoni*), flathead mullet (*Mugil cephalus*) and estuarine round-herring (*Gilchristella aestuarius*). Nowadays several other species occur in the Verlorenvlei, all of them were introduced artificially in recent times and most common are carp (*Cyprinus carpio*) and Mozambique tilapia (*Oreochromis mossambicus*) (Sinclair et al. 1986:53).

Amphibians and Reptiles (tortoises, terrapin, snakes and lizards) are very likely to occur throughout the area but only very few have been recorded so far (Sinclair et al. 1986:54&81f).

Birds are dominated by waders reflecting that the Verlorenvlei is ranked as one of the ten most important wetlands in the south-western Cape with eleven different species of waders occurring. Waterbirds are represented by herons, egrets, ibises, spoonbills, flamingos and the rare Great White Pelicans (Sinclair et al. 1986:54f).

As a gift of the Benguela Current which transports nutrient laden waters from the south to the north along the western coast, there are rich marine resources available at Elandsbay. Shellfish is represented mainly by limpet colonies and mussel beds that live predominantly on the rocky shores. Other marine species that also occur in archaeological contexts are whales, fish, seals and crayfish. Additionally a range of sea-birds can be found living on the marine resources of the coast (Parkington et al. 1988:24).

The Verlorenvlei is an ecotone area and shows therefore a high diversity of vegetation types. The flora is distinguished by Sinclair in four groups: phytoplankton/diatoms, algae, aquatic vegetation and terrestrial vegetation. In respect to Dunefield Midden the last group is mainly of interest. The terrestrial vegetation can be distinguished into strandveld, saltpan vegetation, lowland fynbos, dry mountain fynbos, mountain fynbos, karroid shrubland and marsh vegetation (Sinclair et al. 1986:42ff). Meadows et al. (1996:82f) had summarized these vegetation types as follows:

> "*Strandveld*, a drought-deciduous vegetation type of the sandy plains and littoral dunes typically including hard shrubs, geophytes and grasses and, especially, succulents such as Euphorbiaceae and Mesembryanthemaceae; *Lowland fynbos*, favouring deep, sandy soils, is dominated by Restionaceae as well as drought-resisting elements such as certain Proteaceae and other sclerophyllous fynbos shrubs; *Dry mountain fynbos*, particular to the sandstone outcrops to the south of Verlorenvlei, is characterised by small-leaved sclerophyll shrubland with a high percentage of succulent and drought deciduous species. Many of the typical fynbos elements including Ericaceae, Proteaceae and Restionaceae are present. In sheltered, fire-protected gullies, scrub forest elements including *Olea europaea* subsp. *africana*, *Maytenus oleoides* and *Podocarpus elongatus* cling to the sandstone steps; *Karroid shrubland*, favoring shale on lower slopes, is dominated by members of the Asteraceae, Mesembryanthemaceae and Euphorbiaceae families and include genera such as *Stoebe*, *Lessertia*, *Passerina* and *Elytropappus*; *Marsh vegetation* is highly dependent on conditions of salinity and includes salt-tolerant species such as *Sarcocornia natalensis* and *Scripus marginatus*, while the less saline areas support dense stands of emergent reeds such as *Typha capensis*, *Phragmites australis*, *Cyperus marginatus* and *Juncus* spp."

It can be concluded that the Verlorenvlei provides a wide range and variety of food items that make this area, additionally to the large fresh water source, potentially interesting for human occupation.

Holocene environment

Sea levels are extremely relevant for reconstructing coastal palaeo-environments and seem to have changed dramatically in Holocene times (the last 12000 years) of South Africa. Especially in the case of the Verlorenvlei they played a crucial role in creating specific environments with extremely variable resources available for human occupation as it will be explained later. It was mentioned in the previous chapter that a mid-Holocene sea-level high was thought to have created the beach deposit where most of the finds and features from Dunefield Midden were found on (Parkington et al. 1992:63). Additionally a slightly higher sea-level in the late Holocene might have created a back-barrier washover feature (Miller et al. 1993:39f) that was in the immediate surroundings and probably contemporary to the DFM occupation. This shows that sea-level changes can have a strong influence on the landscape of coastal areas and they have to be seen as an important factor in the temporal and spatial context of Dunefield Midden.

A sea level curve for the Holocene was compiled from data quoted in Miller et al. (1993:41) and Compton (2001:397f) (see Table 5 and Figure 16). In this reconstruction the measurements taken from sea cores and storm beaches were omitted as they tend to give either too low or too high values (see Miller et al. 1993 and Compton 2001 for discussion). Radiocarbon dates provided by the Pretoria dating lab (labelled as 'Pta-XXXX') were cross-checked using the Quadru internet database (www.quadru.co.za, 27-09-2002). All dates were calibrated with the Pretoria Radiocarbon Calibration Program CAL4H and the following calibration datasets were used:

- for marine samples: WC93 (South African West Coast marine calibration curve)
- for terrestrial samples: SH98 (Southern hemisphere calibration data)

From Figure 16 it can be concluded that the general trend of the sea level changes of the last 11500 years shows a steady rise from about -50m to +3m between 9500 BC and 4300 BC, followed by a regression to the present sea level in 4300 BC-1500 BC. The few measurements between about 1500 BC and 250 BC point towards a constantly low sea level around 0m ASL. A last transgression happened in 250BC-1000AD to 1.5m ASL followed by the stabilization to present sea level. Slightly higher sea levels existed probably during the occupation of DFM. For a detailed discussion of the holocene sea level history of the Western Coast of South Africa please refer to Miller et al. (1993) and Compton (2001). It is evident that sea level reconstructions are oversimplified due to a poor sampling resolution; short-term, low-amplitude sea level fluctuations might have happened regularly but are invisible.

Coastal environments are heavily dependent on sea level changes and thus change with them. Humans utilizing the resources provided by these environments have to adapt to their actual characteristics repeatedly over time. How these changes affect human behavior is difficult to answer as one might expect predominantly non-linear effects.

Site	*Context*	*Height ASL (m)*	*Reference*	*C^{14}-Date*	*Material*	*Cal. Date**	*-1 StdDev*	*+1 StdDev*	*Submitter*
Mkomazi River	estuary	-48	Pta-3597	9980±30	wood	-9327	-9355	-9305	Beesley, E.
Mkomazi River	estuary	-28	Pta-3570	8940±30	wood	-8044	-8205	-7980	Beesley, E.
Umgeni	river infill	-29	GaK-1389	8420±140	wood	-7489	-7572	-7300	?
Mkomazi River	estuary	-18	Pta-3622	8280±80	shell	-6586	-6689	-6482	Beesley, E.
Mkomazi River	estuary	-18	Pta-3573	8140±70	shell	-6439	-6498	-6386	Beesley, E.

Table 5: Radiocarbon dates for sea levels lower and higher than present on the Western and Southern Coast of Southern Africa (data from Miller et al. 1993:41 and Compton 2001:397f).

Site	Context	Height ASL (m)	Reference	C^{14}-Date	Material	Cal. Date*	-1 StdDev	+1 StdDev	Submitter
Mkomazi River	estuary	-18	Pta-3575	8070±80	shell	-6386	-6447	-6330	Beesley, E.
Verlorenv-lei Cottage Core CC1	subtidal lagoon	-3.65±1.15	Pta-6596	7840±110	marine carbon	-6152	-6245	-6019	Davies, B.
Verlorenv-lei Cottage Core CC2	subtidal lagoon	-2.65±1.15	Pta-6155	7430±80	marine carbon	-5728	-5822	-5660	Davies, B.
Sundays River	estuary	1.5	Pta-4469	6490±70	shell	-4834	-4915	-4767	Redder-ing, J.S.
Lange-baan Lagoon	salt marsh	1.5±1.5	Pta-7564	6460±70	shell	-4800	-4893	-4736	Compton, J.S.
Gemsbok	marine gravel	0	Pta-1351	5720±60	wood	-4502	-4560	-4456	Fowler, J.A.
Knysna	estua-rine mud-bank	3.3±0.5	Pta-5860	5910±30	shell	-4227	-4248	-4212	Marker, M.E.
Keur-booms Estuary	estuary	1.47	Pta-4317	5580±70	shell	-3830	-3937	-3764	Redder-ing, J.S.
Fishwater Flats 2	estuary	0.9±0.3	Pta-4464	5560±60	shell	-3802	-3917	-3755	Redder-ing, J.S.
Verlorenv-lei Cottage Core CC3	subtidal lagoon	-0.15±1.15	Pta-6591	5490±80	marine carbon	-3744	-3811	-3655	Davies, B.
Stur-mvogel-bucht	beach terrace	3.6	Pta-0419	5340±60	shell	-3616	-3647	-3527	Davies, O.
Lange-baan Lagoon	salt marsh	0.5±0.5	Pta-7557	4850±70	shell	-2923	-3041	-2880	Compton, J.S.
Grootdrift Vlei	estuary	-1.3±0.5	Pta-5812	4340±60	organic matter	-2902	-2924	-2884	Mead-ows, M.E.
Lange-baan Lagoon	salt marsh	-0.35±0.35	Pta-7570	4260±80	organic matter	-2879	-2902	-2682	Compton, J.S.
Langebaan	lagoon	-2	Pta-1598	4660±60	shell	-2751	-2854	-2632	Flem-ming, B.W.
Eerste Mossel Bank 1	buried beach	2	Pta-4705	4640±60	shell	-2698	-2845	-2606	Yates, R.J.

Table 5: (Continued) Radiocarbon dates for sea levels lower and higher than present on the Western and Southern Coast of Southern Africa (data from Miller et al. 1993:41 and Compton 2001:397f).

Site	Context	Height ASL (m)	Reference	C^{14}-Date	Material	Cal. Date*	-1 StdDev	+1 StdDev	Submitter
Lange-baan Lagoon	salt marsh	0±1	Pta-7558	4510±50	shell	-2537	-2582	-2462	Compton, J.S.
Langdam H1/1	back beach	2	Pta-4894	4400±60	shell	-2404	-2462	-2310	Yates, R.J.
Fishwater Flats 1	estuary	1.55±0.05	Pta-4463	4380±60	shell	-2378	-2450	-2282	Redder-ing, J.S.
Keur-booms Estuary	estuary	0	Pta-4462	4280±60	shell	-2210	-2310	-2134	Redder-ing, J.S.
Verlore Vlei Mouth SA/ 1	buried beach	2.8	Pta-4041	4220±50	shell	-2134	-2197	-2048	Yates, R.J.
Klaarfon-tein Spring	?	-0.35±0.35	Pta-6145	3640±60	organic matter	-1946	-2027	-1888	Parking-ton, J.E.
Public Resort 1 Sounding, 1	buried beach	4.5	Pta-4299	4000±50	shell	-1859	-1899	-1757	Yates, R.J.
Lange-baan Lagoon	salt marsh	0.25±0.75	Pta-7773	3470±60	shell	-1208	-1287	-1120	Compton, J.S.
Lange-baan Lagoon	salt marsh	0.25±0.75	Pta-7771	2920±50	shell	-514	-630	-411	Compton, J.S.
Eerste Mossel Bank 2	buried beach	1.5	Pta-4707	2530±45	shell	-34	-94	18	Yates, R.J.
Groenvlei, upper layer	lagoon	0	Y-467	1905±60	gyttja over marine	131	75	231	?
Klaarfon-tein Spring	?	-0.5±0.5	Pta-6146	1900±60	organic matter	134	79	234	Parking-ton, J.E.
Lange-baan Lagoon	shell reef top	0	Pta-1667	2140±50	shell	422	368	461	Flem-ming, B.W.
Lange-baan Lagoon	salt marsh	0.35±0.35	Pta-7597	1390±50	organic matter	668	650	691	Compton, J.S.
Verlore Vlei Mouth bar 1,1	buried bar	1.6	Pta-4311	1850±50	shell	695	667	744	Yates, R.J.
Grosse Bucht	beach	1.5±0.3	Pta-0417	1580±50	shell	999	948	1032	Davies, O.

Table 5: (Continued) Radiocarbon dates for sea levels lower and higher than present on the Western and Southern Coast of Southern Africa (data from Miller et al. 1993:41 and Compton 2001:397f).

Site	Context	Height ASL (m)	Reference	C^{14}-Date	Material	Cal. Date*	-1 StdDev	+1 StdDev	Submitter
Donax Deep Sounding. 1	back beach	2	Pta-4298	1560±50	shell	1014	972	1043	Yates, R.J.
Lange-baan Lagoon	salt marsh	-0.5	Pta-7579	840±45	organic matter	1248	1206	1272	Compton, J.S.
Elands Bay DFHB/1	pebbly beach	0.5	Pta-4477	1230±70	shell	1310	1276	1383	Yates, R.J.
Lange-baan Lagoon	salt marsh	-0.2	Pta-7576	560±45	organic matter	1417	1404	1431	Compton, J.S.
Lange-baan Lagoon	salt marsh	-0.4	Pta-7589	450±70	organic matter	1456	1430	1622	Compton, J.S.
Tietiesbaai	back beach	2	Pta-0090	760±50	shell	1688	1665	1719	Car-rington, A.J.
Groenvlei, lower layer	lagoon	-3	Y-466	6870±160	freshwa-ter peat	-5717	-5856	-5618	?

* Dates calibrated with Pretoria Radiocarbon Calibration Program CAL4H. Calibration dataset for marine samples: WC93 (South African West Coast marine calibration curve). Calibration dataset for terrestrial samples: SH98 (Southern hemisphere calibration data).

Table 5: (Continued) Radiocarbon dates for sea levels lower and higher than present on the Western and Southern Coast of Southern Africa (data from Miller et al. 1993:41 and Compton 2001:397f).

Soil formation and pollen analysis can give substantial information about palaeo-climates and palaeo-environments. In 1996 Meadows et al. did a study of sediment cores taken from the eastern end of the Verlorenvlei near the Grootdrift farm, 15km from the contemporary mouth of the vlei. The results of the pollen analysis is interpreted to be consistent with a 2,8m higher sea level around 4000 BP (uncalibrated) as reported by Miller et al. (1993). The results of sedimentological and geochemistry analyses show estuarine conditions with higher sea-levels between 5000 BP and 4300 BP (uncalibrated) and terrestrial/fresh water conditions before 5000 BP and after 300 BP (uncalibrated; Meadows et al. 1996:86ff). This observation seems to coincide with a sea levels higher (estuarine) or lower (terrestial/fresh water) than ±0 when compared to Figure 16.

Newer studies of soil cores by Meadows and Baxter (2001) were attempted at Klaarfontein, situated further east of Grootdrift, in order to refine the vegetation history of the Verlorenvlei. The composition of the flora yielded clear evidence for holocene sea level fluctuations. The results showed that saline dryer conditions predominate between 6870 BP and 3500 BP (uncalibrated) and terrestrial/fresh water, moister conditions in a more variable, complex environment

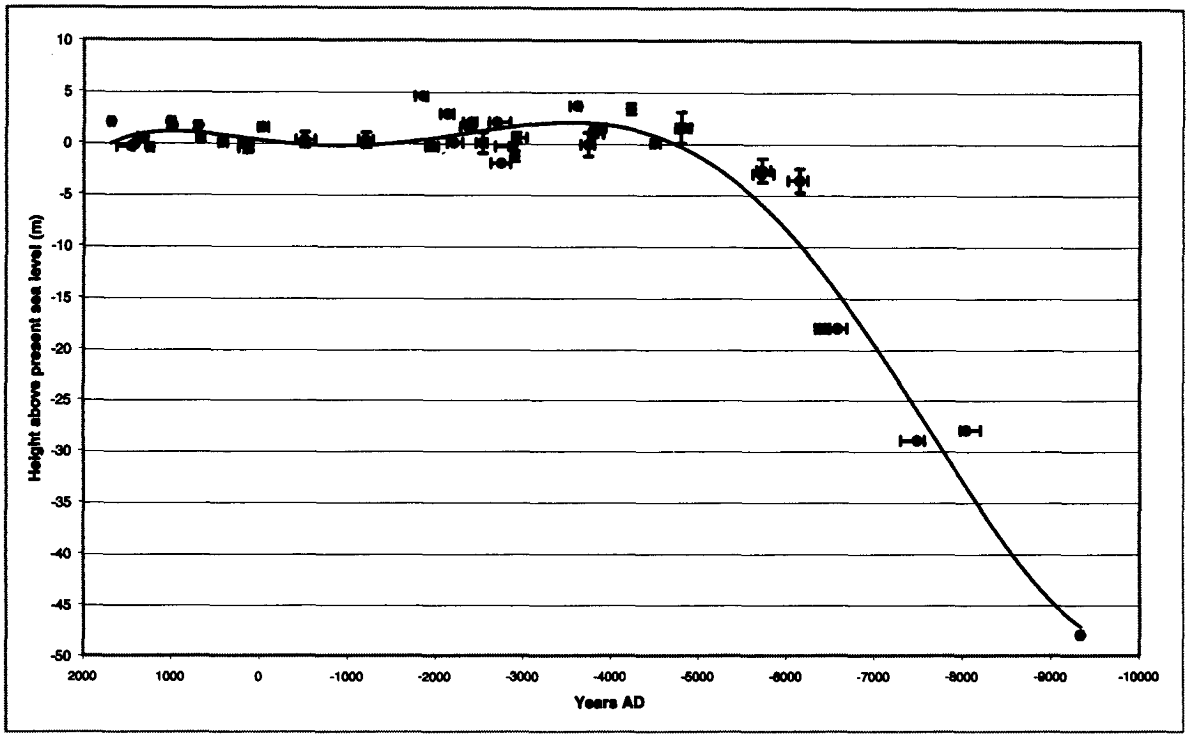


Figure 16: Sea levels of the Western and Southern Coast of South Africa for the last 12000 years (see Table 5 for details).

between 3500 BP and 1900 BP (uncalibrated). This is followed by phase of saline conditions after 1900 BP (uncalibrated) with an unknown end due to a hiatus in the sequence (Meadows and Baxter 2001:704f).

Archaeological evidence from Tortoise Cave (see "Archaeological sites" on page 36), on the other hand, suggested a similar scenario: Sea level maximum of 2-3m ASL around 6000 BP, rapid regression around 4200 BP to about 0m ASL, transgression at 4000-3800 BP to about 2m ASL, regression at 3500-2800 BP to 0m ASL, possible slight transgression around 1800BP, stabilization at present level (all dates uncalibrated; Jerardino 1993:486f). It can be concluded that geological, botanical and archaeological data supports a fluctuating sea level in the Holocene strongly represented by the curve in Figure 16.

Another important factor for reconstructing palaeo-environs are temperature changes. In the Early Holocene of southern Africa temperatures were rising after the last interglacial (11000 BP) reaching the Holocene altithermal between about 7000 BP and 4500 BP. At this time mean annual temperatures were higher than today and rainfall increased significantly. Reconstructed vegetation distributions, however, are much the same as those of today. In the middle and late Holocene temperatures were relatively stable and three major events can be seen in the oxygen isotope records: a cold phase around 5500 BP, the Medieval warming around 1000 AD and the five centuries of the Little Ice Age from 1300 AD to 1800 AD (Tyson et al. 2001:143f).

For Dunefield Midden, dating to 1350±50 AD (Figure 7 on page 12), this last cold period is of special interest. In their conclusion Tyson et al. (2000:124f) report:

> "The Little Ice Age was a 500-year climatic event from around 1300 to 1800...". "The cooling was a regional phenomenon of some consequence throughout the subcontinent of southern Africa. Maximum cooling occurred around 1700, when annual mean daily maximum temperature was depressed by around 1°C. The late fifteenth century was also a period of maximum cooling."

In the same time period, average surface water temperatures of the Atlantic Ocean at Elandsbay were reported to have been slightly lower than today (Cohen et al. 1992). These differences in average air and sea temperatures, however, where most likely too small to have had substantial effects on the environments at Elandsbay.

Archaeological sites

Archaeological sites in the Verlorenvlei area, predominantly from the Later Stone Age, are numerous and show interesting patterns in space and time. The area around Elandsbay has been part of an intensive regional archaeological investigation carried out by the University of Cape Town initiated and guided by John Parkington.

Figure 17 shows the geographical distribution of the most important sites in the immediate surroundings of Elandsbay as a result of a general survey (see Table 6 for key to site prefixes). Chronologically patterns show that only one of the excavated sites (Elands Bay Cave) shows occupation layers dating into the terminal Pleistocene (around 11000 BC). In the early Holocene, Elands Bay Cave and Tortoise Cave (from 7800 BP onwards) were inhabited. On the other hand (Parkington et al. 1988:26),

> "... four of the excavated sites, Elands Bay Cave, Tortoise Cave, Elands Bay South and Spring Cave, contain deposits dating between 3000 and 4000 years old..." ... "The extreme case is presented by the period following the appearance of pottery, that is between 1800 and 300 years ago, when as many as 60 sites within our sample were probably occupied." ... "We take this overall pattern to mean that, there has been a move towards the occupation of many more locations on the landscape through time."

In mid-Holocene times people occupied Elands Bay Cave and Tortoise Cave between 4400 BP and 3000 BP (uncalibrated), while soon "after 3000 years ago both of these caves show minimal occupation and preferred sites were open situations located right next to productive intertidal rocks." (Parkington et al. 1988:27) These 'megamidden'-sites were abandoned soon after 1800 BP (uncalibrated).

Open air sites dating into the past 2000 years are frequent but Dunefield Midden is the only one that has been excavated and analyzed extensively. Unfortunately no other site with a comparable set of excavated material exists.

Prefix	Name	Total No. of Sites
VV	Verloren Vlei Village (original settlement)	3
TT	Tortoise Cave area	2
SC	School	3
DD	Dam (dry)	3
BK	Babbiansberg Kop	12
DP	Du Plessis' Cave area	3
BR	Babbiansberg Ridge	8
EV	Eland's Bay Village	6
PR	Public Resort (proposed)	2
JT	Jetties (crayfish factories)	6
EC	Eland's Bay Cave area	6
ES	Eland's Bay South (Mussel Point)	9
VN	Verloren Vlei North	2
PK	Platklip	2

Table 6: Site prefixes used to identify the archaeological sites in the Verlorenvlei area. (after Buchanan 1985a:48)

3 SHELLFISH AS A SOURCE OF HUMAN SUBSISTENCE

Ethnographical record

As the classic record on contemporary shellfish gathering populations, Betty Meehan's research (Meehan 1982) on the Anbarra people living in Arnhem Land (northern Australia) has to be considered. The results give a rich and complex description of the aboriginal people of this area and their relationship to shellfish. Quantitative analyses include the patterns of predation, hunting performances and the role of shellfish in the total diet. Descriptive elements deal with the ethnography of the people, the occurrence of shellfish species and the ways of collecting, cooking and disposing of them (Meehan 1982). It would however exceed the framework of this section to go into the details of Meehan's work. Important implications for the interpretation of the situation at Dunefield Midden will be discussed in the appropriate chapters.

Recent work in northern Australia was carried out by Bird and Bliege Bird (1997; 2000) where they described contemporary shellfish gathering strategies among the Meriam people of the Torres Strait Islands. Both adults and children were part of their ethnographical investigations and studies focused on the determination of the variability in field

Figure 17: Archaeological sites of the Verlorenvlei area (see text for key; after Buchanan 1985a:4).

processing and transport of shellfish. It was found that patterns in subsistence behavior correlated with expectations predicted by a central place foraging model and they conclude (Bird and Bliege Bird 1997:54):

> "The Meriam data suggest that researchers interested in making inferences about shellfish gathering behavior based on archaeological patterning should consider that under certain circumstances relative to processing costs and foraging range, differential field processing and transport will be an important source of shell midden variability."

More specifically, they made predictions about relative species compositions in archaeological shell middens based on the calculation of an index (*z*) that characterizes "the minimum round trip travel time at which field processing will increase the delivery rate of high quality material" (Bird and Bliege Bird 1997:45): If *z* of a shellfish species is smaller than the estimated round trip travel time from a main camp to the source of collection, it is likely that the meat is field processed. Shells of such a species would be under-represented in the main camp although the overall dietary importance might be high (Bird and Bliege Bird 1997:52f).

Contrary to general expectations, the Meriam children who are very much part of the shellfish gathering activity, did not attempt to directly acquire the knowledge and skills of adults. Their different behavior seemed to be a reflection of their physical constrains and was resembled by effective, 'children-specific' methods and techniques of shellfish gathering (Bird and Bliege Bird 2000:472f). This might have important indications for the interpretation of the archaeological record (Bird and Bliege Bird 2000:473):

> "... if children *are* active in a subsistence economy, we would expect their prey choice to often include a wider array of resources within a given patch, with resources that may often be more visible archaeologically. As a result, children may often exaggerate proportions of low-ranked prey delivered whole to a residence."

In South Africa, an important study on the exploitation of shellfish by coastal communities was conducted by Bigalke (1973). Shellfish gathering was found to be a women activity including all ages (Bigalke 1973:159) and was practiced as a substitute for meat. Subadult individuals were generally left behind as they were expected to continue growing and could be gathered at a later date. Collected shellfish was consumed completely within a day in most cases (Bigalke 1973:165f) and represented "the only source of easily accessible animal protein available in quantity" (Bigalke 1973:167).

More recent work on indigenous shellfish gathering practices in South Africa and their influence on shellfish populations was carried out by Lasiak (Lasiak 1991, 1992). The research took place in the (former) Transkei (East Coast) and resulted in some interesting observations. First it was shown that stock depletion of littoral molluscs is variable by species due to their different biological attributes (geographical distribution, habitat preferences, cryptic behavior, mobile benthic life stage, duration of larval stage and size at maturity/sex change). Thus the impact of human predation on molluscs cannot be generalized. The reproductive potential is seen to be reduced by the removal of larger, more fecund individuals but seems not to diminish the overall stocks as reproduction is still taking place, i.e. in other places that cannot be reached by humans or before the size that is seen to be worth gathering is reached (Lasiak 1991:261f).

Concerning the gathering practices, Lasiak notes (Lasiak 1992:23f):

> "The indigenous coastal inhabitants of Transkei do not collect shellfish randomly; they show marked preferences for certain species...". "Detailed studies of individual meals have shown that these collectors often concentrate their activities on one particular species." ... "The preference of shellfish gatherers for particular species probably reflects the ease with which the animals can be found and harvested, their palatability and digestibility, and also their productivity." ... "Certain species may have been included in the collections either because of the personal preferences of individual members of the family or to add variety to the meal. Others may have been gathered by small children trying to emulate their mothers." ... "The presence of several species in relatively high numbers within a collection might be indicative of an opportunistic rather than a targeted foraging strategy due to a reduction in the availability of preferred prey."

The mussel *Perna perna*, the most frequently collected species observed by Lasiak, showed to vary in density and size composition with the vertical extend of the population on the shore: They were more frequent and larger in sublittoral areas than in the intertidal zone where they were accessible by humans. Size histograms produced from shells sampled from shell middens were positively (small specimens dominant) or negatively skewed (large specimens dominant). This was interpreted as follows (Lasiak 1992:26):

> "The positively skewed mussel size frequency distributions ... may therefore indicate that gathering activities that month were restricted mainly to the upper regions of the mussel stocks due to rough seas. Size frequency distributions exhibiting negative skewness, however, suggest that the collectors either had a marked preference for larger individuals or had greater access to low shore areas where larger mussels predominate. As these midden samples include shell remains from several days' collecting activities per month, such patterns may not be apparent if sea conditions varied during that period."

The results of the controlled exploitation experiment showed that one collector, collecting for 4-6 days a month, would accumulate 284-426kg of shell per year. Thus thin layers of shell accumulations in archaeological middens were seen by Lasiak as a result of short-term occupation whereas the thick substantial shell middens may reflect periods of longer occupations (Lasiak 1992:27). The comparison of Later Stone Age middens with recent ones showed strong similarities though they varied in species diversities. Lasiak (1992), however, warned against using information taken from current shellfish-gathering practices as an analogue for the interpretation of the archaeological record. As the two major limitations, she mentioned the differences in the economic circumstances of prehistoric and recent societies and the incompleteness of the archaeological record (Lasiak 1992:27). As a guide for further archaeological research on shell middens Lasiak suggested (1992:27):

> "In order to assess the impact of shellfish gathering on natural populations, extensive knowledge of numerous factors, other than exploitation, known to influence population density and size composition is required. Without this information, differences in size composition of exploited species, whether they be from modern or prehistoric middens, cannot be attributed solely to the effects of size-selective predation by man."

In the 1970s, Branch (1975:81) reported that intense collection of some intertidal molluscs by people from the Transkei led to a dramatic reduction of their densities and average sizes. Over three to five years the maximum size of *Patella concolor* was reduced by 15-20mm. As a result the wet body size and the gonad output has shrunk exponentially. This did directly affect the use of shellfish species for human subsistence: "The available biomass must have been sharply reduced, thus increasing the need to collect far larger numbers of animals for a comparable amount of meat." (Branch 1975:82f)

It can be concluded that the ethnographical record is relatively rich in some parts of the world while there is almost no information available for the Wester Cape. Shellfish collection behavior seems to be similar in broad terms but differs in details. In specific situations it seems to be possible that shellfish populations are reduced significantly resulting in decreasing average sizes of available prey.

Archaeological record

In their introduction to the archaeology of prehistoric coastlines, Bailey and Parkington (1988b) summarized the opportunities and problems of dealing with archaeological sites located in coastal environments. They pointed out that these areas represent an ecotone, "... a boundary zone at the junction of two major ecosystems, which combines some of the characteristics of each, as well as developing unique characteristics of its own which are a product of the zone of overlap" (Bailey and Parkington 1988b:1). The advantages for humans utilizing this geographically limited ecotone are the variety of biotic resources, especially the organisms living in the intertidal zone of the coast and the high productive terrestrial plants (Bailey and Parkington 1988b:1).

The use of shellfish for human subsistence on the western coast of South Africa provided "an interesting challenge to hunter-gatherers" as Henshilwood et al (1994:104) pointed out; they conclude:

> "Slow moving or sessile and entirely predictable in location, limpets and mussels, for example, are reliable sources of protein available in considerable quantity."..."By definition, though, shellfish have an

> extremely limited strip-like distribution in an environmental window that might not otherwise be attractive to potential shellfish gatherers. Inedible parts constitute a high percentage of the collected mass, making transportation somewhat onerous."

This results in a restricted zone, generally strips of land stretching along the coast next to the utilized sources, where the masses of marine shell that was discarded in prehistoric times can be found. Further inland their occurrence diminishes exponentially (Henshilwood et al. 1994:104).

However, changes in sea levels and ashore sand transport severely limit the visibility of archaeological sites in coastal areas. Various trans- and regressions have altered or submerged living areas of prehistoric people (Bailey and Parkington 1988a:5ff). As a result there are periods in the archaeological time scale were no strong evidence for the extensive use of marine resources was found. On the other hand, if not submerged, sites that are situated in coastal environments show a very high visibility because they are often dominated by shellfish which has a high ratio of non meat-bearing to meat-bearing parts. Combined with good preservation and thus durability of the shells in coastal sediments, these sites are characterized by a high visibility compared to their terrestrial counterparts situated in the interior of the Western Cape.

Coastal environments were not only of local and regional importance. They can "be seen, in a biogeographical sense ..., as 'linear corridors' along which dispersal might be channeled; they might therefore have been an effective route by which early human groups colonized previously unoccupied areas." (Mannino and Thomas 2002:467)

Recently the impact of prehistoric human foraging of intertidal mollusc communities had been analyzed by Mannino and Thomas (2002). They asked one main question that is currently under debate: Were prehistoric humans able to deplete shellfish resources? Over-exploitation is seen to manifest as a continuum of different possibilities that might be visible in the archaeological record. Compiled in a list, Mannino and Thomas (2002:464) summarize them as:

- the reduction in the average size and age of exploited species, below those which would be found in natural populations not exposed to human predation;
- the reduction in the age structure of populations which might reduce breeding capacity and recruitment, and hence population levels of molluscs on shores;
- the reduction in the absence (density) of molluscs on shores to levels at which they are not worth exploiting by human foragers;
- the reduction in breeding capacity which, in the lack of external recruitment, might lead to local, regional or global extinction.

Surely more archaeological work has to be done to provide good evidence that some of these indicators are existing in archaeological contexts of prehistoric times.

In the Western Coast of South Africa three major time periods in the Holocene were distinguished in respect of shellfish utilization with strong connections to settlement patterns (for a discussion see Buchanan 1985a:175f). For the early Holocene and the first half of the mid-Holocene (with a occupational hiatus between 7800 BP and 4400 BP (calibrated: 6600-2900 BC)), shellfish was found in caves and shelters together with typical terrestrial settlement remains (Parkington et al. 1988:28ff). A period of extensive use of shellfish for subsistence was recorded for the second half of the mid-Holocone, between 3000-1800BP (calibrated: 1200BC-250AD). Termed 'megamiddens' they are located along the western coast between Lambert's Bay and Elandsbay and coincide with a late-Holocene sea level low (see Figure 16). This time period was not only exceptional for its voluminous shell middens but also for the occupational hiatus observed in most of the caves and shelters of the area. This was interpreted as a radically different settlement pattern compared to the times before and after (Henshilwood et al. 1994:103, Jerardino and Yates 1997:43). Experiments for mussel drying and food storage suggested that these 'megamiddens' might have been a result of a specialized subsistence strategy, namely to dry large quantities of mussels adjacent to the place of collection and to transport them afterwards to the preferred living areas further inland (Henshilwood et al. 1994:108f). However, Jerardino and Yates (1997) disagreed and saw them serving as camp sites at the same time; previous interpretations that identified them as pure processing sites were seen to be a result of small excavation areas and misinterpretations of the archaeological material (Jerardino and Yates 1997:50). In the late Holocene, after the 'megamidden'-period, occupational layers with shellfish occurred again in caves and rockshelters of the Western Cape and also small scattered open-air sites existed. The total number of sites was much higher than in previous times and many of them contained bones of domestic animals (Parkington et al. 1988:30f; see "Pastoralism in the final LSA" on page 22).

The frequencies of shellfish species through these periods show significant differences. Between 4400 BP and 1800 BP (uncalibrated) shellfish remains consisted almost entirely of mussels. In contrast, sites dated younger that 1800 BP (uncalibrated) "may be limpet dominated if they lie near to sheltered shorelines, or have about equal proportions of limpets and mussels." This was interpreted as a more extensive exploitation of a wider range of marine foods in more recent times (Parkington et al. 1988:27) and may have been directly connected to sea level changes. Changes in average shellfish size found in archaeological contexts of different time periods might have been a result of environmental changes (sea surface temperature, sea level, nutrient transport, water turbidity) and/or human behavior (Jerardino 1997:1033f).

The complex interplay of prehistoric humans, their society and the coastal environment was analyzed in great detail by Jerardino (1996). One major result of this work, that concentrated on the cultural remains of the last 4500 years from Western Cape of South Africa, was the reinterpretation of the cultural remains in terms of the factors that changed the settlement patterns and the associated artefacts in their frequency and composition: humans were seen as the actors that caused changes while the environment represented mainly the basis on which the cultural change had happened (Jerardino 1996:i & 3f). Other topics of this work included the reconstruction of the palaeo-environment of different time periods, a description of the excavations carried out, the material culture of the different time periods and reconstructions of palaeo-diets (Jerardino 1996:ii & iii). Detailed results from Jerardino (1996) will be discussed in the following chapters when needed.

Shellfish species

The morphology, geography and biomass of the Elandsbay beaches has been investigated closely in 1980s (Buchanan 1985a, Rebelo 1982). Three main sectors were distinguished (Figure 19):

- Sector 1: scattered rocks and bouldery beach including the area west of the Verlorenvlei mouth to the beginning of the rocky platform of Baboon Point
- Sector 2: a rocky beach built by a rocky platform at Baboon Point
- Sector 3: scattered rocks at Mussel Point

The generalized beach profiles of these sectors show differences in their intertidal morphologies. Sector 1 and 3 are dominated scattered rocks while sector 2 shows a rocky outcrop in form of a platform (Figure 18). During the mid-Holocene sea level high of about +3m, sector 1 and 3 was dominated by sandy beaches and only sector 2 (Baboon Point) would have provided rocky areas in the intertidal zone. This had a strong impact on the available shellfish biomass and might have had consequences for the timing and duration of visits of prehistoric people (Parkington et al. 1988:30).

Shellfish species distribution and shellfish biomass are generally closely related to morphology of the shore and and the zonation of species in the intertidal zone affects the relative accessibility of limpet species and their mean sizes (Parkington et al. 1988:24). In the intertidal area, sector 2 and 3 provide habitats suitable for *Choromytilus meridionalis* while sector 1 shows a mix of limpets (mainly *Patella granatina* and *Patella granularis*) and the black mussel. In detail Parkington et al. (1988:24) summarized:

> "Among the Patella species, for example, the large *P.argenvillei* occurs only at the infra-tidal fringe, medium-sized *P.granatina* prefer the lower parts of the intertidal zone or mid-tidal rock pools, whilst the

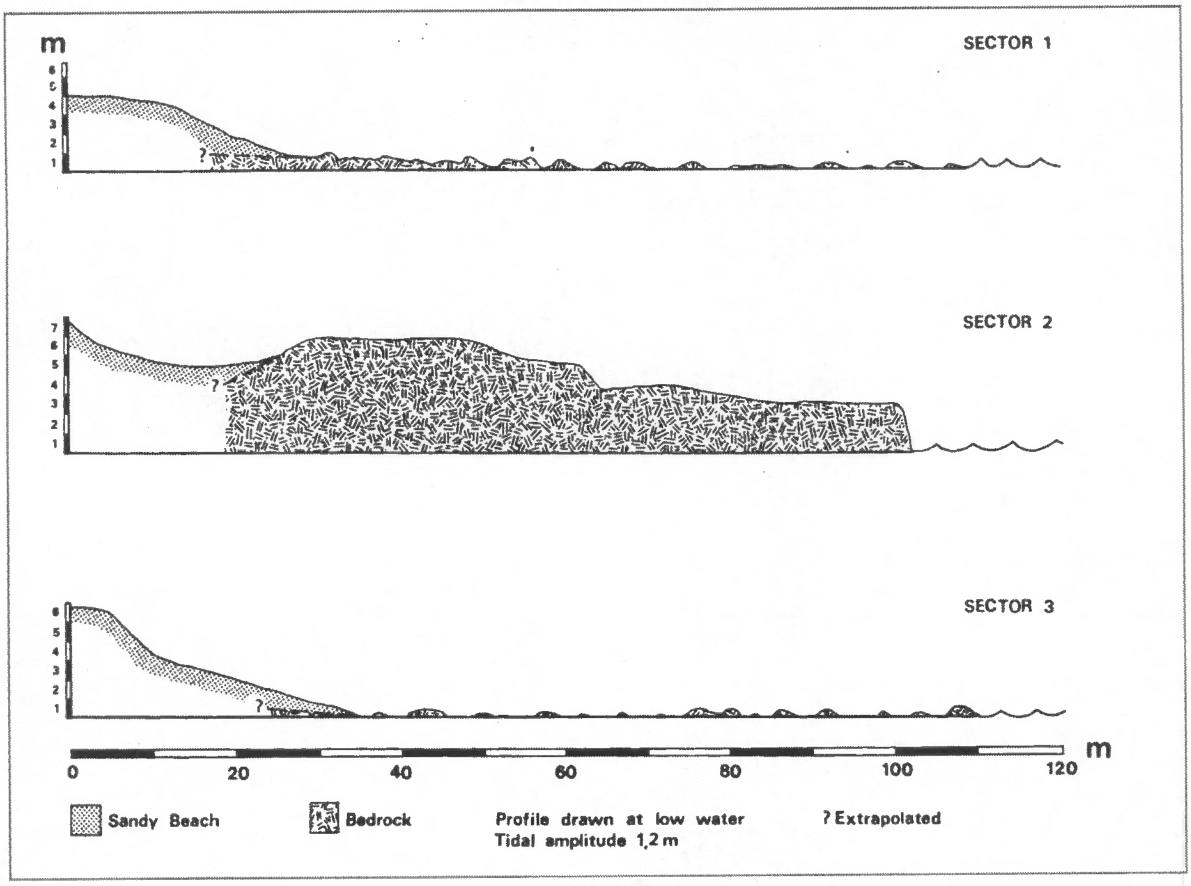


Figure 18: Elandsbay beach profiles (Parkington et al. 1988:31).

> smallest species, *P.granularis*, can stand to be out of the water much of the time and thus lives in the upper half of the intertidal zone." ... "Whelks of various species are very common throughout the intertidal, particularly in gullies and rock pools, but seem to have been relatively neglected by prehistoric collectors. Among the mussels the ribbed mussel, *Aulacomya ater*, is largely confined to the infra-tidal, but small animals may occur in the lowest intertidal levels. The black mussel lives intertidally and also infratidally in very extensive colonies, particularly on broad rock platforms such as that at Mussel Point."

The ecology of the most important limpet species and the black mussel have been described in detail by Buchanan (1985a:16ff); Table 7 summarizes briefly the most important observations. Growth rates and population structure of *Patella granatina* and *Patella granularis* from the Cape Peninsula have been investigated by Branch (1974). Part of the results of this research were multi modal population histograms and life tables that showed the rapid increase in size and a steady decrease in surviving individuals (Figures 20-23). From growth rates and population histograms, the age classes associated with certain sizes and Elandsbay were derived (Table 8). Growth curves for *Choromytilus meridionalis* at False Bay have been calculated by Griffiths (1981) and show clearly that the maximum shell length varies very much with shore level. Three different zones produced distinct size ranges (Griffiths 1981:113): (1) intertidal

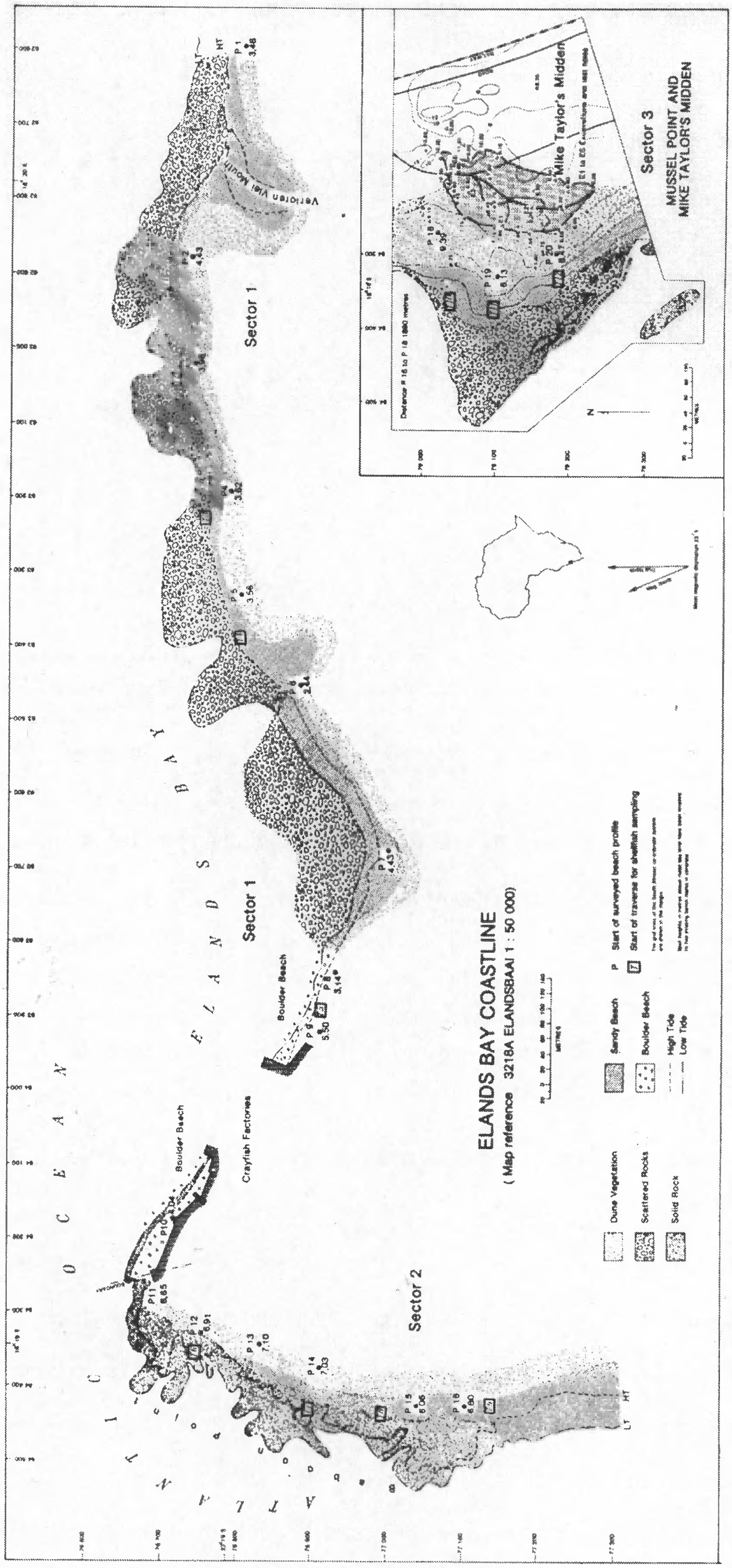


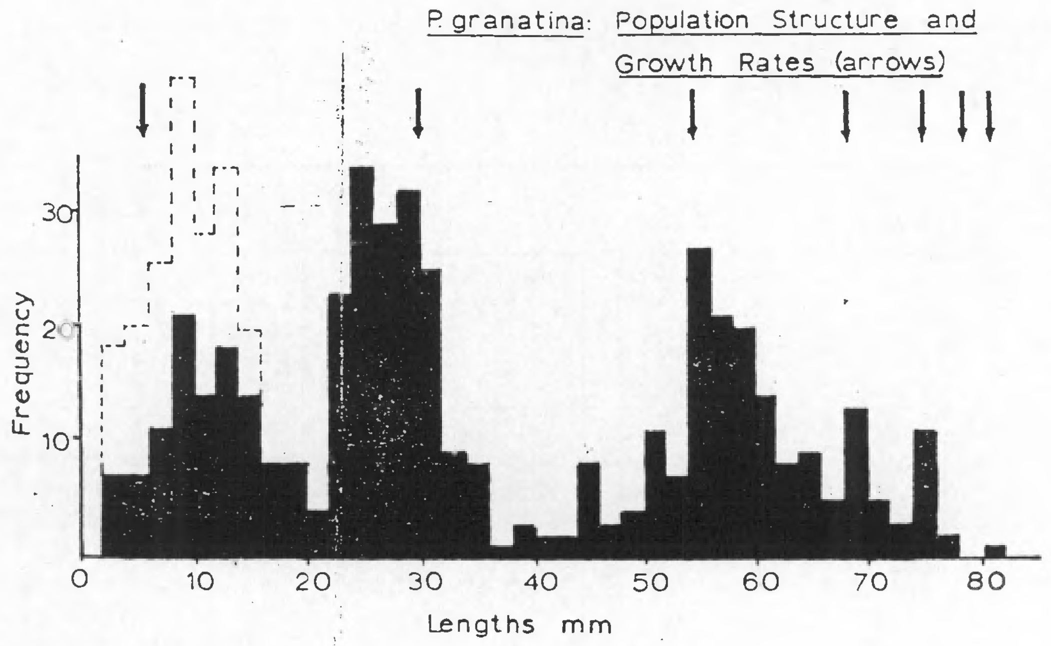
Figure 19: Elandsbay beach sectors (Buchanan 1985a:34).

zone (35-50mm), (2) low water mark zone (40-80mm), (3) zone below low water mark (40-100mm). At Saldanha Bay, *C. meridionalis* was found to grow generally faster and bigger than in False Bay as a result of higher nutrient contents of the water due to upwelling processes. Average sizes in the sublittoral of 84mm to 90mm were reached after two years growth (du Plessis 1977:312).

Species	Maximum Size (mm)	Range	Zonation	Growth and Reproduction
Patella granatina	102	Namibia to Danger Point; range restricted to the colder waters.	Upshore and downshore but mostly downshore.	Rapid growth, reaching 80mm by 3 years; sexually mature at 30-35mm after one year's growth with high reproductive output; lifespan 7/8 years.
Patella granularis	75	Entire South African coast but larger and more numerous on the west coast.	Mostly upshore; numbers progressively decrease downshore.	Fairly rapid but variable growth rates with sexual maturity after one years growth; high reproductive output; lifespan 7 years but only 1% survive beyond 5 years.
Patella argenvillei	104	Namibia to Transkei	Usually form a belt at about low spring tide level.	Slow growth with low reproductive output; high survival rate and long lifespan; populations remain fairly stable.
Patella barbara	100	Entire South African coast but larger and more numerous on the west coast.	Low spring tide level to infratidal but also in submerged situations.	Slow growth with low reproductive output; high survival rate and long lifespan; populations remain fairly stable.
Choromytilus meridionalis	154	Namibia to Algoa Bay but more abundant in the cold waters of the west coast.	Covers rock surfaces and sand filled gullies extending from 0.75m subtidal to 1m above long spring tide level.	Attain shell length of 60mm in one year; gametonesis occurs throughout the year and gametes are released mainly between July and February.

Table 7: Ecology of the most important *Patella* species and *Choromytilus meridionalis* (Buchanan 1985a:22ff & 28ff).

The exploitation potential of *Patella granatina* an *Patella granularis* for commercial purposes was evaluated by de Villiers (1976) in a small case study close to Lamberts Bay, north of Elandsbay. The intertidal strip under examination provided "excellent conditions for limpets" (de Villiers 1976:13). Relative species frequencies were similar to the situation in Elandsbay with *P. granatina* and *P. granularis* dominating the limpet populations with the latter being more abundant. Indications were found that average sizes were increasing with distance from the low-water mark making large individuals easily accessible. The small sizes of *P. granularis* and therefore low meat yields make it less interesting for exploitation than *P. granatina* which was seen as a possible candidate for commercial harvesting with a minimum size of about 50mm or 2 years age (de Villiers 1976:14f).



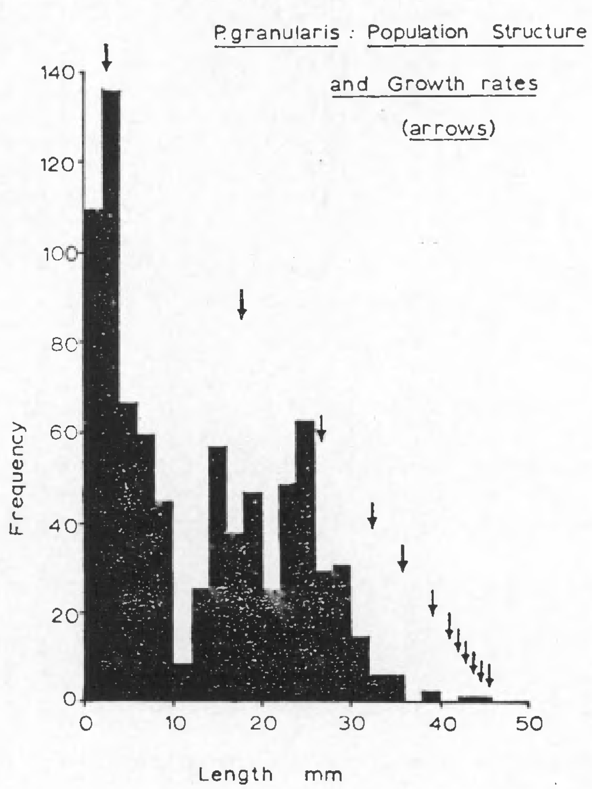


Figure 20: Population structure and growth rates of *P. granatina* from the Cape Peninsula (Branch 1974:187). (Top)

Figure 21: Population structure and growth rates of *P. granularis* from the C. P. (Branch 1974:188). (Bottom)

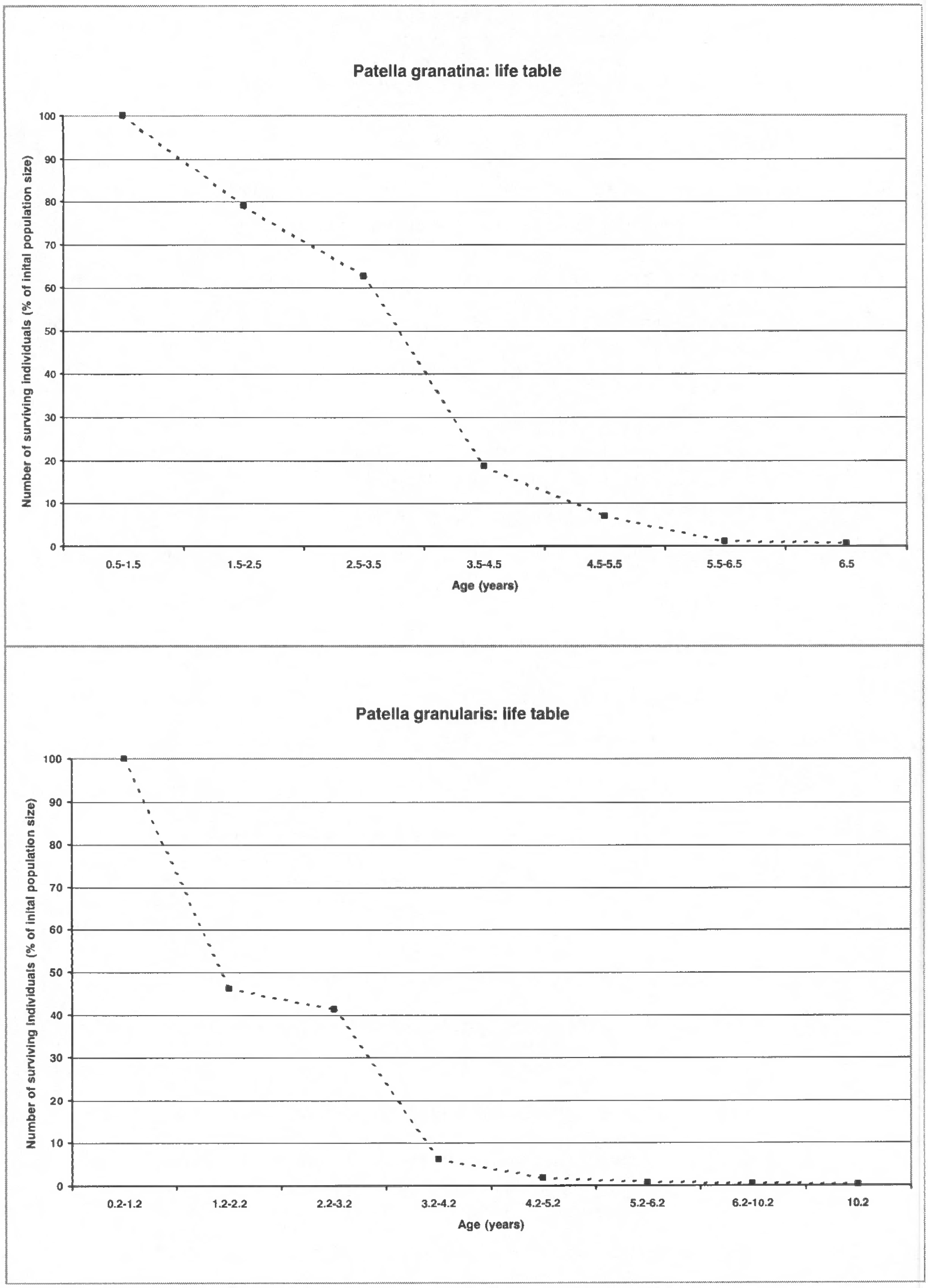


Figure 22: *Patella granatina*: life table (after Branch 1974:186). (Top)

Figure 23: *Patella granularis*: life table (after Branch 1974:186). (Bottom)

Species	Sizes (mm) for age classes			
	< 1 year	1 - 2 years	2 - 3 years	> 3 years
Patella granatina	< 30	30 - 54	54 - 68	> 68
Patella granularis	< 28	28 - 40	40 - 47	> 47

Table 8: Age classes and their associated shell sizes for *Patella granatina* and *Patella granularis* from Elandsbay (derived from Branch 1974:172 & 187).

In 1989, during the beginning of the excavations at Dunefield Midden, a group of students under the supervision of John Parkington recorded the natural availability of shellfish in the bay of Elandsbay (unpublished). Four transects, each one meter wide, were laid out in regular intervals in the area between the Verlorenvlei River Mouth and Baboon Point (sector 1), which was most likely the primary area where the occupants of DFM were collecting shellfish in the intertidal (Figures 1 and 2, page 2f). For each square meter, shells were counted and identified to species and the maximum shell lengths of *Patella granatina* and *Patella granularis* were measured. The results of this survey (see appendix "Elandsbay beach transects" on page 191) can be used as a proxy for the natural availability of shellfish and the population structure of limpets can be expected not to have changed since the occupation of DFM (Parkington, pers. comm.).

The reconstruction and analysis of prehistoric diets is of great interest to archaeological research and the nutritional values of the fauna and flora found in the material remains has therefore to be known. In case of the shellfish remains found on the western coast of South Africa, Rebelo (1982) did an extensive study on the dietary values and biomass distribution of shellfish in the Elandsbay area. Table 9 shows the results for the conversion of shell size classes of *P. granatina* and *P. granularis* into dry flesh weights which will be needed later on in this thesis for further analyses.

In order to create a framework for the availability of resources for human subsistence, biomass distributions of palaeoenvironments are investigated. In the case of the Elandsbay region, the total recent shellfish biomass for each of the three beach sectors was calculated by Buchanan (1985a) following the nutritional evaluations done by Rebelo in 1982 (Table 10, Table 11 & Table 12). Sector 3, most distant from DFM, was found to dominate clearly in terms of the available biomass, producing more than twice as much as the other two sectors together. This is emphasized by the fact that at the same time the total accessible intertidal area of sector 3 is the smallest of the three. Clearly the geographical position and the species composition are the main reasons for the extreme prominence of the Mussel Point area (i.e. sector 3): As Parkington et al. (1988:24) report, "biomass per m^2 is strongly influenced by exposure, direct wave action and swell". Compared to sector 1 and 2, Mussel Point is exposed to strong wave action and thus the water reaching the rocks contains more nutrients. In case of Baboon Point (sector 1 and 2), less nutrients are available due to a more sheltered location in the bay and to a kelp forrest that directly reduces swell (Parkington et al. 1988:24).

As these two areas (Mussel Point and Baboon Point) show morphological differences, they are characterized by a different composition of total nutritional yields per species (Figure 24). Black mussel *Choromytilus meridionalis* dominates sector 3, whereas in sector 2 *Patella* spp. and the black mussel show about equal percentages. In sector 1 the relative frequencies are the opposite of sector 3, showing high percentages for *Patella* spp. and low percentages for *C. meridionalis*. Whelks are represented in all three sectors with very similar frequencies.

These nutritional distributions by species are subject to change over time and today's reconstructions cannot simply be extrapolated to the past. Especially changes in sea-level and the nutritional load of the Benguela Current affect the species composition and the available biomass. Any implications for the interpretation of the Dunefield Midden shellfish will be addressed in the appropriate chapters.

Size Class (mm)	***Dry flesh mass (g)***	
	P. granatina	***P. granularis***
< 20	0.18	0.01
20 - 30	0.22	0.08
30 - 40	0.29	0.40
40 - 50	0.57	1.48
50 - 60	1.72	2.60
60 - 70	3.19	3.68
70 - 80	4.31	4.67
80 - 90	5.71	-
90 - 100	6.94	-

Table 9: *Patella granatina* and *Patella granularis*: Conversion of shell size classes into dry flesh weights (Rebelo 1982:3-1).

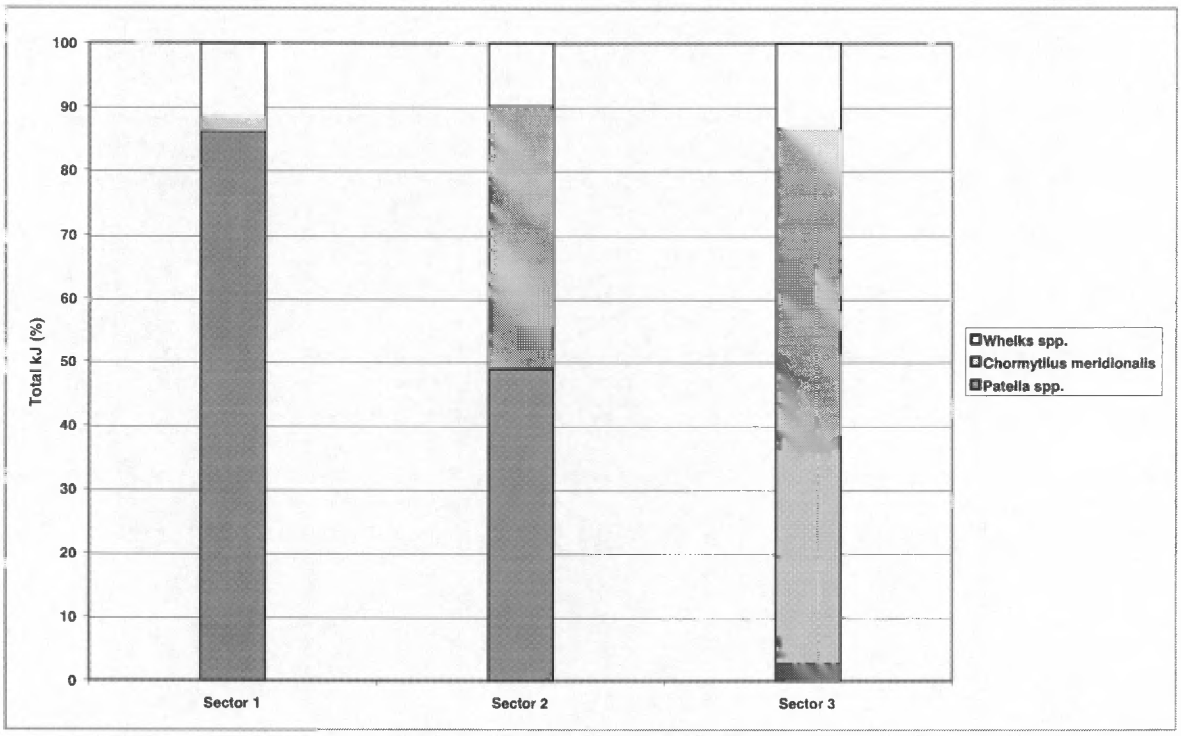


Figure 24: Total nutritional yields of different shellfish species from Elandsbay beach sectors.

Species	*kJ/m²*	*n/m²*	*Area (m²)*	*Total kJ*	*Total kJ (%)*	*Mean kJ per animal*
Patella granatina	394.3	9.3	58,170	22,933,000	43.0	42.4
Patella granularis	314.3	20.3	58,170	18,280,000	34.2	15.5
Patella argenvillei	22.5	0.3	23,820	765,000	1.4	75.0
Patella barbara	70.8	1.3	56,470	3,999,000	7.5	54.5
Total Patella	801.9	31.2	-	45,977,000	86.1	25.7
Choromytilus meridionalis	34.7	1.3	34,350	1,191,000	2.2	26.7
Whelks spp.	107.6	14.4	57,630	6,200,000	11.6	7.5
TOTAL	944.2	46.9	-	53,368,000	99.9	20.1

Table 10: Biomass of intertidal zone at Elandsbay beach sector 1 (Buchanan 1985a:347).

Species	kJ/m²	n/m²	Area (m²)	Total kJ	Total kJ (%)	Mean kJ per animal
Patella granatina	9.6	0.4	12,500	121,000	0.9	26.9
Patella granularis	68.6	32.8	12,500	858,000	6.6	2.1
Patella argenvillei	425.2	9.6	12,500	5,315,000	40.7	44.3
Patella barbara	6.2	0.2	12,500	77,000	0.6	24.6
Total Patella	509.6	43.0	12,500	6,371,000	48.8	11.9
Choromytilus meridionalis	430.9	21.8	12,500	5,386,000	41.3	19.8
Whelks spp.	103.2	13.7	12,500	1,290,000	9.9	-
TOTAL	1,043.8	78.5	12,500	13,047,000	100.0	13.3

Table 11: Biomass of intertidal zone at Elandsbay beach sector 2 (Buchanan 1985a:348).

Species	kJ/m²	n/m²	Area (m²)	Total kJ	Total kJ (%)	Mean kJ per animal
Patella granatina	152.9	3.9	11,980	1,832,000	1.2	39.2
Patella granularis	197.8	46.1	11,980	2,369,000	1.5	4.3
Total Patella	350.7	50.0	11,980	4,201,000	2.7	7.0
Choromytilus meridionalis	11,071.0	697.3	11,980	132,628,000	83.9	15.9
Whelks spp.	1766.0	235.5	11,980	21,158,000	13.4	7.5
TOTAL	13,187.7	982.8	11,980	157,987,000	100.0	13.4

Table 12: Biomass of intertidal zone at Elandsbay beach sector 3 (Buchanan 1985a:349).

4 SITE FORMATION PROCESSES

Cultural formation processes and refuse structure

The refuse of coastal archaeological sites is often dominated by shellfish. Together with the other cultural remains (bones, lithics, etc.) they represent the major source of information for the reconstruction of prehistoric lifestyles and their structure holds valuable information about the organization of excavated living areas. For a spatial analysis, the spatial distribution and the processes that lead to these distributions are of particular interest.

Generally, refuse can be divided into three groups (Wilson 1994:42f): (1) primary refuse, (2) secondary refuse and (3) de facto refuse. Primary refuse is associated with activity areas while secondary refuse is found in discard areas. De facto refuse are objects that were left at the abandonment of a site and is therefore relatively rare.

To understand the different kinds of refuse, the processes that produced them have to be explained. Tani (1995:233) distinguished two main 'cultural formation processes' (CFP): (a) a primary CFP and (b) a secondary CFP. These two processes are responsible for all three refuse groups: Primary CFPs produce primary refuse and de facto refuse whereas secondary CFPs are responsible for secondary refuse. There are distinct behaviors associated with each of them: Dropping, tossing and placing with primary CFP and dumping with secondary CFP (Tani 1995:344ff).

In most archaeological contexts the activity of dropping is only visible through microrefuse deposits as they do not get cleaned away from activity areas. While dropping generally happens with small sized objects, larger objects are tossed away with the result that they are scattered around the activity areas. Placing of objects can be identified when objects are concentrated in clusters in the activity areas (Tani 1995:236).

Dumping, often a result of activity area maintenance, moves objects of primary refuse deposits to new locations and is often characterized by "a distinctive midden of crescent, scallop, or doughnut shape along the edge of an activity area" with high artefact densities (Tani 1995:237). Damaged objects indicating trampling and cleaning activities may be found inside these middens.

Many formation processes are part of a general waste management scheme on a site (Figure 25). The main driving factor for waste management behavior is the hindrance of refuse. Net hindrance can be seen to be influenced mainly by the type of refuse and the intensity of activity area usage. For the type of refuse three factors are most important: amount, size, material of refuse. The intensity of activity area usage is determined by three basic elements: variety, mobility and duration of an activity (Tani 1995:238f). Waste management behavior has to be seen from the perspective of the inhabitants during the occupation of a site. The factors that influence the estimation of hindrance are always related to a present situation and do not necessarily take into account what might happen in the future (e.g. the length of stay at a site might have been anticipated to be short, whereas in the end it was long).

While the conventional interpretation of artifact assemblages are often used to specify distinct human behaviors, cultural formation processes can help to infer site functions and occupational variability (Tani 1995:243ff). In many cases the archaeological record does not provide enough information for a study of cultural formation processes (Tani 1995:249):

> "Data collection in fieldwork has to be refocused in order to obtain and record relevant information on refuse structure. ... In order to examine refuse structure, excavation units have to be systematic, arbitrary, and of equal size so that one can examine refuse distribution without reference to predetermined features, measure the artifact densities across the site, and determine the size and location of refuse deposits. Clearly, the main information on refuse structure lies between structures and features."

For most of the Dunefield Midden material, however, these demands are fulfilled so that the analysis of refuse structure and cultural formation processes can be applied to the information available in the DFM Spatial Database.

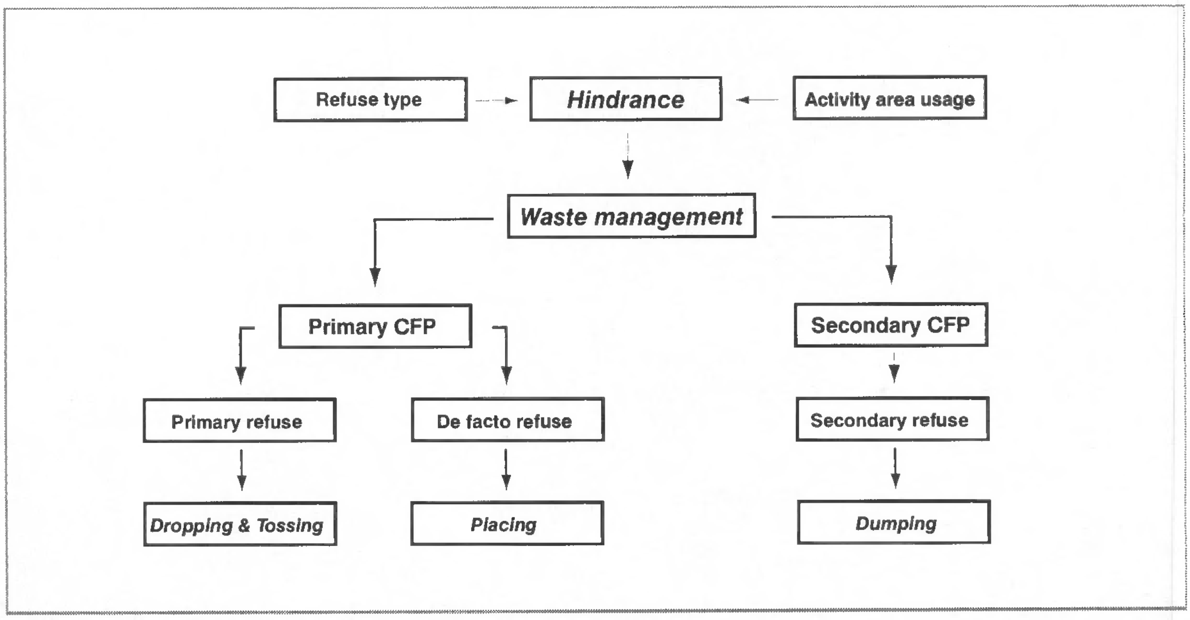


Figure 25: Basic waste management model (based on Wilson 1994 and Tani 1995).

Shellfish accumulation processes

Ethnographic and ethnoarchaeological observations have shown that there are a number of factors that influence the composition and size of shellfish assemblages found in archaeological contexts, such as availability of shellfish species, human preferences, differential transport, etc. (see "Ethnographical record" on page 37 for details). These factors can be combined into a simple model that describes the processes that may lead to spatial patterning in shellfish remains at archaeological sites (Figure 26). The two main factors identified are the environment and human behavior. The environment, on the one hand, determines the variables (substrate, nutrients, water temperature, etc.) that provide a specific habitat suitable for a certain combination of shellfish species. Human behavior, on the other hand, plays the key role in how the resources are utilized for subsistence and how the refuse is managed.

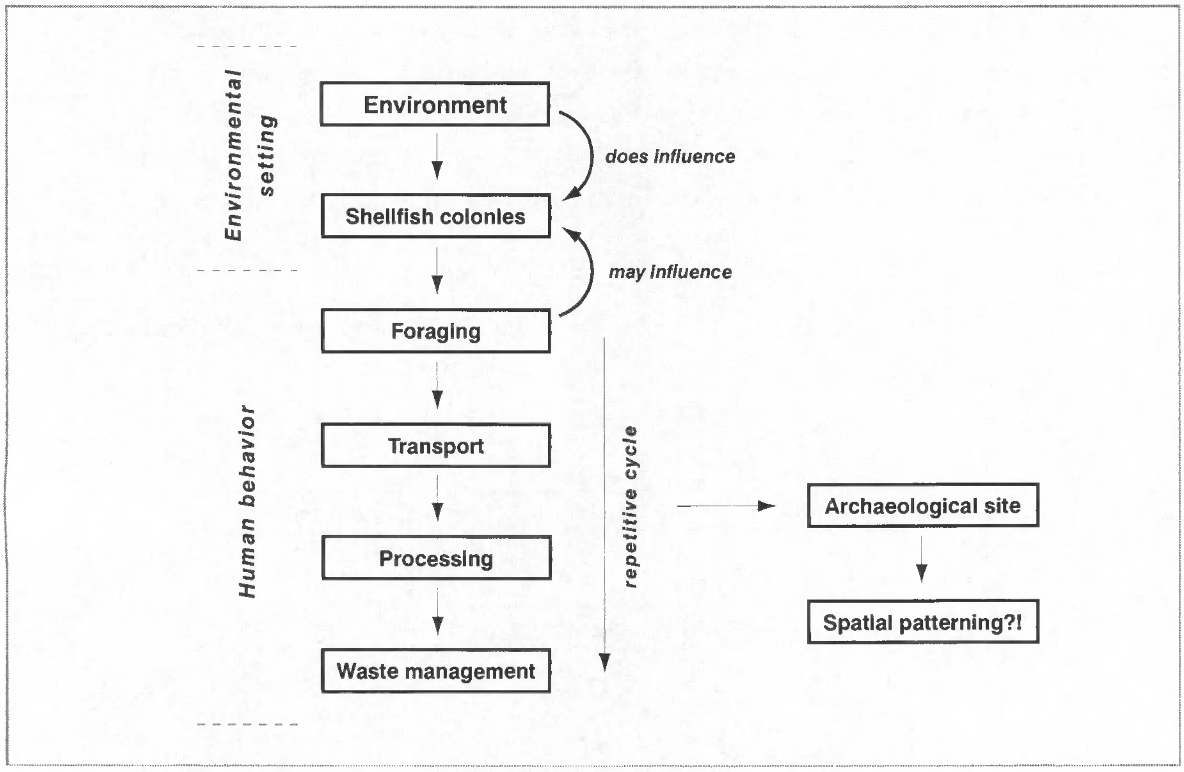


Figure 26: Simplistic model of processes that may lead to spatial patterning in shellfish remains.

In other words, the environment is responsible for the initial availability of shellfish, its species composition and age structure. When humans are involved as a predator for shellfish, they have the capability to change the species composition and age structure through a selective foraging behavior. After the food has been gathered it may be processed somewhere close to the area of collection or transported to other places, such as a camp. Inside the camp shellfish may be processed in different ways and the accumulating waste may be dumped regularly. As this cycle of collection, transport, processing and discard is repetitive, most archaeological sites are the result of cumulative episodes of shellfishing. Patterning observed in the refuse can therefore be due to all of these factors and specific analysis strategies may be able to eliminate unlikely causes and lead to a better understanding of the relevant processes. Whether the archaeologist can find patterns in the refuse may specifically depend on the size of the represented *time* *interval* and the *resolution in space*. It was shown in the first chapter ("Dunefield Midden" on page 5) that the likelihood of observing patterns at DFM is very high as the material remains were deposited in a short time interval with minimum overlap and superposition. Additionally the large size of the excavation provides repetitive examples of similar activities that ware carried out by the inhabitants. The information that has been presented in this chapter forms the basis on which the spatial analysis of the DFM shellfish remains will be conducted.

CHAPTER III METHODOLOGICAL FRAMEWORK

1 SPATIAL ANALYSIS OF HUNTER-GATHERER SITES

Introduction

Excavations are the main source of information for archaeologists and they provide a detailed record of the position of finds and features in reference to an excavation grid. As a result, the location and the spatial relationships of the material remains are known and thus facilitate the reconstruction, analysis and interpretation of the observed archaeological contexts. Distribution maps are the most common medium to visualize the data whereas spatial analysis is concerned with the identification, quantification and interpretation of spatial patterns.

Since the 1970s, the analysis of hunter-gatherer site patterning and site structure has been intensively pursued by many archaeologists and two main lines of research can be distinguished: "1) ethnoarchaeology among extant hunter-gatherers; and 2) the application of quantitative techniques to spatial analysis" (Fisher and Strickland 1991:215). Ethnoarchaeological investigations have been conducted intensively in North America, Australia, Southwest Asia and especially in sub-Saharan Africa (David and Kramer 2001:256f). For quantitative spatial studies methods and techniques were borrowed from other disciplines (e.g. ecology and geography) and adapted to archaeological and ethnoarchaeological contexts (Fisher and Strickland 1991:215).

There is a substantial amount of literature on the analysis of spatial camp structures in ethnoarchaeological contexts (Binford 1978; Binford 1983; Brooks and Yellen 1987; Fisher and Strickland 1989; Fisher and Strickland 1991; Fisher 1993; Gamble and Boismier 1991; Gifford-Gonzalez et al. 1999; Gould and Yellen 1987; Hitchcock 1987; Kent and Vierich 1989; Kent 1995; Kroll and Price 1991; O'Connell 1987; O'Connell et al. 1992; Whitelaw 1990; Yellen 1977) and in archaeological contexts (Baales 2001; Balme et al. 2002; Blankholm 1990; Cziesla et al. 1990; Fisher and Frison 2000; Hietala 1984; Kent 1998; Kroll and Price 1991; Metcalfe and Heath 1990; Simms and Heath 1990; Vaquero and Pastó 2001). In most of this research the central interest had been the identification and description of human behavior that lead to the material consequences observed. Although there is no general theory of behavior available that could explain the variability of observed patterning in ethnoarchaeological contexts (see O'Connell 1995 for discussion), researchers have studied and described intensively contemporary and archaeological sites.

In many of these publications a number of questions are regularly asked when hunter-gatherer sites are analyzed in terms of their spatial structure:

(1) How are finds and features distributed?

(2) What patterns exist?

(3) Can the patterns be statistically demonstrated and how significant are they?

(4) Which cultural formation processes led to the patterning of the material culture?

(5) Can the patterning give insight into and identify past human behavior?

In some cases only questions (1), (2) and (5) are investigated and thus distributions of finds and features are plotted and then the eye of the archaeologist interprets these maps (Hodder 1976:1ff; Kintigh and Ammerman 1982:31). More recent approaches also include questions (3) and (4): A critical analysis of the patterns concerning their quality and thus validity for interpretation of cultural formation processes is conducted, and patterns are statistically quantified to support the strength of an interpretation and to enable comparisons to data from other sites. The author agrees with O'Connell (1995) that human behavior is extremely variable and that there is no general theory that would facilitate an in-depth behavioral interpretation of spatial patterns.

As this project was specifically concerned with providing substantial data management for DFM, only the first three questions were asked and the shellfish data of the DFM Spatial Database provided the material for the analyses. Further research might concentrate especially on identifying cultural formation processes and, if possible, on reflections of specific human behavior.

The following sections elaborate on the methodology used to identify and quantify spatial patterning and refuse structure of shellfish remains at Dunefield Midden (Figure 27). For question (1) distribution maps with the GIS linked to the DFM Spatial Database were plotted, for questions (2) and (3) statistical analysis techniques (k-means cluster analysis and spatial autocorrelation) were applied.

Statistics

There are several general statistics that were applied to the shellfish data in this thesis, such as descriptive statistics, correlation analysis, analysis of variance, etc. They have all become common tools in the sciences and are therefore not explained here. A good basic introduction into statistics in archaeology is given by Shennan (1988) and

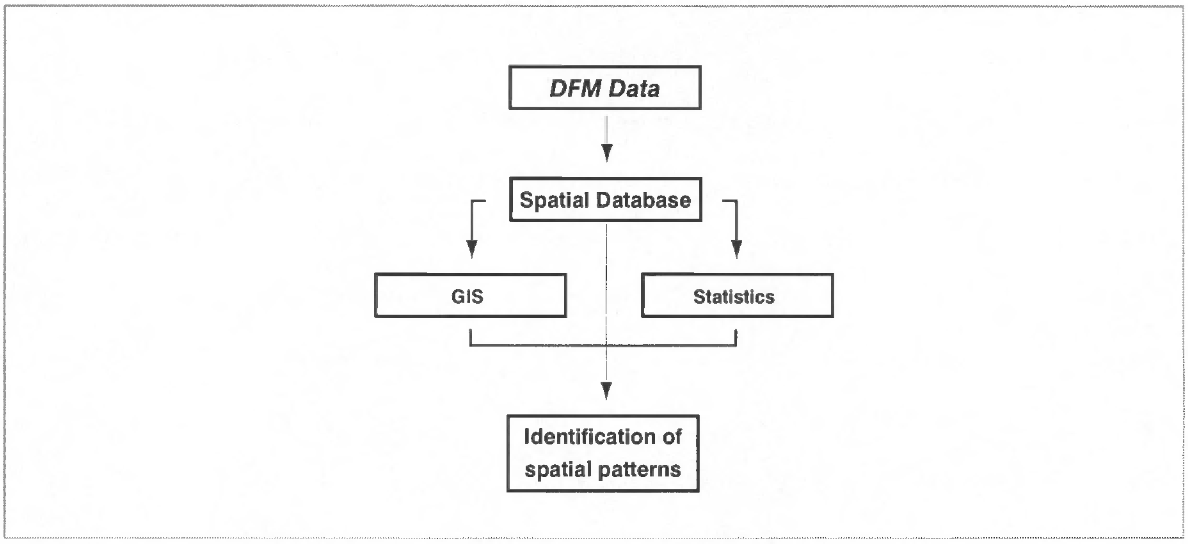


Figure 27: Spatial analysis methodology of this project.

reviews about recent trends and developments of quantitative methods in archaeology were compiled by Aldenderfer (1998) and Cowgill (2001).

Numerous statistical methods can be used for the identification and quantification of spatial patterning (see Blankholm 1990 for an overview). 'Spatial analysis in archaeology', the classic work on this topic, was first published in 1976 (Hodder and Orton 1976). Its main aim was to present methods for archaeologists that help to identify and quantify spatial patterns in archaeological data in a scientific, i.e. statistical way (Hodder and Orton 1976:1). As this was a pioneering study, it provided "... a comprehensive review of the state-of-the-art methods of spatial analysis used in archaeology" (Kintigh and Ammerman 1982:32).

Kintigh and Ammerman (1982:32), however, pointed out that there are substantial problems involved in these classic approaches as they do not consider the context of a given problem, such as a combination of several known variables. They proposed that spatial archaeological information should be analyzed heuristically assisted by computer technology and thereafter they elaborated a specific methodology for the identification of clusters in point patterns (Kintigh and Ammerman 1982:33ff).

In a similar approach, Whallon (1984) demonstrated successfully that 'unconstrained clustering' is a powerful method for spatial analysis in archaeology. The major advantage over other methods (for example dimensional analysis of variance, nearest-neighbor analysis, principal components or factor analysis) is its independence of constraints such as "... size, shape, density, composition, and internal organization or structure of the clusters which are identified" (Whallon 1984:243f). As the only disadvantage Whallon mentions the "... inability to define overlapping distributions" (Whallon 1984:276).

In a combination of the clustering analysis procedures proposed by Whallon (1984) and Kintigh and Ammerman (1982), Gregg et al. (1991) evaluated the extent they can be used to analyze ethnographically recorded sites. As the object of their investigations they chose one of Yellen's (1977) !Kung camps (number 14). The spatial analysis experiments were not only conducted on the original find and feature distributions but included several stages of simulated disturbances of the site (Gregg et al. 1991:149). The main results were that cluster analysis was able to identify objectively the number and location of social units that were previously observed by Yellen during occupation. Furthermore it provided a detailed description of the site data structure and was therefore seen as a valuable tool for guiding the interpretation of a site by archaeologists. The results of the experiments on the simulation of the disturbed site showed that even in the context of randomly changed positions of features and finds, cluster analysis was able to describe the original site structure to a satisfactory degree.

Kintigh and Ammerman (1982), Whallon (1984) and Gregg et al. (1991) demonstrated methods that are of potential interest for the identification of spatial clusters at DFM. For this project, k-means cluster analysis was chosen to facilitate parts of the spatial analysis and therefore the author had to learn the relative complex procedures associated with the statistics. As it is of crucial importance that the reader has a detailed understanding of how cluster analysis works, the technique is carefully explained and illustrated with examples in the following section. In context of this project, there are some differences in how k-means cluster analysis was applied to the archaeological data: instead of evaluating the spatial distribution of finds, non-coordinate data, such as weight percentages, related to excavated squares was analyzed for clusters. For illustrationary purposes, however, the example of spatially distributed finds seems to be the easiest to comprehend.

Additionally a method for the quantification of spatial patterning was needed; in geographical contexts, spatial autocorrelation is regularly used for this purpose. Particularly object-related information (such as the shellfish remains from DFM are related to squares) can be analyzed for the degree and type of spatial distribution. In this thesis, cluster analysis and spatial autocorrelation were applied to the shellfish remains in a complementary way as the former divides areas into clusters that show similar values and the latter quantifies and characterizes the resulting spatial distributions.

K-means cluster analysis

For this project the software 'Statistica' (StatSoft 2000) was used to perform the k-means clustering. The basic procedure is relatively simple: In the first step, the variables on which the statistics will be performed (e.g. x- and y-coordinates of finds) and the number (*k*) of desired clusters has to be defined. Note that the choice of variables is not restricted to spatial information as any interval data can be used and that it is also possible to include more than two variables into the cluster analysis. In the next step, the software distributes these values randomly into *k* clusters. The goal of the analysis is to "(1) minimize variability within clusters and (2) maximize variability between clusters" (StatSoft 2000:k-means Clustering - Introductory Overview). An algorithm moves the values between the clusters until an optimal result is achieved. The k-means cluster analysis produces four outputs: (1) Analysis of variance, (2)Cluster means & Euclidean distances, (3) Descriptive statistics for each cluster and (4) Members of each cluster & distances.

For the evaluation of the clustering results, (1) and (4) are of primary interest. The 'analysis of variance' quantifies the clusters according to the variance within and between them and can be used to evaluate the significance of the clustering. The 'Members of each cluster & distances'-output generates a table by merging the original table used for the analysis with two additional columns: the first column contains the cluster number to which the record belongs and the second lists the distance of the record to the cluster mean. This new table can be used for the visualization of the results and for further analysis.

As Kintigh and Ammerman (1982:43) have pointed out, the calculation of clusters and their description does not provide the means to identify significant patterns but merely forces any kind of distribution into a given number of clusters. The tool used by Kintigh and Ammerman (1982) and Gregg et al. (1991) to separate 'useful' clusters from 'not useful' ones, is the 'global Sum Squared Error' (SSE) statistic: First, cluster analyses with increasing numbers of clusters (*k*s) are performed for the values subject to investigation. Next, during each stage of clustering, the results of the analysis of variance within each cluster of the data under investigation is compared to the results of a random distribution. Finally, these differences of variance of each clustering stage are plotted next to each other and stages that show a significant clustering can be identified (Kintigh and Ammerman 1982:44ff; Gregg et al. 1991:153f). Three different types can be distinguished with this method: uniform, random and clustered patterns. To illustrate the complete process of a k-means cluster analysis, the distribution of finds at Yellen's !Kung camp 14 (Yellen 1977) was evaluated as an *example*. Previously, Gregg et al. (1991) used the same camp for the demonstration of the cluster analysis methodology that they had developed.

Camp 14 was occupied for seven days by 18 adults and eight children (including Yellen and two of his assistants). The spatial location of seven huts, several fire places and charcoal scatters and a total of 231 finds, mostly faunal remains, was recorded shortly after the abandonment of the camp (Figure 31). During the occupation, Yellen noted that eight social units (plus one created by himself and his colleagues) were present: six nuclear families, two of the category 'other' and Yellen's group (Yellen 1977:221ff & 251).

In contrast to the analysis carried out by Gregg et al. (1991), the scatters produced by the observers (the finds around feature 'A', Figure 31) were included into this example investigation. The coordinates of finds facilitated as the objects for cluster analysis - huts were not included in the evaluation and are only added to the distributions maps for illustrationary purposes; the location of features and their distributions were ignored.

Before the spatial analysis of the find scatters could be performed, the site plan of camp 14 drawn by Yellen had to be scanned and then imported into MapInfo where the shape of the huts and the positions of the finds were digitized (Figure 32). An important result of Yellen's observations was that he could relate scatters of finds to certain events and especially to specific social units of the group. His identification of subjective clusters of finds and features serves as the reference against which the results of the spatial analysis can be evaluated (Figure 33).

As a result of the digitizing process, the positions of the finds relative to an arbitrary meter grid were known and their coordinates could be extracted and saved in a table. This table was imported to Statistica and a k-means cluster analysis on the find coordinates was performed for a total of 15 clustering stages (k=2, k=3, ..., k=15). Each stage produced a list of variables that were transferred to an Excel spreadsheet for the evaluation of significance (Table 13). For a detailed explanation of the methodology for the log(%SSE)-statistic refer to Kintigh and Ammerman (1982:45ff).

To assess the clustering of each stage, the data from this spreadsheet was used to generate two graphs: In the first, the variables 'YellenLog(%SSE)', 'RandomLog(%SSE)' and 'Random2Log(%SSE)' are plotted against each stage of clustering (Figure 34). The curves of the two statistical random runs are then used as a reference against which the cluster analysis results can be evaluated and there are three main possibilities that the curve of the real data can take in each clustering stage (Figure 28; Kintigh and Ammerman 1982:46ff):

(1) it *follows closely* the random runs and has therefore the characteristics of *random* patterning,

(2) it *shifts below* the random runs and is therefore identified as a *clustered* patterning or

(3) it *shifts above* the random runs and thus represents a *uniform* patterning.

In the second plot, the information from the first is combined into one curve by plotting 'DeltaLog(%SSE)' against the clustering stage (Figure 35). Again, there are three possibilities the curve can take (Figure 29):

(1) it stays *around 0* and represents *random* patterning,

(2) it tends to *positive* values and represents *clustered* patterning or

(3) it tends to *negative* values and represents *uniform* patterning.

The advantage of the latter plot is that the values on the y-axis indicate the strength of patterning. Thus the clustering stages with the strongest patterning can be identified. High positive values indicate strong clustering (theoretical maximum of +2.0), high negative values strong uniform patterning (theoretical minimum of -2.0). Additionally the strength of change from each clustering stage to the next is an important factor that has to be considered. As a general rule of thumb it can be said that 'the stronger a positive change is, the more interesting it is'. The interpretation of these graphs is not always easy and some experience with the methods has proven to be very helpful.

Column(s)	Content	Description
Cluster Stage	Variable from Statistica	Cluster Number
• XYellenSSE • XRandomSSE • XRandom2SSE	Variables from Statistica	Sum Squared Error of x-variables (Yellen's data and two random runs).
• YYellenSSE • YRandomSSE • YRandom2SSE	Variables from Statistica	Sum Squared Error of y-variables (Yellen's data and two random runs).
• YellenSumSSE • RandomSumSSE • Random2SumSSE	• XYellenSSE + YYellenSSE • XRandomSSE + YRandomSSE • XRandom2SSE + YRandom2SSE	Adds the Sum Squared Errors of x- and y-variables.
• Yellen%SSE • Random%SSE • Random2%SSE	• YellenSumSSE / YellenMaxSSE • RandomSumSSE / RandomMaxSSE • Random2SumSSE / Random2MaxSSE	Divides the sum of the Sum Squared Errors by the maximum sum squared error of the complete data set (values from Statistica).
• YellenLog(%SSE) • RandomLog(%SSE) • Random2Log(%SSE)	• log (Yellen%SSE) • log (Random%SSE) • log (Random2%SSE)	Transforms the percentages by using the log-function (100% becomes 2.00).
MeanRandomLog(%SSE)	[RandomLog(%SSE)+Random2Log(%SSE)] / 2	Calculates the mean log(%SSE)-value of the random runs.
DeltaLog(%SSE)	MeanRandomLog(%SSE) - YellenLog(%SSE)	Subtracts the log(%SSE)-value from Yellen's data from the mean of the two random runs.

Table 13: Scheme used in Excel to evaluate the significance of the k-means cluster analysis results.

With these guides for the interpretation of the Log(%SSE)- and DeltaLog(%SSE)-graphs the k-means cluster analysis of Yellen's !Kung camp 14 can be evaluated: Figure 34 shows that the distribution of finds is random from cluster-

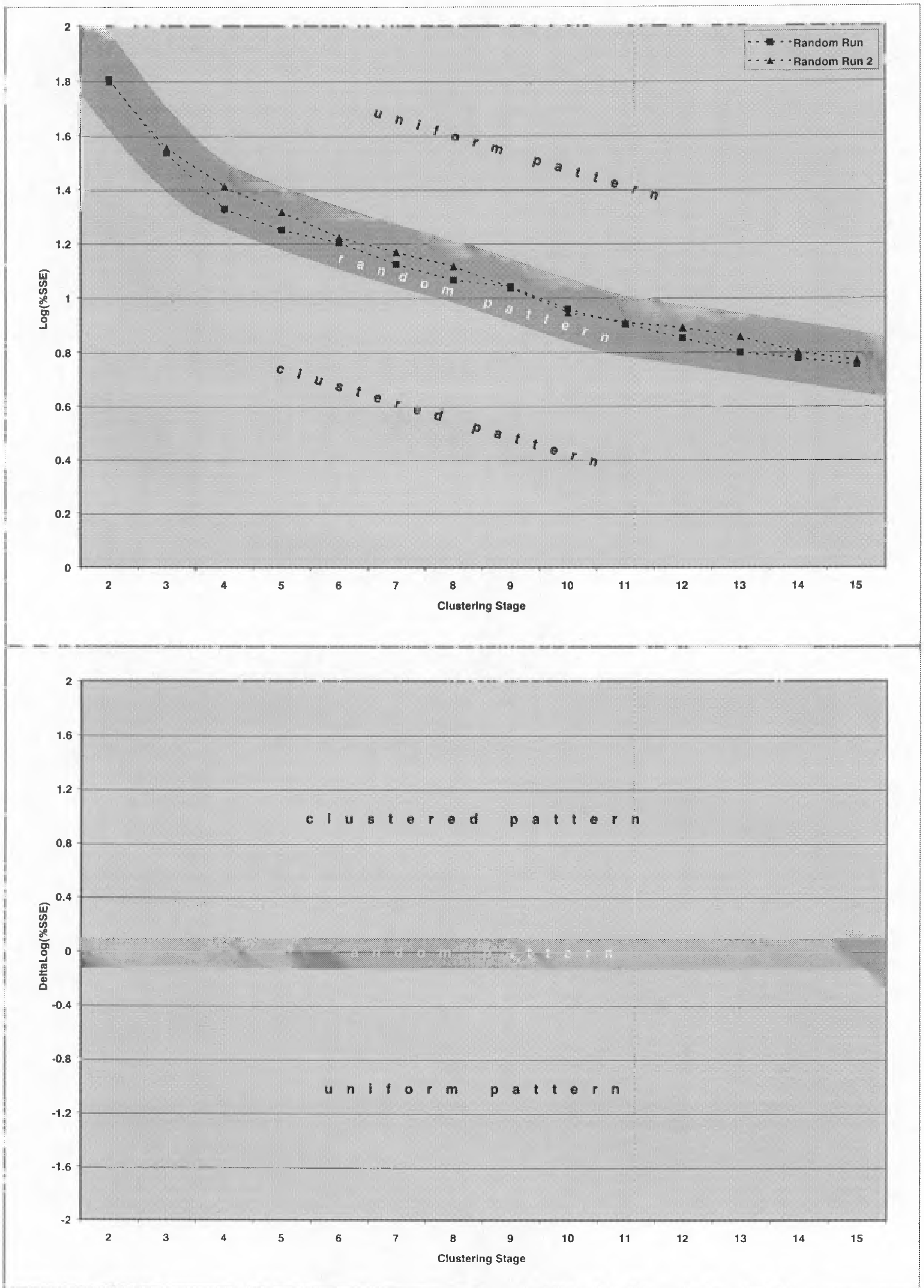


Figure 28: Guide for the interpretation of the Log(%SSE)-chart.

Figure 29: Guide for the interpretation of the DeltaLog(%SSE)-chart.

ing stage two to six and clustered from stage seven to fifteen. A closer investigation (Figure 35) indicates that stage seven and nine represent very strong clustered patterning. It can be concluded that the log(%SSE)-statistic helped to describe the patterning of camp 14 and identified the relevant clustering stages that are worth further investigation.

The two most significant solutions of seven and nine clusters were visualized in MapInfo (Figure 36 and Figure 37) and can be compared to Yellen's interpretation (Figure 33). The seven cluster solution created six clusters in the !Kung and one in Yellen's living area, whereas the nine cluster solution lead to seven clusters in the !Kung and two in Yellen's living area. The latter conforms well to the results of Gregg et al. (1991:159) and Yellen (1977): Seven out of the eight limited scatters (LS1 to LS8 in Yellen's map) were identified correctly - only LS1 and LS7 were combined into cluster 2. Gregg et al. (1991:157) had already pointed out in their analysis that these two limited scatters were produced by two brothers of which one was not married and thus shared much of his time with his brother. The combination reflects the close relationships of these two social units.

In the seven cluster solution, LS5 is additionally split and incorporated into clusters 1 and 2. This shows a limitation of *k*-means cluster analysis: Although the identification of discrete scatters is possible, there might be several solutions that are more or less feasible. If Figure 35 is consulted again, it shows clearly that the nine cluster solution has the highest DeltaLog(%SSE)-value and is therefore identified as the clustering stage with the strongest and clearest patterning.

This example analysis has demonstrated that the *k*-means cluster analysis is a valuable tool for the analysis of *point* distributions. In the case of Dunefield Midden, however, some information is only provenanced to *square meter* (e.g. shellfish) as the main strategy was not the time-expensive resolution of the exact location of all finds and features but the excavation of a large area in order to be able to analyze site patterning and site structure. It has to be demonstrated that the same methodology of cluster analysis can be used for distributions that are *square*-related.

To simulate the situation at Dunefield Midden, a square meter grid was superimposed in MapInfo over Yellen's plan of camp 14 starting at a randomly chosen zero point (Figure 38). Then, the number of finds per square was counted and the result can be seen in Figure 39. Square-related information can be displayed in another way: dots, each representing one find, can be projected randomly into the squares using the 'dot density plot'-function of MapInfo to simulate the original density distribution of the finds (Figure 40).

A table was generated with the number of counts for each square and then imported to Statistica for the *k*-means cluster analysis. The process was generally the same as in the first analysis where the exact coordinates of each finds were used. Now, however, only the center coordinates of each square and the number of finds it contains were known.

The center coordinates were defined as the objects for the cluster analysis and the number of finds were defined as a weight variable. After the analysis was performed, the log(%SSE)-statistic resulted in Figure 41 and Figure 42. Although the curves do not follow the exact course of the initial analysis (Figure 34 and Figure 35), they still show generally the same picture: random patterning occurs during clustering stages two to six, clustered patterning from seven onwards (excluding 10 and 14). Again, the seven and nine cluster solutions are dominant with the latter being stronger - both were visualized with MapInfo (Figure 43 and Figure 44). When compared to the initial results (Figure 36 and Figure 37) there are no substantial differences between the *find-coordinate-based* method and the *square-related* method of *k*-means cluster analysis.

Spatial autocorrelation

In their classic publication 'Spatial analysis in archaeology', Hodder and Orton (1976) introduced spatial autocorrelation as a method to analyze spatial distributions. They stressed the importance of having a statistic that is able to demonstrate and quantify the existence of structure in archaeological contexts and concluded that spatial autocorrelation is an appropriate approach (Hodder and Orton 1976:174f). This section introduces briefly the basics of spatial autocorrelation techniques; the calculation of the statistics is discussed in detail in the appendix "Spatial autocorrelation" on page 197. An in-depth explanation and discussion of applications and models is provided by Cliff and Ord (1981) and a good introduction was written by Goodchild (1986).

In a very general sense "... spatial autocorrelation is concerned with the degree to which objects or activities at some place on the earth's surface are similar to other objects or activities located nearby" (Goodchild 1986:3). It provides statistical techniques that are able to distinguish between randomly distributed phenomena (spatially independent from each other), and positively or negatively correlated phenomena (spatially related to each other). In most of the applications, the objects for analyses are variables that are describing specific characteristics of spatial objects (e.g. in geography: population in countries; in archaeology: finds in excavated squares). Spatial autocorrelation is then used to compare the values of the variables of adjacent objects with each other. The results are interpreted by comparing them to random distributions.

There are three ways to compute indices of spatial autocorrelation: Moran's *I*-statistic, Geary's *c*-statistic (*c*) and the 'Join count statistic' (*jcs*). The first two are very similar in method and the results are generally identical (Goodchild 1986:16). As the spatial analysis of this project is only concerned with nominal data, the 'Join count statistic' was used when required.

Similar to the *k*-means cluster analysis, there are three extremes of possible outcomes for the 'Join count statistic' of a two color distribution (see Figure 30 for examples):

- The distribution is random (c): number of joins of same or different colors are as expected;
- the distribution is clustered (d & e): number of joins of same color are more frequent than expected and number of joins of different colors are less frequent than expected;
- the distribution is uniform (a & b): number of joins of same color are less frequent than expected and number of joins of different colors are more frequent than expected.

Although this method looks similar in its approach to the k-means cluster analysis, there are technical and methodological differences. The main difference is the data source: the 'Join count statistic' has to be applied to nominal data whereas cluster analysis needs interval or ranked data. Additionally the former is used to describe the distribution of values over a number of objects - the latter splits the objects into clusters and quantifies their relationship between each other. Both approaches can be combined as it is possible with the 'Join count statistic' to analyze distributions *within* clusters or to evaluate distributions that were identified by a non-spatial cluster analysis.

The calculation of the 'Join count statistic' is extremely time consuming without the use of a computer. For this project, the DFM Spatial Database acted as a tool to perform the numerous counting procedures. The values of the variables were calculated with a database and then transferred into an Excel spreadsheet which contained the equations for the calculation of the *jcs* and performed the significance tests (for details see "Spatial autocorrelation" on page 197).

It can be concluded that spatial autocorrelation is a method to describe and quantify the distribution of values that are related to spatial objects. Neither spatial autocorrelation nor k-means cluster analysis provide any means to identify the source of reason for patterning. They are statistical methods that can be applied to spatial phenomena in order to investigate their structure. For this project they proved to be powerful tools for the analysis of spatial patterning in the shellfish remains at Dunefield Midden. It would have been difficult to gain the same insights with other statistical methods.

2 DATABASES AND GEOGRAPHICAL INFORMATION SYSTEMS

A brief overview

Information technologies are becoming more and more part of our daily life. Today, there is rarely a university student who was not confronted with computer hard- and software and it seems that proper knowledge about these elec-

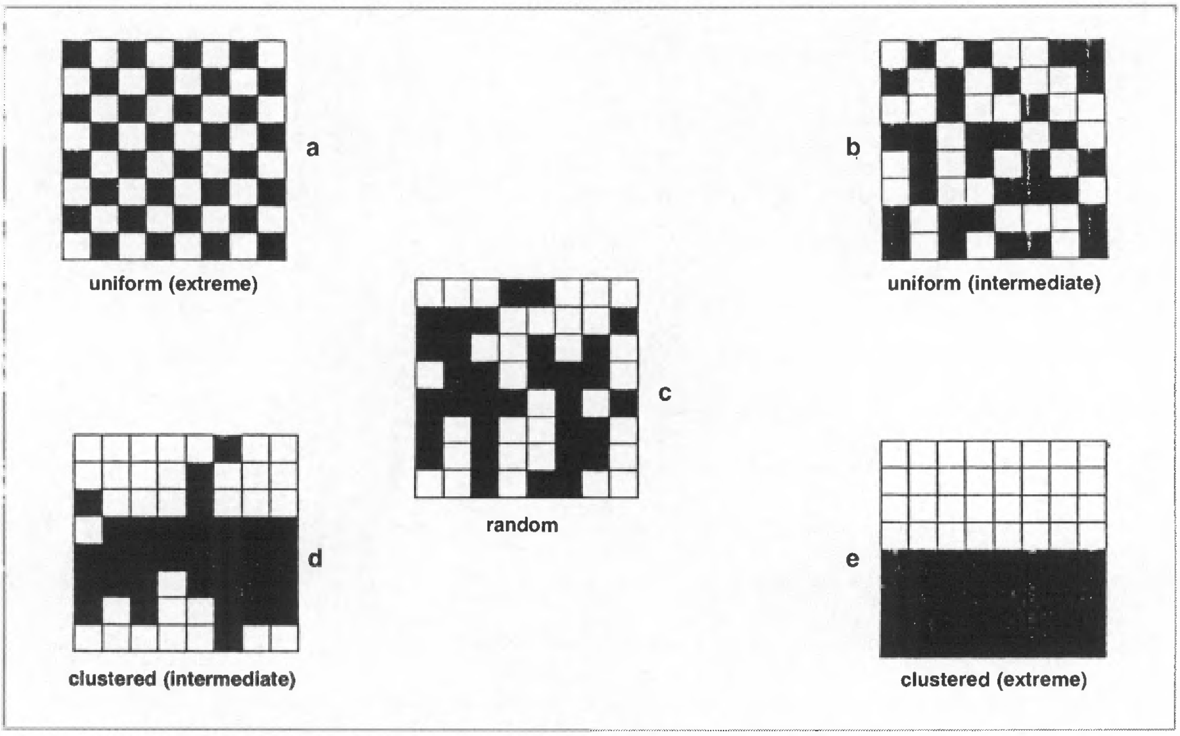


Figure 30: Examples of possible patterning that can be distinguished with the 'Join count statistic'.

tronic machines is the key to success in a many careers. It is probably true that computer technology provides the means to an in-depth analysis of large quantities of data, however, it has to be kept in mind that applications are always biased towards the method and theory of their creators. Additionally they are unable to interpret the obtained results and can therefore never replace the skilled archaeologist.

Every researcher involved with archaeological field work produces large quantities of information and is sooner or later confronted with questions about the data management. Although it is well known that computer databases are powerful tools for storing, managing and analyzing information, most archaeologist even do not know what advantages computer technology might hold for them (Schlader 2002).

For this project it was decided to create a relational computer database to store a comprehensive set of information retrieved from artefact analysis of material remains from Dunefield Midden. As virtually all information was spatially referenced, a Geographical Information System was linked to the database in order to facilitate visualizations and spatial analysis. For the quantitative analysis of the shellfish remains, a statistical software package was used (for details see "The DFM Spatial Database" on page 83.

Computer hard- and software is changing rapidly as processor technology, operating systems and computer applications improve in a constant manner. This extremely fast process leads to a great difficulty for research: archaeological publications from the early 1990s dealing with computer issues are already heavily outdated (e.g. Allen et al. 1990 or Reilly and Rahtz 1992). The strong temporal factor associated with the technology leads to a fast development of computer applications which are even quicker replaced with new ones making it difficult to create a general archaeological data management system that can be used for a long period of time. Although there are some approaches to establish such a system (e.g. Fronza et al. 2001), there seem to be two main factors why archaeologists are still struggling to make a step forward towards extensive use of computer technology:

- Theory and method of archaeological research is very inhomogeneous making it difficult to agree on a set of techniques that are appropriate to answer a wide range of questions.
- Researchers, archaeologists in particular, are still highly technology illiterate.

However, there is a branch of archaeology which is very interested in developing computer systems that help to analyze information retrieved from excavations. Recent developments in computer applications in archaeology were intensively reviewed by Richards (1998) and Kvamme (1999) and the basics of archaeological databases were explained by Schlader (2002). Other examples for more recent database applications can be found in Tsakirakis (2001), Fronza (2001) and Shinoto (2002) and for GIS applications in Constantinidis (2001), Fronza (2001) and Barcelo et al. (2002).

From these publications in can be concluded that the DFM Spatial Database reflects very much the general trend of archaeological computer applications as relational database systems, GIS and quantitative analyses have been developed and used extensively over the last ten years (Richards 1998). The following chapter explains the basic concepts and functions of the DFM Spatial Database.

Figure 31: !Kung camp 14 as recorded by Yellen (Yellen 1977).

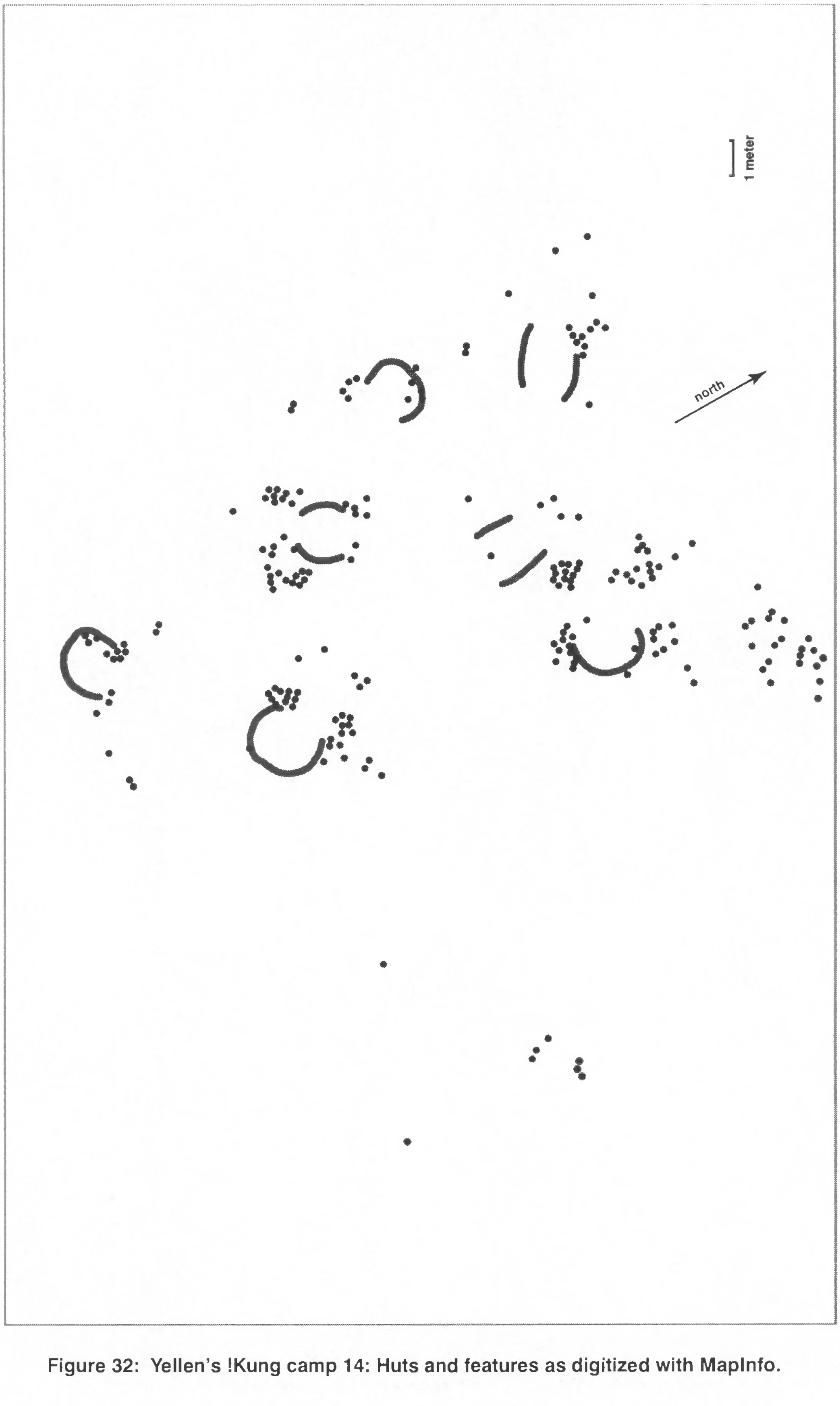


Figure 32: Yellen's !Kung camp 14: Huts and features as digitized with MapInfo.

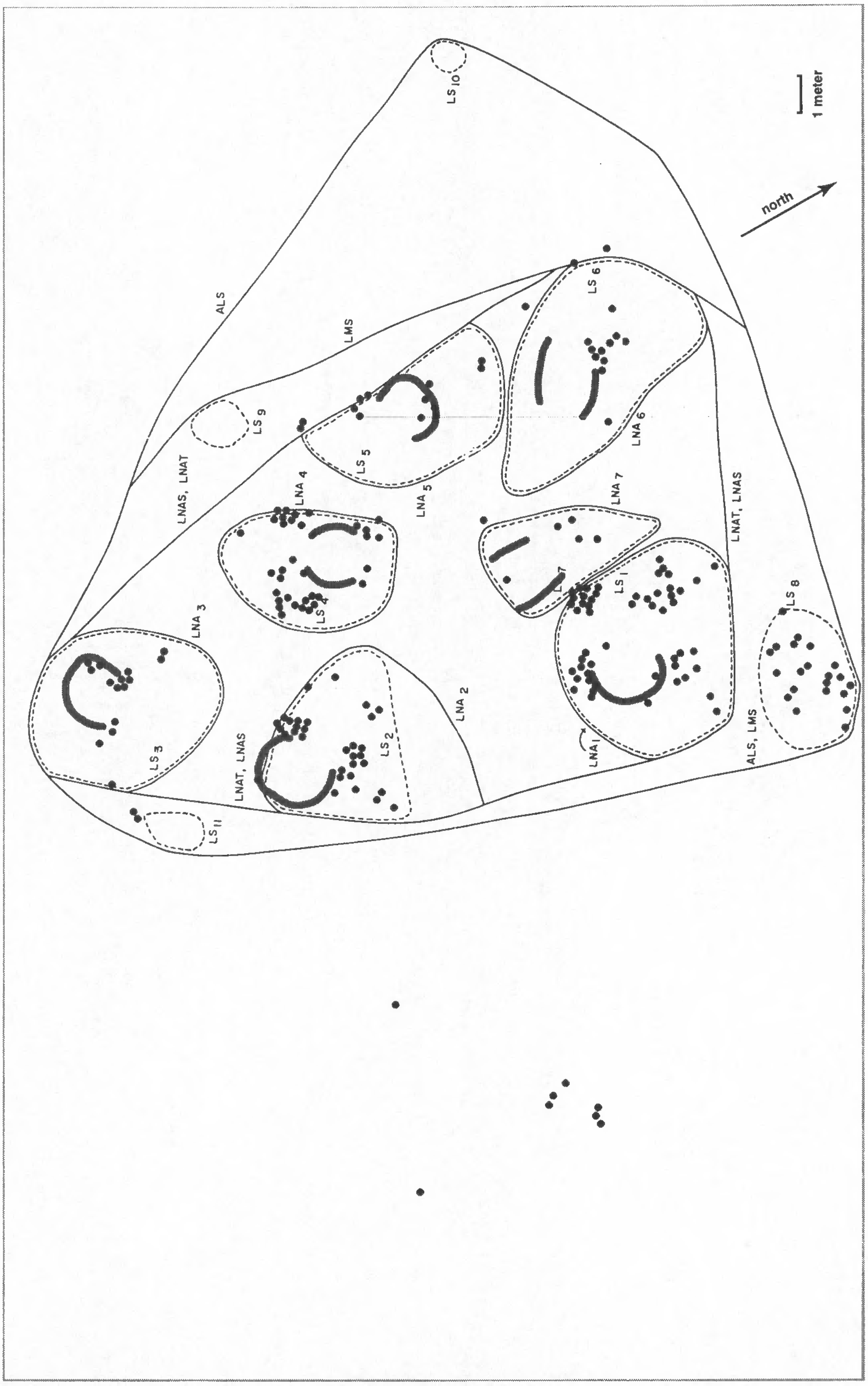
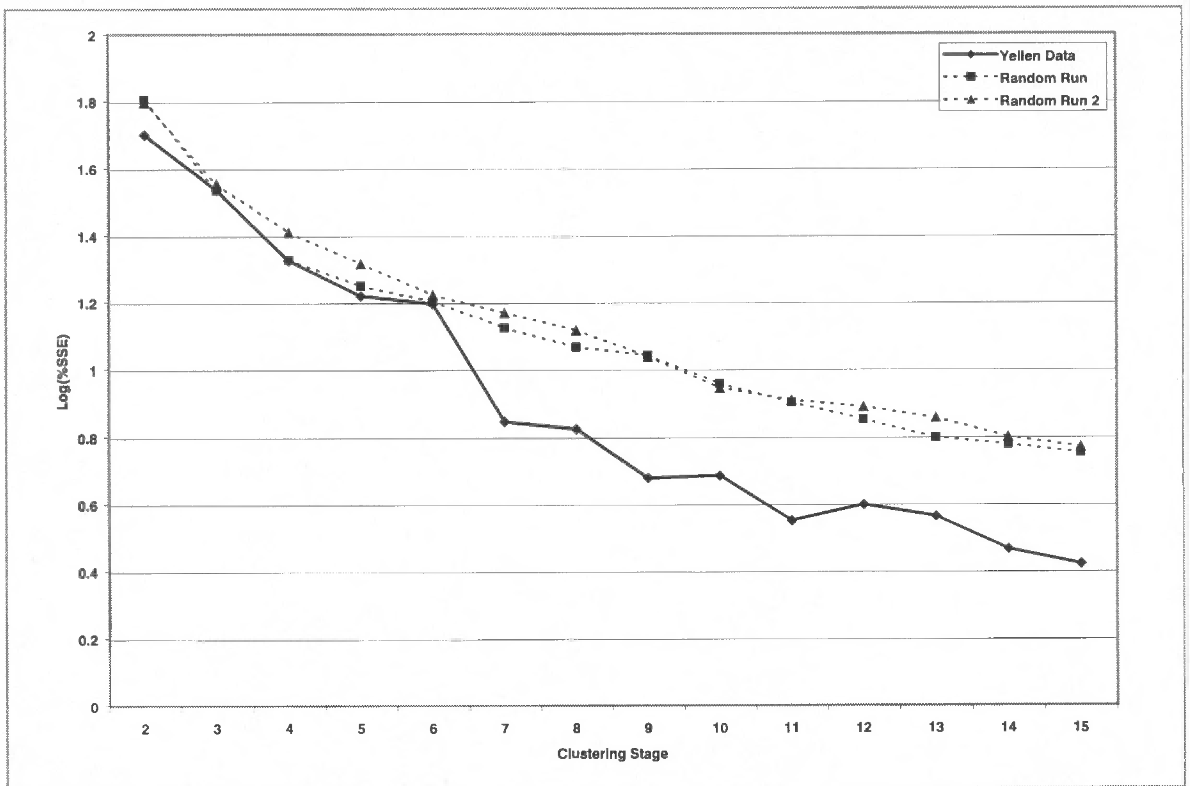


Figure 33: Yellen's !Kung camp 14: Digitized finds and huts with Yellen's scatter outlines; note that the find scatter caused by Yellen and his colleagues was excluded (Yellen 1977).



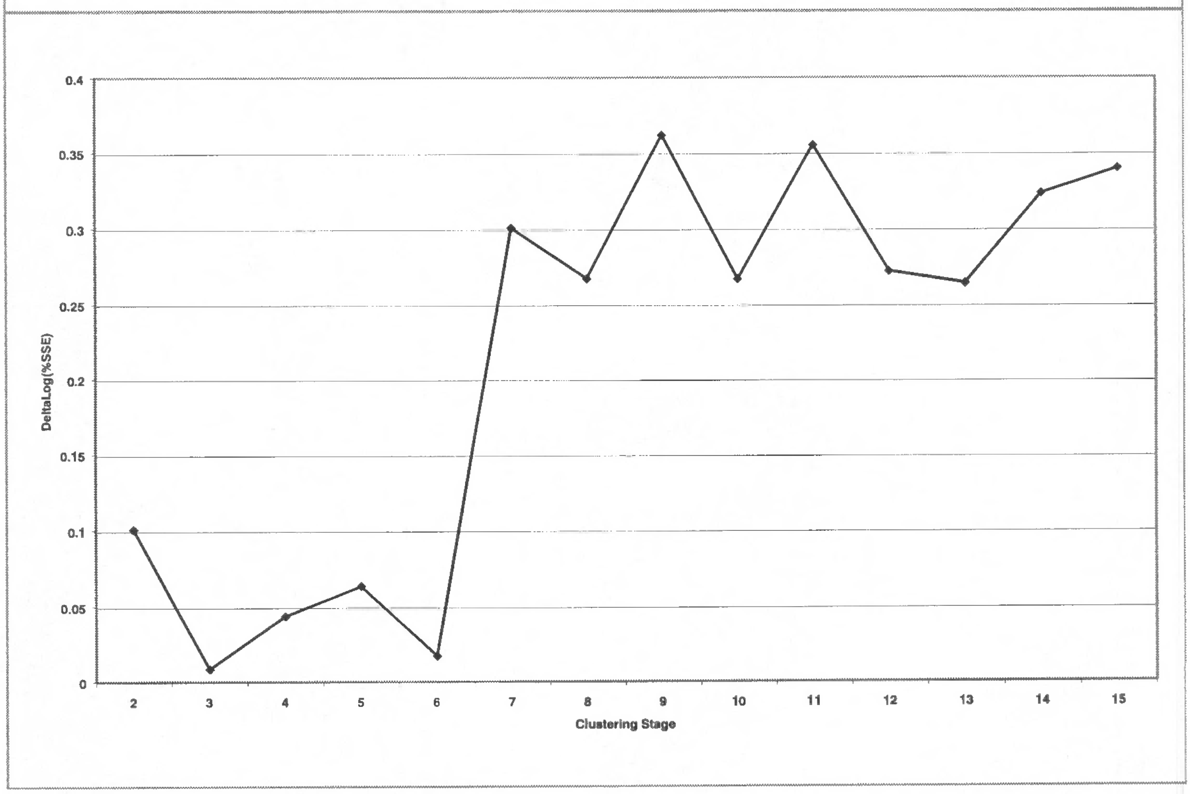


Figure 34: Yellen's !Kung camp 14: Plot of Log(%SSE) for k-means clustering on x- and y-coordinates of finds. (Top)

Figure 35: Yellen's !Kung camp 14: Plot of DeltaLog(%SSE) for k-means clustering on x- and y-coordinates of finds. (Bottom)

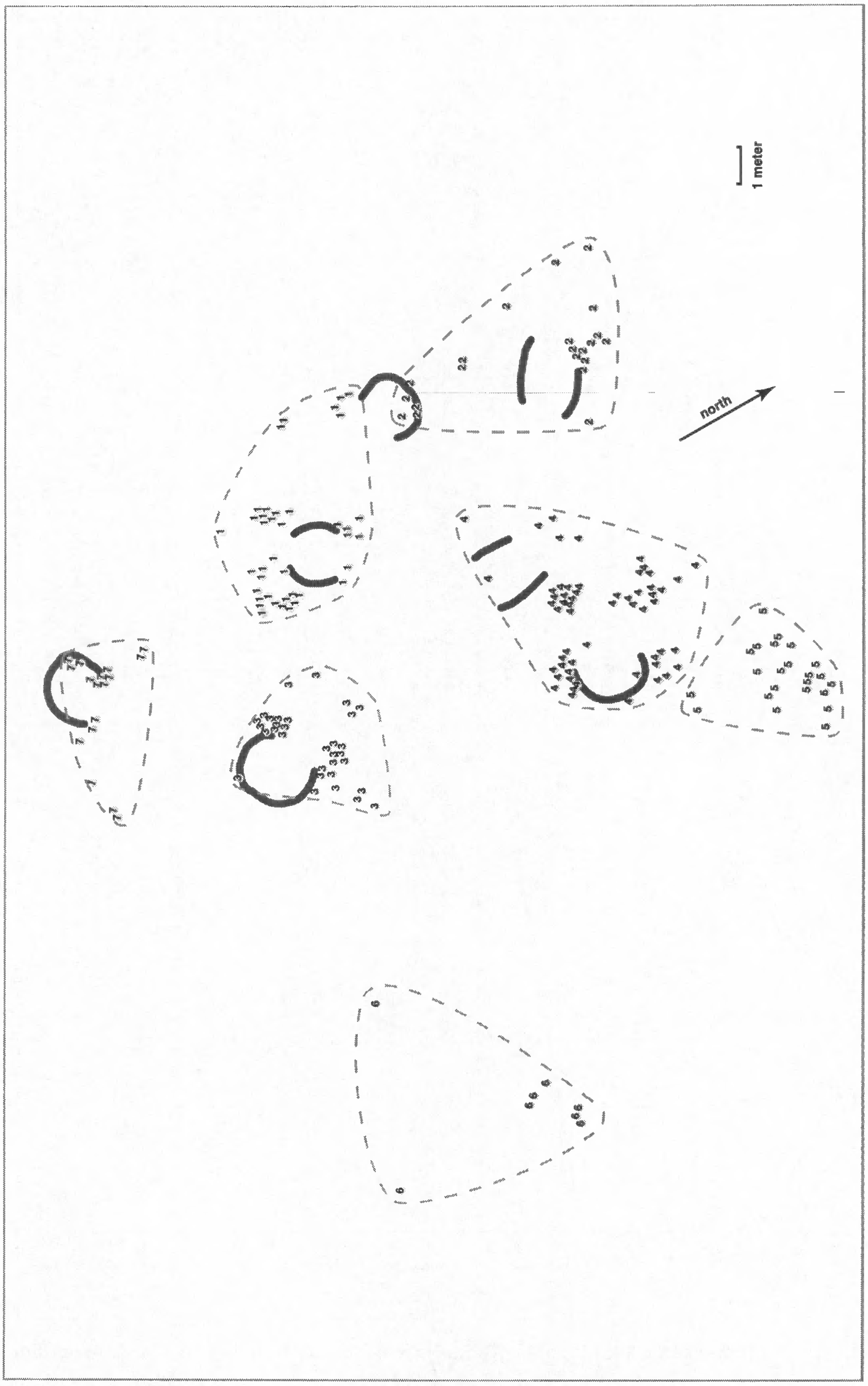


Figure 36: Yellen's !Kung camp 14: Spatial distribution of the seven cluster solution on x- and y-coordinates of finds.

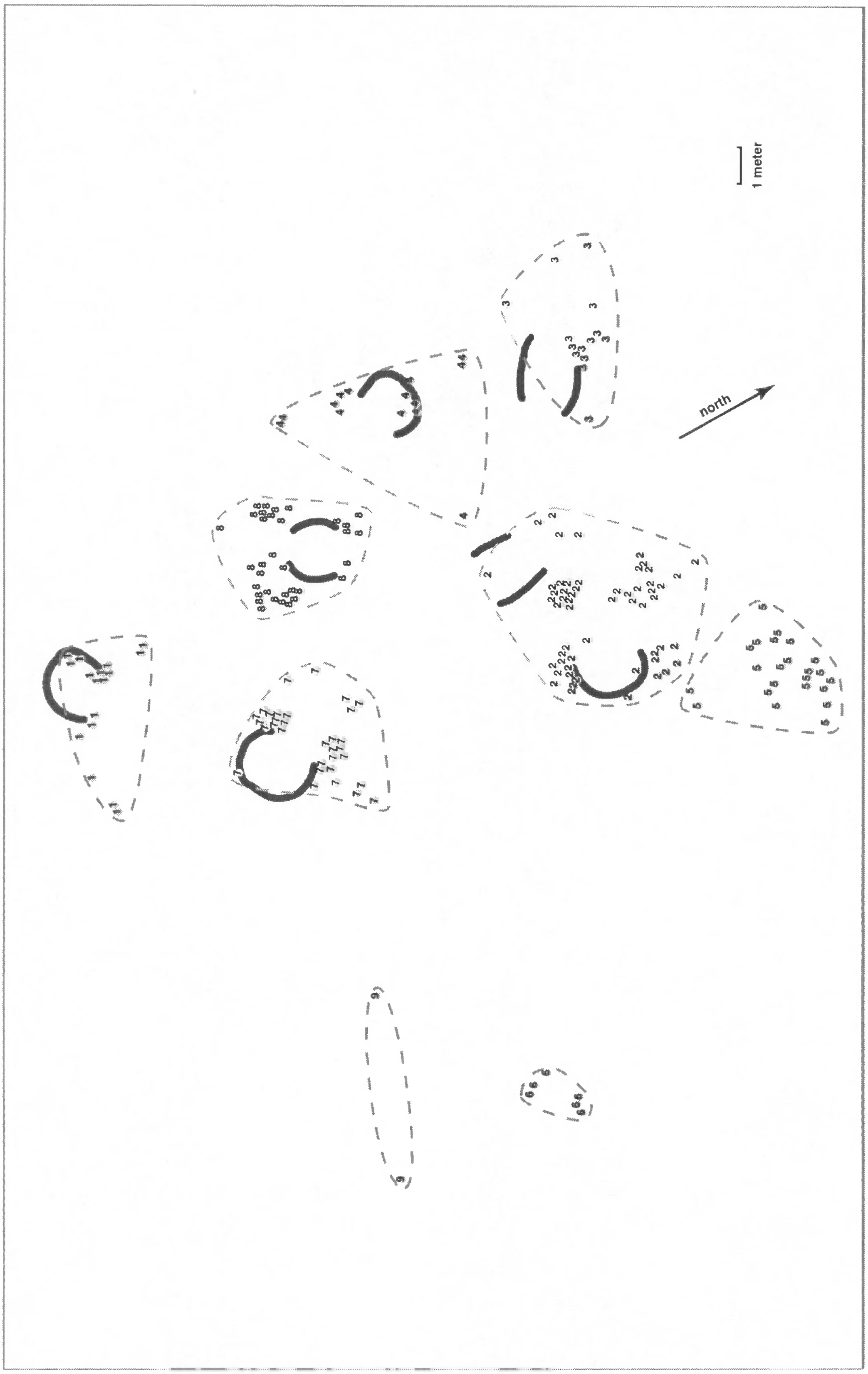


Figure 37: Yellen's !Kung camp 14: Spatial distribution of the nine cluster solution on x- and y-coordinates of finds.

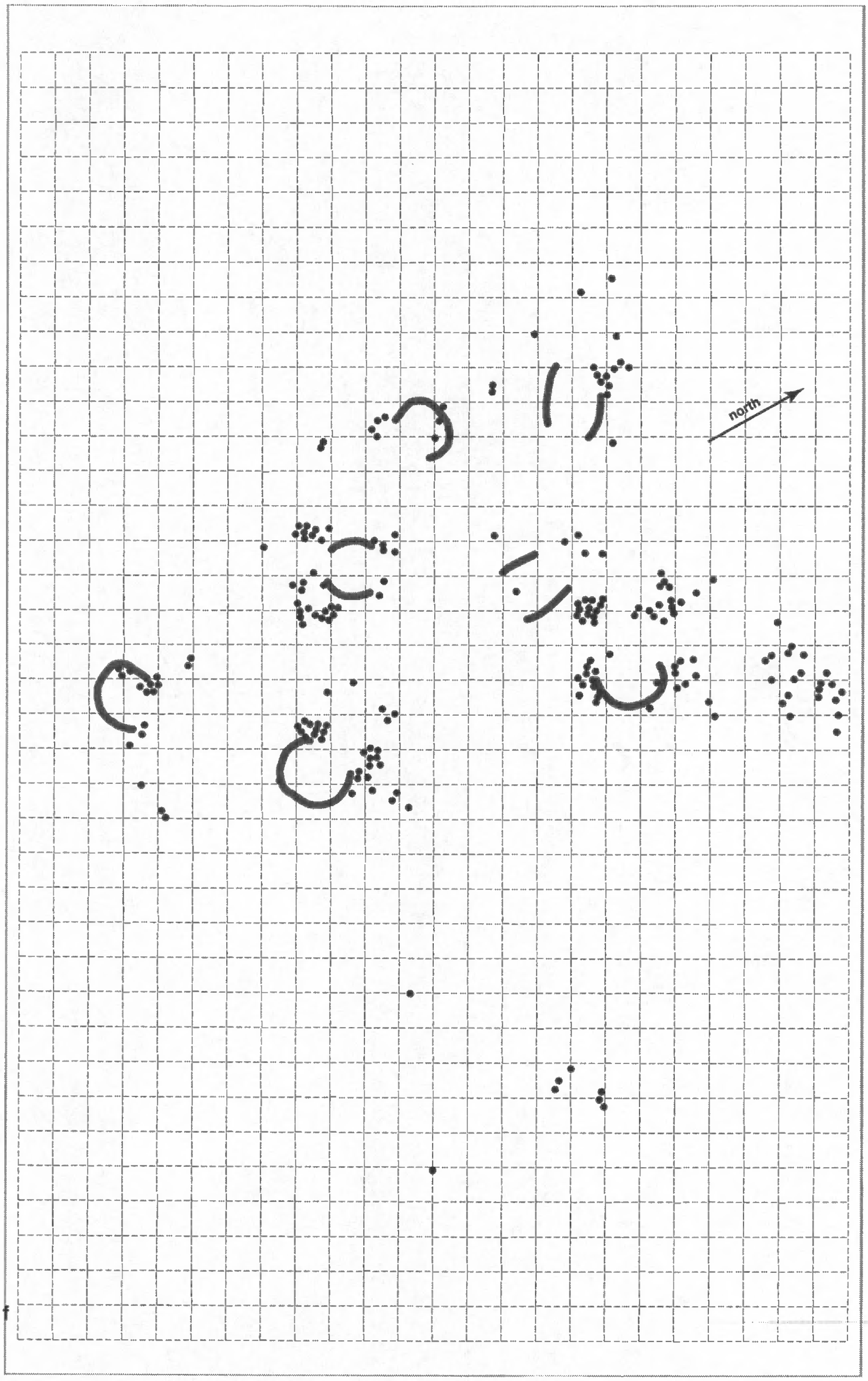
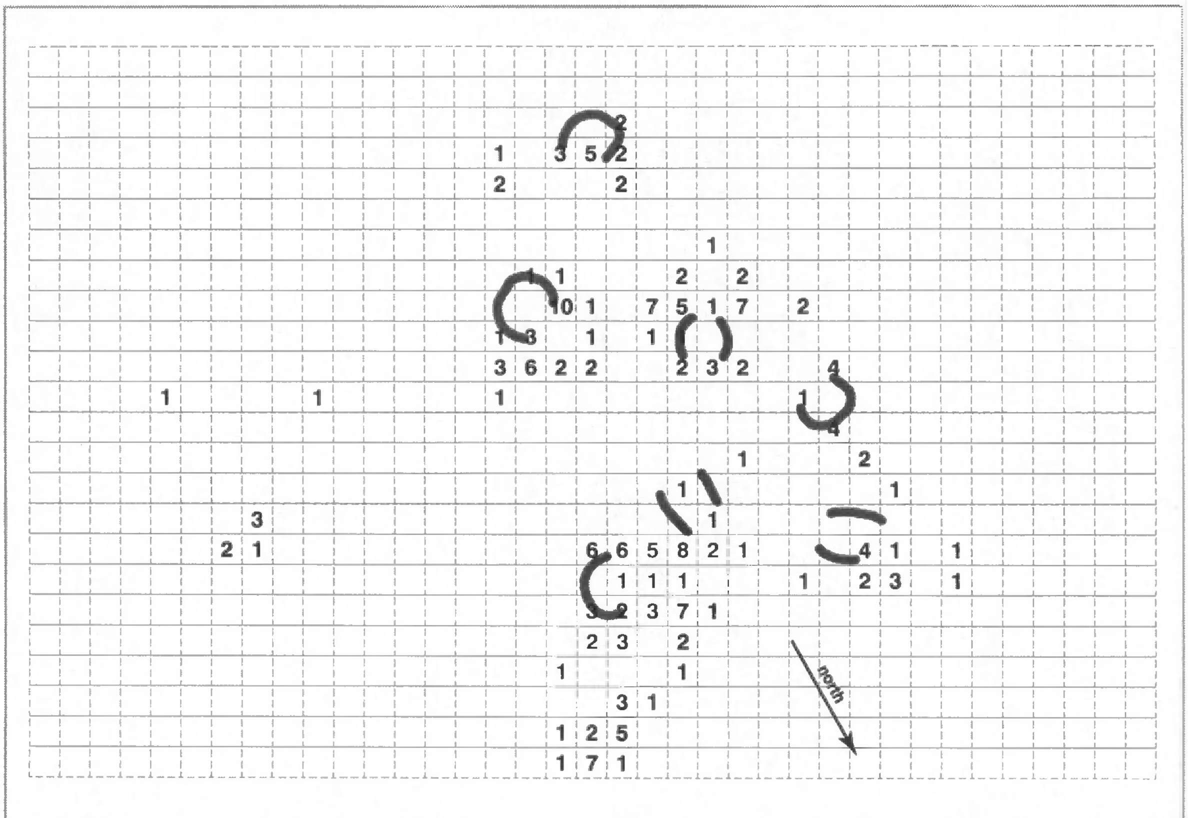


Figure 38: Yellen's !Kung camp 14: Digitized huts and finds with a square meter grid.



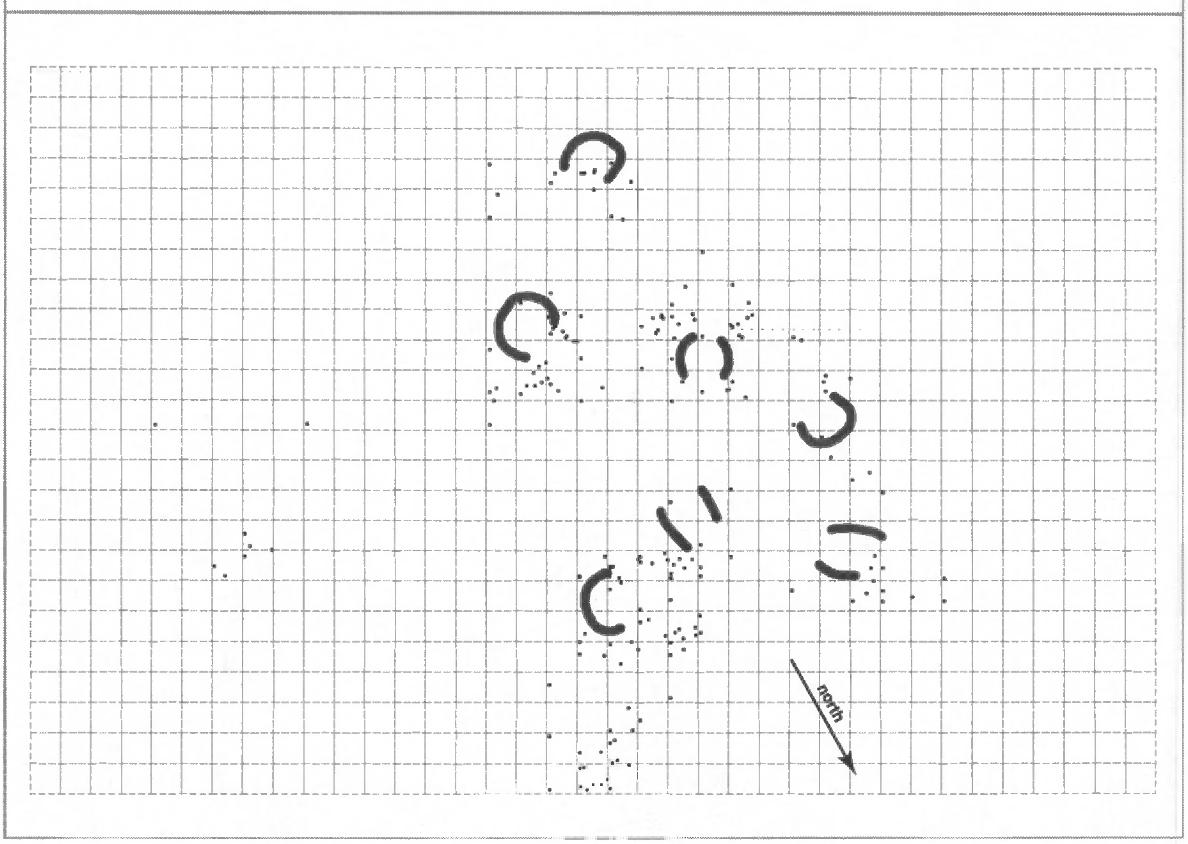
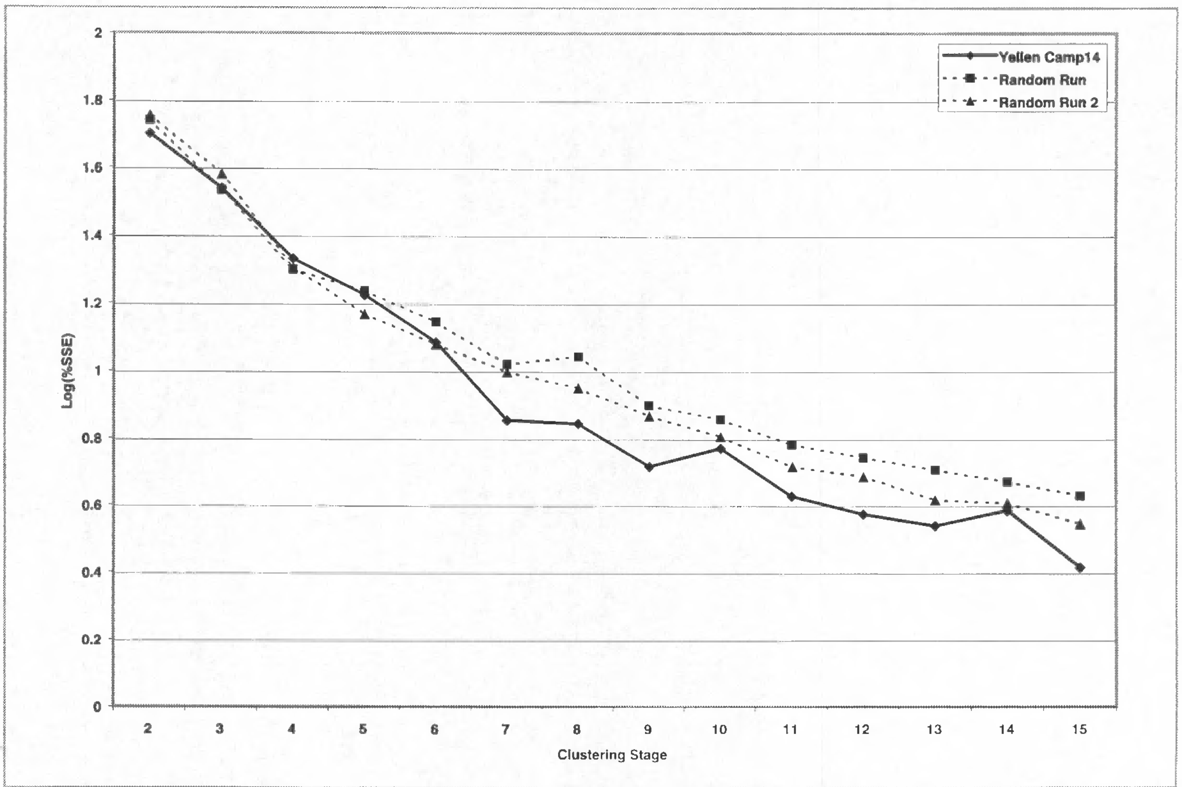


Figure 39: Yellen's !Kung camp 14: Counts of finds per square. (Top)

Figure 40: Yellen's !Kung camp 14: Dot density plot of counted finds per square (compare to Figure 38). (Bottom)



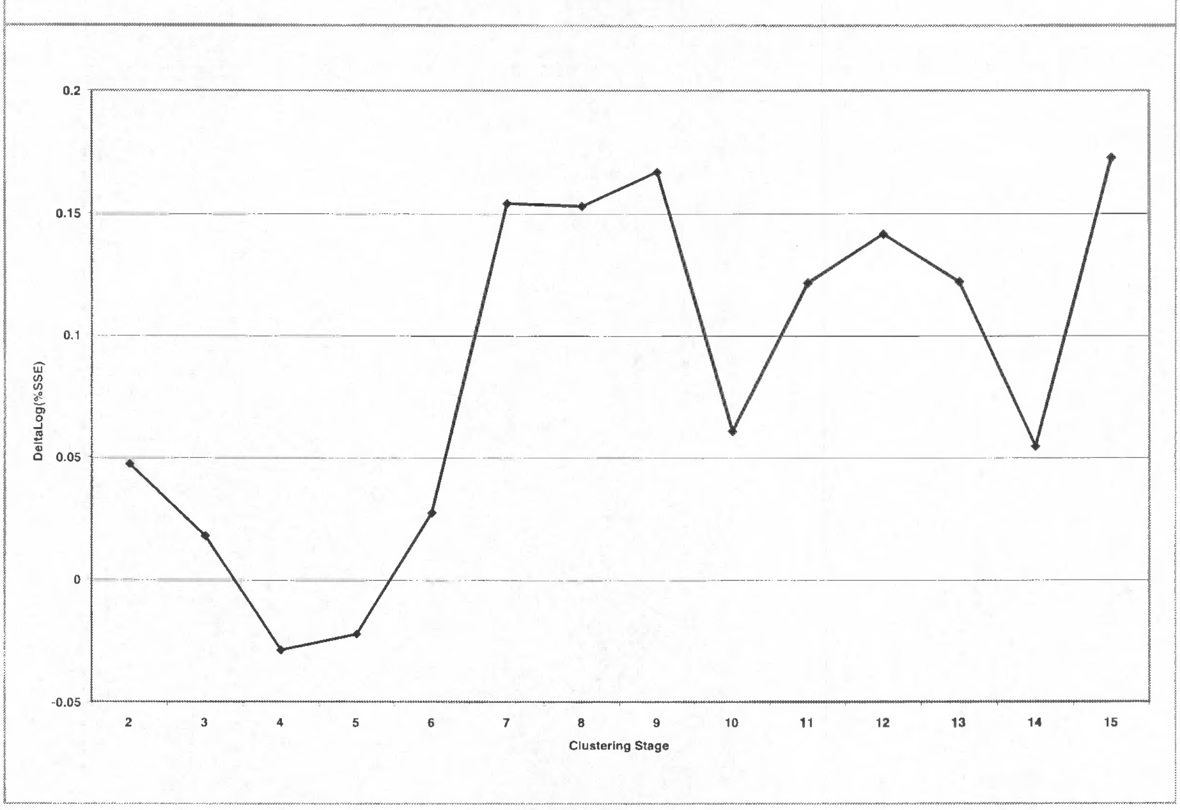


Figure 41: Yellen's !Kung camp 14: Plot of Log(%SSE) for k-means clustering on counts of finds per square. (Top)

Figure 42: Yellen's !Kung camp 14: Plot of DeltaLog(%SSE) for k-means clustering on counts of finds per square. (Bottom)

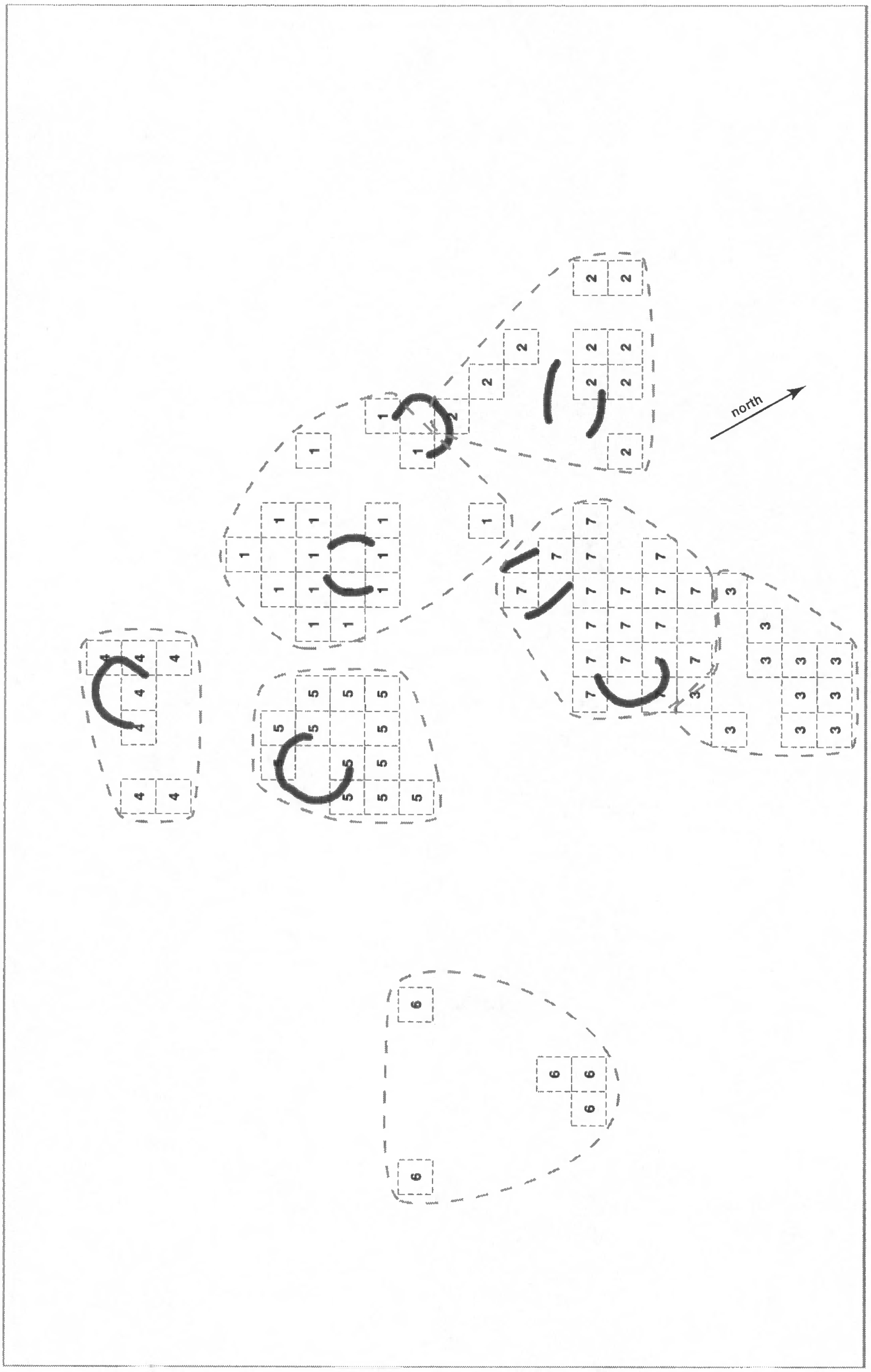


Figure 43: Yellen's !Kung camp 14: Spatial distribution of the seven cluster solution on counts of finds per square.

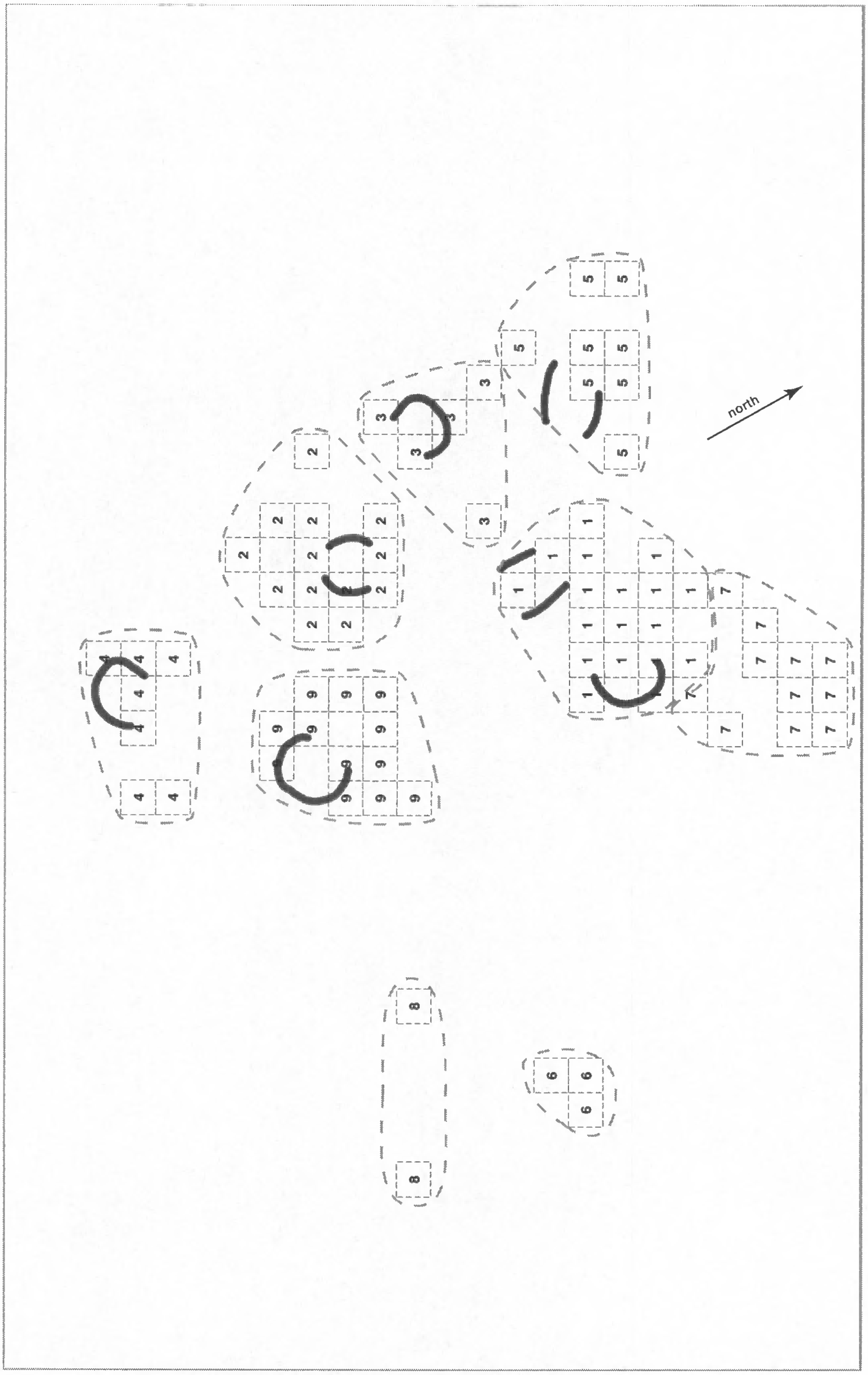


Figure 44: Yellen's !Kung camp 14: Spatial distribution of the nine cluster solution on counts of finds per square.

CHAPTER IV THE DFM SPATIAL DATABASE

1 INTRODUCTION

Archaeological databases

In today's Stone Age excavations archaeologists meticulously record the smallest finds, describe the matrix, shape and position of features and apply complex categorization systems in their post-excavation analysis of the recovered material. The history of archaeological fieldwork shows that there has been a growth in the amount, diversity and detail of recovered information from archaeological sites. This growth of data for potential analysis creates the need for intelligent data management systems making databases more and more important in archaeological research.

Several excavations use computer databases as a tool for data storage and replace the 'traditional' method of recording on paper and others have developed computer data management systems and use them for analyzing their data. However, the majority of archaeological projects are not equipped with modern hard- and software and if they are, they have only little know-how for using it.

Creating a database for an archaeological site can be seen as part of a process leading to an understanding of the material culture and its implications to behavior and social organization of humans. Figure 45 illustrates this process that starts with the excavation of a site and ends with an interpretation of the occupational remains. The archaeological database has its place somewhere in the middle of this scheme and contributes essentially in means of data management and data analysis.

A productive database provides both the flexible availability of all the raw data and an intelligent data processing strategy. Complex categorization systems are very often applied in archaeological data analysis and thus demand a complex data management system. It is generally accepted that spatial information can be perceived best when displayed on maps. Therefore it needs a portal for visualization and spatial analysis. Today's software packages for database applications, spatial and statistical analysis can provide the tools for creating an integrated Spatial Database.

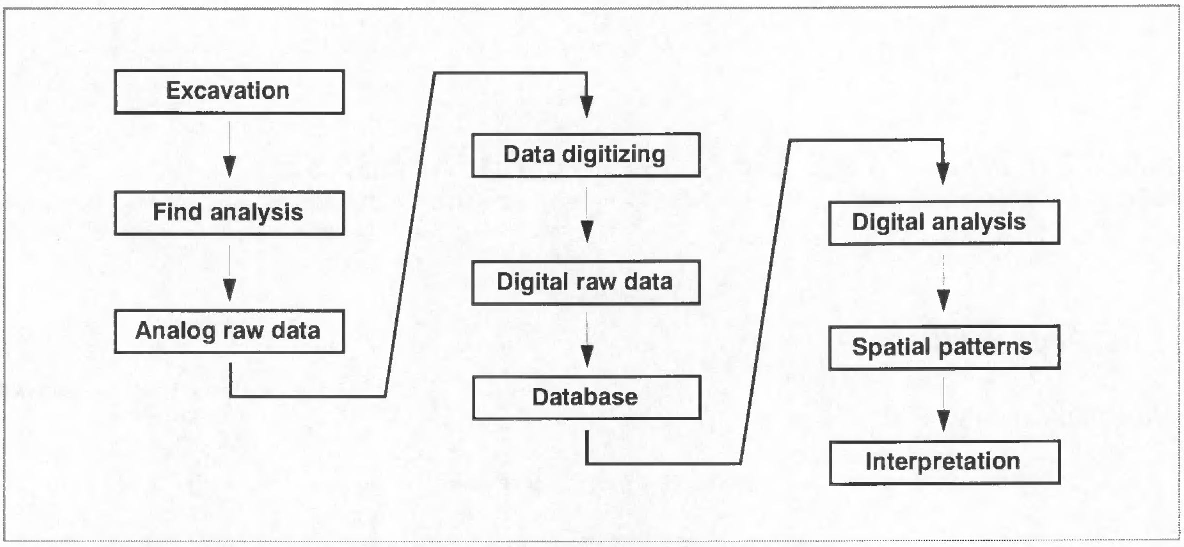


Figure 45: Schematic chart of the research process.

It was in this sense that the Dunefield Midden Spatial Database Project was launched. Its main goals were defined as follows:

(a) to make all numerical and spatial raw data digitally available

(b) to design queries for manipulation of the raw data

(c) to link statistical analysis tools to the spatial database

(d) to link a Geographical Information System to the spatial database for visualization and spatial analysis.

Hard- and Software

The Dunefield Midden Spatial Database covers two areas: data management and data analysis. A decision had to be made as to which hardware systems and software packages would be used. Two options were available concerning the hardware which strongly influenced the availability of software packages: Personal Computer (PC) and Apple Macintosh (MAC). MAC computers are partly used in the Archaeology Department of UCT, especially for rock art research projects and John Parkington's 'Living Landscape Project'. However, the majority of computer users on campus and in the archaeological computer world in general are using PCs.

Table 14 shows the results of a brief survey of available software packages for MAC and PC concerning the three important application areas of databases, Geographical Information Systems and statistics. Licensed versions of Microsoft Access and Statistica were available from ITS of UCT for research purposes. ArcView/ArcInfo was available through the Geomatics Department of UCT but no licensed copy could be obtained for the use in the Archaeology Department. Work with this GIS software, therefore, could only be done in the Geomatics Department. Filemaker Pro,

Software type	MAC	PC
Database	FileMaker Pro, 4th Dimension	Microsoft Access, FileMaker Pro, 4th Dimension
Geographical Information System	ArcView/ArcInfo, GRASS	MapInfo, ArcView/ArcInfo
Statistics	DataDesk	Statistica, SPSS, DataDesk

Table 14: Available software packages for MAC and PC.

4th Dimension, SPSS and DataDesk were not used at UCT regularly and must be purchased. A version of GRASS was freely available through the internet.

It was decided to use a PC system with regard to the abundant software packages. As a statistical analysis software Statistica was chosen because it was readily available through UCT. For the GIS part, a fairly priced educational version of MapInfo was purchased. Microsoft Access is the most popular application on the PC of the three considered databases. Together with its wide range of capabilities for a complex database design and the full support by MapInfo it presented the best alternative for the Dunefield Midden Spatial Database.

Database design

Database design has to be based on the raw data structures. These have to be evaluated and then transformed into a database structure. The type, size and valid entries for fields have to be considered in order to setup the tables of the database correctly. In some cases the raw data structure has to be modified if it doesn't concur with the database structure striven for. The actual needs of later analysis have to be evaluated to guarantee the proper capabilities of the final database system. Given the ideal case there are no restrictions in data query options and the database provides maximum inter-connectivity of all its parts.

Archaeological work produces several data sets representing different data categories. They can be distinguished by the type and format of information they contain (Table 15). In order to make this information available in a database, different *digitizing processes* need to be applied based on the raw data format. The result is a specific digitized format that can be used as raw data for an archaeological database.

The complexity of the DFM raw data made it necessary to design separate databases for each find category (see "Archaeological material" on page 10). The advantage was a clear differentiation between separate parts of the DFM analysis as well as the smaller sizes of individual databases compared to one large database containing all the information. Through links between the databases, tables or queries from different databases could be connected to each other.

Category	Information type	Raw data format	Digitizing process	Digitized format
Pictorial data	Prints or slides	Hard copies	Scanning	Pixel
	Digital photos	Pixels	n/a	Pixel
Descriptive data	Field notes	Letters	Keyboard input	Text
	Drawings	Shapes, points	CAD digitizing	Vector
Quantitative data	Analog measurements	Letters	Keyboard input	Number
	Digital measurements	Numbers	n/a	Number

Table 15: Archaeological data categories in analog and digital formats.

The data management and the data analysis were integrated into one database system. This could be achieved through inter-connectivity between these two parts enabling 'up-to-date' exchange of information. MapInfo and Statistica are both supporting 'Open Database Connectivity' (ODBC) which enables them to access the database information directly (Figure 46).

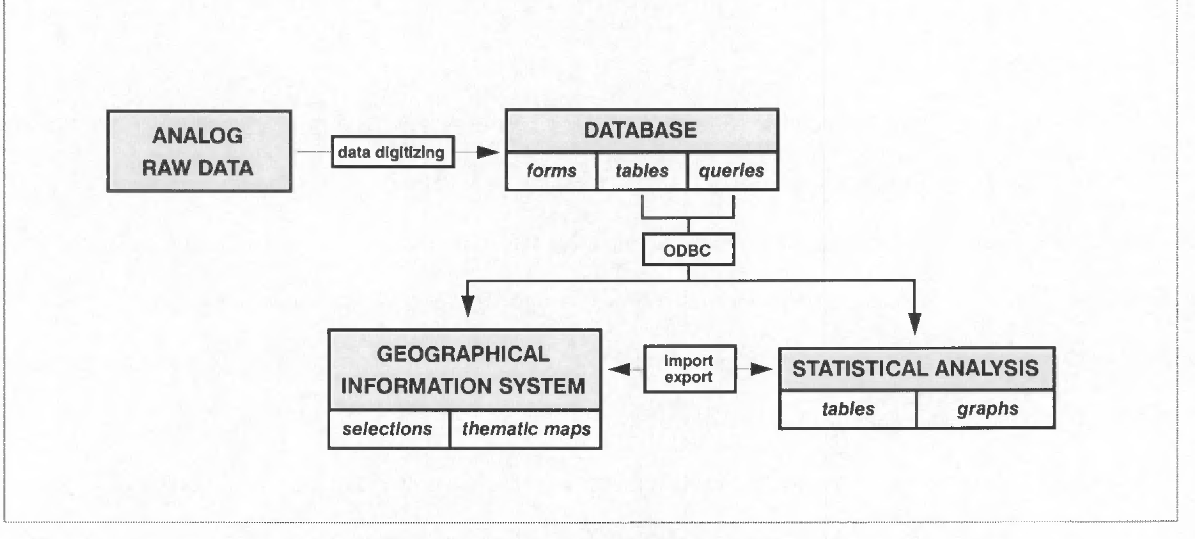


Figure 46: DFM Spatial Database Flow Chart.

Only in few occasions the raw data was already available in digital format. In all the other cases, data had to be inputted manually (see "Raw data evaluation" on page 91). Specific forms were created for all database parts to make the data input easy and to prevent the user from entering invalid or wrong data. Data queries were designed to produce primary processed data for further analysis. Table 16 gives an overview of the number of tables, queries and forms existing in each database (see "Database structure" on page 201 for details). A GIS map of all the features was produced to serve as a base map for distribution plots and as spatial reference for spatial analysis ("Feature Map" on page 12).

Database	Tables	Queries	Forms
Spatial Reference	8	8	-
Shellfish	47	53	45
Lithics	60	60	75
Bones	28	6	14
Features	19	30	13
Ceramics	5	7	5
OES	7	8	6
Charcoal	6	1	2
Refits	4	1	-
Transects	5	8	5

Table 16: DFM Spatial Database parts and their counts.

Please note that only numerical and spatial information was transferred into the DFM Spatial Database. This was for two reasons: (1) Other information would not contribute significantly to the spatial analysis of the site structure. (2) Time constrains limited the amount of data that could be entered. Thus the following information is not included in the DFM Spatial Database: photographs, field notes, top plans and section drawings.

Datasets

Although it was an initial goal of this project to create a complete DFM dataset, this could not be achieved. Primarily this was due to the fact that several find categories were not completely analyzed by the time this database was produced. In general there is more information available about finds recovered in earlier seasons (see Table 17 for an overview). Nonetheless the major datasets of shellfish, lithics and large fauna remains from Dunefield Midden are complete. The content of the DFM Spatial Database can be quantified by the number of specimen for each find category (Table 18). Additionally there are several thousand measurements of individual shells from different shellfish species available (Table 19). These quantitative overviews can only give an outline of the amount of data stored in the database as each specimen may have several quantifying or describing attributes.

	Ceramics	Crayfish mandibles	Large fauna	Lithics	Microfauna	OES	Shellfish
Years	1988	1988	1988	1988	1988	1988	1988
	1989	1989	1989	1989	1989	1989	1989
	1990	1990	1990	1990	1990	1990	1990
	1991	1991	1991	1991		1991	1991
	1992	1992	1992	1992		1992	1992
	1993	1993	1993	1993		1993	1993
	1994		1994	1994		1994	1994
	1997		1997	1997		1997	1997
	1998		1998	1998		1998	1998
	1999		1999	1999		1999	1999
			2001	2001			2001

Table 17: Excavation seasons by find category that have been analyzed and entered into the DFM Spatial Database (on 10-12-2002).

	Ceramics	Crayfish mandibles	Large fauna	Lithics	Microfauna	OES	Shellfish
Specimen	1004	9157	9073	18287	1745	1204	>384196

Table 18: Specimen counts for DFM finds available in the DFM Spatial Database (on 10-12-2002).

	Patella granatina	*Patella granularis*	*Patella barbara*	*Patella argenvillei*	*Patella miniata*	*Patella cochlear*	*Patella compressa*	*Choromytilus meridionalis*
Measurements	27914	26544	1873	728	134	128	10	31691

Table 19: Measurement counts for DFM shellfish available in the DFM Spatial Database (on 10-12-2002).

Data analysis

With the Structured Query Language (SQL) options of MapInfo, the raw or processed data of the DFM Spatial Database can be spatially linked to the feature map. Distribution plots can be created by using the 'Thematic Maps' tools of MapInfo. Statistica provides a large range of statistical analysis tools. Tables from the database are imported and new tables with statistical results can be produced. Graphs of the raw data or of the analysis results can be used as a visual display and help to identify significant patterns. Tables with statistical results can be exported to MapInfo to perform spatial analysis or for visualization.

The following paragraphs give a broad overview about the principal design and functions of the database, GIS and statistical analysis. For a detailed description of the database structure please refer to the appendix "Database structure" on page 201.

2 DATABASE FUNCTIONS

Introduction

In this project Microsoft Access 2000 was used as a database software. Access provides a wide range of design and programming tools to create a complex database which generally involves four basic steps: (1) evaluation of the raw data structure, (2) design of database tables and their relationships, (3) data input / import, (4) design of data queries.

It was mentioned before that the DFM Spatial Database consists of several small databases, each containing the analysis results of one find category. All of them are connected to the Access Spatial Reference database and to the feature map in MapInfo (Figure 47). The 'Spatial Reference Database' provides all numerical spatial information about units, squares and finds while the feature map contains the location and size of all features and serves as a visual spatial reference.

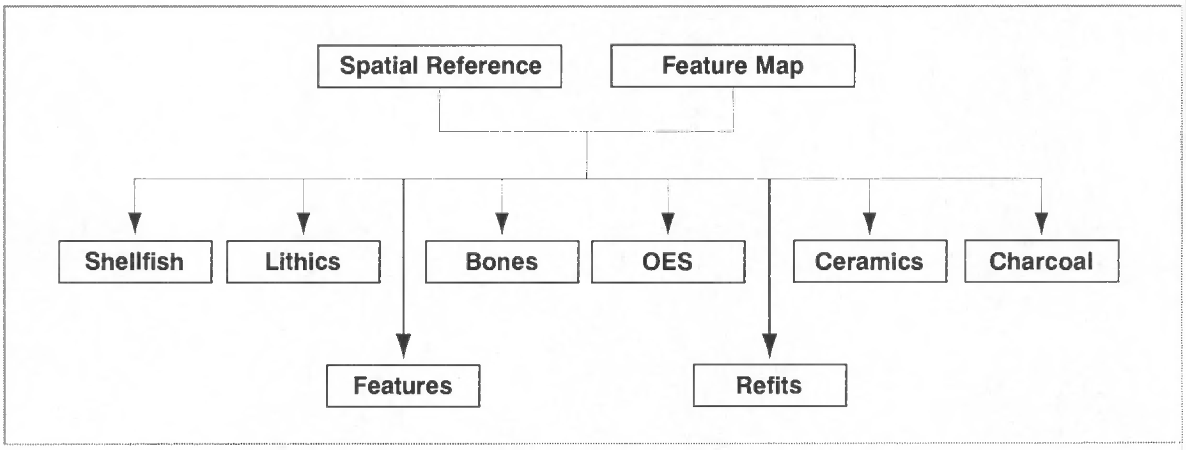


Figure 47: DFM Spatial Database: the individual databases.

Access uses objects as a structuring component in a database. In version 2000 seven objects exist (Table 20) representing different areas where specific information / instructions are stored and different tasks of the database are performed. The most important objects for our area of interest are 'Tables', 'Queries' and 'Forms'. Tables are used to store raw data, queries to process the raw data and forms to manage the data from the tables and queries. Figure 48 shows the object menu in Microsoft Access in the middle of the left side.

Object	*Content*	*Task*
Tables	raw data and field definitions	data storage
Queries	SQL instructions how to process data	data processing
Forms	instructions how to display data	data management
Reports	instructions for data printouts	data presentation
Pages	instructions how to display data for internet pages	data sharing via internet
Macros	code for automated data processing in macro language	simple database programming
Modules	code for automated data processing in visual basic language.	advanced database programming

Table 20: Objects in Microsoft Access and their contents and tasks.

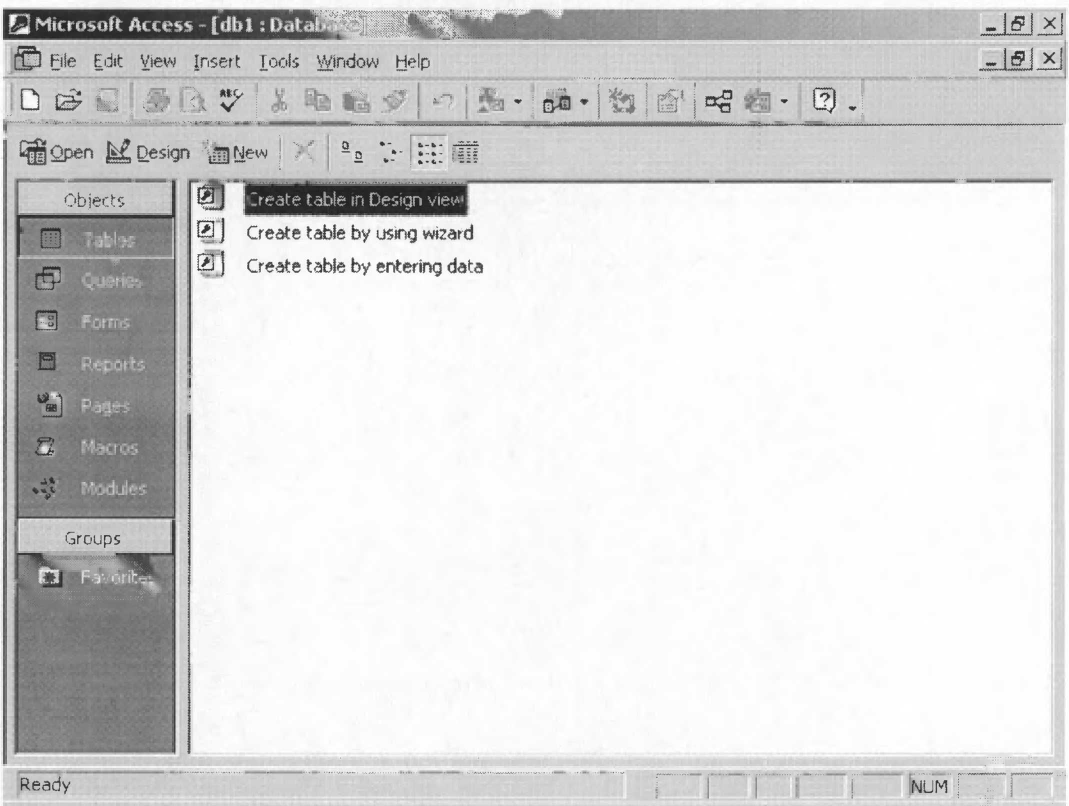


Figure 48: Screenshot of objects menu in Microsoft Access.

Raw data evaluation

Before starting to design a database the original raw data formats and the raw data quality have to be surveyed. Data types, sizes, range of values and the relationships of fields need to be known in order to specify tables that will make up the database structure. The original find analysis processes should be evaluated to be able to judge data quality.

For DFM the survey of the data showed that there were several formats that had to be considered (Table 21). Most of the information was not digitally available (i.e. handwritten on paper) and had to inputted manually. Digital information (AutoCAD, Access and Excel files) had to be restructured to fit the general database layout. A detailed description of data types and relationships can be found in appendix IV (see "Access tables" on page 201).

The original analysis of DFM finds was done by dozens of people (mostly students) and supervision was usually given by several specialists. Data quality has to be evaluated by testing ongoing analyses processes or by checking analyzed data. For this project only the shellfish category was checked for data quality (see "Data quality" on page 19 and "Variability of DFM shellfish analysis" on page 109).

Data category	*Raw data formats*
Shellfish	Handwriting
Lithics	Excel tables
Bones	Excel tables, handwriting
OES	Excel tables, handwriting
Ceramics	Excel tables, handwriting
Charcoal	Handwriting
Refits	Excel tables
Features	AutoCAD, Access
Catalogue	Excel tables, handwriting
Transects	Handwriting

Table 21: DFM data categories and their raw data formats.

Table design

The advantages of a relational database to a normal spreadsheet program (like Microsoft Excel) lie in the ability to relate tables to each other. These *relationships* are the key to a complex database. The design of the tables and their relationships determine the abilities and the productivity of the system. For example every excavated DFM square containing information from analyzed shellfish is connected to the Spatial Reference Database which holds the information about the exact location of the square on the site (Figure 49). Thus the shellfish data can be plotted at the right point in space. The information about the location does not have to be repeated in each new table where the name of a square occurs. The tables can retrieve information from each other because they contain fields with matching keywords.

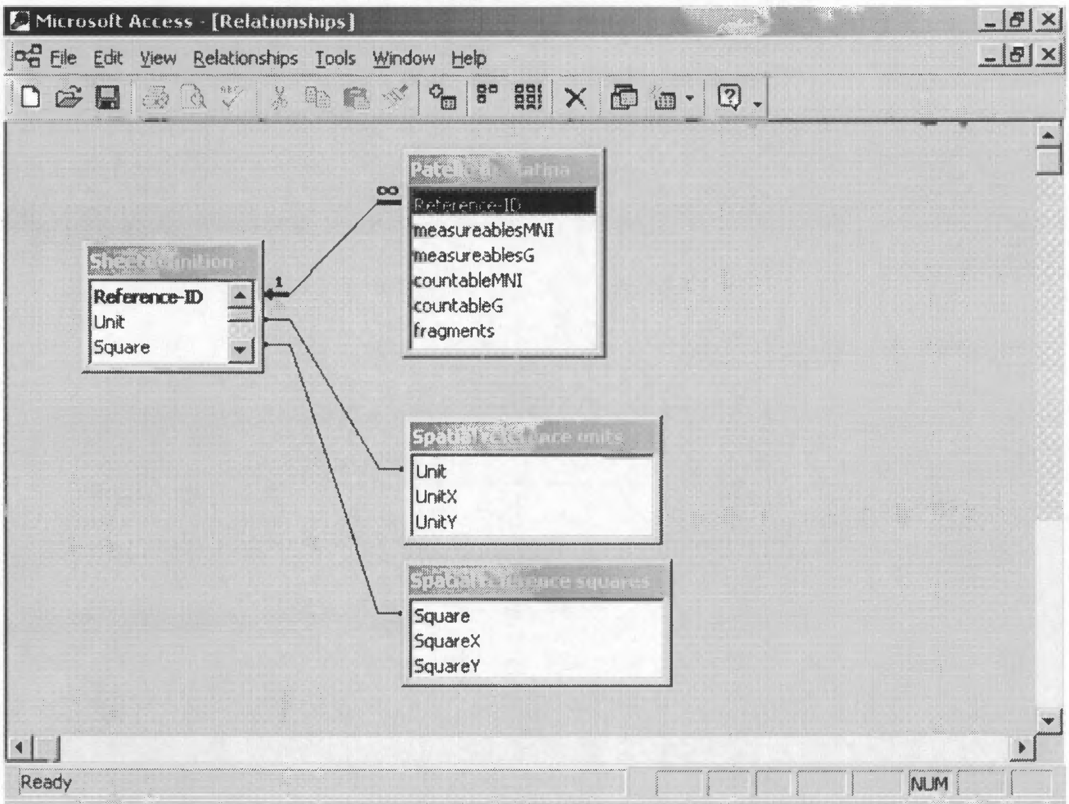
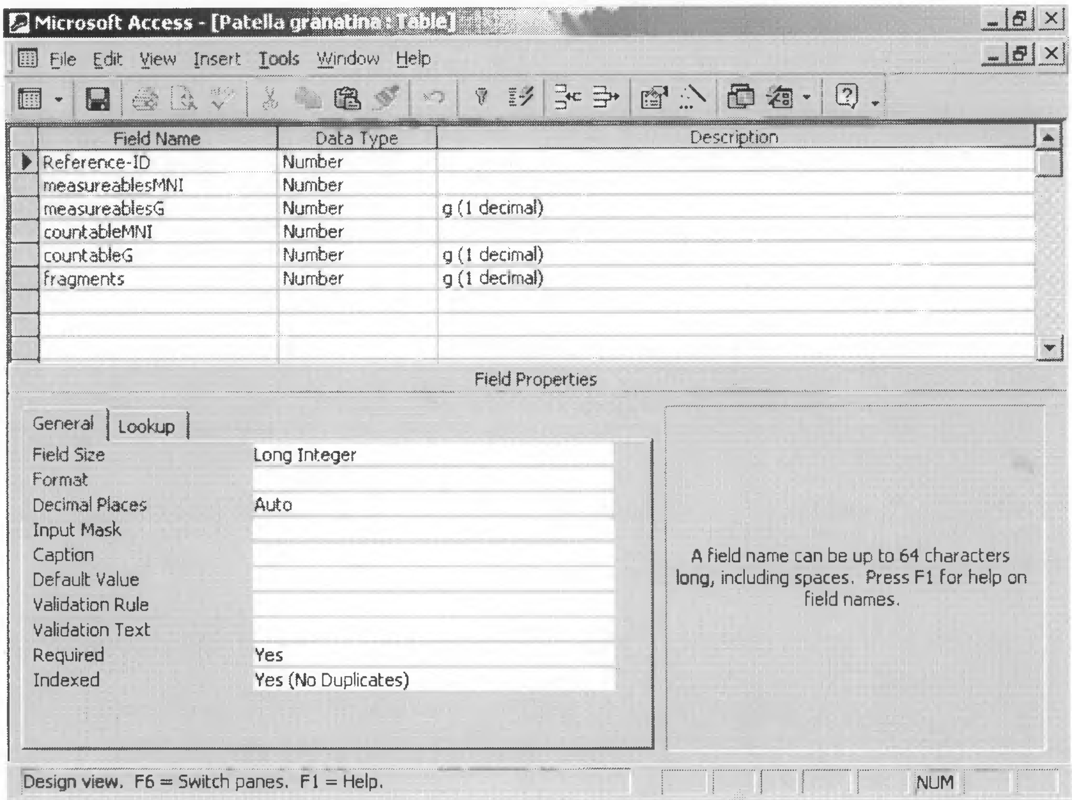


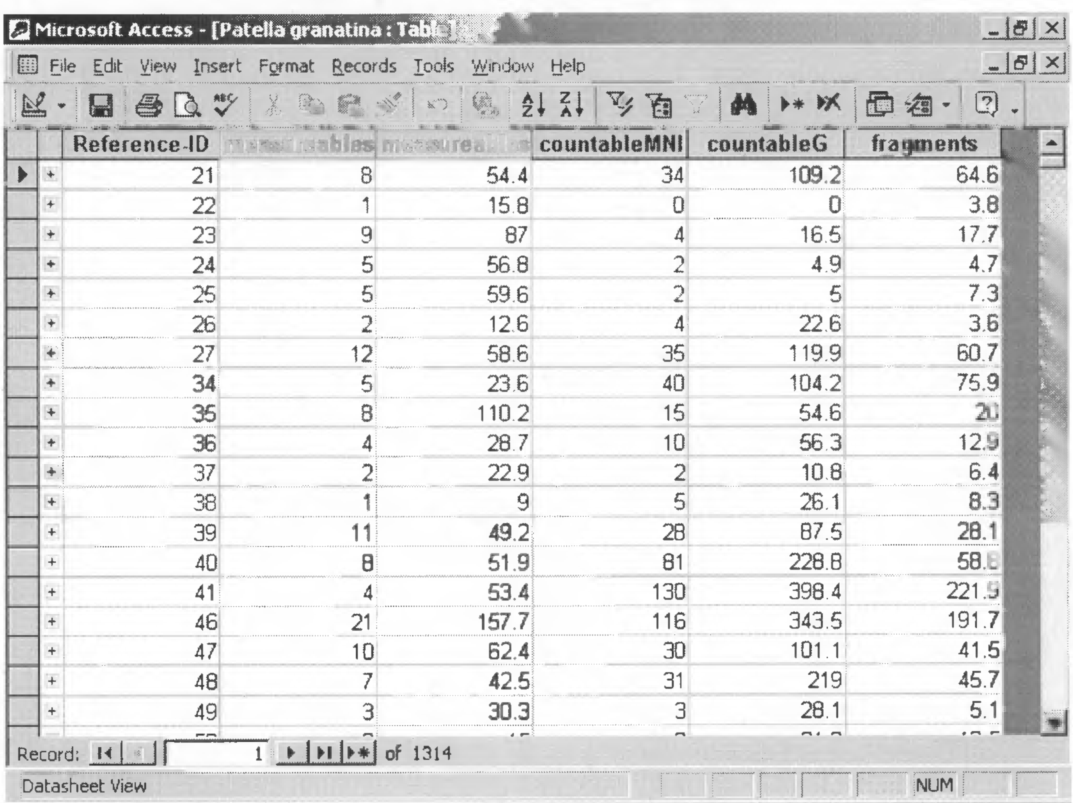
Figure 49: Screenshot of 'Relationships' window in Microsoft Access.

When designing a table, its specific structure has to be defined. A clear idea about how this table will function in the database is required. As an example Figure 50 shows a table from the shellfish database in design view. 'Field name' is used to designate each column of the table with an proper name, the 'Data Type' defines the kind of data column (such as text or numbers) and in the 'Description' field short explanations about content can be made. The 'Field Properties' area defines the exact structure of the data and gives several options about how each column (field) will operate. Figure 51 shows the same table but in the data sheet view with the previously entered information being displayed.



Field Name	Data Type	Description
Reference-ID	Number	
measureablesMNI	Number	
measureablesG	Number	g (1 decimal)
countableMNI	Number	
countableG	Number	g (1 decimal)
fragments	Number	g (1 decimal)

Field Size	Long Integer
Format	
Decimal Places	Auto
Input Mask	
Caption	
Default Value	
Validation Rule	
Validation Text	
Required	Yes
Indexed	Yes (No Duplicates)



Reference-ID	[illegible]	[illegible]	countableMNI	countableG	fragments
21	8	54.4	34	109.2	64.6
22	1	15.8	0	0	3.8
23	9	87	4	16.5	17.7
24	5	56.8	2	4.9	4.7
25	5	59.6	2	5	7.3
26	2	12.6	4	22.6	3.6
27	12	58.6	35	119.9	60.7
34	5	23.6	40	104.2	75.9
35	8	110.2	15	54.6	2[illegible]
36	4	28.7	10	56.3	12.9
37	2	22.9	2	10.8	6.4
38	1	9	5	26.1	8.3
39	11	49.2	28	87.5	28.1
40	8	51.9	81	228.8	58.[illegible]
41	4	53.4	130	398.4	221.[illegible]
46	21	157.7	116	343.5	191.7
47	10	62.4	30	101.1	41.5
48	7	42.5	31	219	45.7
49	3	30.3	3	28.1	5.1

Figure 50: Screenshot of a table in design view in Microsoft Access. (Top)

Figure 51: Screenshot of a table in data sheet view in Microsoft Access. (Bottom)

Data input areas

Working in a large database needs a system to display and to work with information in a clear way. Microsoft Access provides the 'form' object which can be used as a structured visualization of table data and is thus ideal for data input. As an example Figure 52 shows the shellfish input form from the shellfish database in design view. Every form is related to a table or a query where field information and field content is retrieved from. Microsoft Access provides several tools for the design of forms. Its fairly complex nature will not be discussed in this thesis. As an example, however, the forms of the shellfish database and their usage is presented on page 203. Figure 53 shows the same form but in form view which was used to do the shellfish data input.

Data queries

To process the raw data, queries can be created. They produce new tables from the raw data tables through specific instructions. As an example Figure 54 shows a query from the shellfish database in design view. The upper part is reserved for the tables that will be used for the query and their relationships. In the lower part are the instructions for the query. Usually they contain a selection of fields from the chosen raw data tables and the procedures that will be applied to them. In this case the query produces a list of all the squares that have been analyzed for shellfish and calculates their center coordinates. Figure 55 is the same query but in data sheet view with results being shown in a new table.

Analysis

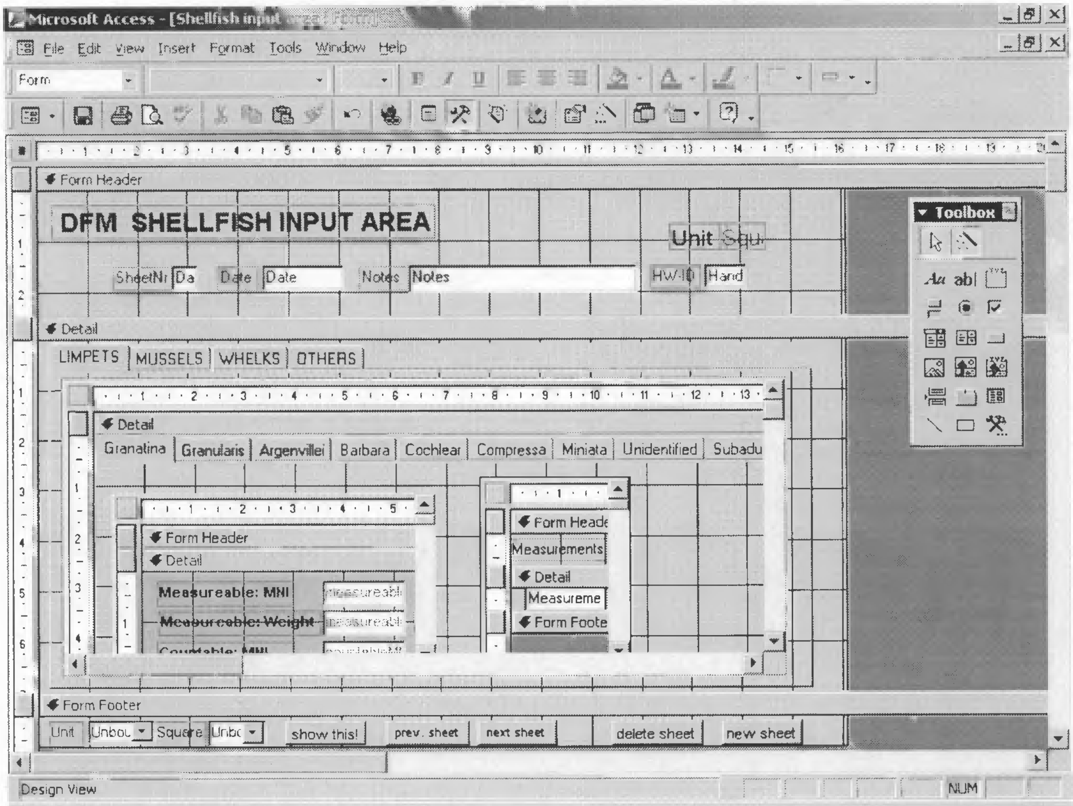
The analysis options of Microsoft Access are fairly limited. Simple calculations like sums, standard deviations or averages can be done with query objects. For this project the software 'Statistica' was used to do all numerical statistical analysis and MapInfo was responsible for the spatial analysis part.

3 GEOGRAPHICAL INFORMATION SYSTEM FUNCTIONS

Introduction

Today Geographical Information Systems (GIS) are regularly used in archaeology. Adapted from geography they provide useful tools for spatial analysis. In the DFM Spatial Database the MapInfo Professional GIS (Version 6.5) is used and has three tasks: (1) data selection, (2) data visualization, (3) spatial analysis.

Spatial information needs spatial reference: a feature map including all features and the excavation grid was produced by Fisher and Parkington serving as an interactive base map layer. All find data from database are linked



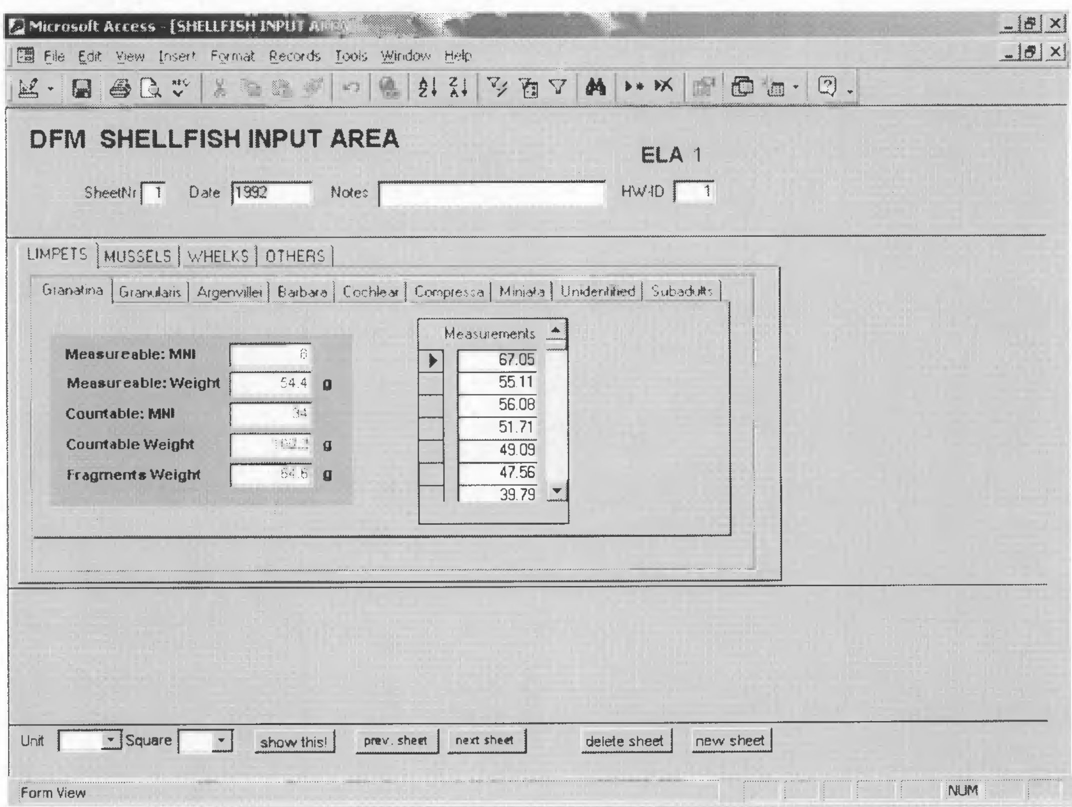
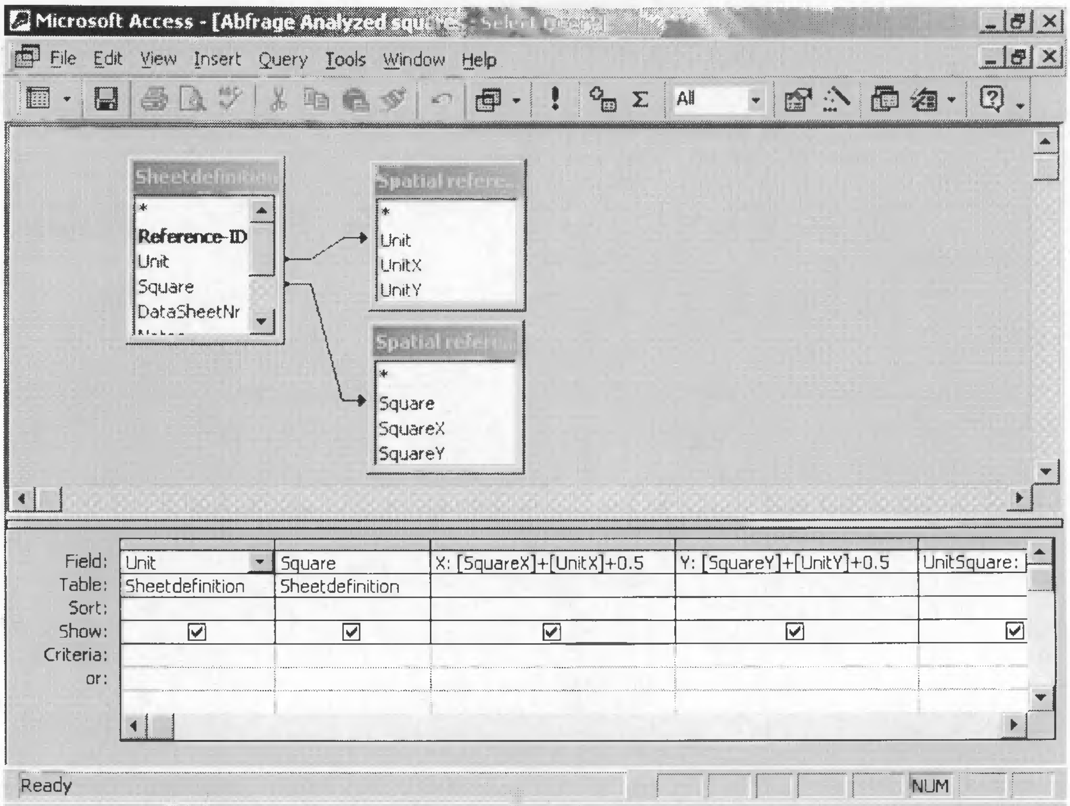


Figure 52: Screenshot of a form in design view in Microsoft Access. (Top)

Figure 53: Screenshot of a form in form view in Microsoft Access. (Bottom)



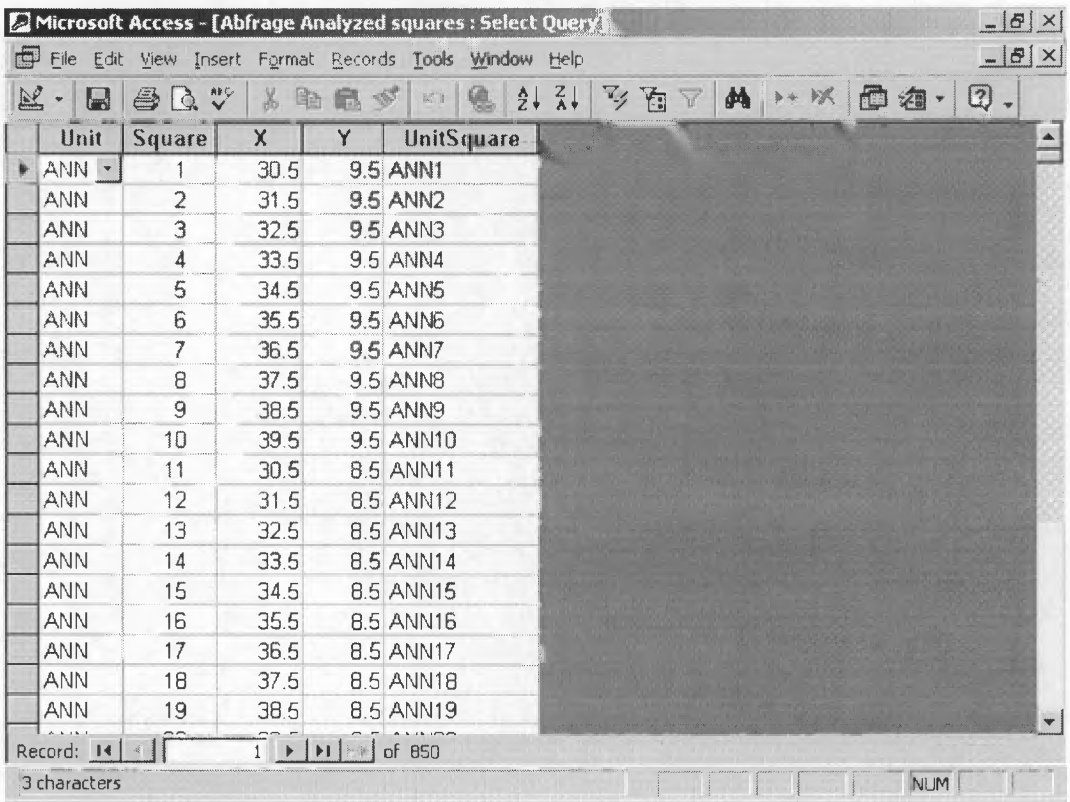


Figure 54: Screenshot of a query in design view in Microsoft Access. (Top)

Figure 55: Screenshot of a query in data sheet view in Microsoft Access. (Bottom)

through ODBC and can be selected and analyzed with MapInfo SQL. Spatial distributions can be visualized with the thematic maps tools and several layers of plots can be managed with the layer control. Each feature is linked to the Access feature database and with the info tool of MapInfo detailed descriptions can be displayed. Figure 56 gives an idea of how the feature map looks like in MapInfo with additional information shown in the info box (upper right corner) for one of the hearth features.

For a detailed description of MapInfo an introduction by Johnson (1996) into the functions and usage of this GIS in archaeological context is recommended. Although it deals with an earlier version of MapInfo than used in this project, it provides all information for a basic understanding of MapInfo.

Data selection

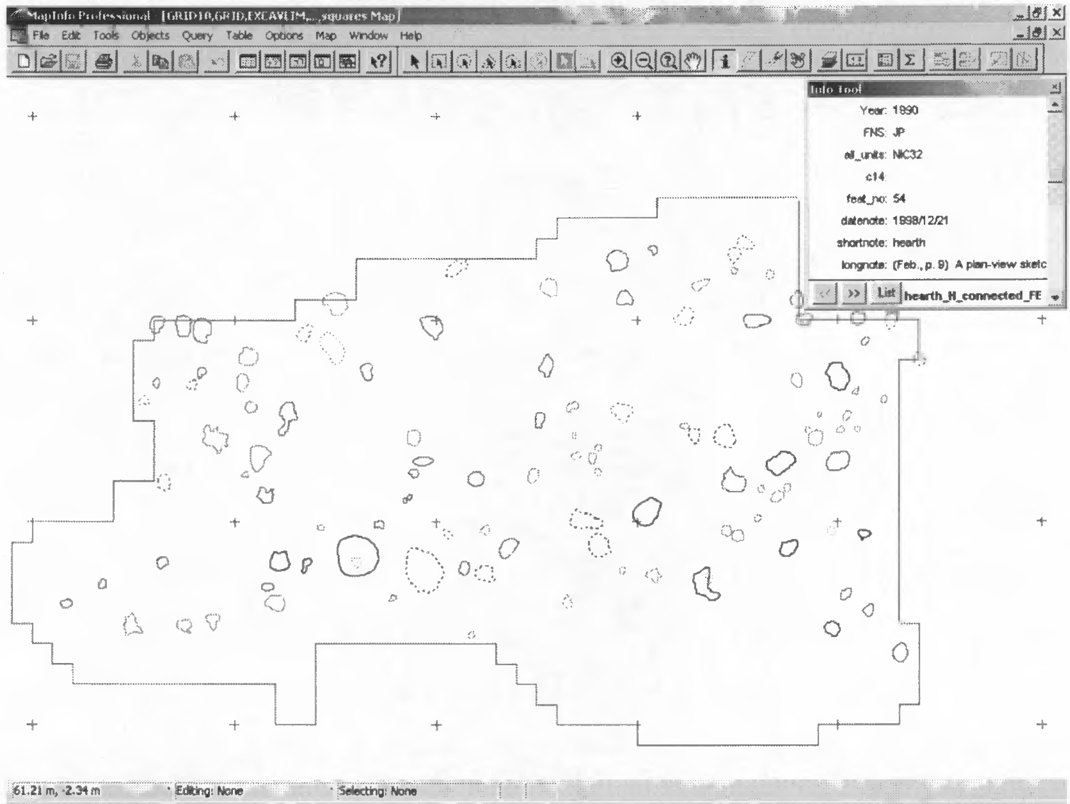
MapInfo can be used as a tool to select data from the database and to display the results visually with distribution plots. Selections can be made in two ways: with a pointer (e.g. computer mouse) or with SQL. The former is a manual way and the latter a programmed way where specific criteria have to be defined in which the data has to match in order to get selected. An example would be to show all squares with more than 5kg total shellfish weight. Figure 57 shows the instructions for a SQL selection in the small window in the middle and the result of this query in a table on the left side of the screenshot. Once the relevant data for a specific question is selected it can be visualized in MapInfo or transferred to Statistica for statistical analysis.

Layers

As a GIS is regularly used for visualization of tabular data, vector lines and pixel images, different types of plots and pictures are often projected onto each other. They can be distinguished by 'layers', each layer representing the visualization of a unique data source (e.g. table, vector drawing or pixel image). In MapInfo their properties are managed with the layer control. The visibility, selectivity and edit ability in the current workspace can be switched on or off and the visual appearance of their content can be defined. Figure 58 shows the feature map together with the layer control in the upper right corner. Note that the visibility (tick column with the symbol of an eye) of the excavation border (layer name 'EXCAVLIM') is switched off.

Data visualization

Visualization and in general mapping plays a very important role in archaeology. Spatial patterns can be seen more easily if they are plotted on a map. As a simple example the SQL selection of the squares with more than 5kg of



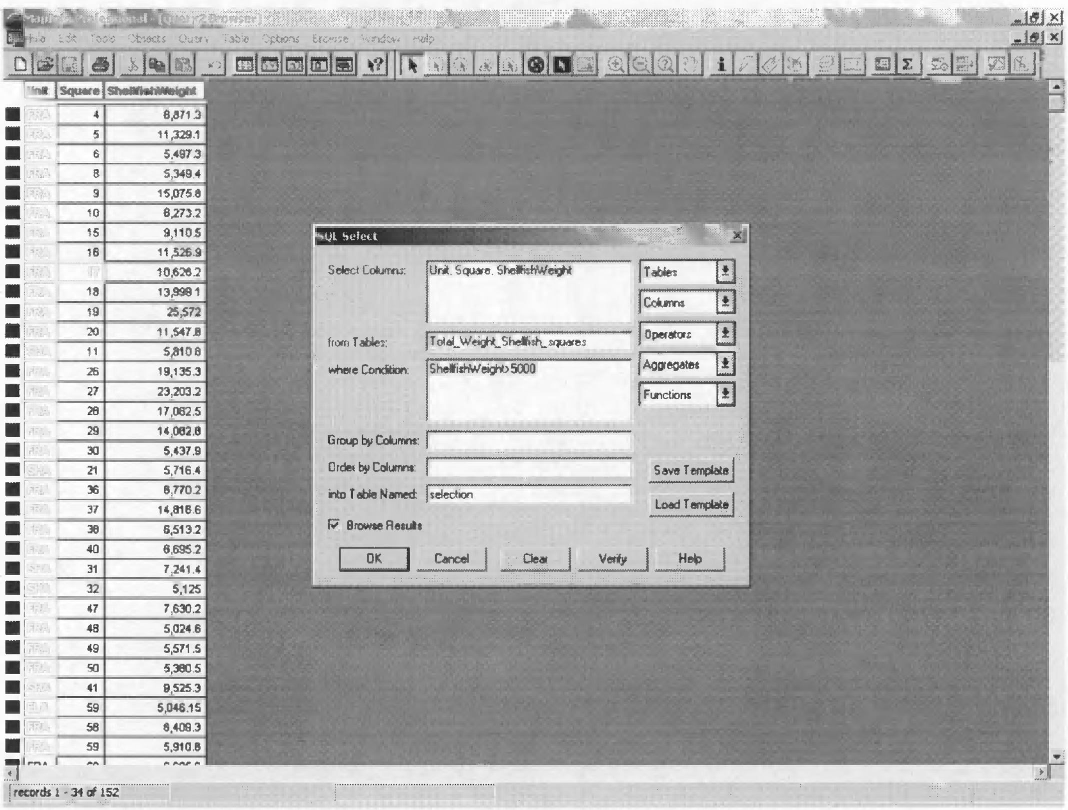
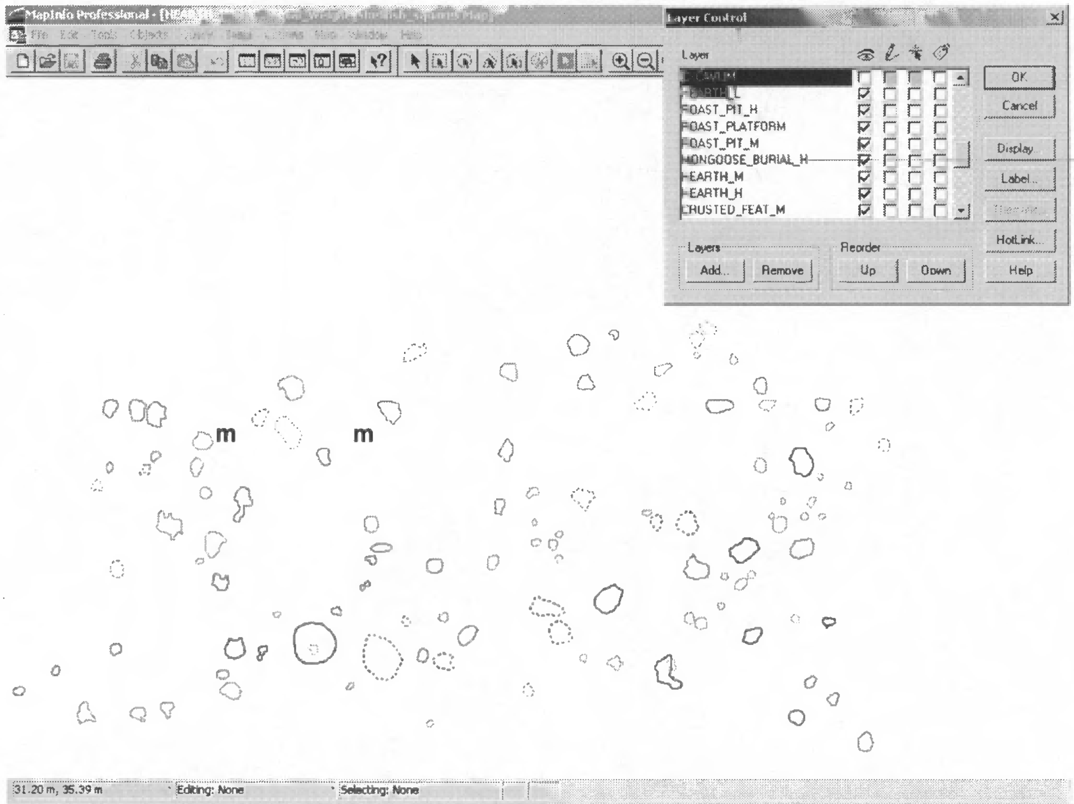


Figure 56: Screenshot of the DFM feature map with info box in MapInfo. (Top)

Figure 57: Screenshot of the SQL selection in MapInfo. (Bottom)



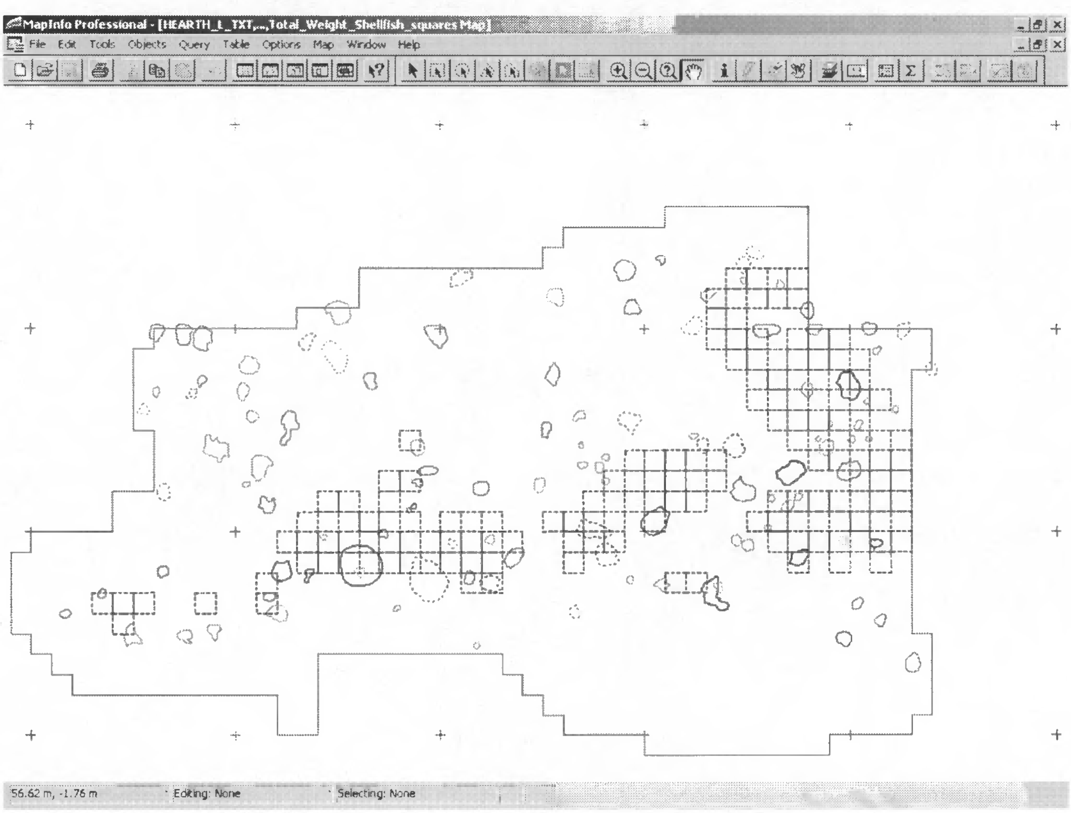


Figure 58: Screenshot of the layer control in MapInfo. (Top)

Figure 59: Screenshot of the highlighted squares in MapInfo. (Bottom)

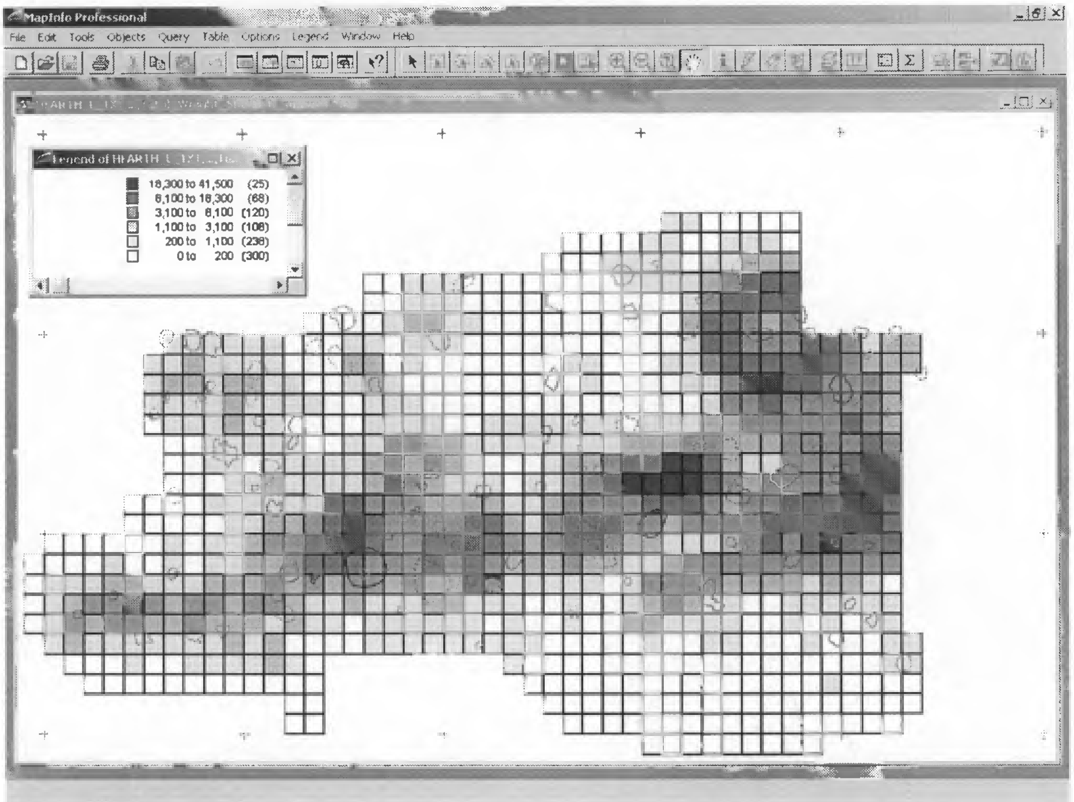
total shellfish weight can be highlighted (Figure 59) and their distribution becomes evident and is much more comprehensible than by viewing the same data in the table (Figure 57).

For more complex data visualizations MapInfo provides so-called 'Thematic Maps' for visualization. Several themes are available (Table 22) and two kinds are particularly important for displaying interval data: Range Plots and Dot Density Plots. Range Plots shade a square according to data from the database relating to those squares (e.g. light color for small numbers and dark color for high numbers of any given variable). Dot Density Plots work in a similar way but instead of shading the squares they put randomly spaced distributions of dots into them (e.g. few dots equals small numbers and many equal high numbers of any given variable).

Thematic map type	***Description***
Ranges	Color or pattern shading of a map object based on metrical values.
Bar Charts	Creates bar charts representing metrical values of several variables that refer to the same map object.
Pie Charts	Creates pie charts representing metrical values of several variables that refer to the same map object.
Graduated	Representing metrical values of a map object by graduating the size of a symbol.
Dot Density	Shading of map objects with random patterns of dots based on metrical values.
Individual	Coding map objects having limited alternative values with symbols or colors.
Grid	Creates a continuos raster grid by interpolation of point data.

Table 22: Thematic map t pes in MapInfo.

As an example the distribution of total shellfish weights can be plotted onto the DFM feature map (see Figure 60 for a Range Plot, Figure 61 for a Dot Density Plot and Figure 62 for the Dot Density Plot overlaid on the Range Plot; all legends are in the upper left corner).



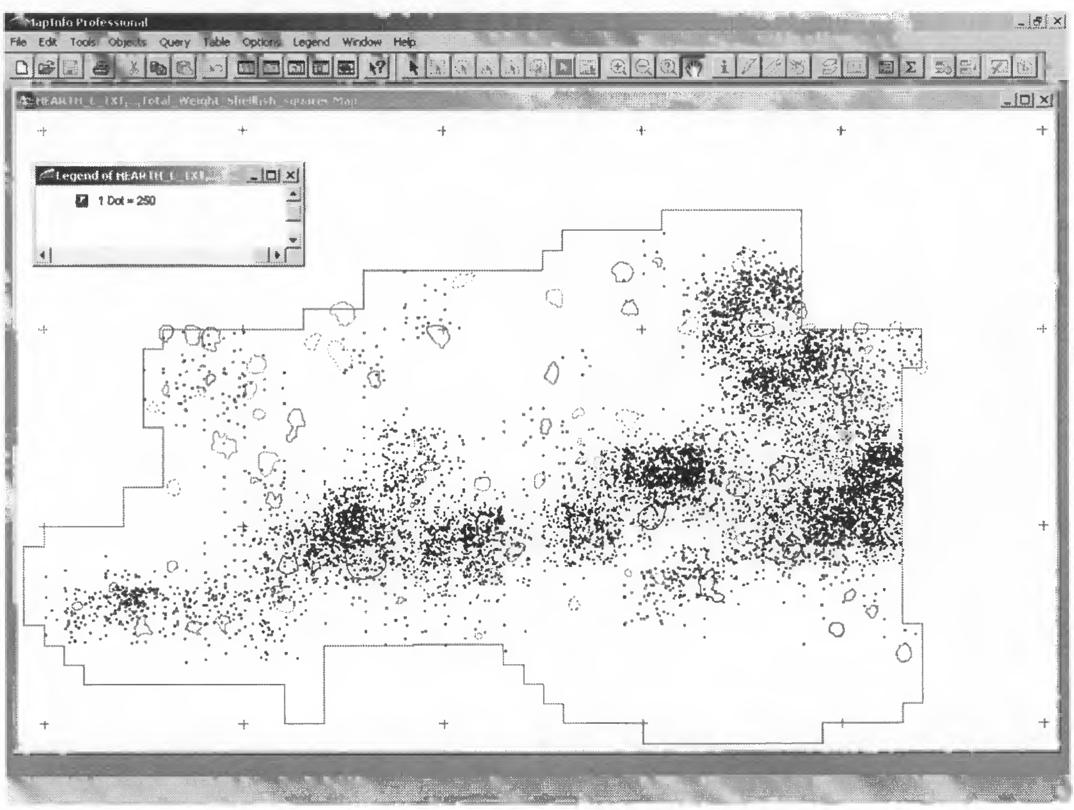
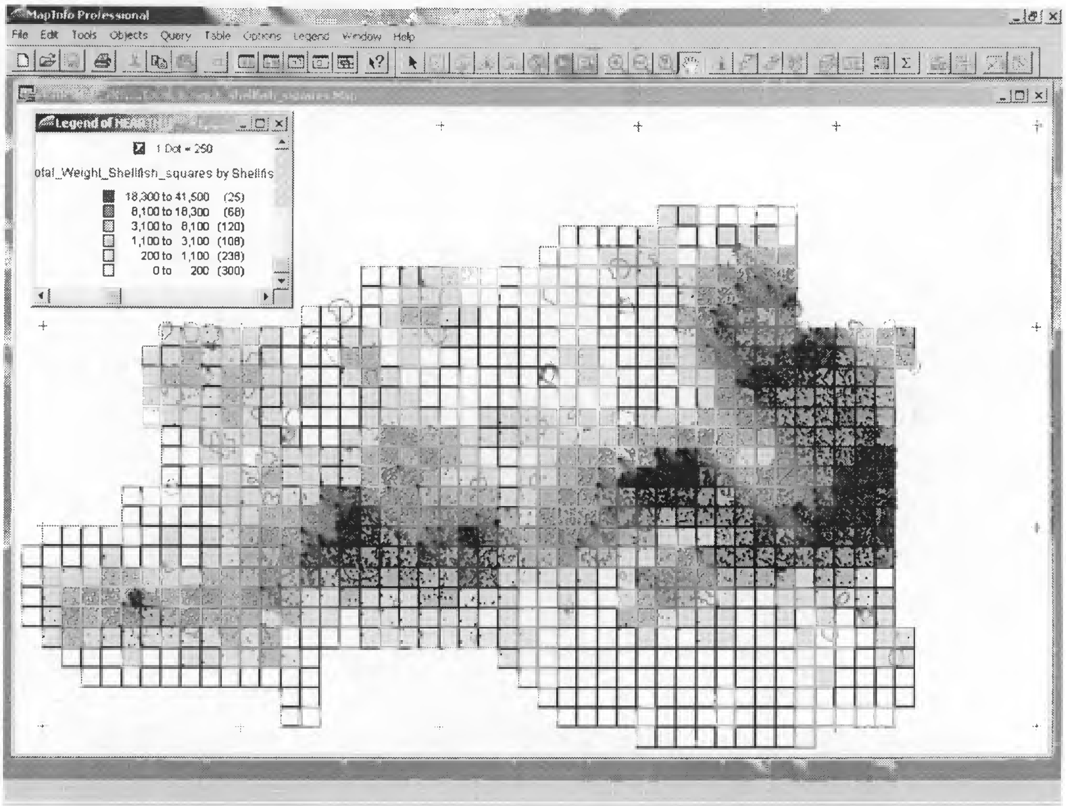


Figure 60: Screenshot of a Range Plot in MapInfo. (Top)

Figure 61: Screenshot of a Dot Density Plot in MapInfo. (Bottom)



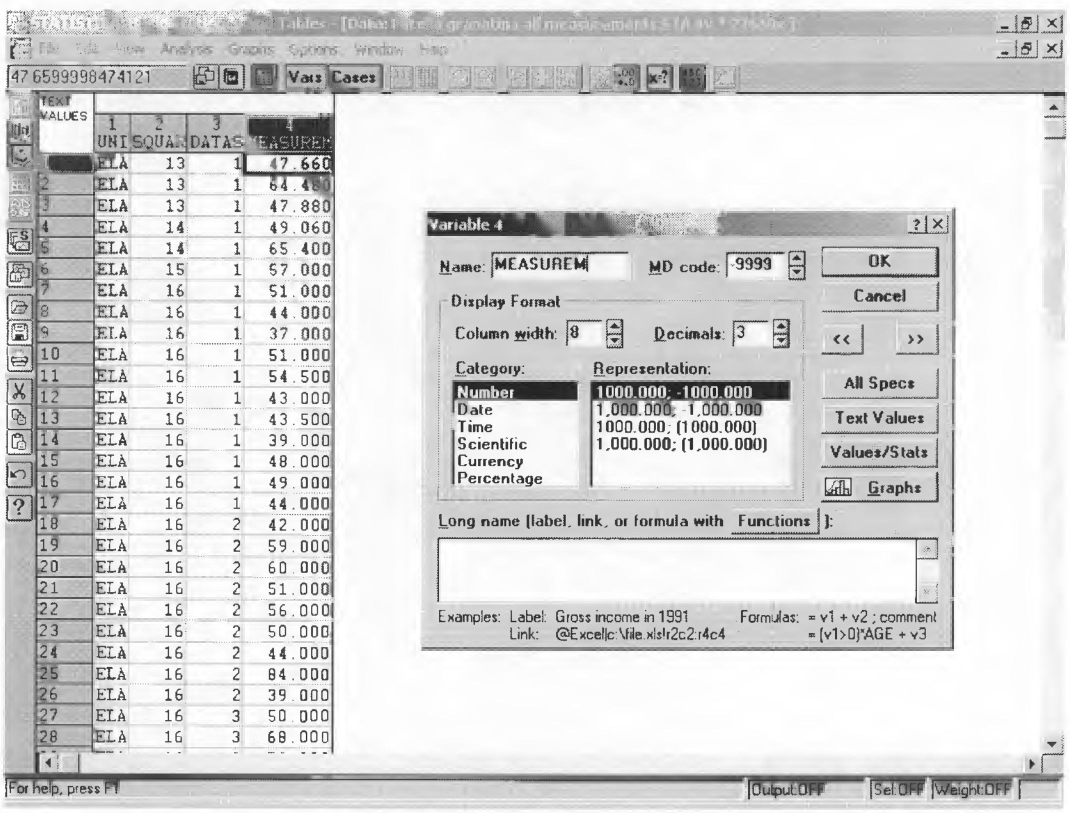


Figure 62: Screenshot of a Range Plot and Dot Density Plot overlaid in MapInfo. (Top)

Figure 63: Screenshot of an imported table and the variable definition window in Statistica. (Bottom)

4 STATISTICAL ANALYSIS FUNCTIONS

Introduction

For the DFM Spatial Database the software Statistica from StatSoft (Kernel release 5.5) was used for numerical statistical analysis. Statistica is built of different modules, each representing a specific area of statistical analysis. Altogether there are 28 modules available with this version. Table 23 summarizes those used in this thesis and lists their functions.

Similar to MapInfo, data can be imported to Statistica with ODBC. Tables are handled like to those in spreadsheet programs (e.g. Microsoft Excel). Columns can be added, calculations on the data can be performed. After a table is imported to Statistica, the columns (here called 'variables') can be formatted to fit the analysis needs (e.g. numbers of decimals, see an example in Figure 63). A typical analysis process does involve four steps: (1) data import and preparation, (2) data analysis, (3) interpretation of results.

Module	***Functions***
ANOVA/MANOVA	Analysis of Covariance (ANCOVA); Multivariate Designs: MANOVA/MANCOVA; Contrast Analysis and Post hoc Tests; Assumptions and Effects of Violating Assumptions; Methods for Analysis of Variance
Basic Statistics	Descriptive statistics; Correlations; t-test for independent samples; t-test for dependent samples; Breakdown: Descriptive statistics by groups; Frequency tables; Cross tabulation & stub-and-banner tables: Statistics in cross tabulation tables, Multiple responses/dichotomies; Probability Distribution Calculator; Other Significance Tests
Cluster Analysis	Joining (Tree Clustering); Two-way Joining; K-means Clustering

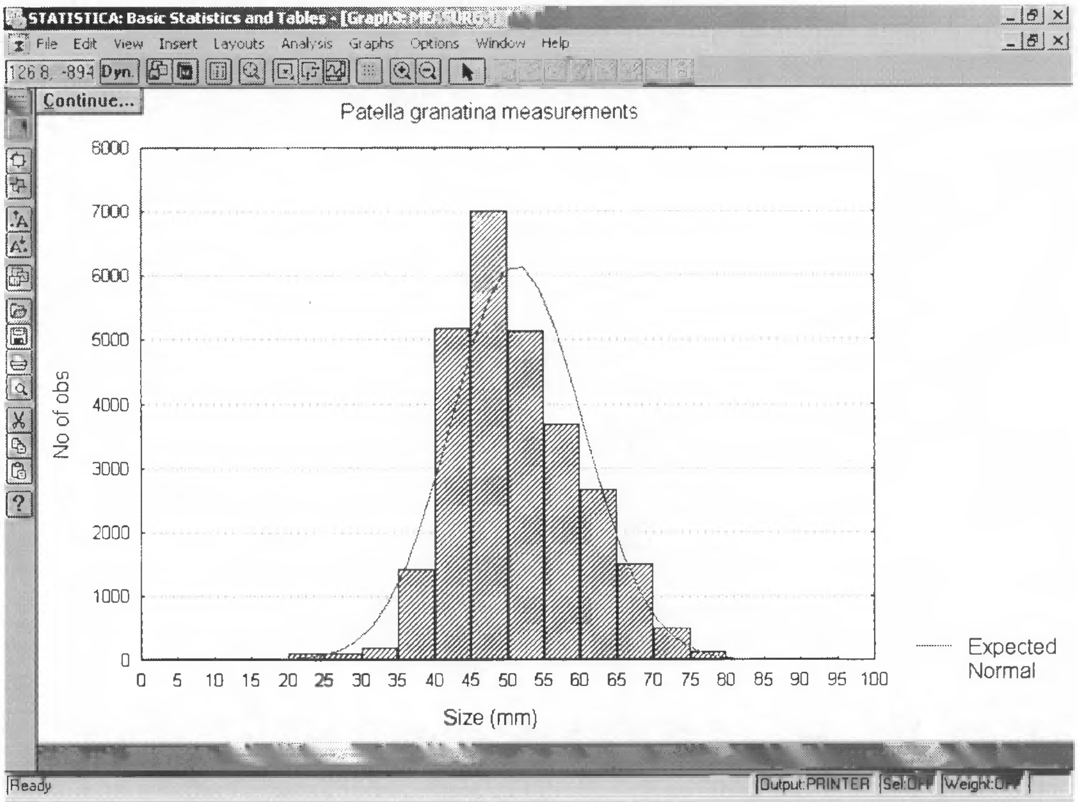
Table 23: Statistical analysis modules of Statistica and their functions (StatSoft 2000).

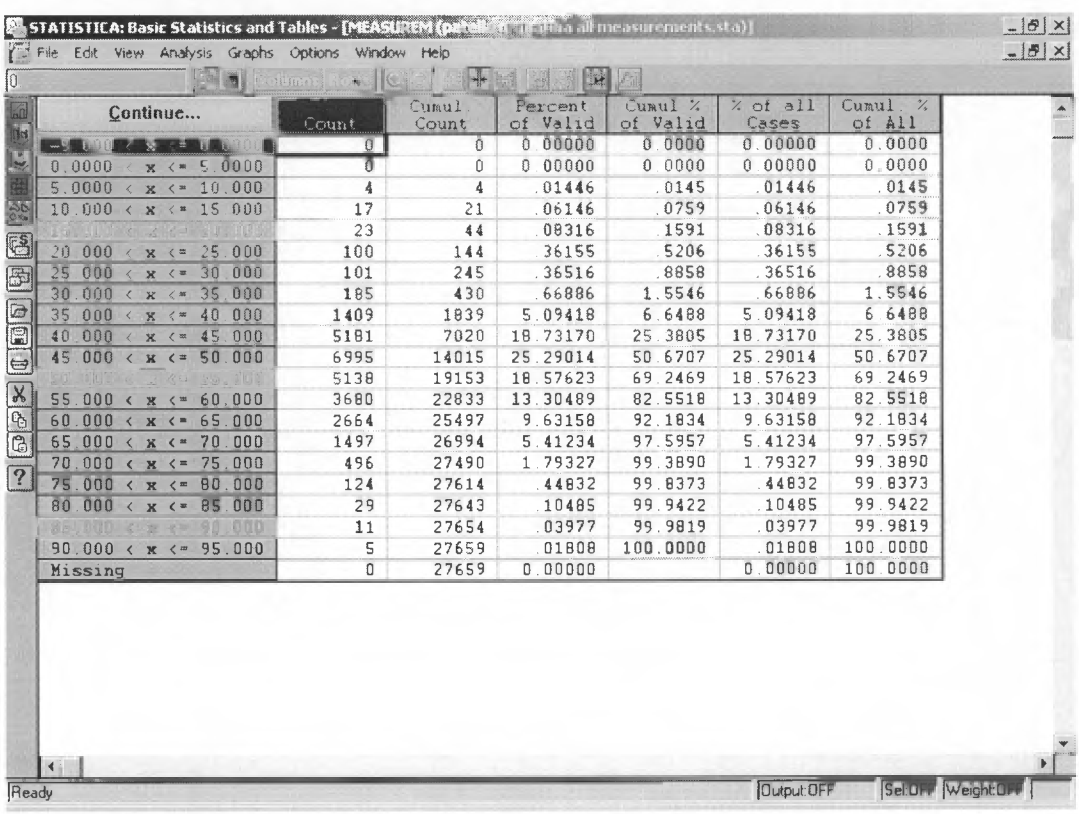
Data analysis

The module used for analysis has to be chosen by the question that is asked. Results can be displayed as tables or graphs. To give a simple example, Figure 64 shows a size histogram of the shellfish species *Patella granatina* and Figure 65 the same data in table format. More complex analyses are possible with Statistica. For this project the '*k*-means cluster analysis' will be used regularly and the following example illustrates the process how this can be done (for a detailed discussion see "K-means cluster analysis" on page 63): Two clusters are calculated from a table produced by the DFM Spatial Database that provides the frequencies of three most abundant shellfish species (*Patella granatina*, *Patella granularis* and *Choromytilus meridionalis*) for each square (Figure 66). The '*k*-means cluster analysis' is performed and the results can be displayed in form of a new table containing the square names and the number of the cluster they belong to (Figure 67). The clusters are easily characterized by the means they yield for each of the shellfish species and this is best illustrated in a graph (Figure 68). The spatial distribution of squares belonging to a distinct cluster is of great interest and can provide important information for further analysis and the interpretation of the clusters. For visualization purposes the table can be exported to MapInfo (Figure 69). As this is a purely constructed example no further interpretation of the patterning shown is considered.

Interpretation

Statistical data itself never provides an interpretation of the results. It may show patterns in numerical data and may help in interpreting it. Methods for statistical analysis have to be chosen carefully. The significance of the results has to be evaluated and interpretation has to be critically checked against the general framework of archaeological research and the principals of human logic.

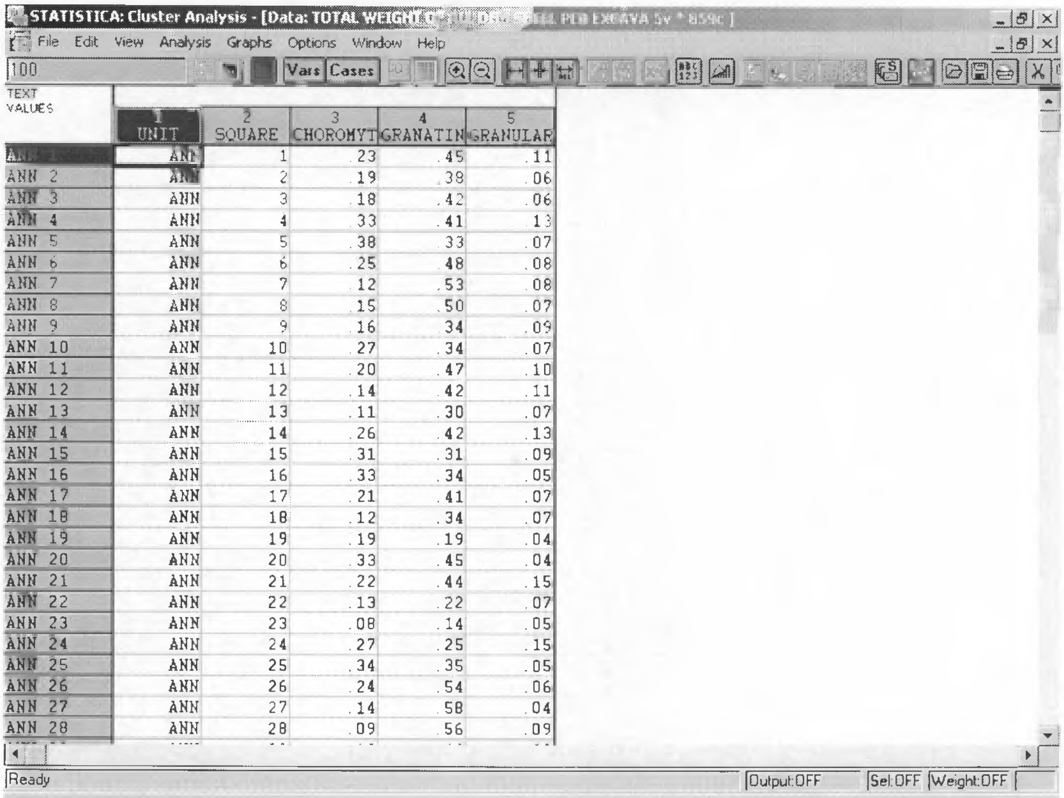




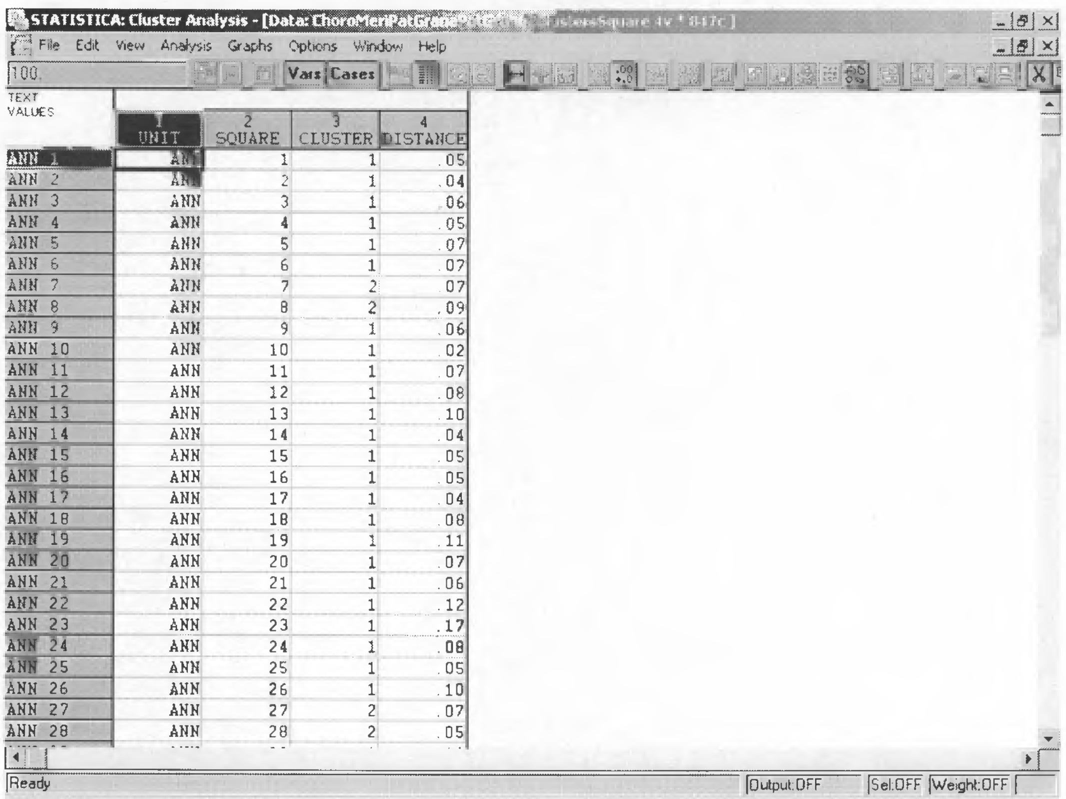
Continue...	Count	Cumul. Count	Percent of Valid	Cumul % of Valid	% of all Cases	Cumul. % of All
[illegible]	0	0	0.00000	0.0000	0.00000	0.0000
0.0000 < x <= 5.0000	0	0	0.00000	0.0000	0.00000	0.0000
5.0000 < x <= 10.000	4	4	.01446	.0145	.01446	.0145
10.000 < x <= 15.000	17	21	.06146	.0759	.06146	.0759
[illegible]	23	44	.08316	.1591	.08316	.1591
20.000 < x <= 25.000	100	144	.36155	.5206	.36155	.5206
25.000 < x <= 30.000	101	245	.36516	.8858	.36516	.8858
30.000 < x <= 35.000	185	430	.66886	1.5546	.66886	1.5546
35.000 < x <= 40.000	1409	1839	5.09418	6.6488	5.09418	6.6488
40.000 < x <= 45.000	5181	7020	18.73170	25.3805	18.73170	25.3805
45.000 < x <= 50.000	6995	14015	25.29014	50.6707	25.29014	50.6707
[illegible]	5138	19153	18.57623	69.2469	18.57623	69.2469
55.000 < x <= 60.000	3680	22833	13.30489	82.5518	13.30489	82.5518
60.000 < x <= 65.000	2664	25497	9.63158	92.1834	9.63158	92.1834
65.000 < x <= 70.000	1497	26994	5.41234	97.5957	5.41234	97.5957
70.000 < x <= 75.000	496	27490	1.79327	99.3890	1.79327	99.3890
75.000 < x <= 80.000	124	27614	.44832	99.8373	.44832	99.8373
80.000 < x <= 85.000	29	27643	.10485	99.9422	.10485	99.9422
[illegible]	11	27654	.03977	99.9819	.03977	99.9819
90.000 < x <= 95.000	5	27659	.01808	100.0000	.01808	100.0000
Missing	0	27659	0.00000		0.00000	100.0000

Figure 64: Screenshot of a graph in Statistica. (Top)

Figure 65: Screenshot of graph data in table format in Statistica. (Bottom)



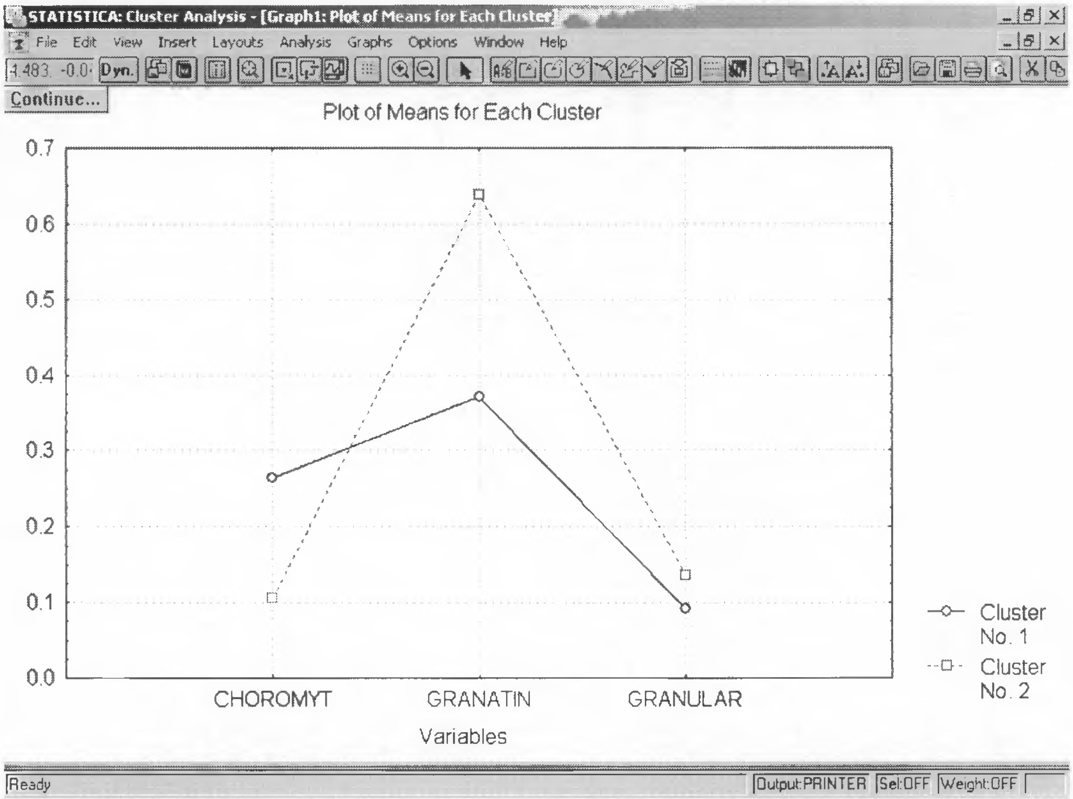
	UNIT	SQUARE	CHOROMYT	GRANATIN	GRANULAR
ANN 1	ANN	1	.23	.45	.11
ANN 2	ANN	2	.19	.38	.06
ANN 3	ANN	3	.18	.42	.06
ANN 4	ANN	4	.33	.41	.13
ANN 5	ANN	5	.38	.33	.07
ANN 6	ANN	6	.25	.48	.08
ANN 7	ANN	7	.12	.53	.08
ANN 8	ANN	8	.15	.50	.07
ANN 9	ANN	9	.16	.34	.09
ANN 10	ANN	10	.27	.34	.07
ANN 11	ANN	11	.20	.47	.10
ANN 12	ANN	12	.14	.42	.11
ANN 13	ANN	13	.11	.30	.07
ANN 14	ANN	14	.26	.42	.13
ANN 15	ANN	15	.31	.31	.09
ANN 16	ANN	16	.33	.34	.05
ANN 17	ANN	17	.21	.41	.07
ANN 18	ANN	18	.12	.34	.07
ANN 19	ANN	19	.19	.19	.04
ANN 20	ANN	20	.33	.45	.04
ANN 21	ANN	21	.22	.44	.15
ANN 22	ANN	22	.13	.22	.07
ANN 23	ANN	23	.08	.14	.05
ANN 24	ANN	24	.27	.25	.15
ANN 25	ANN	25	.34	.35	.05
ANN 26	ANN	26	.24	.54	.06
ANN 27	ANN	27	.14	.58	.04
ANN 28	ANN	28	.09	.56	.09



	UNIT	SQUARE	CLUSTER	DISTANCE
ANN 1	ANN	1	1	.05
ANN 2	ANN	2	1	.04
ANN 3	ANN	3	1	.06
ANN 4	ANN	4	1	.05
ANN 5	ANN	5	1	.07
ANN 6	ANN	6	1	.07
ANN 7	ANN	7	2	.07
ANN 8	ANN	8	2	.09
ANN 9	ANN	9	1	.06
ANN 10	ANN	10	1	.02
ANN 11	ANN	11	1	.07
ANN 12	ANN	12	1	.08
ANN 13	ANN	13	1	.10
ANN 14	ANN	14	1	.04
ANN 15	ANN	15	1	.05
ANN 16	ANN	16	1	.05
ANN 17	ANN	17	1	.04
ANN 18	ANN	18	1	.08
ANN 19	ANN	19	1	.11
ANN 20	ANN	20	1	.07
ANN 21	ANN	21	1	.06
ANN 22	ANN	22	1	.12
ANN 23	ANN	23	1	.17
ANN 24	ANN	24	1	.08
ANN 25	ANN	25	1	.05
ANN 26	ANN	26	1	.10
ANN 27	ANN	27	2	.07
ANN 28	ANN	28	2	.05

Figure 66: Screenshot of a table in Statistica with the shellfish species frequencies per square. (Top)

Figure 67: Screenshot of a table in Statistica with the results of a 'k-means cluster analysis'. (Bottom)



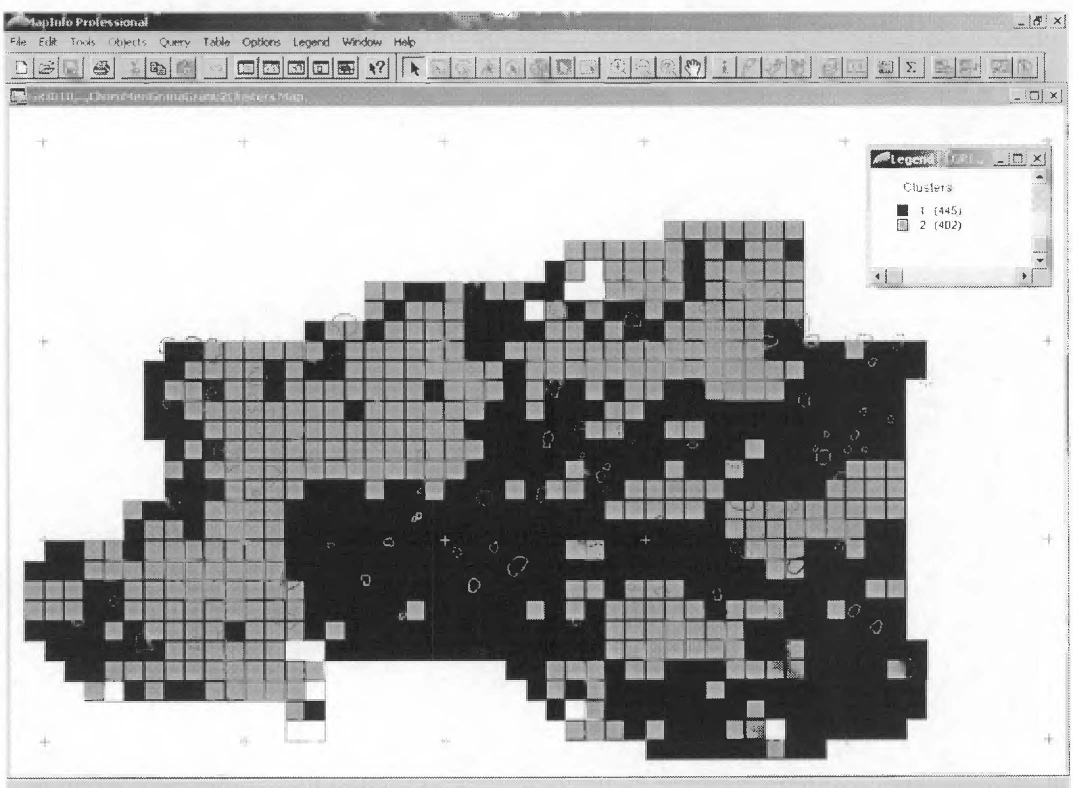


Figure 68: Screenshot of a graph in Statistica showing the means for two clusters. (Top)

Figure 69: Screenshot of a range plot in MapInfo showing the distribution of squares coded with the color of the cluster they belong to. (Bottom)

CHAPTER V VARIABILITY OF DFM SHELLFISH ANALYSIS

1 INTRODUCTION

Objective

It was mentioned earlier that the shellfish remains from Dunefield Midden were analyzed over a 14 year period by more than a dozen different analysts. These were operating in four different analysis groups (including the present one of the years 2001 and 2002) with one supervisor each who trained the analysts. When a new group took over, he or she taught the next supervisor the methods and techniques of the shellfish analysis process. Although there was a continuity in the succession of supervisors, no central teaching facility and no continuous monitoring of the analysis process existed. It is unclear if the instructions of 'how-to' identify shellfish species and 'how-to' measure shells were carried out in a consistent manner over the whole time period. The degree of variability induced by human actions into specific parts of the DFM shellfish analysis process, influences and restricts directly the resolution to which spatial patterning of the shellfish remains can be investigated. To gain more information on how and in what order of magnitude the analysts themselves influenced the data, the variability of shellfish analysis was evaluated. This is the first time such an investigation has been conducted in Southern African archaeology (Parkington, pers. comm.).

Two experiments were performed that gave insight into two separate levels of shellfish analysis variability: the first one was concerned with variations produced by individuals within an analysis group (i.e. on the *intra*-group level) and the second with variations produced by individuals from different analysis groups, i.e. on the *inter*-group level. As it was the primary goal of these investigations to quantify the magnitude of variability induced by the human factor onto the results of shellfish analysis, it was not anticipated to resolve the actual factors that led to the variability. More experiments that are specifically designed to identify the reasons for varying analysis results have to be conducted to give insight into these issues.

In the evaluation of the experiment results, each variable is examined independently. Variation is defined as the range of the values of a variable (minimum value subtracted from maximum value). Each variation is standardized by calculating the relative variation (range divided by average value). These relative values are used to generalize over the experiments and estimate the actual relative variability of each variable for the whole DFM site. In the final step, these variabilities are used to define the maximum resolution that can be achieved when using the different shellfish variables for spatial analysis.

Shellfish analysis fundamentals

In the shellfish sorting process, specimens were not only differentiated into species but also separated into categories and sub-categories (Table 24). A special shellfish analysis form was used to record the results of the analysis, listing all species, categories and sub-categories that may occur. For the important species the minimum number of individuals (MNI) was identified and size measurements were taken (in millimeters with two decimals). For all species the weights were recorded (in grams with one decimal).

2 EXPERIMENT METHODOLOGY

Intra-group experiment

In the first experiment the variations occurring within a group were investigated. The three present shellfish analysts were asked to analyze the same shellfish sample independently. The shells were taken from the Dunefield Midden material by randomly choosing one of the excavated squares with a reasonable high number of shells. The sample was given to the first analyst who sorted and measured the shells according to the DFM system (Table 24). The results of the analysis were written down on a standard analysis sheet and then all the shells were mixed up again to simulate their original, unsorted state. At this point the second analyst took over and performed the same analysis procedure as the first. When the second analysis was finished the shells were mixed up again and the third analyst did as the others had done before.

The intra-group experiment was carried out in 2001 at the Spatial Archaeology Research Unit (SARU) of the Department of Archaeology at UCT. The three analysts were given the shellfish remains from the randomly chosen Dunefield Midden square 'PET45'. It contained almost 5kg shell represented mainly by nine different shellfish species whose weight percentages of the total were (as analyzed by the supervisor of the group): *Patella granatina* (47.94%), *Patella granularis* (19.95%), *Patella barbara* (2.12%), *Choromytilus meridionalis* (29.66%), *Aulacomya ater* (0.08%), *Donax serra* (0.08%), *Burnupena & Nucella* (0.02%), *Helcion* spp (<0.01%), *Siphonaria capensis* (<0.01%). Only the first four species provided a sample size suitable for the assessment of intra-group variability; the others with less than

Species	Category	Sub-categories	Variables
Patella spp: granatina, granularis, argenvillei, barbara, cochlear, compressa, miniata, unidentified	measurable	-	MNI, Weight, Size
	countable	-	MNI, Weight
	fragments	-	Weight
Choromytilus meridionalis	left valves	countable	MNI, Weight, Size (if applicable)
		measurable not countable	MNI, Weight, Size
	right valves	countable	MNI, Weight, Size (if applicable)
		measurable not countable	MNI, Weight, Size
	fragments	-	Weight
Aulacomya ater, Donax serra, Venerupis corrugata	left valves	-	MNI, Weight
	right valves	-	MNI, Weight
	fragments	-	Weight
Burnupena & Nucella, Argobuccinum pustulosum, Oxystele spp., Bullia spp.	apices	-	MNI, Weight
	fragments	-	Weight
Crepidula spp., Helcion spp., Tricholia capensis, Littorina spp., Chiton plates, Fissurellidae	-	-	MNI, Weight
Sub-adults: Patella spp., Choromytilus meridionalis, Aulacomya ater, Whelks, Bullia spp.	-	-	MNI, Weight
Barnacles	-	-	Weight
Other	-	-	MNI, Weight
WWS, WWP	-	-	Count, Weight

Table 24: Dunefield Midden shellfish analysis form: list of species, categories and subcategories and their variables.

1% of the total weight were generally identified and measured correctly and were not included in the variability evaluation.

Inter-group experiment

In the experiment on the variability between groups, three squares, one for each of the former three groups were reanalyzed by the present one. Again, squares were selected randomly from sets of squares where the former analyst groups were known. The main difference to the inter-group experiment was the assumption that each group is working as a unit and would therefore generally reflect the abilities of the supervisor who taught, checked and corrected the mistakes of the others. Therefore the variability induced by individuals within a group was expected to be smaller than between groups.

The inter-group experiment was carried out in the same environment and at the same time as the intra-group experiment. The three squares chosen were DFM squares ELA70 for 'Group A', PET45 for 'Group B' (the same square that was used for the intra-group analysis) and KIR92 for 'Group C'. In the following, the results from the present analysts are referred to 'present group' or 'Group P'. A description of the total contents for each of these three squares (as recorded by the present group) is given in Table 25.

Species	***ELA70***		***PET45***		***KIR92***	
	Weight (g)	% of total	Weight (g)	% of total	Weight (g)	% of total
Patella granatina	1836.7	59.69	2374.8	47.94	3338.1	30.28
Patella granularis	664.9	21.61	988.5	19.95	414.4	3.76
Patella argenvillei	2.0	0.06	-	-	29.6	0.27
Patella barbara	5.8	0.19	105.0	2.12	227.0	2.06
Patella miniata	-	-	-	-	20.9	0.19
Patella unidentified	-	-	2.9	0.06	0.4	0.00
Choromytilus meridionalis	537.6	17.47	1469.1	29.66	3415.9	30.98
Aulacomya ater	4.9	0.16	3.8	0.08	10.3	0.09
Donax serra	23.3	0.76	4.0	0.08	7.2	0.07
Burnupena & Nucella	-	-	0.9	0.02	1257.4	11.40
Argobuccinum pustulosum	-	-	-	-	364.7	3.31
Crepidula	-	-	-	-	24.3	0.22
Helcion	-	-	0.1	0.00	0.5	0.00
Barnacles	-	-	-	-	1910.6	17.33
Siphonaria capensis	-	-	0.0	0.00	-	-
Patella spp. subadults	1.8	0.06	2.4	0.05	3.6	0.03
Choromytilus meridionalis subadults	-	-	0.6	0.01	-	-
Whelks subadults	-	-	-	-	0.0	0.00
WWS	-	-	1.7	0.03	0.3	0.00
TOTAL	3077.0	100.00	4953.8	100.00	11025.2	99.99

Table 25: Inter-group shellfish analysis: Contents of DFM squares ELA70, PET45 & KIR92 used in the experiment as recorded by the supervisor of the present group.

3 RESULTS

Introduction

At Dunefield Midden, the shellfish assemblage is dominated by three species: *Patella granatina*, *Patella granularis* and *Choromytilus meridionalis*. Together they constitute about 80% of the total DFM shell mass and therefore they provide the core for the spatial analysis of shellfish in the following chapter.

Shellfish analysis variability can be investigated best with species that occur frequently and in adequate sample sizes. For both experiments this was true for *Patella granatina*, *Patella granularis* and *Choromytilus meridionalis*. Only the experiment results for these three species are evaluated.

Many figures and tables were created to visualize and summarize the results of the two experiments and they are reprinted in the fifth appendix of this thesis (see "Shellfish analysis variability" on page 251). The following sections present a summary of the evaluation results and the implications they have for the spatial analysis of the DFM shellfish remains.

During the evaluation of the experiment results, it was found that the variability can be defined by the range of the values of each variable. To facilitate comparison, the absolute range values were transformed into relative variations by dividing the range by the average value of a variable.

The design of the experiments does not provide an objective measure (i.e. the 'correct results') against which the results can be evaluated. It cannot, therefore, be said that certain individuals did better or worse than others - the results merely indicate the general variability that is innate to the shellfish analysis process as it is carried out by subjective human actions.

Summary

From the tables and figures in the second appendix, the results of the two variability experiments were compiled into Table 26. Each shellfish species and the appropriate categories and subcategories are listed separately on the left side. The right side of the table shows the average relative variations that occurred on the intra- and inter-group level.

The average relative variations of the variables of the intra-group experiment range from 0.004 to 0.336 (mean 0.076±0.071) and of the inter-group experiment from 0.007 to 0.919 (mean 0.139±0.238). Table 26 indicates that the higher values of variation for each variable (in bold) are distributed more or less equally over the two experiments. If plotted against each other (outliers with relative variations higher than 0.500 omitted), the relative variations are correlating with r^2=0.49, significant at 0.001 level (Figure 70). This linear correlation shows that there are parts of the analysis process where decisions of 'how-to' categorize or measure are more difficult to make than in others, independently from group-related factors. It was expected that the relative variation on the inter-group level would be generally higher than on the intra-group level. However, the gradient of the regression curve (about 0.7) implies that this is not the case: there is a trend that the relative variations between analysts within a group are higher than between groups. This probably indicates that the variations detected with both experiments are a reflection of the general abilities and the decision making of individuals and are not significantly influenced by group factors.

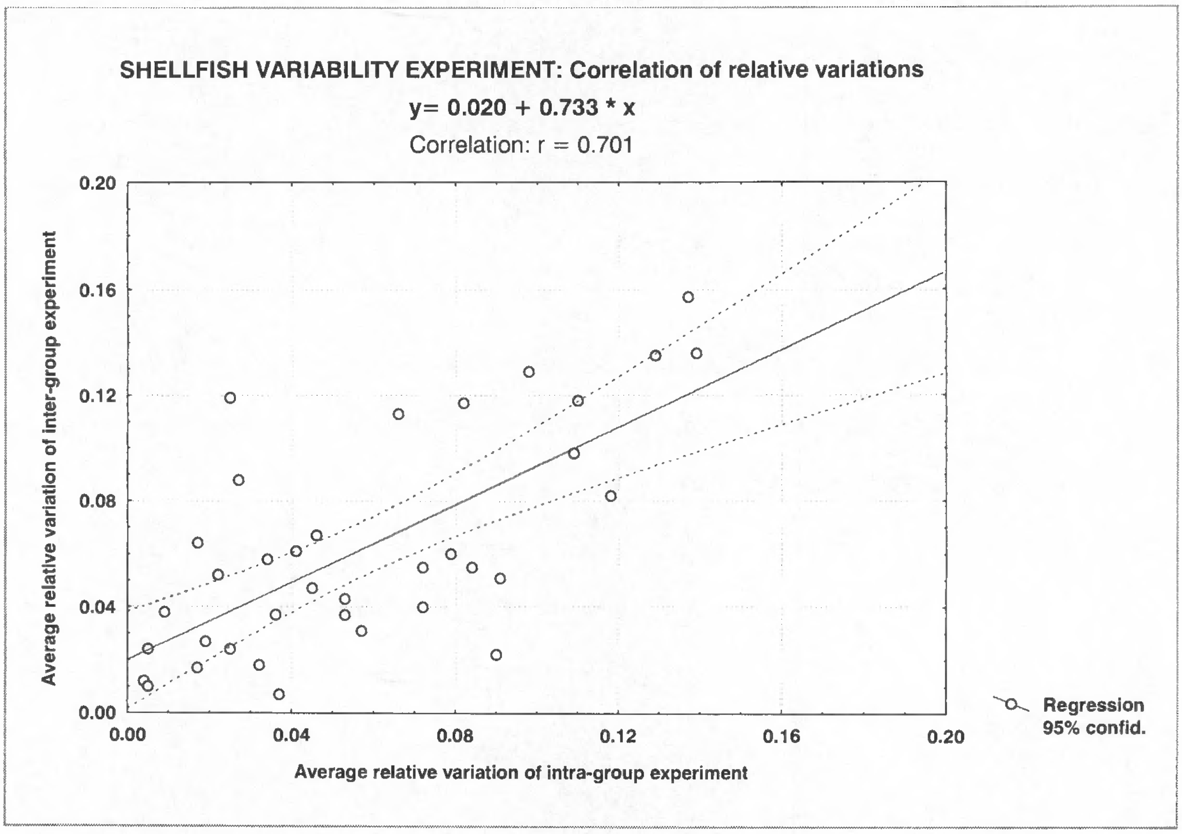


Figure 70: Correlation of the average relative variations from the shellfish variability experiments.

In the shellfish analysis process (see "Shellfish analysis fundamentals" on page 110, Table 24), three stages of categorization were performed: first the identification to 'species', then to 'category' and finally to 'subcategory' (if applicable). The results of the variability experiments show clearly that there is an increase of relative variation with each stage of analysis. While the identification to species, resembled by the total weight, shows extremely low variations (0.005 to 0.064), the identification to category, reflected in MNIs and weights of measurable and countable specimens of *Patella granatina* and *Patella granularis*, produced considerable variations of 0.043 to 0.139. Finally the identification to subcategories, only performed with *Choromytilus meridionalis*, showed the highest variations that lie between 0.031

and 0.919. It can be concluded from both experiments that an increase in the number of categorizing decisions leads to an increase of variability in the shellfish analysis process. Quantitatively, the kind of a decision plays an important role: the more difficult it is, the higher the variability of the results (e.g. identification of the subcategory 'measurable' of the black mussel).

Directly affected by the relative variations is the size measurement category of each shellfish species: the variability in the number of measurable shells leads directly to different sample sizes that are available. Relative variations for the size measurements were calculated for average and median values of the size distributions. Partly as a result of the different analysis stages, they are low for the two limpet species (0.004 to 0.052) and higher for the black mussel (0.027 to 0.091). Another factor that might be responsible for these differences between limpets and black mussel is their different nature of measurement: While the maximum shell length is determined with the limpets, the maximum width of the prismatic band is measured with the black mussel. It is generally accepted that the latter is more difficult as a subjective decision has to be made at what location of the prismatic band the measurement is taken.

Whether the changes of sample sizes that are available for shell size measurements had a directional influence on the average and median values is questionable. For *Patella granatina* and *Patella granularis* of the intra-group experiment, there seems to be evidence that a larger sample size leads to an decrease of the average and median values of the size measurements (Table 27). The regression results are all positive (r^2-values between 0.63 to 0.93) but due to the small sample size (n=3) they are not significant at the 0.05 level. In case of the size measurements of *Choromytilus meridionalis* no directional influences were found.

As there are differences in the average and median values of the measurements within a group and between groups, an attempt was made to investigate if this leads to size frequency distributions that are significantly different from each other: in case of the intra-group experiment a statistical analysis of variance (ANOVA) was performed (Table 28) and in case of the inter-group experiment a double sided t-test was applied (Table 29). The results of the ANOVA were negative (high p-values indicate high similarity) and therefore the variability sample sizes does not lead to significantly different size frequency distributions, except for the subcategory 'right measurable' of *Choromytilus meridionalis* where the hypothesis is true at the 0.05 level. The results of the t-test were generally negative (high p-values indicate high similarity) for the limpet species; the positive value for *Patella granatina* in Group C/P can be explained by subadult specimens that were incorrectly included into the measurements by Group C. For the black mussel four out of ten sub-categories produced positive t-test results at the 0.05 level, indicating that these distributions are significantly different from each other. It can be concluded that there are human factors that can alter significantly size frequency distributions of shellfish measurements. *Choromytilus meridionalis* is affected the most and *Patella granatina* and *Patella granularis* can be generally seen to be robust against these factors.

Implications for spatial analysis

In the previous section the relative variations of each shellfish variable were presented. This information is used in this section to define the maximum resolutions they can be reliably used for the spatial analysis of Dunefield Midden shellfish.

As spatial analysis identifies patterns through changes in variable values that are distributed over space (e.g. the total weight of a shellfish species per square), the differences of these changes are of crucial importance. Regularly the values of the variable chosen for spatial analysis are grouped into distinct intervals (e.g. 0-2kg, 2-5kg, 5-10kg of shellfish weight per square). Through this categorization, spatial patterns usually become clearer for the perception of the naked eye and are prepared (smoothed) for an analysis, but the intervals do affect the appearance of distributions and the results of an investigation and therefore have to be chosen carefully. In most cases, it will be up to the spatial analyst to decide on the interval sizes and thus the resolution of his/her analysis. However, in terms of the DFM shellfish data, the magnitude of the relative variation and thus the 'noise' induced by the analysis process is known and can be used to define a maximum resolution of spatial analysis for each variable.

It was shown in the previous section that the relative variations were most likely caused by *individuals* and are not related to group-effects (Figure 70). The group experiments can therefore be seen as six equal experiments (three on intra- and three on inter-group level), each evaluating the results of two individuals conducting an analysis on the same shellfish sample. Thus, a total average relative variation can be calculated by averaging the two relative variations of the two experiments (Table 30).

The Maximum Spatial Analysis Resolution (MSAR), i.e. the minimum interval size to be used, was defined to be the product of the maximum value of a variable (in a DFM square) with its total average relative variation.[1] Through this

1. The proposed method of calculating the minimum interval size from the maximum value (MaxValue) provides a set of *regular* intervals for each variable. This *linear* calculation does not acknowledge that the *relative* variation always relates to actual values from the whole range of a variable. However, this relatively crude method is totally sufficient for the purposes of this thesis. For the exact calculation of each (n) interval limits (IL) the following formula can be used:

$$\mathbf{IL_n = MaxValue \cdot (1\text{-}MSAR)^{n-1}}$$

The first interval limit (n=1) is the maximum value of a variable and thus the upper limit of the first interval, the second (n=2) is the lower limit of the first interval and the upper limit of the second interval, the third (n=3) is the lower limit of the second interval and the upper limit of the third interval,etc.

definition it is ensured that the variations induced by the subjective analysis are always smaller than the interval sizes. Therefore, patterning that occurs at interval sizes larger than indicated by the MSAR are unlikely to be an artefact of the analysis processes. The maximum values of the variables could be easily determined by querying the DFM Spatial Database.

In Table 30 the Maximum Spatial Analysis Resolution is calculated. The median values of size measurements are omitted as they will not be used for investigations into DFM site patterning. It turns out that most of the variables can be used for spatial analysis. This excludes the subcategory 'measurable' of the left and right valves of *Choromytilus meridionalis*. Both MNI and weight measurements have total average relative variations higher than 0.500. It is therefore impossible to create a minimum of two intervals for these four variables and thus they are not applicable for spatial analysis. All other variables have relative variations that are smaller than 0.140 and for most of them a minimum of ten intervals can be defined. Of particular interest are the total weights and some of the size measurements of each species. It was demonstrated that the analysis process had only marginally influences on their variability (relative variations smaller than 0.050) - they are therefore not problematic for spatial analysis.

The results of the shellfish analysis variability experiments will be used in the following chapter for the investigation of significant spatial patterning in the shellfish remains of Dunefield Midden.

Species	***Measurement***	***(Sub-)Category***	***INTRA-group experiment: average relative variation***	***INTER-group experiment: average relative variation***
Patella granatina	MNI	Measurable	**0.139** ‡	0.136 ‡
		Countable	**0.053** †	0.043 •
		Total	**0.032** •	0.018 •
	Weight	Measurable	0.098 †	**0.129** ‡
		Countable	0.046 •	**0.067** †
		Fragments	0.019 •	**0.027** •
		Total	0.009 •	**0.038** •
	Size: average length	-	0.022 •	**0.052** †
	Size: median length	-	**0.025** •	0.024 •
Patella granularis	MNI	Measurable	0.066 †	**0.113** ‡
		Countable	**0.118** ‡	0.082 †
		Total	**0.037** •	0.007 •
	Weight	Measurable	0.082 †	**0.117** ‡
		Countable	0.129 ‡	**0.135** ‡
		Fragments	0.110 ‡	**0.118** ‡
		Total	0.017 •	**0.064** †
	Size: average length	-	0.004 •	**0.012** •
	Size: median length	-	0.005 •	**0.010** •

Table 26: Summary of results of intra- and inter-group shellfish analysis experiments: relative variation of each variable (higher values bold; see key for symbols at end of table).

Species	Measurement	(Sub-)Category	INTRA-group experiment: average relative variation	INTER-group experiment: average relative variation
Choromytilus meridionalis	MNI (left)	Countable	0.137 ‡	**0.157** ‡
		Measurable	0.336 ‡	**0.808** §
		Total	**0.090** †	0.022 •
	MNI (right)	Countable	**0.109** ‡	0.098 †
		Measurable	0.191 ‡	**0.919** §
		Total	**0.084** †	0.055 †
	Weight (left)	Countable	**0.057** †	0.031 •
		Measurable	0.276 ‡	**0.770** §
		Count.+Meas.	0.025 •	**0.119** ‡
	Weight (right)	Countable	**0.072** †	0.040 •
		Measurable	0.157 ‡	**0.874** §
		Count.+Meas.	**0.053** †	0.037 •
	Weight	Fragments	0.017 •	* 0.017 •
		Total	0.005 •	*** 0.024** •
	Size: average width of prismatic band	left countable	0.027 •	**0.088** •
		right countable	0.036 •	**0.037** •
		left measurable	0.045 •	**0.047** •
		right measurable	**0.079** ‡	0.060 †
	Size: median width of prismatic band	left countable	0.041 •	**0.061** †
		right countable	0.034 •	**0.058** †
		left measurable	**0.072** †	0.055 †
		right measurable	**0.091** †	0.051 †

•: relative variation smaller than 0.050
†: relative variation between 0.050 and 0.100
‡: relative variation between 0.100 and 0.500
§: relative variation higher than 0.500
*: Excludes weight result from Group A/P as additional material (fragments) was added in the reanalysis of the present group.

Table 26: (Continued) Summary of results of intra- and inter-group shellfish analysis experiments: relative variation of each variable (higher values bold; see key for symbols at end of table).

Species	***Variables***	r^2	*p*
Patella granatina	Sample size vs. Average of measurements	0.93	**0.176**
	Sample size vs. Median value of measurements	0.92	**0.179**
Patella granularis	Sample size vs. Average of measurements	0.64	**0.411**
	Sample size vs. Median value of measurements	0.88	**0.230**

Table 27: Intra-group shellfish analysis: Regression results of sample size vs. size measurement averages/ median values of limpet species.

Species (sub-category)	*F*	*p*
Patella granatina	1.399	**0.249**
Patella granularis	0.182	**0.834**
Patella barbara	0.305	**0.744**
Choromytilus meridionalis (left countable)	1.294	**0.277**
Choromytilus meridionalis (right countable)	2.289	**0.106**
Choromytilus meridionalis (left measurable)	1.245	**0.301**
Choromytilus meridionalis (right measurable)	4.123	***** ***0.024***

* significant at the 0.05 level.

Table 28: Intra-group shellfish analysis: ANOVA for shellfish size measurements.

Species (sub-category)	**Group**	*t*	*p*
Patella granatina	A/P	-0.239	**0.813**
	B/P	-1.341	**0.182**
	C/P	4.381	***0.000**
Patella granularis	A/P	-0.476	**0.641**
	B/P	0.961	**0.338**
	C/P	0.582	**0.574**
Choromytilus meridionalis (left countable)	A/P	-1.677	**0.076**
	B/P	-1.910	**0.059**
	C/P	4.074	***0.000**
Choromytilus meridionalis (right countable)	A/P	-0.188	**0.853**
	B/P	-1.100	**0.272**
	C/P	3.854	***0.000**
Choromytilus meridionalis (left measurable)	A/P	-	-
	B/P	-2.951	***0.003**
	C/P	0.648	**0.529**
Choromytilus meridionalis (right measurable)	A/P	-	-
	B/P	-2.629	***0.016**
	C/P	0.800	**0.438**

* significant at the 0.05 level.

Table 29: Inter-group shellfish analysis - Group A, B & C compared to Present Group: two-sided t-tests of shellfish size measurements frequency distributions.

Species	***Measurement***	***(Sub-)Category***	***Maximum value***	***Total average of relative variation***	***Maximum spatial analysis resolution (MSAR)***
Patella granatina	MNI	Measurable	382	0.1375	**53**
		Countable	3687	0.0480	**177**
		Total	4069	0.0250	**102**
	Weight (g)	Measurable	2923.9	0.1135	**331.9**
		Countable	9886.8	0.0565	**558.6**
		Fragments	12637.3	0.0230	**290.7**
		Total	24367.3	0.0235	**572.6**
	Size: average length (mm)	-	75.70	0.0370	**2.80**
Patella granularis	MNI	Measurable	345	0.0895	**31**
		Countable	969	0.1000	**97**
		Total	1294	0.0220	**28**
	Weight (g)	Measurable	1481.9	0.0995	**147.4**
		Countable	2147.7	0.1320	**283.5**
		Fragments	1026.5	0.1140	**117.0**
		Total	4252.6	0.0405	**172.2**
	Size: average length (mm)	-	47.36	0.0080	**0.38**

Table 30: Maximum Spatial Analysis Resolution (MSAR) for each shellfish variable calculated from maximum value of variable multiplied by its maximum relative variation.

Species	Measurement	(Sub-)Category	Maximum value	Total average of relative variation	Maximum spatial analysis resolution (MSAR)
Choromytilus meridionalis	MNI (left)	Countable	346	0.1470	**51**
		Measurable	62	* 0.5720	*** 35**
		Total	405	0.0560	**23**
	MNI (right)	Countable	321	0.1035	**33**
		Measurable	65	* 0.5550	*** 36**
		Total	383	0.0695	**27**
	Weight (left) (g)	Countable	1107.4	0.0440	**48.7**
		Measurable	132.1	* 0.5230	*** 69.1**
		Count.+Meas.	1239.5	0.0720	**89.2**
	Weight (right) (g)	Countable	1023.0	0.0560	**57.3**
		Measurable	154.1	* 0.5155	*** 79.4**
		Count.+Meas.	1177.1	0.0450	**53.0**
	Weight (g)	Fragments	7594.0	0.0170	**129.1**
		Total	10010.6	0.0145	**145.2**
	Size: average width of prismatic band (mm)	left countable	12.80	0.0575	**0.74**
		right countable	11.86	0.0365	**0.43**
		left measurable	12.22	0.0460	**0.56**
		right measurable	11.12	0.0695	**0.77**

*: Maximum relative variation is higher than 0.5000; therefore it is impossible to create a minimum of two intervals; these variables cannot be used for spatial analysis.

Table 30: (Continued) Maximum Spatial Analysis Resolution (MSAR) for each shellfish variable calculated from maximum value of variable multiplied by its maximum relative variation.

CHAPTER VI SPATIAL ANALYSIS OF DFM SHELLFISH

1 INTRODUCTION

A brief review

The spatial analysis of DFM shellfish is based on three pillars which were constructed at the beginning of this thesis: the analytical framework providing the knowledge in which the research is integrated, the methodological framework that defines the environment in which the analysis takes place and the Dunefield Midden data as the subject of the investigations. Together they form a unit that allows to test specific hypotheses.

At the end of the second chapter, a model of the most important factors that may cause spatial patterning in shellfish remains was developed (Figure 26 on page 56). The environment was identified as the first major source although the environmental variables (sea level, sea-surface temperatures, nutrient transport, substrate, etc.) are very unlikely to have changed during the short occupation of DFM and differed only slightly from what can be observed today. Human behavior, therefore, has to be seen as the likely source for patterning in shellfish remains at DFM. The species composition, population sizes and growth-rates of the shellfish colonies were most likely in equilibrium and any divergence from the expected can be seen to be due to specific human interventions.

A review of the ethnoarchaeological and archaeological literature pointed out that there are four main processes that have to be considered:

(a) *Foraging:* selective, related to availability, location, preferences and physical abilities.

(b) *Transport:* differential, related to processing cost and foraging range.

(c) *Processing:* differential, related to species and preferences.

(d) *Waste management:* small-scale spatial, related to hindrance.

In addition to likely spatial patterning on archaeological sites, there has been a substantial interest in possible influences of human predation on coastal resources as researchers have argued that shellfish could have been depleted by hunter-gatherer societies (Mannino and Thomas 2002 for a recent review). Changes in shellfish sizes, therefore, had been interpreted as the result of changes in the population structure of certain species during intensive gathering episodes.

From this analytical framework, three questions were formulated to guide the spatial analysis of DFM shellfish:

(1) Was foraging selective and are there indications for differential transport?

(2) Was processing differential and how was shellfish waste managed?

(3) Did human predation lead to a significant depletion of shellfish colonies?

With the DFM Spatial Database developed for this project and quantitative methods for spatial analysis these questions are investigated by analyzing the weights and size measurements of relevant shellfish species. These were shown previously to be generally robust against variations induced by the shellfish analysis process. A substantial proportion of the primary results is reprinted in the appendix "DFM Shellfish" on page 165 and will be referenced frequently.

DFM shellfish

During the excavations at Dunefield Midden large quantities of shellfish were recovered and the analysis of which showed that all species were of marine origin. The main source for collection was most likely the intertidal zone from Baboon Point to the mouth of the Verlorenvlei river (Figure 1 on page 2 and Figure 2 on page 3). Black mussels (*Choromytilus meridionalis*) were probably also gathered as washups from up along the sandy beach north of the river mouth (Parkington et al. 1992:67). The minimum transport distances from the sources to the site, therefore, were about 2000m for the intertidal shellfish colonies and about 600m for the washups from the subtidal.

Five main 'taxa' were of high interest for people at DFM (Figure 97 and 98 on page 168): *Patella granatina*, *Choromytilus meridionalis*, *Patella granularis*, Whelks and Barnacles. Their weight constitutes 95% of the total shell weight of which *Patella granatina* is, with a share of more than 50%, the 'most popular' on site. A similar situation was reported by Meehan (1982) from the Gidjingali people of northern Australia: they focussed their collection strategy on 6 of 29 possible species and those made up 95% of the total weight, with 61% represented by only one species.

The DFM 'top 5' are also dominating space, as they occur in most of the excavated squares (Figure 96 on page 167): *P. granatina* and *C. meridionalis* in 98%, *P. granularis* in 96%, Barnacles in 82% and Whelks in 81% of the total number of squares. In contrast to its relatively low total weight, *Donax serra* occurs very frequently on the site (90% of the squares). This can be explained by its natural occurrence in the former beach deposit on which DFM is situated (*Donax serra* is the 'sand mussel') and by random bird droppings. The distribution map of *Donax serra* emphasizes this point (Figure 124 on page 182): unlike the other species, the total weight per square of *Donax serra* is scattered randomly over the whole site appearing as a 'background smear'. This is an important fact as any pattern created by human behavior can be expected not to result in a spatially random distribution. *Donax serra* can therefore be used to demonstrate the clear difference in appearance of natural scatters vs. refuse deposits of human activities at DFM.

Of medium importance were *Patella barbara* and *Patella argenvillei* (Figure 97 on page 168) while others, such as the mussel *Aulacomya ater*, or the limpets *Patella miniata* and *Patella cochlear* were only of marginal interest to collectors as they occur in small quantities (Figure 98 on page 168). All other species were probably brought very infrequently, associated with other shell or by accident to the site (e.g. on the backs of other collected items).

If all shellfish weights per square are taken together, the total spatial distribution as it appeared after the final abandonment of the last occupation can be reconstructed. From the histograms of the number of squares that fall into a specific weight class (Figures 111-114, page 176ff), five distinct intervals were defined:

(1) *'Clean'* squares with *0-600g* shell weight (54% of total),

(2) *'messy'* squares with *600-1,800g* shell weight (16% of total),

(3) *'scattered dump'* squares with *1,800-7,500g* shell weight (19% of total),

(4) *'dump'* squares with *7,500-26,000g* shell weight (10% of total) and

(5) *'dense dump'* squares with *26,000-41,500g* shell weight (1% of total).

Space without much shell is dominating the excavated area (54%) followed by dump squares (30%) while 'messy' areas are ephemeral with 16% of the total. The distribution can be seen in Figure 71 and shows the basic spatial structures and relationships at DFM: Several dump areas in a line approximately parallel to the dune cordon become well defined and shellfish weights decrease *gradually* and in *regular fashion* around them. Disassociated are 'messy' patches in the north-east and east of the excavation. These are possibly related to the last phase of occupation where waste management became unnecessary (Parkington et al. 1992:68; see Fisher and Strickland 1989 for a comparable ethnoarchaeological situation). High concentrations of 'dump' and 'dense dump' squares in the south are likely to be a results of overlapping occupations - the area with a high chance of a minimum of palimpsests is represented by the complete northern half of the site (Parkington, pers. comm. and DFM field notes). As most of the hearth features were found in the east of the shellfish dumps, the living areas of the inhabitants were probably situated between the dune cordon and the dump. The density of occupational remains fades out quickly to the west indicating that camp related activities were concentrated in the excavated area.

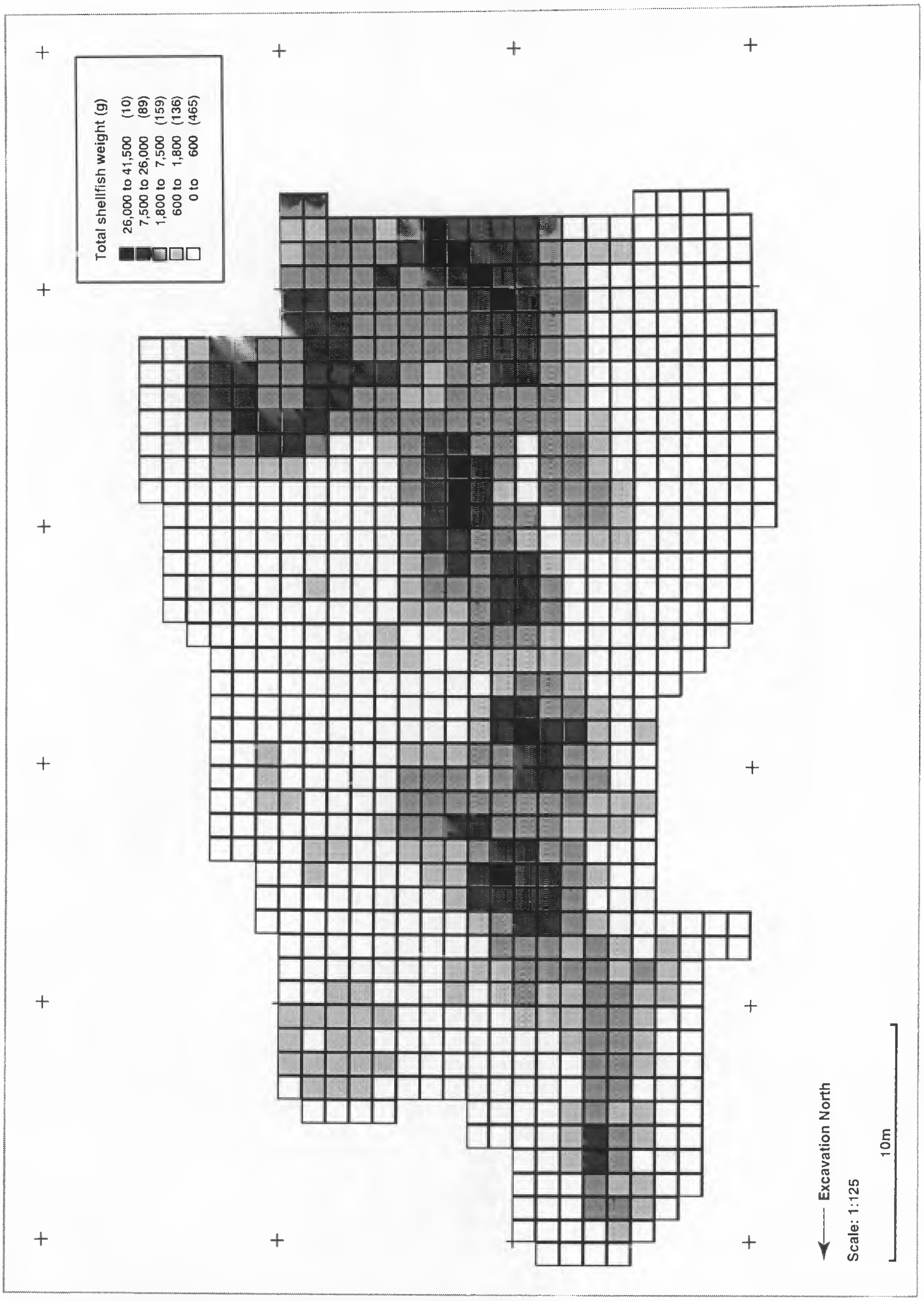


Figure 71: Spatial distribution of squares within previously defined ranges of total shellfish weights.

Most of the shellfish species reflect this general dump-pattern with a few exceptions by species of marginal or very small interest (Figures 115-132, page 178ff): the limpets *Patella miniata* and *Patella cochlear* (Figures 119 and 120) have stronger concentrations in the south of the site while the mussels *Aulacomya ater* and *Venerupis corrugata* (Figures 123 and 125) occur more frequently in the northern dump area. Whale barnacles (Figure 128) are very much concentrated in a zone in the southern part and the distributions of Helcion, *Crepidula* spp. and Fissurellidae (Figures 129-131) seem to be slightly shifted to west if compared to the general shellfish distribution. The randomly scattered *Donax serra* (Figure 124) remains have already been mentioned.

Shellfish size measurements were taken for all limpets (maximum length) and for the black mussel *Choromytilus meridionalis* (width of prismatic band). Size histograms of all measurements from DFM describe well the total populations that were targeted and brought to the site by the inhabitants. While the size distributions of *Choromytilus meridionalis* follow remarkably well a normal curve (Figures 107-110, page 174ff), the distributions of limpets are bimodal or skewed (Figures 101-106, page 171ff). The bimodality of *P. barbara*, *P. argenvillei*, *P. miniata* and *P. cochlear* results mainly from juveniles that were brought to the site while sitting on adult specimens. Of particular interest are the distributions of *P. granatina* and *P. granularis* as they do not completely follow a normal curve but are slightly positively skewed with a stronger effect observed with *P. granatina* (subadults were separated from adults in the shellfish analysis process and recorded separately).

The population structure of *P. granatina* and *P. granularis* that were collected and transported to DFM was estimated roughly from the size measurements using yearly growth rates determined by Branch (1974) with the assumption that fragmentation rates were independent of shell sizes. Table 43 on page 170 holds the results and shows clearly that both assemblages are dominated by 1-2 years old individuals. In case of *P. granatina* 65.0% of all measurable shells are of this age class and in case of *P. granularis* they constitute to 77.5%. 2-3 years old individuals are far less common (30.1% for *P. granatina* and 19.8% for *P. granularis*) and shells that are of an age older than 3 years are scarce at DFM (4.1% for *P. granatina* and 1.9% for *P. granularis*). Shells that were younger than one year are virtually non-existent at DFM although they are relatively frequent on the shore (Branch 1974). It was shown by Branch (1974:178) that body weight grows exponentially as shell age increases making older animals much more attractive for collectors following an optimal foraging theory. It is therefore likely that young individuals had been avoided in the collection process as their nutritional values are extremely low.

The average length of *Choromytilus meridionalis* brought to DFM can be calculated from the width measurements of the prismatic band multiplied by the factor 10 (Buchanan 1985b) and results in a mean size of about 89±15mm

(Table 42 on page 170). This size ranges is unlikely to be found in intertidal zone (Griffiths 1981; du Plessis 1977). The source of the black mussel is therefore probably the zone below the low water mark that is not accessible without stepping into the water. As it is relatively dangerous to access the sublittoral zone at Elandsbay due to heavy wave action and as there are no indications that hunter-gatherers were collecting shellfish in the sublittoral zone, the hypothesis of washup collections (Parkington et al. 1992) seems to be feasible.

2 SPATIAL PATTERNING

Was foraging selective and are there indications for differential transport?

The total shell weight of almost 2,500kg indicates that the inhabitants of Dunefield Midden were visiting intensively the coast to collect limpets, mussels, barnacles and whelks (Figure 97). It is accepted that most of the shell brought to the site came with flesh, resulting therefore in at least twice the total weight. It was mentioned before that limpets were probably collected in the zone between the Verlorenvlei mouth and Baboon Point. Resources in this area are plenty and the travelling distance is short. Whether the black mussel *Choromytilus meridionalis* was collected from washups in the same area where the limpets came from or directly from the beach close to DFM is difficult to establish.

To test the hypothesis that the process of collection was selective, the shellfish sample from DFM has to be compared to the natural species composition and population structure at its intertidal source. Modern samples from beach transects at Elandsbay are available and the results are summarized in the appendix "Elandsbay beach transects" on page 191. If foraging was not selective and therefore random, there should be no substantial differences between the DFM assemblage and the natural occurrence of shellfish on the coast. Optimal foraging theory, on the other hand, would predict that shellfish collectors would favor species that are predictable, available and in high numbers and have high nutritional values per individual to others that do not have these characteristics. In this context, the possibility of differential transport as pointed out by Bird and Bliege Bird (1997) has to be considered as it may affect the frequencies of species composition ("Ethnographical record" on page 37).

In the case of DFM, the collection process of shellfish is associated with the serial removal of single individuals from the rocky substrate (except for washups). A specific *effort* had to be made to remove the animals and the result might be represented well by the minimum number of individuals (MNI) brought to the site (Figures 99 and 100): Again, *P. granatina* dominates the assemblage with more than 50% of the total, followed by *P. granularis* with about 20%. Whelks and *C. meridionalis* are third and fourth with about 9% and 6% respectively. Unfortunately there are no MNI counts for barnacles available as the analysis process recorded only the total weights (MNI calculation is difficult).

Other high meat-bearing taxa are well below 1% of the total and although *Patella* spp. subadult, *Crepidula* spp. and Helcion have relatively high MNI counts, they have to be considered irrelevant for subsistence because of their very low flesh weights. It can be concluded that there was a particular interest for collecting and then transporting *P. granatina* to DFM.

As the most important species (*P. granatina*, *P. granularis* and *C. meridionalis*) show significant differences in the flesh meat weights per average sized individual, the MNI frequencies do not adequately represent the roles they played for subsistence. However, the dry flesh weights for each of them, which correlates well with their relative nutritional values (about 20kJ/g; Rebelo 1982:3-1), can be estimated. The results are presented in Table 44 on page 170: *C. meridionalis* shows the highest flesh weights in the range of the most common individuals at DFM, followed by *P. granatina* and *P. granularis*. It can be concluded that in respect to their dietary importance, the MNI counts are under-representing the black mussel (at least 40%) and slightly over-representing *P. granularis* (at least 15%) relative to the *P. granatina*. Again, this provides evidence that *P. granatina* was the dominant species brought to Dunefield Midden.

In strong contrast to DFM, the natural situation at the Elandsbay beach shows a different picture (Figures 133-136, page 192ff): MNI counts of *P. granularis* dominate all four transects with an average 34% of the total MNI, followed by Whelks (18%), *P. granatina* (14%) and *C. meridionalis* (8%), the latter only being reported in two of them. Helcion is strongly represented but is irrelevant for subsistence purposes; all other species are only marginally present. It can be concluded that there are significant differences between the MNI counts of DFM and the MNI counts from the natural source at the beach. Causes could be either a selective process or differential transport; the environmental setting with its influence on the species composition can be excluded from further considerations as it has not changed significantly since the occupation of DFM to be able to produce the observed differences.

The phenomenon of washups of *C. meridionalis* occurs along the whole coastline near Elandsbay. It seems to be reasonable, therefore, to distinguish two possible collection scenarios: (a) the black mussel was collected in *specific trips* at the sand beaches close to DFM and/or (b) the black mussel was gathered additionally or instead of limpets at the rocky shore in the south. For (a) the transport costs would have been significantly lower than for (b). It could be argued, on the other hand, that the unpredictability of washups would favour (b) to (a) as trips to the rocky intertidal zone were likely to have happened regularly. The argument of unpredictability, however, seems to be weak as stormy weather that leads to rough seas and washups of sublittoral shellfish could be certainly seen and felt by the inhabitants of DFM as their camp was not far away from the sea. If there is no good other reason why the distance would produce an advantage for subsistence, it has to be assumed that scenario (a) is far more likely than (b). Accordingly there could have been at least two processes going on: regular trips to the more than 2km distant limpet colonies and irregular trips to the about 600m distant washups. It is likely that foraging strategies would have been specifically adapted to the different tasks. Following these assumptions, it was seen to be appropriate to investigate *P. granatina* and *P. granularis* independently from *C. meridionalis* in terms of the hypothesis that foraging was selective.

Although *P. granularis* is most common at the beach in terms of individuals, its general population structure indicates that a potential predator is unlikely to find high numbers of large individuals which are particularly interesting for subsistence (Figure 21 on page 48). The DFM sample shows clearly that only individuals of *P. granatina* and *P. granularis* that were larger than about 30mm were collected by the inhabitants of DFM which is equivalent to an minimum age of one year (Figures 101 and 102). Taking the four transects together, it can be calculated that only 49% of *P. granularis* MNI but 77% of *P. granatina* MNI are bigger than 30mm (Figures 138 and 140). Another important factor is that the flesh weight increases exponentially with age, making individuals older than 2 years particularly interesting for a potential predator. Life tables, however, show that only about 40% of the initial population of *P. granularis* survive to the second year, while about 70% of *P. granatina* reach this age (Figures 22 and 23, page 49; Table 8 on page 50 for key to sizes of age classes). This is clearly reflected by the data of the beach transects as only 18% of the observed MNI of *P. granularis* (>=40mm) and still 37% of *P. granatina* (>=54mm) appear to be older than two years. The weight-gaining factor becomes especially evident when both species reach the age of about 2.5 years, when *P. granatina* produces about twice as much dry flesh mass than *P. granularis* (Rebelo 1982:3-1). Taking all these observations together, it can be concluded that *P. granatina* is far more interesting as a basis for a predictable, long-term subsistence collection strategy than is P. *granularis*, although it occurs less often at the Elandsbay beach. Differential transport as outlined by Bird and Bliege Bird (1997) is very unlikely as cause for this inverse ratio of occurrence because both species share the same habitat, can be gathered in about equal amounts of time and have the same edible to inedible weight ratio. The overall picture supports strongly that a *selective process* was responsible for the abundance of *P. granatina* at Dunefield Midden.

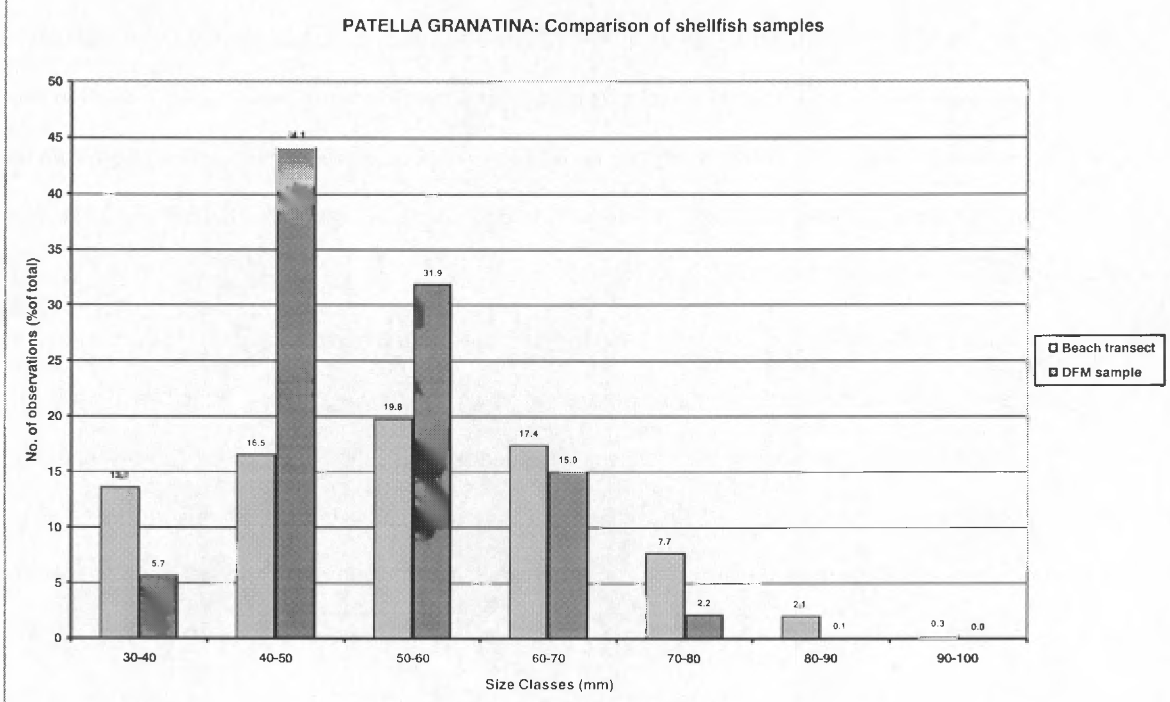
It was mentioned before that the total size frequency distribution of the two main limpets is significantly positively skewed with a stronger signature of *P. granatina*. There are two likely causes that may explain why this is the case: (1) the distribution reflects the natural availability on the beach or (2) it is a product of selective behavior for specific sizes of individuals. It was already shown, that a minimum size of potential prey was an important criterion in the collection process, but there might be other specific criteria that an individual has to fulfil in order to be gathered.

When the size measurements of the DFM samples are compared to the beach transects (Figures 72 and 73), there are substantial differences, especially in the case of *P. granatina* where four observations can be made: (1) Although the minimum size was found to be set to about 30mm, there had been less individuals gathered of sizes between 30 and 40mm than were most likely available. (2) More specimens than expected in a random process of collection were gathered with sizes were between 40 and 60mm. (3) The proportion of individuals with sizes between 60-70mm are similar between the beach transects and DFM . (4) Significantly fewer individuals from the DFM sample had sizes of over 70mm than were found on the beach transects.

In the case of *P. granularis*, only the size class of 30-40mm is represented more frequently at DFM than at its natural source. Specimen sized between 40mm and 50mm were found only slightly more common at the beach while Individuals larger than 50mm are less common in the archaeological deposit than in the transects. It can be concluded that comparisons of size frequency distributions found at DFM with a natural sample from the Elandsbay beach points towards a selective behavior relating to shellfish size in particular with *P. granatina* as individuals of ages between about 1 and 3 years are more frequently represented at DFM than expected in a random collection process.

The foraging strategy of *Choromytilus meridionalis* was already assumed to be different from the limpets as they were most likely gathered from washups. Unfortunately there is no information on species composition and their population structures available for washups in the Elandsbay area. Although one might think that larger specimens are more likely to be removed by stormy seas, the following investigation has to be based on the untested assumption that the process removing *C. meridionalis* from the substrate in the sublittoral is not differential in terms of population structure. In other words, the individuals removed and washed onto the shore are assumed to be randomly chosen from the total sublittoral population.

It is therefore very interesting that, in strong contrast to the limpets, the total DFM sample of *C. meridionalis* shows size frequency distributions that do perfectly follow a normal curve (Figures 107-110, page 174f). As selective behavior for size can be expected to result in slightly skewed distributions, it seems to be unlikely that the collection process of the black mussel was selective for a *specific* size (about 89mm). *C. meridionalis* with an average size of about 90mm can be regularly found in the sublittoral after about 2 years of growth. The DFM sample therefore supports a more *opportunistic* collection process as washups provided immense and dense loads of shellfish. Gathering would have been characterized by *randomly* picking many individuals with sizes reflecting a sublittoral population of the average age of 2 years. Size selective behavior, however, might have been involved by intentionally avoiding unattractive small individuals that were washed up together with the sublittoral specimens from the intertidal.



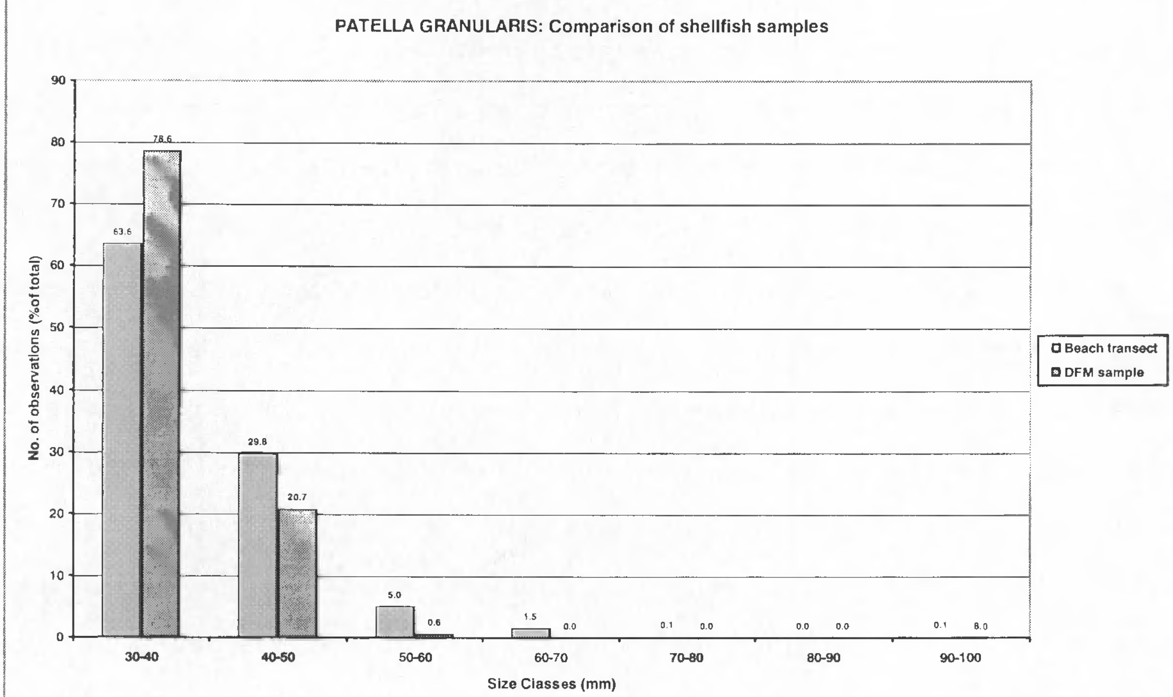


Figure 72: *Patella granatina*: Relative size structure of the DFM sample and the beach transects. (Top)

Figure 73: *Patella granularis*: Relative size structure of the DFM sample and the beach transects. (Bottom)

The strong focus on limpets from the intertidal sources might have been stimulated by the fact that their energy yields are relative high compared to *C. meridionalis*: The largest intertidal black mussels of about 70mm length (Griffiths 1981:113) produce a dry flesh mass of about only 1g (Rebelo 1982:3-1) and are relatively rare. Equal amounts of flesh per individual can be obtained from about 2 year old *P. granatina* (50mm) or *P. granularis* (40mm) that are both available in large numbers. This situation changes when large sublittoral black mussels are washed up onto the shore: *C. meridionalis* with an average size of 90mm were abundant, each yielding 1.9g of dry flesh mass; equal amounts would have only been available from *P. granatina* and *P. granularis* individuals older than 3 years which are very rare and probably not worth searching for. If the inhabitants would have followed an optimal foraging strategy, they would have switched from limpets to black mussels when washups were available.

It can be concluded that a possible foraging strategy for DFM could have looked like this: Several people would regularly travel to the *intertidal* between the Verlorenvlei mouth and Baboon Point to gather limpets, mainly *P. granatina* and possibly some *P. granularis*, both aged between 1 and 3 years, while avoiding black mussels because of their relatively low nutritional values. In the beginning, older animals with their extremely high dry flesh mass yields would have been the main target while younger specimen became more import with the decreasing numbers of the older ones. Most of the collected individuals were transported back to DFM for processing and consumption, some may have been field processed as 'a snack' (see Meehan 1982 for an ethnoarchaeological example). Rough seas would irregularly washup large quantities of black mussel close to DFM with relatively high energy yields per individual. Trips to the intertidal would be sustained in the meantime to make use of this fortunate event and a group of people would quickly gather large amounts of the mussels and transport them back to DFM. The flesh had to be processed within a short time as it becomes inedible after a few days; drying could have been used to preserve the flesh and create a small stock for consumption in the foreseeable future (Henshilwood et al. 1994).

Was processing differential and how was shellfish waste managed?

It was shown in the previous section that two different foraging strategies were likely to have coexisted with each other at DFM: the first concentrating on the regular collection of limpets and the second replacing the first in specific situations where large black mussels were available. Additionally it was mentioned in the introduction of this chapter that the overall spatial distributions of shellfish species weights define the space at DFM into dump zones, 'messy' and 'clean' areas. It is assumed in the following that the result of different foraging strategies, processing and waste management is reflected within these 'messy' and dump areas while 'clean' patches were probably related either to living areas that were kept free from hindering refuse or define spaces that were not used for any activities related to shellfish.

Correlation matrices were calculated to describe the overall situation of shellfish weight distributions at DFM (Tables 45-47, page 187ff). The results summarized in Table 31 show clearly that *P. granatina*, *P. granularis* and *C. meridionalis* are spatially related to each other, supporting the visual observations made previously. Additionally the strong correlation and therefore spatial relationship of *C. meridionalis* and Barnacles has to be emphasized. The analyses of the DFM Barnacle sample has shown that most of them have characteristic marks that indicate that they were originally attached to the shells of large black mussels (Parkington, pers. comm.). This occurs in the natural environment predominantly in the sublittoral zone where large *C. meridionalis* exist. Other interesting correlations are not discussed in this context.

The two questions asked in this section are closely associated with each other as the processing of shellfish created the need for extensive waste management. Unfortunately it is unlikely that these two processes can be distinguished in most parts of DFM as the clear signatures characterizing shellfish processing activity were likely to be altered sooner or later by maintenance processes (see "Cultural formation processes and refuse structure" on page 54 for a general discussion). The result of processing and waste management, however, can be spatially analyzed and might reveal some general patterning.

If it is true that the black mussel was collected independently from limpets and vice versa than there is a good chance for significant differences in the spatial distribution of these taxa as a result of differential processing and dumping. The overall frequencies of shellfish weights species per square indicate that there is some variability in the species composition between squares over space (Figure 74). Very strong variations are shown by *P. granatina* and *C. meridionalis* which were identified previously as the two relevant species that may have influenced foraging strategies, followed by *P. granularis*, Whelks and Barnacles with lower variations. It is these five taxa that dominate the shellfish assemblage and their spatial distribution should reflect specific processing and waste management behavior. Non-differentiallity would be represented by proportional weight relationships while differentiallity should result in distinguishable relative shellfish weight combinations per square.

K-means cluster analysis was used to identify squares with similar species composition (refer to "K-means cluster analysis" on page 63 for a detailed discussion of the method). Only squares that fell at least into the total shellfish weight category 'messy' (total weight > 600g) were included into the analysis to reduce the noise from squares with virtually no shellfish content. Fifteen cluster stages were processed and the test statistics indicated that the 4-cluster

Species	strong correlation with
P. granatina	P. granularis
	C. meridionalis
	P. spp. subadult
P. granularis	P. granatina
	P. spp. subadult
	C. meridionalis
P. spp. subadult	P. granularis
	P. granatina
	C. meridionalis
C. meridionalis	Barnacles
	P. granatina
	P. granularis
	P. spp. subadults
	Whelks
Aulacomya ater	Whelks subadult
Venerupis corrugata	Whelks subadult
C. meridionalis subadult	Whale barnacles
Whelks	Crepidula spp.
	C. meridionalis
	Barnacles
Whelks subadult	Aulacomya ater
	Venerupis corrugata
Barnacles	C. meridionalis
	Whelks
Whale barnacles	C. meridionalis subadult
Crepidula spp.	Whelks

Table 31: Shellfish weights per square: species with strong correlations.

solution was particularly interesting (Figures 75 and 76). The analysis was designed to return species compositions that occur relatively often at DFM and the results reveal a complex picture (Figure 77 and Table 32): Cluster 1 is very much dominated by *P. granatina* (about 2/3 of total shellfish weight) with other species being only marginally present. Cluster 2 is still dominated by *P. granatina* but it gives shares to *C. meridionalis* which has doubled its average weight to about 20% compared to the first cluster. The trend continues in the third where both *C. meridionalis* and *P. granatina* share about the same weight percentage (35-40%) with the others still being marginal. Cluster 4, with only 20 squares

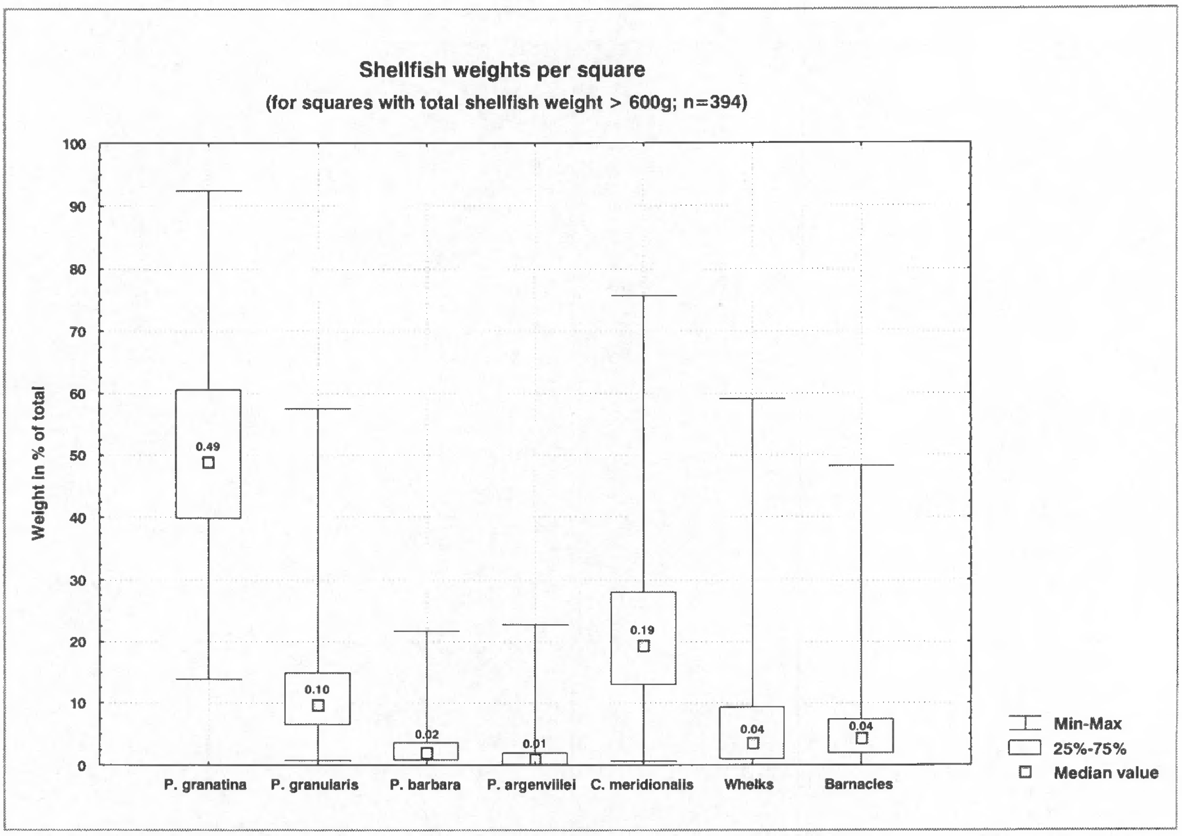


Figure 74: Shellfish weights per square of the seven most abundant taxa (for squares with a total shellfish weights > 600g).

the smallest of all, presents an unusual picture: Whelks and *P. granatina* are about equally abundant with each 30% share, followed by *C. meridionalis* (about 15%). Note that the standard deviations are higher than the variations created by the shellfish analysis process (see "Variability of DFM shellfish analysis" on page 109 for the investigation): the total weight of *P. granatina* per square was found in the experiments to vary in the *range* of 2.4%, *P. granularis* by 4.1% and *C. meridionalis* by 1.5%. Similar percentages can be assumed for Whelks and Barnacles. These low values together with the non-directionality of variation from the 'correct measurements' makes it very unlikely that the results of the cluster analysis were produced by the shellfish analysis process and it can be therefore concluded that the cluster analysis was able to identify specific species compositions that are distributed over space at Dunefield Midden. This is consistent with the hypothesis that processing and / or dumping was differential. The reason for this could be rooted in the distinct underlying foraging strategies that where described previously. Accordingly, high frequencies of *C. meridionalis* should indicate the remains of activities strongly associated with the black mussel. High concentrations of *P. granatina*, on the other hand, should resemble areas with strong dependence of subsistence on the most common limpet.

Shellfish processing and dumping can be seen as strongly space defining activities as huge amounts of shell waste create very high hindrance rates compared to other common activities such as meat processing or stone chipping. It was shown before that correlations of total shellfish weights per square described the overall picture of spatial shell distribution very well but could not illustrate spatial differences in species composition per square. With the results of the cluster analysis and the DFM Spatial Database system, this can be visualized: MapInfo was used to display the spatial distribution of the 4-cluster solution (Figure 78). The visual inspection of the map shows clearly that the clusters on shellfish weights per square are not randomly distributed: they are *spatially* clustered as squares with the same numbers occur in the same areas. The strength of spatial clustering was investigated utilizing spatial autocorrelation techniques (see "Spatial autocorrelation" on page 68 for details). As the distribution is characterized by objects that contain nominal values, the 'Join count statistic' was applied. The results show clearly that there are more joins of objects with same values than would have been expected in a random distribution providing strong statistical evidence (all significant at 0.01 level) that the objects with same values are spatially clustered (Table 33).

The comparison of the spatial cluster distribution with the definitions of 'messy' and 'dumpy' areas (Figure 71 on page 128) shows no strong correlation, indicating that the species composition is independent from the total shellfish weight per square. Following the general argument of this section, it is likely that the spatial distribution of relative shellfish frequencies is the result of differential processing and waste managing behavior. The relationships of activity areas resembled by processing features to these distinct refuse areas might hold the key for the detailed identification of these behaviors. This investigation, however, is beyond the scope of this thesis.

Early in the excavation of DFM, Parkington et al. (1992) showed particular interest in the spatial distribution of limpet shellfish sizes assuming that "the pattern of sizes and proportions reflect the time span of the visit, with larger animals and the larger species preferred in early collections and smaller animals gathered as the visit progressed and the shellfish population impacted" (Parkington et al. 1992:68). In other words, selective shellfish collection behavior for large sized limpet specimen with high flesh yields was expected to be differentially distributed over the site as processing and waste management changed its location over time. This very detailed hypothesis can be tested and investigated with the DFM Spatial Database.

In cases where shellfish constituted a significant share of subsistence, optimal foraging theory would expect that the decision to gather specimens is dependent on two main factors that are closely related to each other: (a) the size as it indicates flesh amounts and (b) the available numbers of shells of a certain size. It can be expected that there is a specific threshold where collection is 'paying off' most, as the increase of size is related to a decrease in available numbers. There are two extremes that could be considered: collecting few very large individuals or collecting many small ones. The gain of flesh by collecting very large limpets is reduced as they are scarce and the time spent to find them takes great amounts of energy. The time-saving collection of abundant small limpets, on the other hand, is associated with low flesh yields per specimen and a strong increase of shell weight relative to flesh weight which makes them less suitable for transport. Somewhere in between these extremes might have been the 'ideal size range' of a limpet for subsistence purposes. Within this range it is likely that larger individuals were gathered first and later smaller ones.

The comparison of size frequency distributions from the DFM sample with beach transects had shown that shellfish gathering was selective for 1-3 year old *P. granatina* (>30mm and <68mm) and *P. granularis* (>28mm and <47mm). It is therefore assumed that this represents the size range that was 'paying off' most for the inhabitants of DFM. One way to investigate the distribution of limpet sizes is to plot the average size per square (Figures 79 and 80). Note that the interval sizes for shading were chosen to fit about the minimum spatial analysis resolution defined previously (see results in Table 30 on page 122). Any patterning observed visually is therefore very unlikely to be a result of the shellfish analysis process. Both distributions seem to follow a similar basic pattern: larger average sizes of *P. granatina* and *P. granularis* tend to be in the east and smaller average sizes in the west. To reduce the amount of information, the DFM Spatial Database was used to count the number of individuals per square that were 1-2 years old and 2-3 years old respectively and the results were again visualized with MapInfo (Figures 81-84). The abundance of 1-2 year old individuals is emphasized by the darker shades, representing higher percentages of the total number of measurements per square. A distinct zone at the very eastern fringe of 'the dump' has equal or higher relative amounts of 2-3 year old specimen and most of the rest is mixed or dominated by the younger group. Accordingly to the analysis of taxa weight per square, the *k*-means cluster analysis method can be used to ask the question 'Are there squares with distinct age class compositions per square?'. For *P. granatina* the cluster analysis results (Figures 85 and 86) suggested that the 3 cluster solution was particularly interesting while the test statistics for *P. granularis* did not result in a recommendation for further analysis (Figures 87 and 88). Perhaps the overall small numbers of 2-3 year old *P. granularis* individuals made it impossible to create significant clusters. For *P. granatina*, however, the descriptive statistics of the three clusters (Figure 89 and Table 32) indicates that there are indeed squares that are dominated by 2-3 year old individuals with about 60% of the total number of measurable shells (cluster 2), while others are dominated the younger age group with more than 75% (cluster 3). An intermediate cluster (number 1) is constituted of about 55% 1-2 year old specimen and about 40% that are 2-3 years old. The spatial distribution of these clusters shows again that they are not randomly distributed (Figure 90). Spatial autocorrelation was used to quantify the distribution and resulted in the demonstration of significant clustering (Table 36). It can be concluded that the age classes of *P. granatina* are significantly spatially distributed at Dunefield Midden. Older individuals can be found predominantly in the eastern part of 'the dump' while the dominating younger specimen are in the western part. In the middle both age classes are found.

A visual evaluation may suggest that average sizes of *P. granatina* and *P. granularis* change in a similar fashion over space (Figures 79 and 80). This was quantitatively investigated by calculating correlation values for squares with different minimum counts of measurable shells (Table 34): When all squares that have at least one measurement for *P. granatina* and *P. granularis* are included, the correlation is very weak. As the number of squares was reduced by restricting valid number of measurements per limpet to a minimum of 10, 20, 30, 40 or 50, the correlations get stronger. The reduction, however, did not significantly increase the correlation values from the setting of 20 measurements per limpet onwards (Figure 91). Although a r^2-value of 0.5 does not seem to be a strong correlation, it has to be considered that at least three different processes (selection at the beach, processing on site and dumping of shells) were involved in creating this pattern. Additionally this observation can be compared to the correlations between average sizes of the black mussel and the limpets (Table 34), which show a maximum r^2-value of only 0.12. This indicates that the magnitude of the correlation between *P. granatina* and *P. granularis* is very high *within the context* of Dunefield Midden. The spatial distribution of squares with at least 20 measurements for the two limpets encompasses all dump squares and some 'messy' squares (Figure 92). It can be concluded, therefore, that changes in average size of *P. granatina* and *P. granularis* are significantly spatially correlated. As size differentiation processes *on site* seem to very unlikely, the source of the patterning was most likely the *collection processes at the shore*. Natural causes, such as short time variations of low water levels can be excluded as large limpet individuals are not restricted to the low intertidal but more frequent towards the high level mark where they are daily accessible. It can be concluded that a change in selective behavior over time was the most likely reason for spatial patterns in shell sizes at Dunefield Midden. The hypothesis of Parkington et al. (1992), is therefore confirmed.

Did human predation lead to a significant depletion of shellfish colonies?

It was shown in the previous section that there is a strong case for a decrease of limpet sizes transported to DFM over time. This was associated with selective foraging behavior for larger individuals: If the primary target size is reduced significantly, smaller sizes classes have to be collected until, in a extreme case, the size is reached where gathering and transport does not 'pay off' anymore. It was also presented that two age classes were preferred: 1-2 year old and 2-3 year old individuals. Included in this model is the assumption that there was a depleting factor involved directly linked to age. It is very difficult, if not impossible, to prove that age classes were reduced by human actions as the size of the area of collection and the involved time spans are unknown. However, it can be estimated how strong the impact on the population could have been in a extreme case by calculating the minimum total biomass of *P. granatina and P. granularis* transported to DFM.

The DFM Spatial Database was used to count the minimum number of individuals per size class (10mm intervals from 20mm to 100mm). Then the counts were multiplied by conversion factors to estimate the dry flesh mass per size class (Rebelo 1982; see Table 9 on page 51). The results were summed up providing the minimum dry flesh mass of *P. granatina* and *P. granularis* transported to DFM.

The overall importance of *P. granatina* as the main limpet prey was emphasized again by the results presented in Table 37 on page 158 as it provided more than twice as much dry flesh than *P. granularis*. Individuals of *P. granatina* that had sizes between 50mm and 70mm (2-3 years old) were making up about half of all specimens and were most important for subsistence as they compromised more than 70% of the total dry flesh weight of this limpet. A similar picture is given by *P. granularis* as the age class of 2-3 year old individuals provided about 50% of dry flesh weight although they made up only about 20% of the total count.

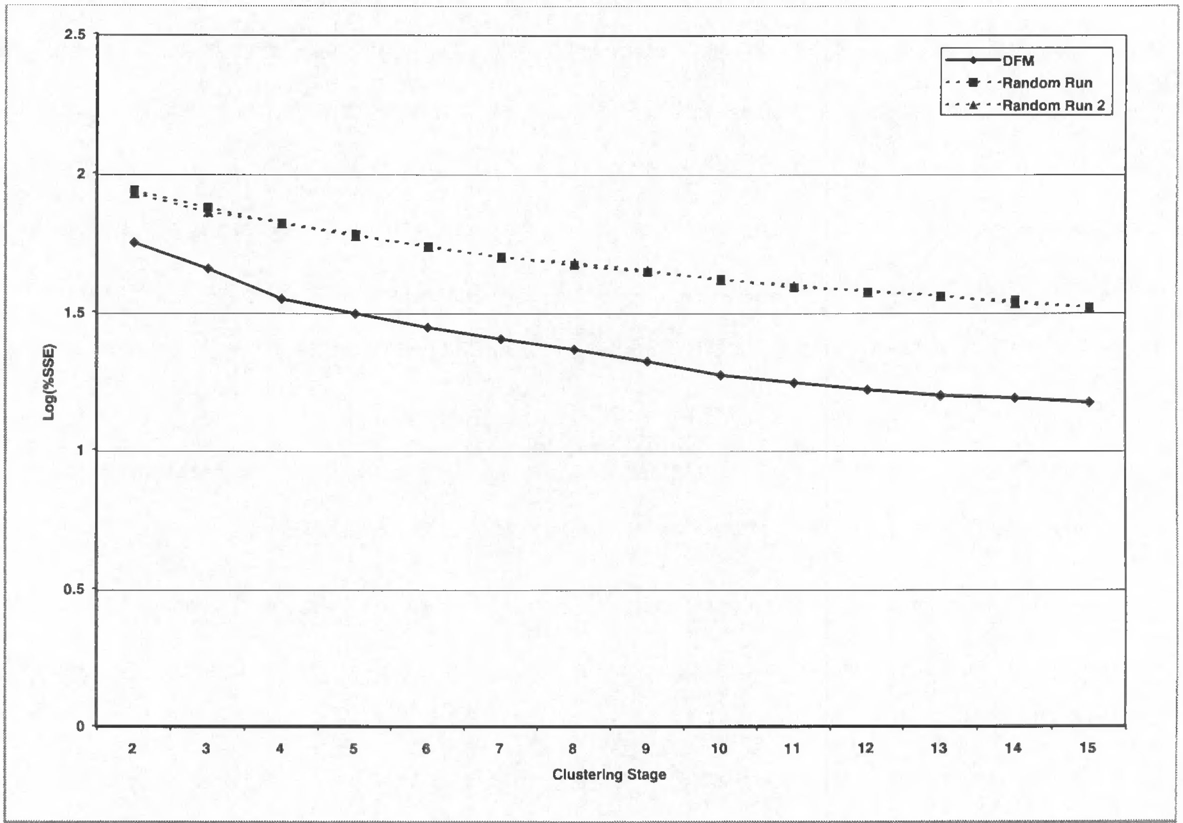
Biomass distributions at Elandsbay were investigated by Buchanan (1985). For the area between Baboon Point and the Verlorenvlei River Mouth (sector 1), Buchanan found that *P. granatina* constitutes today to about 43% and *P. granularis* to about 34% of the total available shellfish biomass of the intertidal, while the black mussel is only very marginally represented with about 2% of the total (Table 10 on page 52). The total nutritional values (in kJ) of the two limpets transported to DFM can be calculated by multiplying the total dry flesh mass (in g) by the factor 20 (Rebelo 1982:3-1), resulting in 791,366kJ for *P. granatina* and 337,396kJ for *P. granularis*. Compared to the available biomass in sector 1, these figures are extremely low. *P. granatina* from DFM represents only 3.5% of the potential nutrients available in the intertidal and for *P. granularis* the equivalent percentage is 1.8%. It can be concluded from this observation that the population in sector 1 was unlikely to have been significantly reduced by the people living at DFM. Changes in average sizes of limpets transported to DFM, therefore, could not have been a result of the overall depletion of shellfish resources in the area between Baboon Point and the Verlorenvlei River Mouth.

Following the general question of the human impact, it might be of interest how large the intertidal area was that had been affected by shellfishing processes. With the information of the Elandsbay beach transects the minimum area for *P. granatina* and *P. granularis* was estimated: First the mean dry flesh weight yields per size class of the intertidal zone were calculated (Table 38 on page 158). Next the total biomass for each size class from DFM was divided by the values from the transects and the results were visualized in Figures 93 and 94, page 159f. Individuals of *P. granatina* with ages between 2 and 3 years had to be gathered from at least 6,500m^2, while specimen from the 1-2 year age class had to be collected from at least 11,000m^2. With *P. granularis* the numbers are much lower: at least 2,100m^2 for 2-3 year olds and at least 3,600m^2 for 1-2 year olds. It has to be stressed that this an extreme scenario as no single individual of that age group would be existing any more in the specified areas. In reality it can be expected that there is a certain threshold where the density distribution of a shellfish species over a given area is already so thinned out that it does not 'pay off' any more to collect it. Thus the target area must have been significantly larger the these calculations of the extreme minumum.

The question remains what specific process(es) reduced the size classes significantly as they were available in such large amounts in sector 1. There are at least three possible scenarios that could explain this:

- The size of the intertidal area where limpets were collected was several times smaller than sector 1.
- The shellfish resources were already impacted by repetitive visits over a longer time period *previous* to the occupation of DFM.
- There were substantially more people collecting shellfish in sector 1 during the occupation at DFM than proposed for the Dunefield Midden site alone.
- Although very unlikely, it is theoretically possible that most of the shellfish was processed in the field and only few individuals were brought back to DFM. In this case, the shellfish remains found at the site are not representative for the total collected biomass.

Clearly more research has to be carried out in order to isolate the main reasons resulting in changes of shellfish sizes. The extremely well researched Elandsbay area, however, is seen to be one of the rare places in the world where this could be pursued successfully.



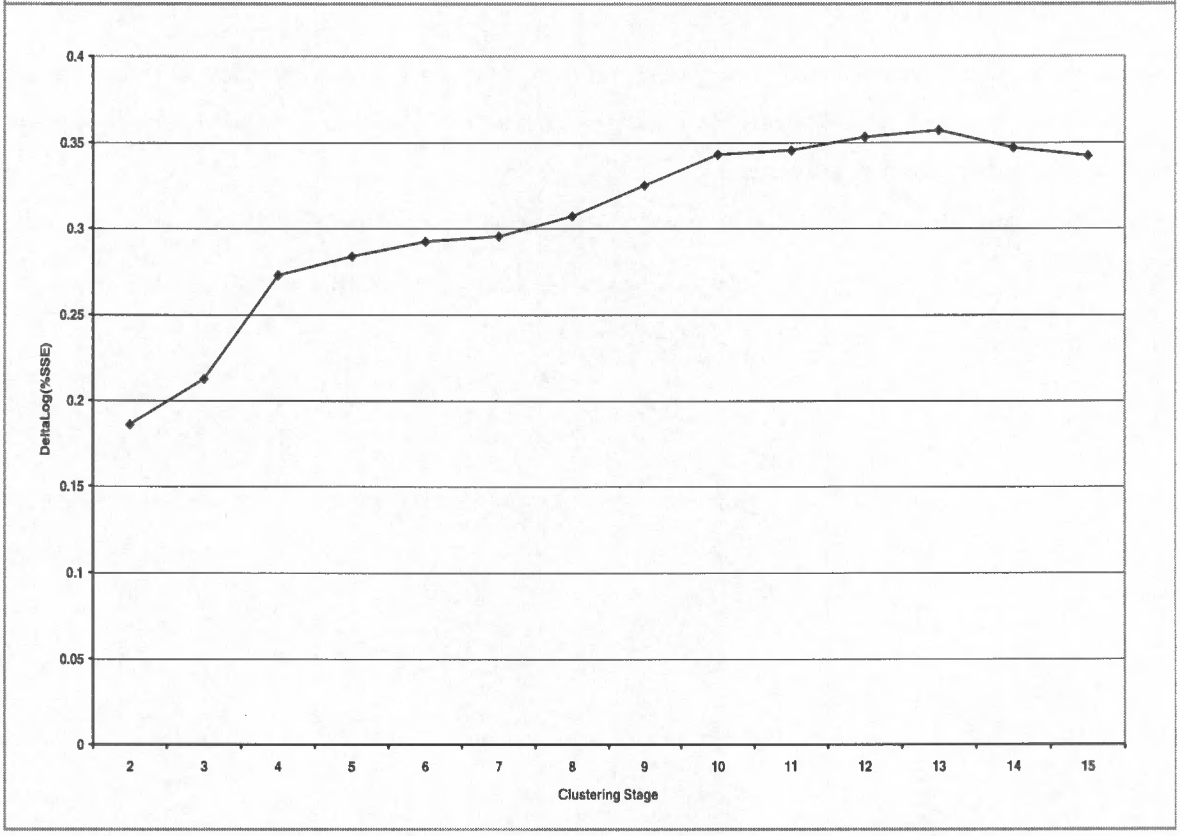


Figure 75: Log(%SSE)-graph of cluster analysis on shellfish weights per square. (Top)

Figure 76: DeltaLog(%SSE)-graph of cluster analysis on shellfish weights per square. (Bottom)

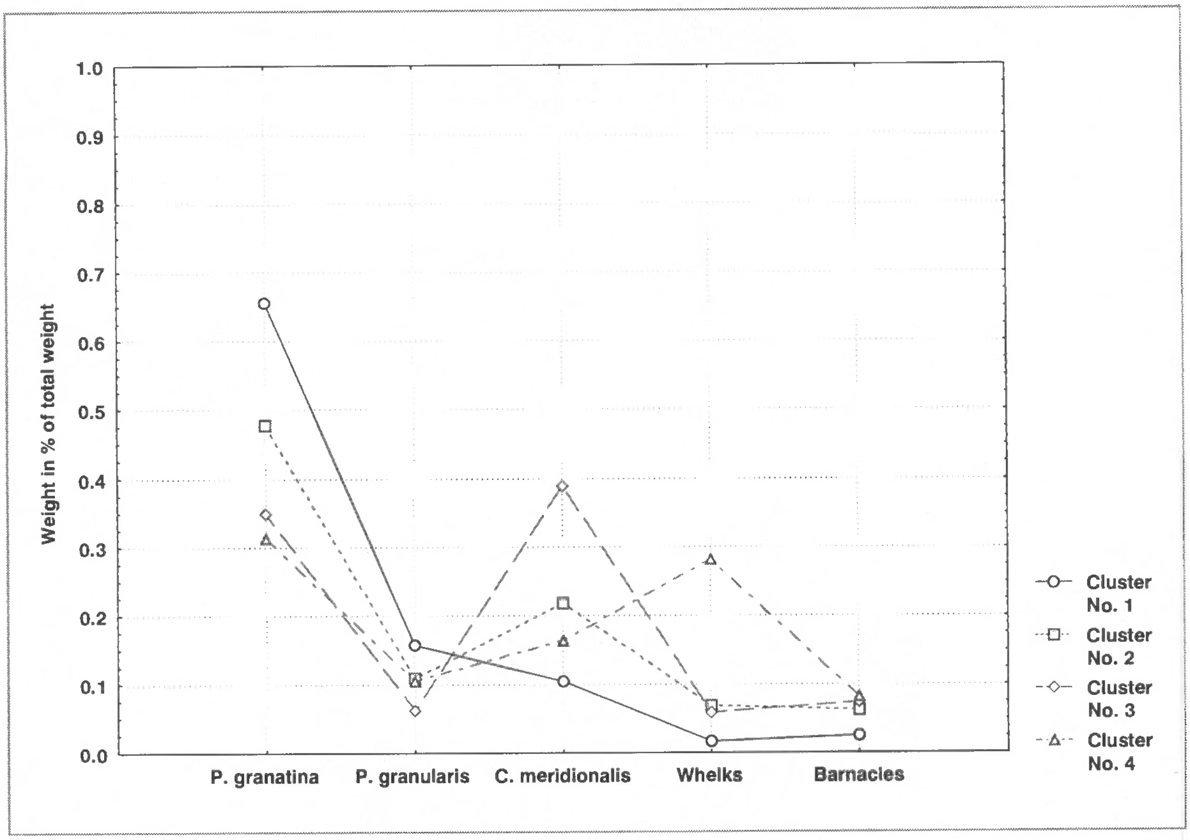


Figure 77: Cluster analysis: Cluster means of 4-cluster solution on shellfish weights per square of the five most abundant taxa.

Species	*Cluster 1 (n=127)*		*Cluster 2 (n=159)*		*Cluster 3 (n=78)*		*Cluster 4 (n=30)*	
	Mean (%)	*StDev (%)*	*Mean (%)*	*StDev (%)*	*Mean (%)*	*StDev (%)*	*Mean (%)*	*StDev (%)*
P. granatina	65.6	7.0	47.8	6.0	35.0	6.6	31.4	7.3
P. granularis	15.8	7.9	10.9	6.3	6.2	3.0	10.5	5.3
C. meridionalis	10.4	4.8	21.8	5.5	38.9	9.8	16.4	4.1
Whelks	1.6	2.1	6.8	5.3	5.9	4.7	28.2	11.6
Barnacles	2.5	2.8	6.1	4.5	7.4	5.6	8.2	8.3

Table 32: Cluster analysis: 4-cluster solution on shellfish weights per square of the five most abundant taxa.

Variable	Number of observed joins	Number of expected joins of a random distribution		Significance level (p)	
		resampling (N)	randomization (R)	resampling (N)	randomization (R)
Cluster 1	149	68.9	68.5	0.01	0.01
Cluster 2	156	108.0	107.6	0.01	0.01
Cluster 3	78	26.0	25.7	0.01	0.01
Cluster 4	30	3.8	3.7	0.01	0.01

Table 33: 'Join count statistic' on the spatial distribution of the 4-cluster solution on shellfish weights per square.

Variable 1	Variable 2	Limitation	No. of squares	r
Average size of Patella granatina per square	Average size of Patella granularis per square	-	684	* 0.28
		at least 10 measurables each	345	* 0.58
		at least 20 measurables each	255	* 0.68
		at least 30 measurables each	191	* 0.68
		at least 40 measurables each	153	* 0.70
		at least 50 measurables each	136	* 0.66
Average size of Patella granatina per square	Average size of Choromytilus meridionalis (left countable) per square	-	559	* 0.14
		at least 10 measurables each	263	* 0.27
		at least 20 measurables each	179	* 0.21
		at least 30 measurables each	145	* 0.24
		at least 40 measurables each	106	* 0.24
		at least 50 measurables each	75	* 0.26
Average size of Patella granularis per square	Average size of Choromytilus meridionalis (left countable) per square	-	551	* 0.11
		at least 10 measurables each	254	* 0.35
		at least 20 measurables each	174	* 0.30
		at least 30 measurables each	129	* 0.27
		at least 40 measurables each	94	0.18
		at least 50 measurables each	65	0.20

*: significant at the 0.05 level

Table 34: Correlations (r-values) of average sizes of shellfish species per square.

Figure 78: Cluster analysis: Spatial distribution of the 4-cluster solution on shellfish weights per square of the five most abundant taxa.

Figure 79: Distribution of average sizes per square of *Patella granatina* (only squares that have at least 10 measurements).

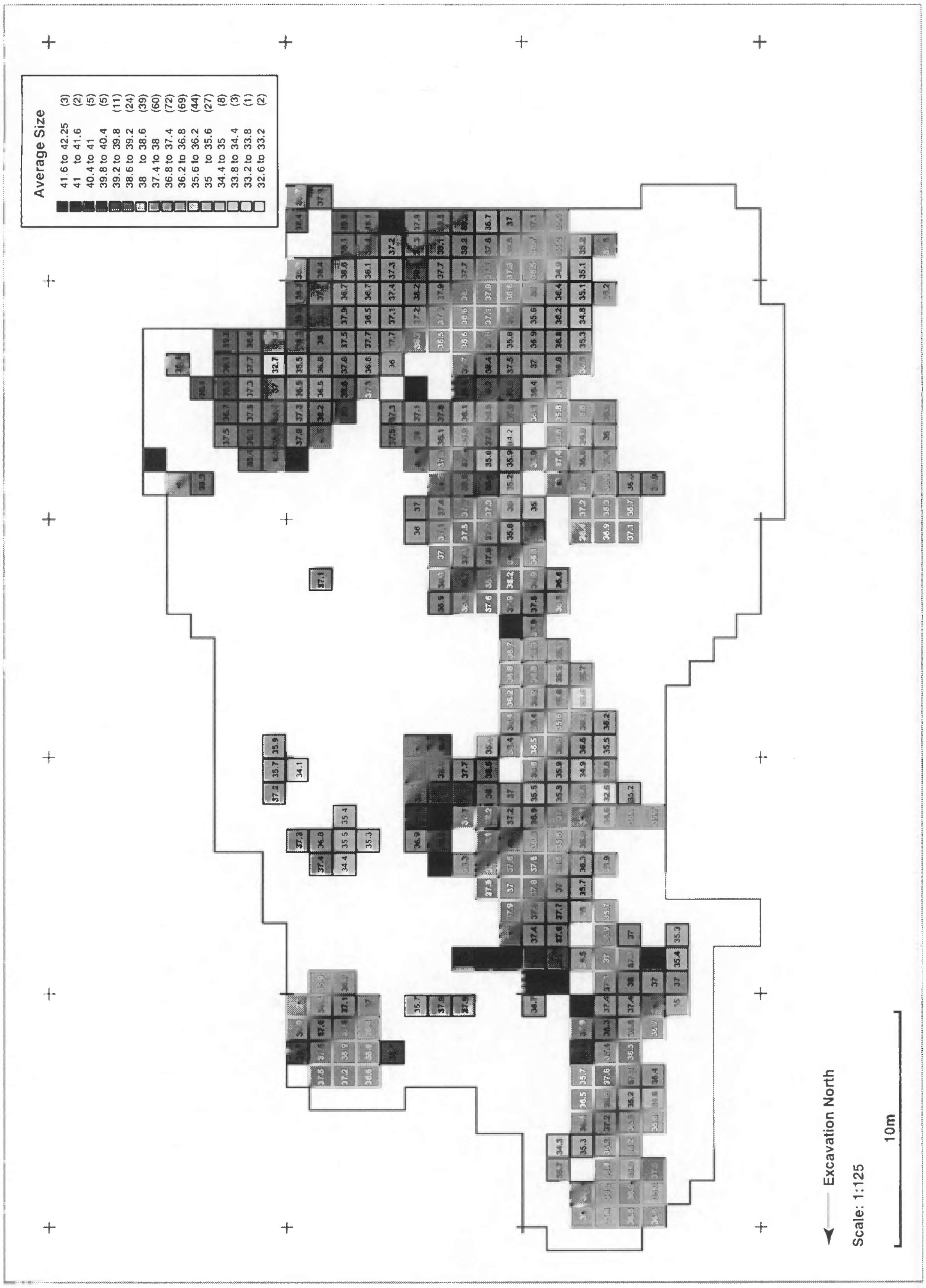
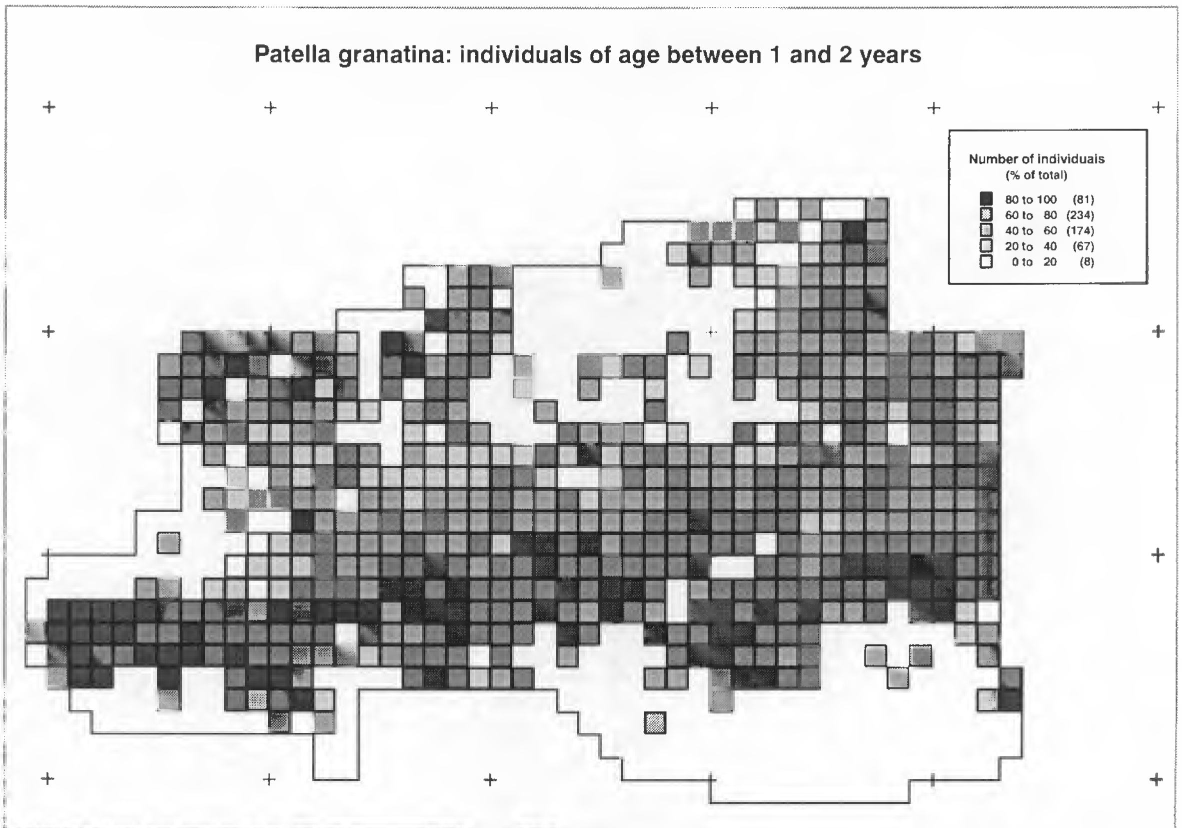


Figure 80: Distribution of average sizes per square of *Patella granularis* (only squares that have at least 10 measurements).



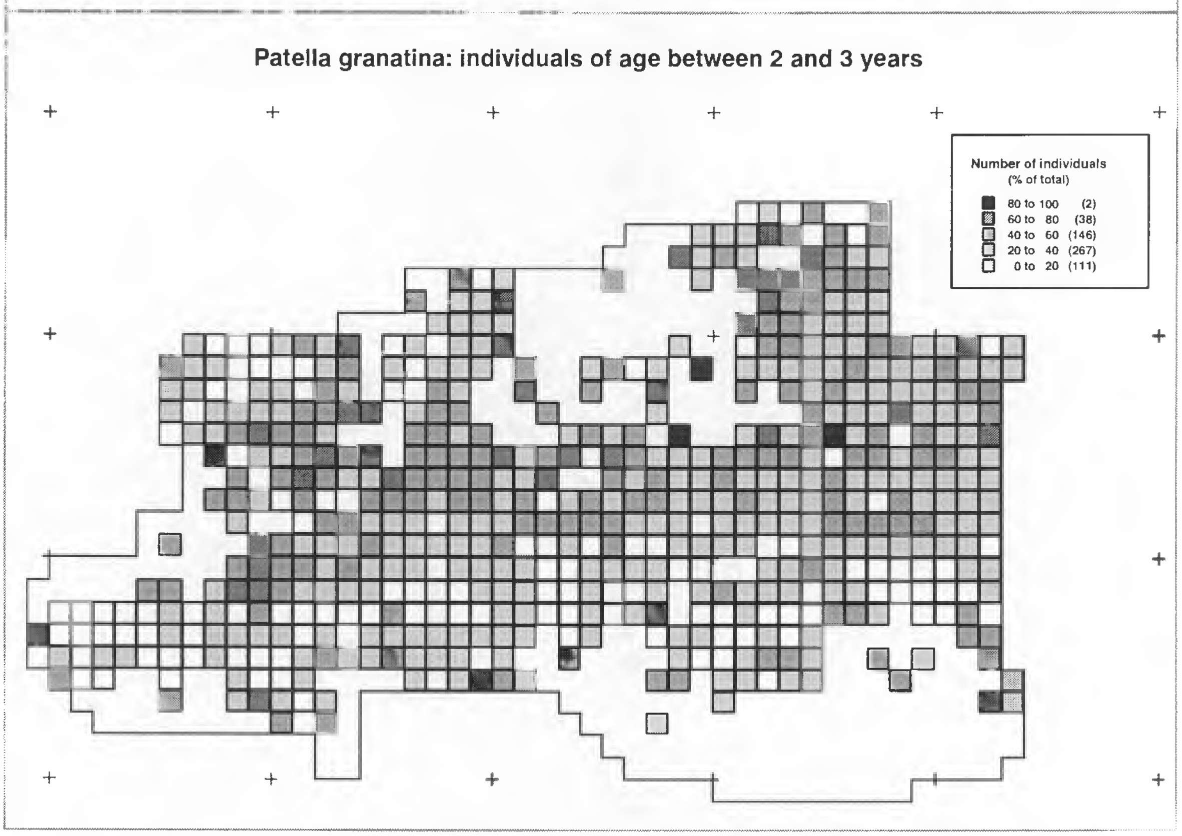
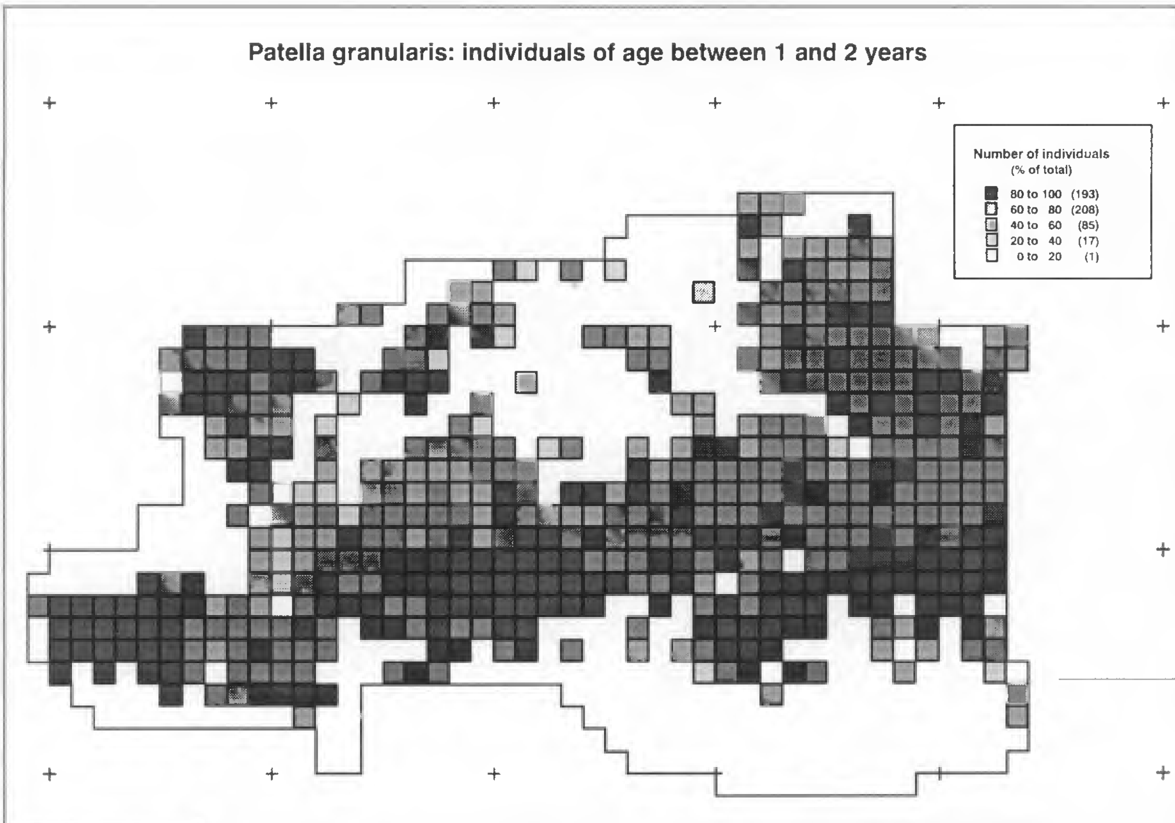


Figure 81: Spatial distribution of *Patella granatina*: individuals of age between 1 and 2 years. (Top)

Figure 82: Spatial distribution of *Patella granatina*: individuals of age between 2 and 3 years. (Bottom)



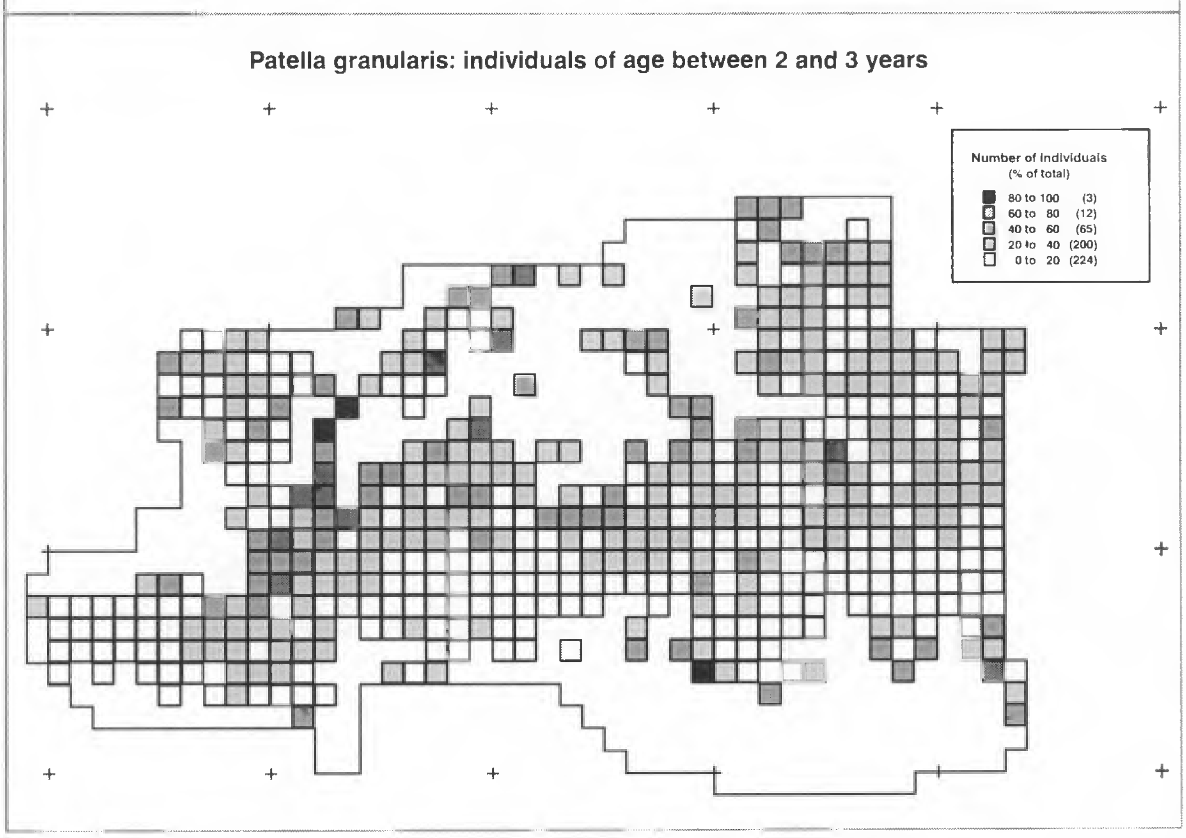


Figure 83: Spatial distribution of *Patella granularis*: individuals of age between 1 and 2 years. (Top)

Figure 84: Spatial distribution of *Patella granularis*: individuals of age between 2 and 3 years. (Bottom)

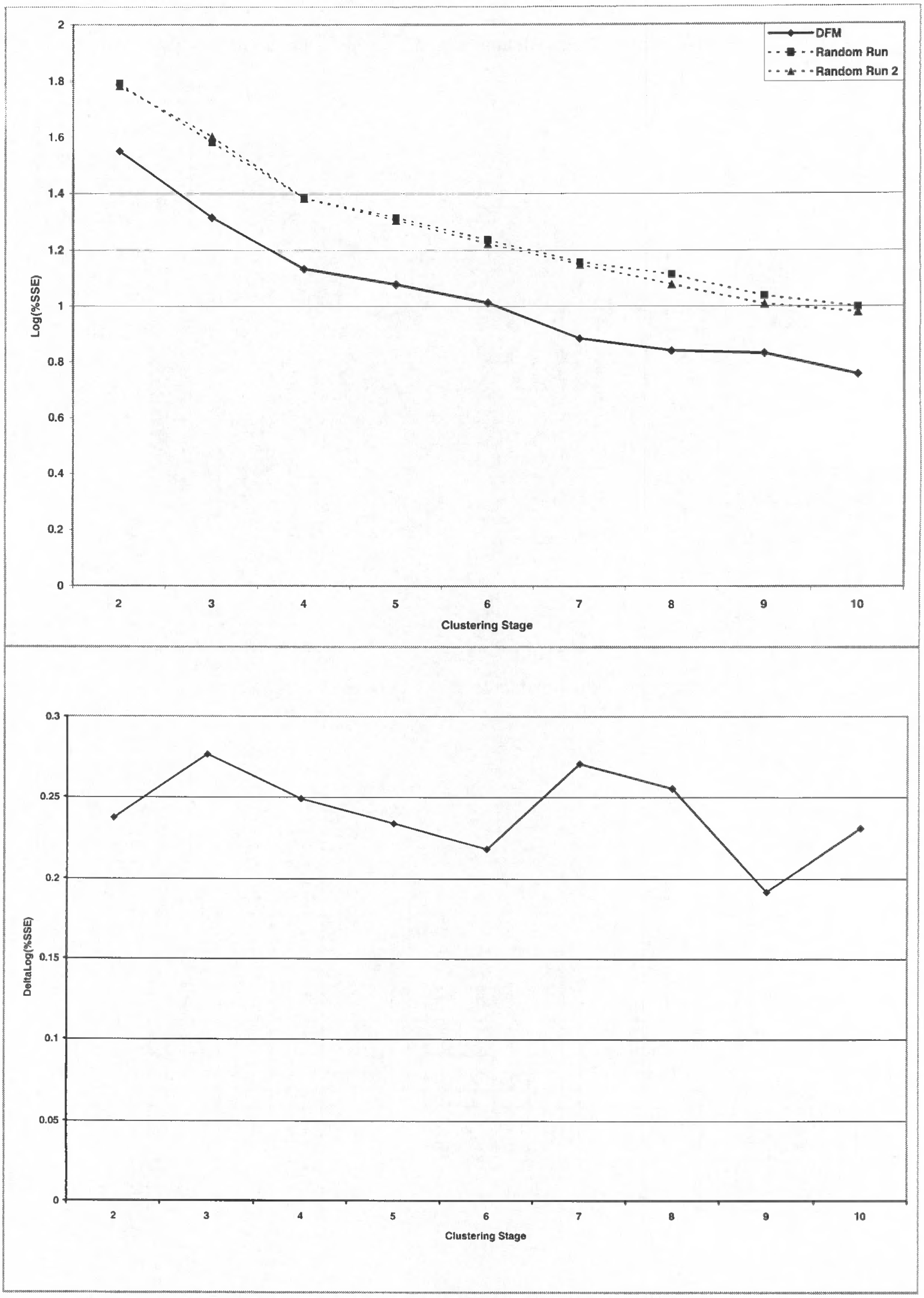
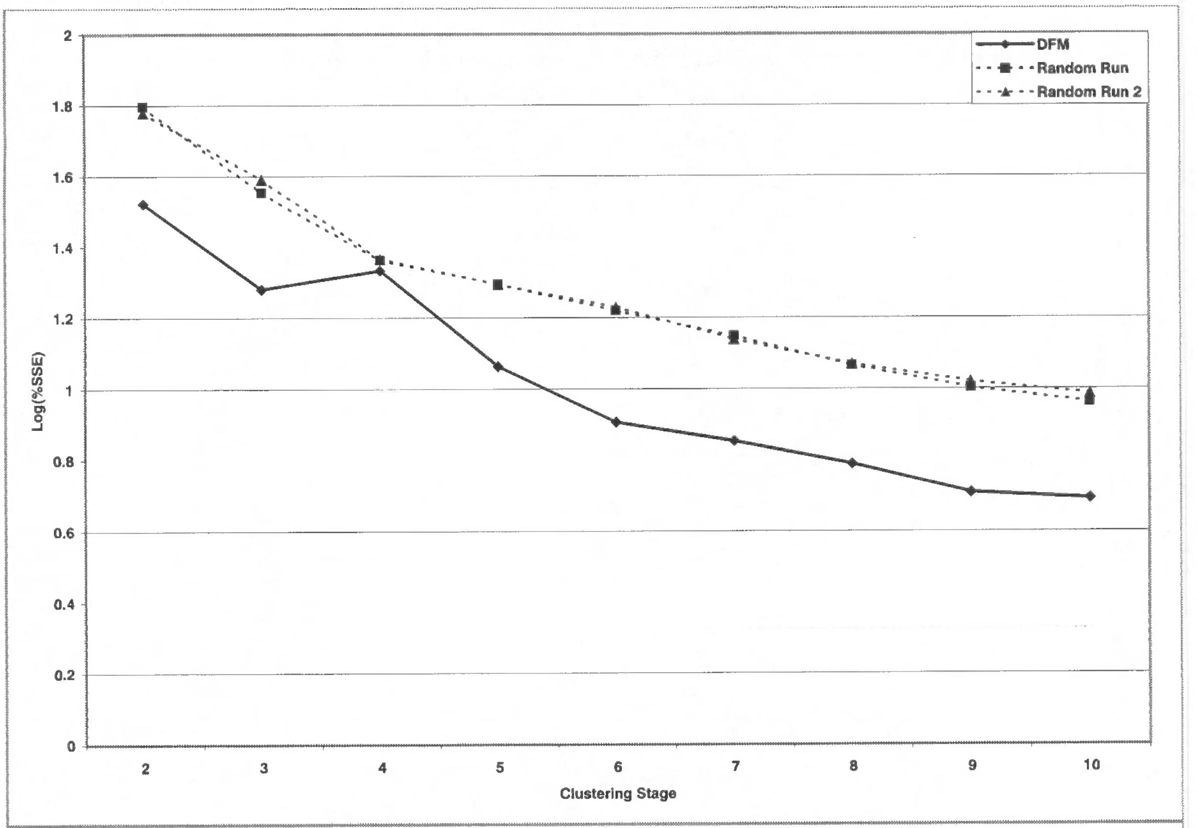


Figure 85: Log(%SSE)-graph of cluster analysis on *Patella granatina* age classes per square. (Top)

Figure 86: DeltaLog(%SSE)-graph of cluster analysis on *Patella granatina* age classes per square. (Bottom)



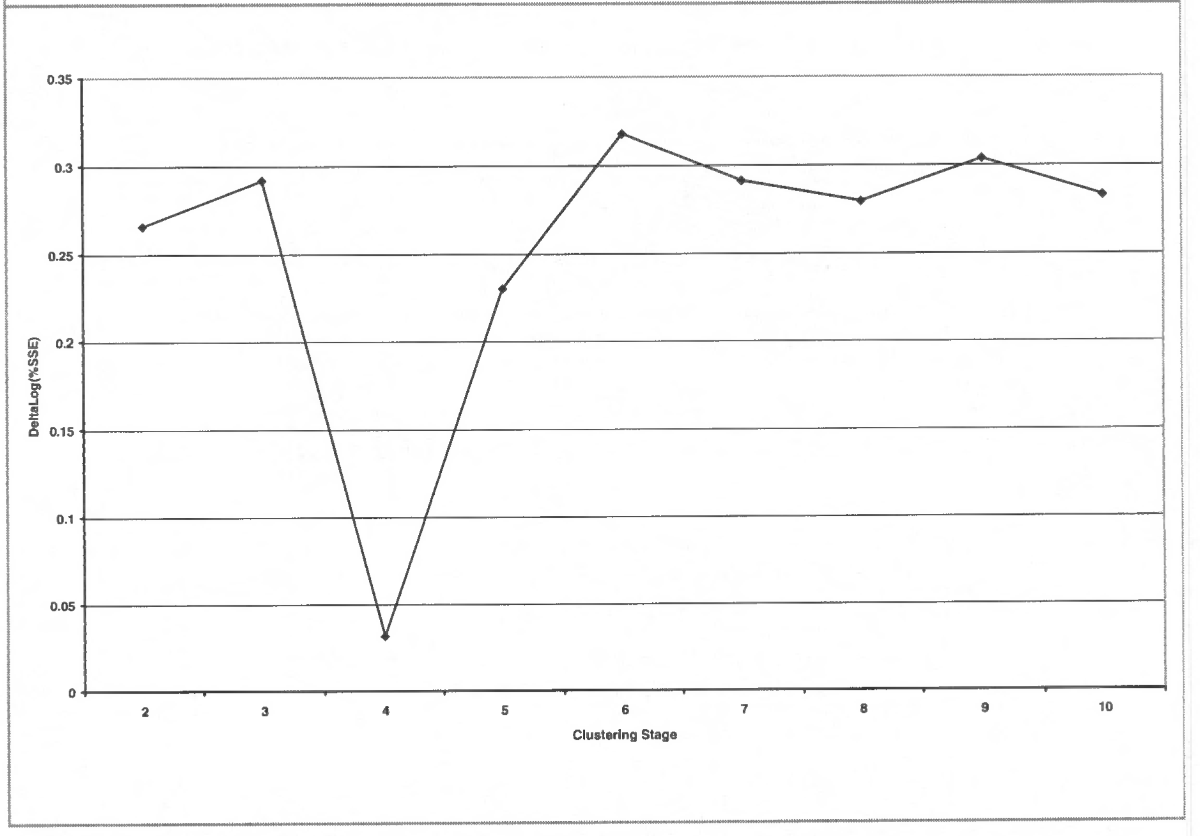


Figure 87: Log(%SSE)-graph of cluster analysis on *Patella granularis* age classes per square. (Top)

Figure 88: DeltaLog(%SSE)-graph of cluster analysis on *Patella granularis* age classes per square. (Bottom)

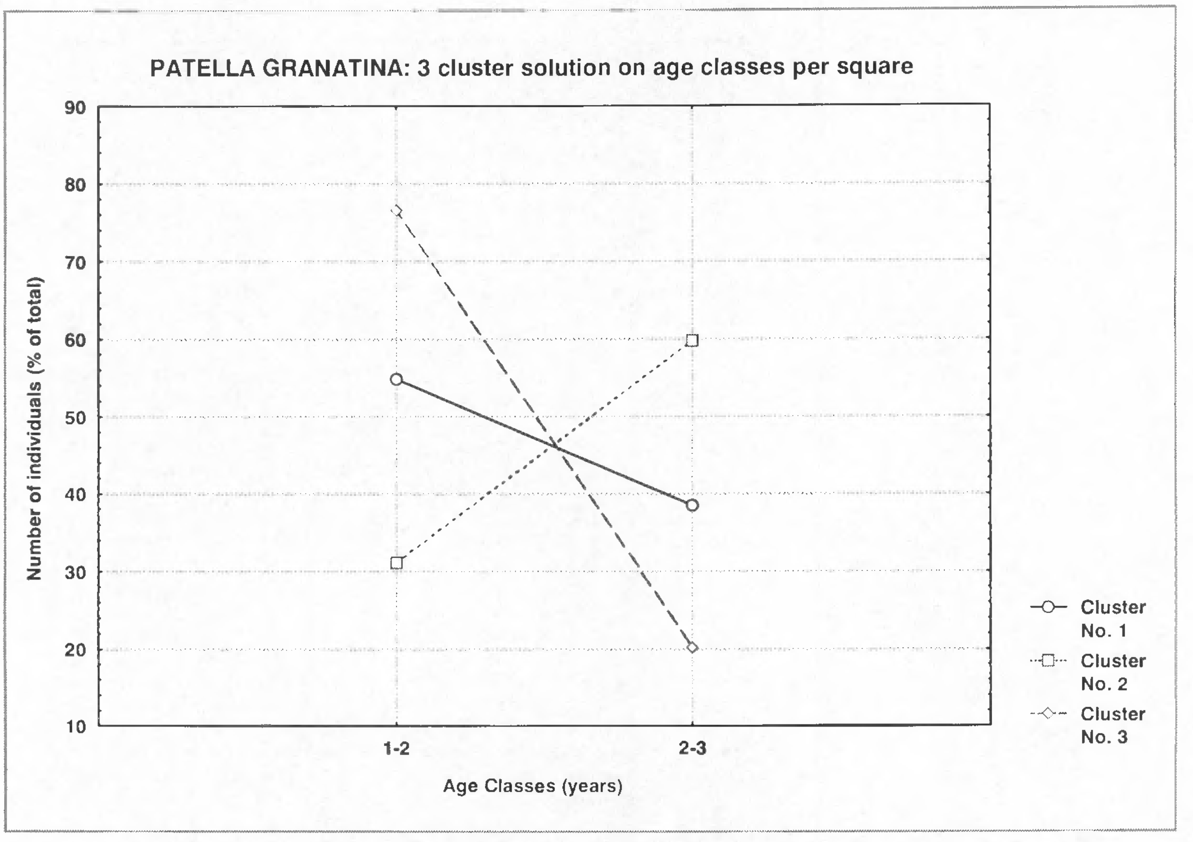


Figure 89: Cluster means of 3-cluster solution on *Patella granatina* age classes per square.

Age Class	*Cluster 1 (n=245)*		*Cluster 2 (n=85)*		*Cluster 3 (n=235)*	
	Mean (%)	*StDev (%)*	*Mean (%)*	*StDev (%)*	*Mean (%)*	*StDev (%)*
1-2 years	54.8	8.2	31.2	8.3	76.6	7.4
2-3 years	38.4	7.5	59.8	8.7	20.2	6.3

Table 35: Cluster analysis: 3-cluster solution on *Patella granatina* age classes per square.

Variable	*Number of observed joins*	*Number of expected joins of a random distribution*		*Significance level (p)*	
		resampling (N)	*randomization (R)*	*resampling (N)*	*randomization (R)*
Cluster 1	245	174.5	174.1	0.05	0.01
Cluster 2	85	21.0	20.8	0.01	0.01
Cluster 3	235	160.5	160.1	0.01	0.01

Table 36: 'Join count statistic' for 3-cluster solution on *Patella granatina* age classes per square.

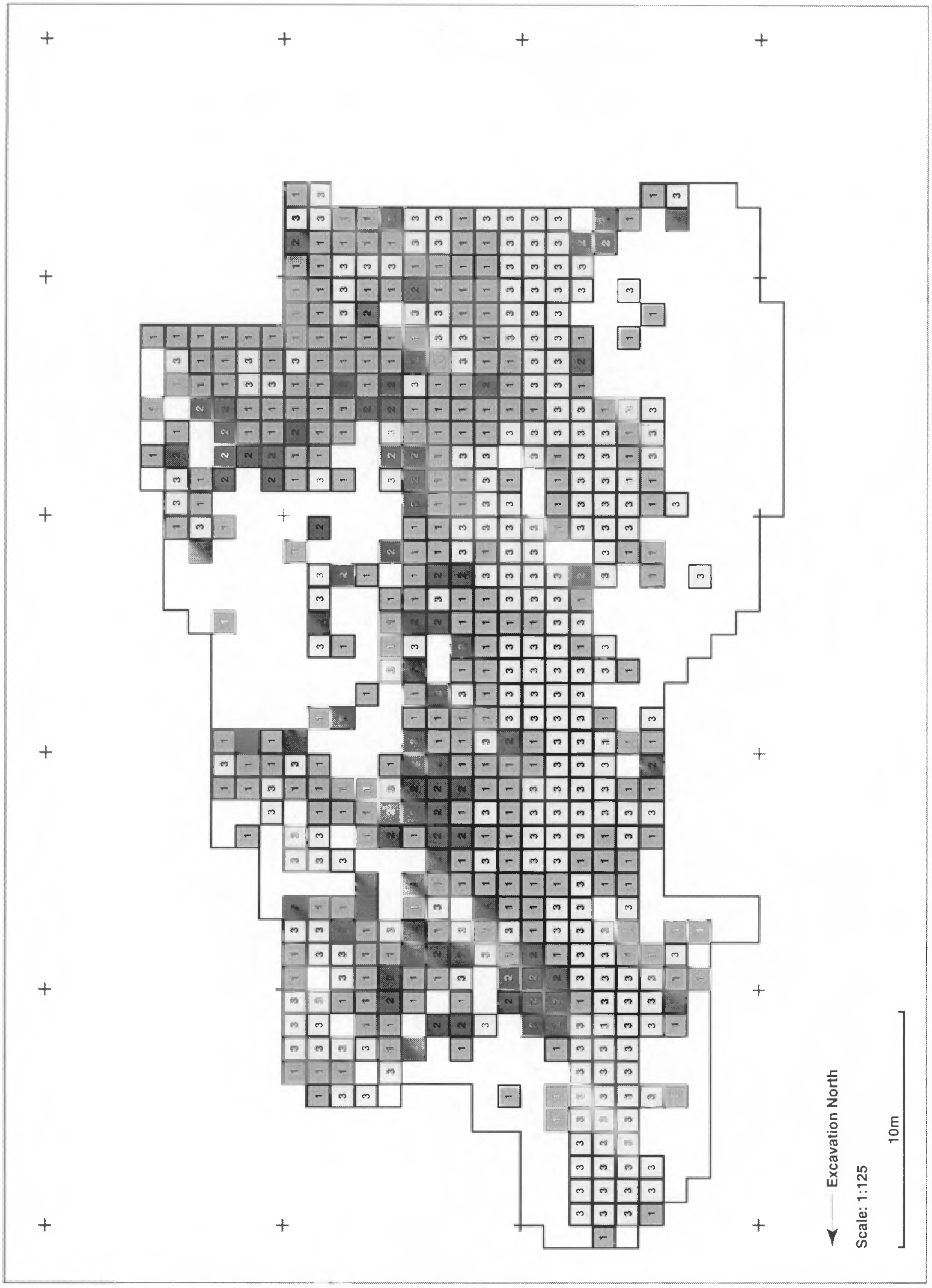


Figure 90: Cluster analysis: Spatial distribution of the 3-cluster solution on *Patella granatina* age classes per square.

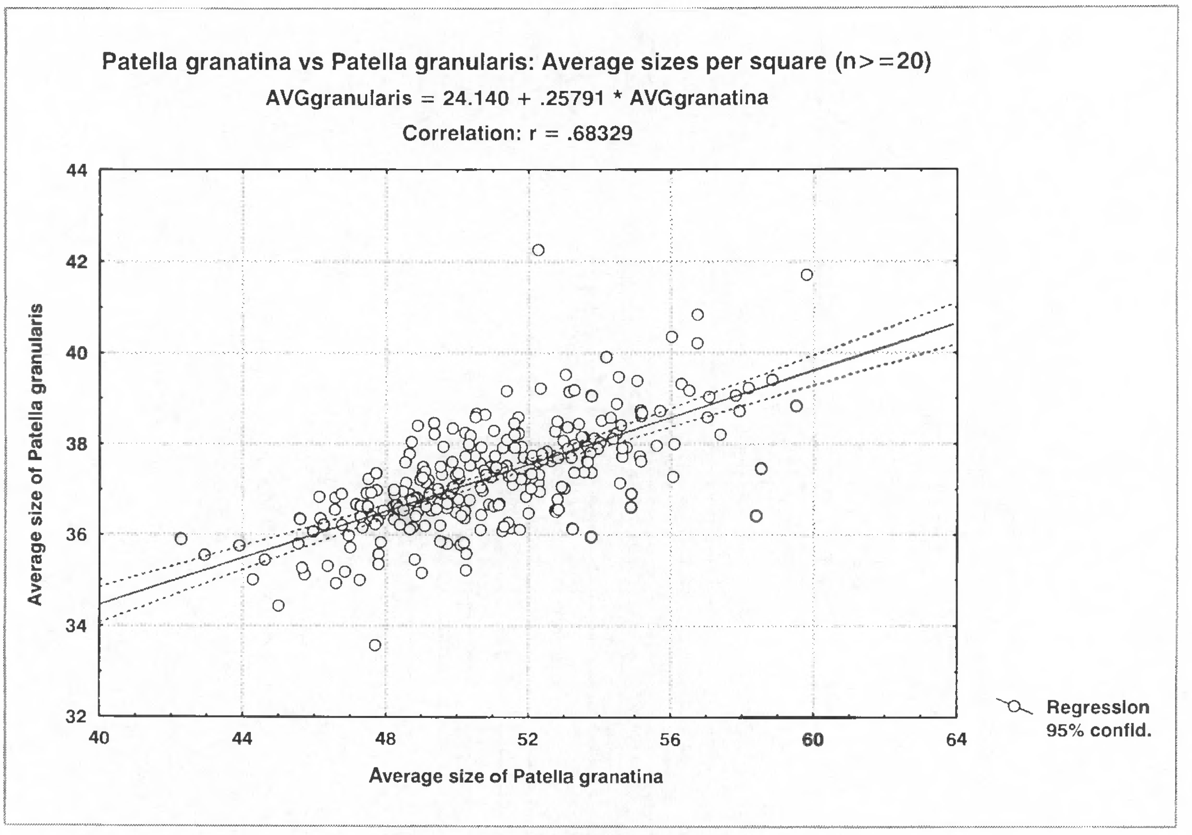


Figure 91: *Patella granatina* vs. *Patella granularis*: correlation of average sizes per square (n>=20 for each limpet).

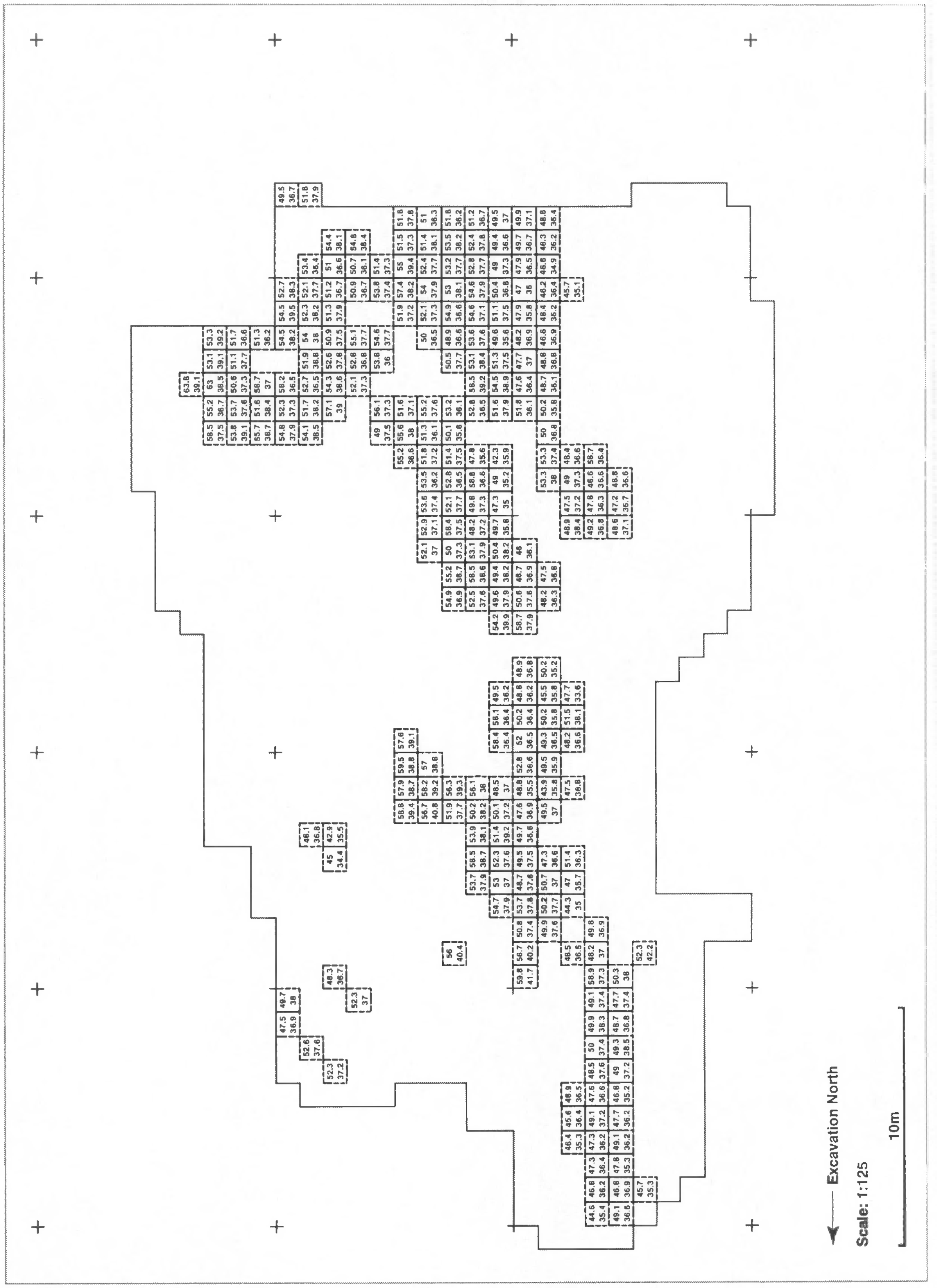


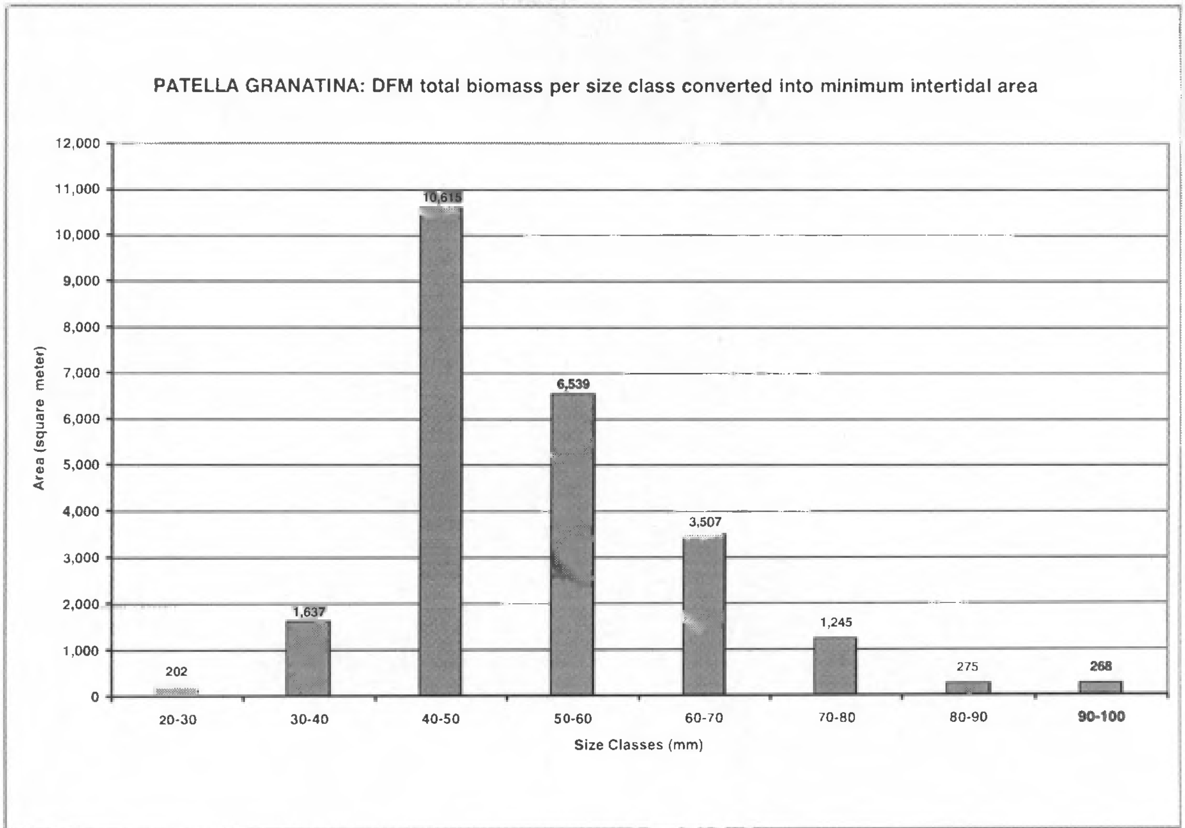
Figure 92: ***Patella granatina*** **and** ***Patella granularis*****: Spatial distribution of average sizes per square (n>=20 for each limpet; upper number for** ***P. granatina*****, lower number for** ***P. granularis*****).**

Size Classes (mm)	Counts		Dry flesh weight (g)	
	Patella granatina	*Patella granularis*	*Patella granatina*	*Patella granularis*
20-30	196	540	43.1	43.2
30-40	1545	20203	448.1	8081.2
40-50	12197	5583	6952.3	8262.8
50-60	8976	172	15438.7	447.2
60-70	4248	2	13551.1	7.4
70-80	665	6	2866.2	28.0
80-90	41	3	234.1	n/a
90-100	5	-	34.7	-
TOTAL	27873	26509	39568.3	16869.8

Table 37: *Patella granatina* and *Patella granularis* of the DFM sample: counts per size class and dry flesh weights.

Size Classes (mm)	Counts per square meter		Dry flesh weight (g) per square meter	
	Patella granatina	*Patella granularis*	*Patella granatina*	*Patella granularis*
0-10	0.16	0.98	0.028	0.010
10-20	0.44	3.07	0.079	0.031
20-30	0.97	5.01	0.213	0.400
30-40	0.94	5.55	0.274	2.219
40-50	1.15	2.60	0.655	3.852
50-60	1.37	0.43	2.361	1.130
60-70	1.21	0.13	3.864	0.480
70-80	0.53	0.01	2.302	0.029
80-90	0.15	0.00	0.851	0.000
90-100	0.02	0.01	0.129	0.000
TOTAL	6.94	17.78	10.757	8.151

Table 38: *Patella granatina* and *Patella granularis* of the beach transect sample: counts per size class and dry flesh weights (both per square meter of intertidal zone).



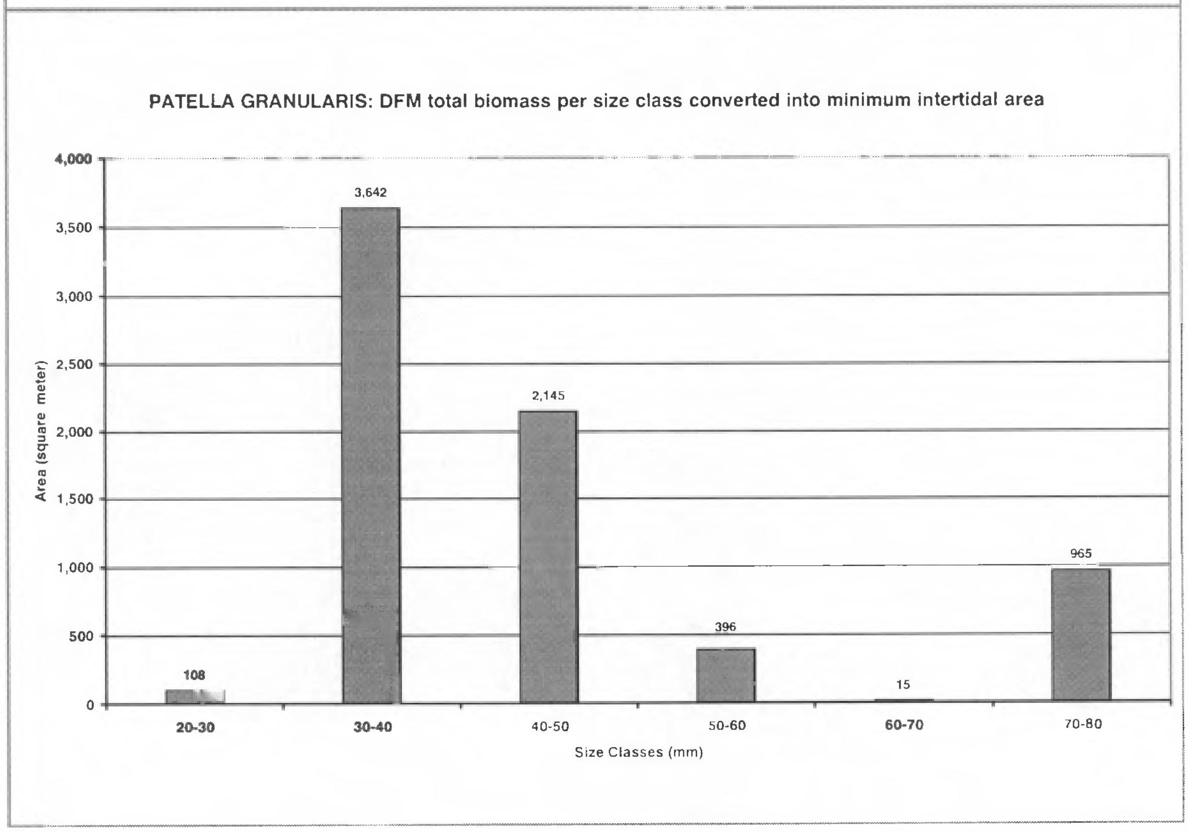


Figure 93: *P. granatina*: DFM total biomass per size class converted into minimum intertidal area. (Top)
Figure 94: *P. granularis*: DFM total biomass per size class converted into minimum intertidal area. (Bottom)

CHAPTER VII CONCLUSION

1 DFM SPATIAL DATABASE AND SPATIAL ANALYSIS

DFM Spatial Database

The accumulated results of 14 years of excavation and analyses at Dunefield Midden (DFM) were the subject for the development of the DFM Spatial Database. A substantial amount of time (more than one year) was invested for data evaluation, data structuring and data input. The merit of this work is a research database that makes large amounts of numerical data available for any kind of analysis.

One main aim was the integration of data management and data analysis which allows any interested researcher to access and evaluate the information available on DFM. This was achieved by combining a relational database, a Geographical Information System (GIS) and a statistical analysis software package. Additionally the structure of the database was described in great detail in form of metadata (see appendix four) to enable any skilled person to alter database properties or to make structural changes.

Microsoft Access 2000 was chosen to facilitate as the relational database in the system and proved to be very powerful in the given context: Analog data structures were converted into relational tables and data input windows were designed for convenient data management while queries were used to prepare datasets for further analyses.

The GIS software MapInfo Professional 6.5 was linked to the relational database to visualize spatial information and as a basis for spatial analysis. With the 'Thematic map' mapping tools, distribution plots were created and queries were used to link datasets.

Statistica from StatSoft provided statistical analysis tools for a wide range of statistics. Data was imported from the relation database and spatial statistical results were exported to MapInfo for visualization. Especially in the context of cluster analysis, Statistica played an important role in the spatial analysis of the shellfish remains from Dunefield Midden.

initial idea "to derive a resolved episode in the history of western Cape settlement" (Parkington et al. 1992:64) can now be pursued successfully.

Environmental setting	SOURCE	INTERTIDAL		WASHUPS
	SHELLFISH SPECIES	Patella granatina	Patella granularis	Choromyilus meridionalis
Human behavior	SELECTIVE FORAGING?	yes (species and size)	yes (size)	probably not
	DIFFERENTIAL TRANSPORT?	unlikely	unlikely	possible
	DIFFERENTIAL PROCESSING?	not within limpets	not within limpets	different from limpets
	TYPE OF WASTE MANAGEMENT	regular dumping of small amounts	regular dumping of small amounts	occasional and intensive dumping episodes

Figure 95: Basic model of shellfish handling behavior at the Dunefield Midden.

APPENDIX I DFM SHELLFISH

Quantitative description

Table 39: Index to figures and tables for the quantitative description of DFM shellfish.

Spatial distribution

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Figure 114	Histogram of total shellfish weight per square: squares with 10,000-42,000g. (Bottom)	177
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Note to Figures 115-132: Number of ranges were predetermined to five while the range sizes were automatically calculated by MapInfo with the 'natural break' function of the Thematic Map tools.

Table 40: Index to figures showing the spatial distribution of DFM shellfish.

Correlations

Table	Description	Page
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Table 41: Index to tables showing the correlations of DFM shellfish weights per square.

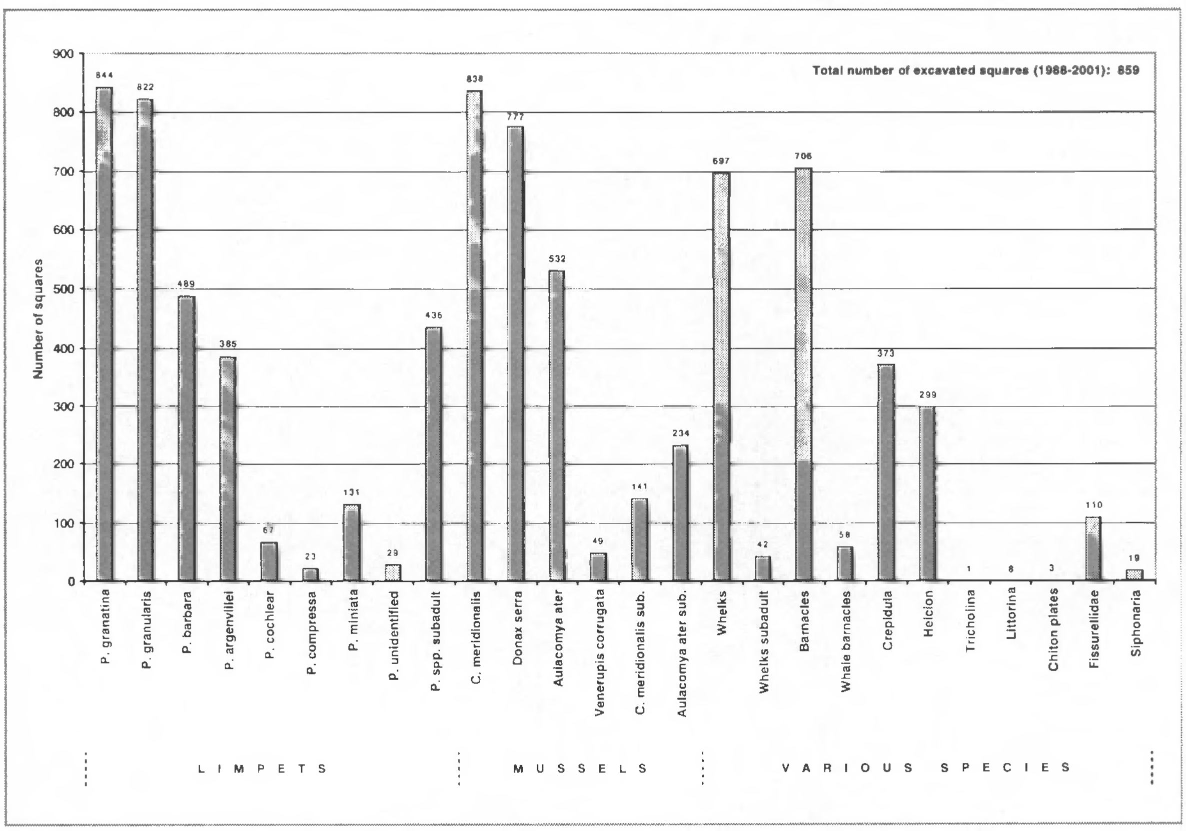
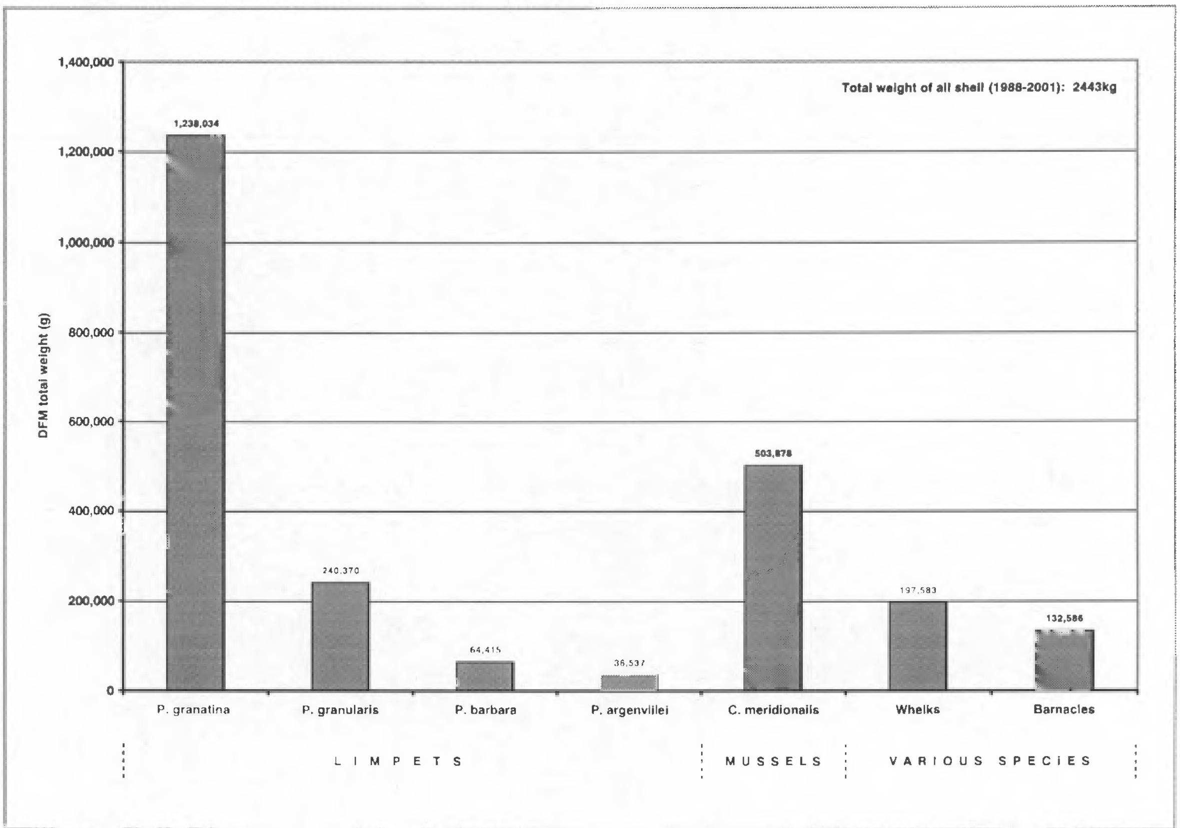


Figure 96: DFM shellfish species and the number of squares they occur in.



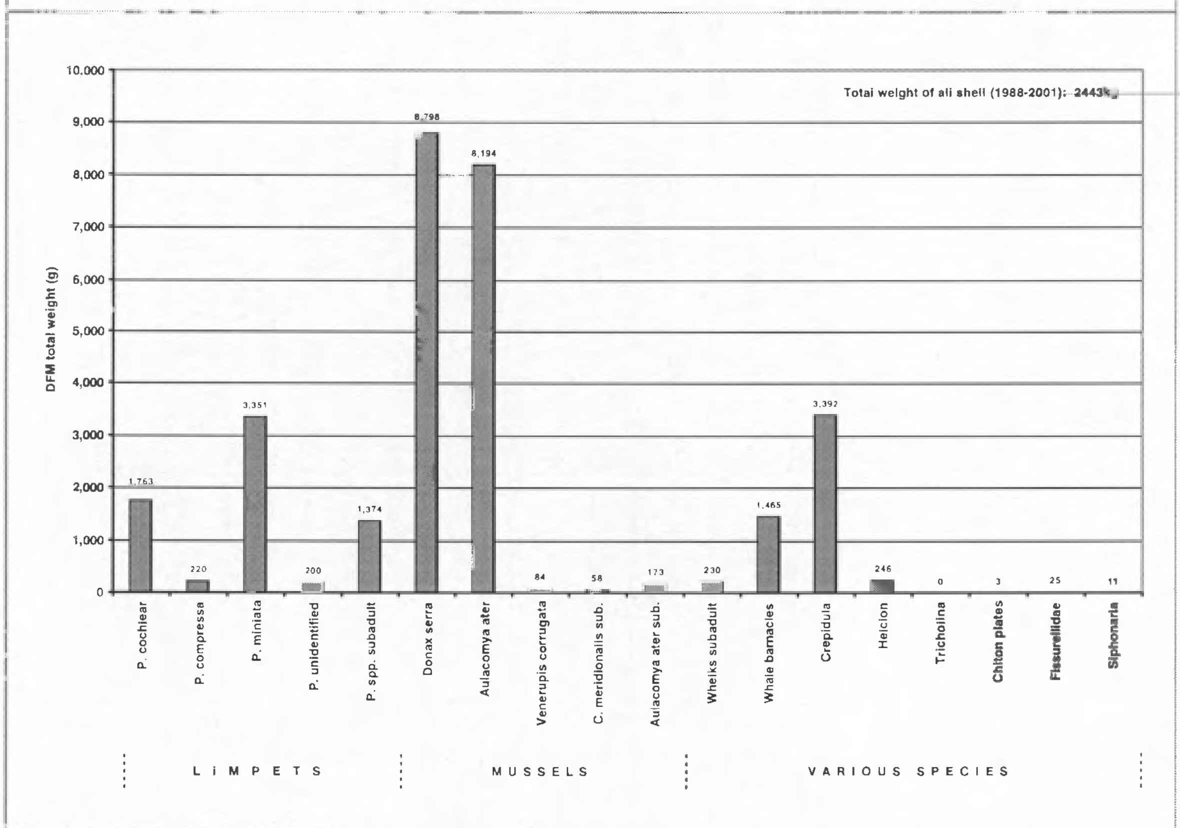
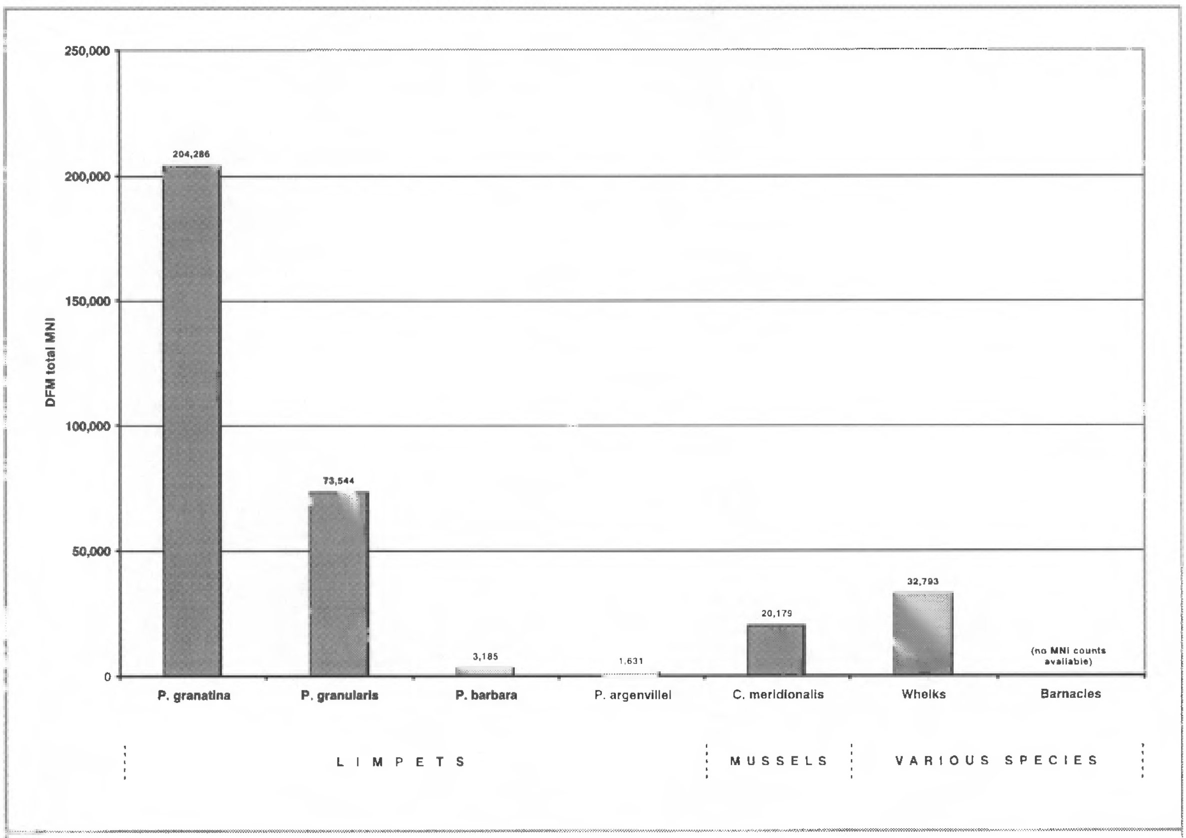


Figure 97: DFM total shellfish weights of the seven most abundant species. (Top)

Figure 98: DFM total shellfish weights of the less frequent species (and species categories). (Bottom)



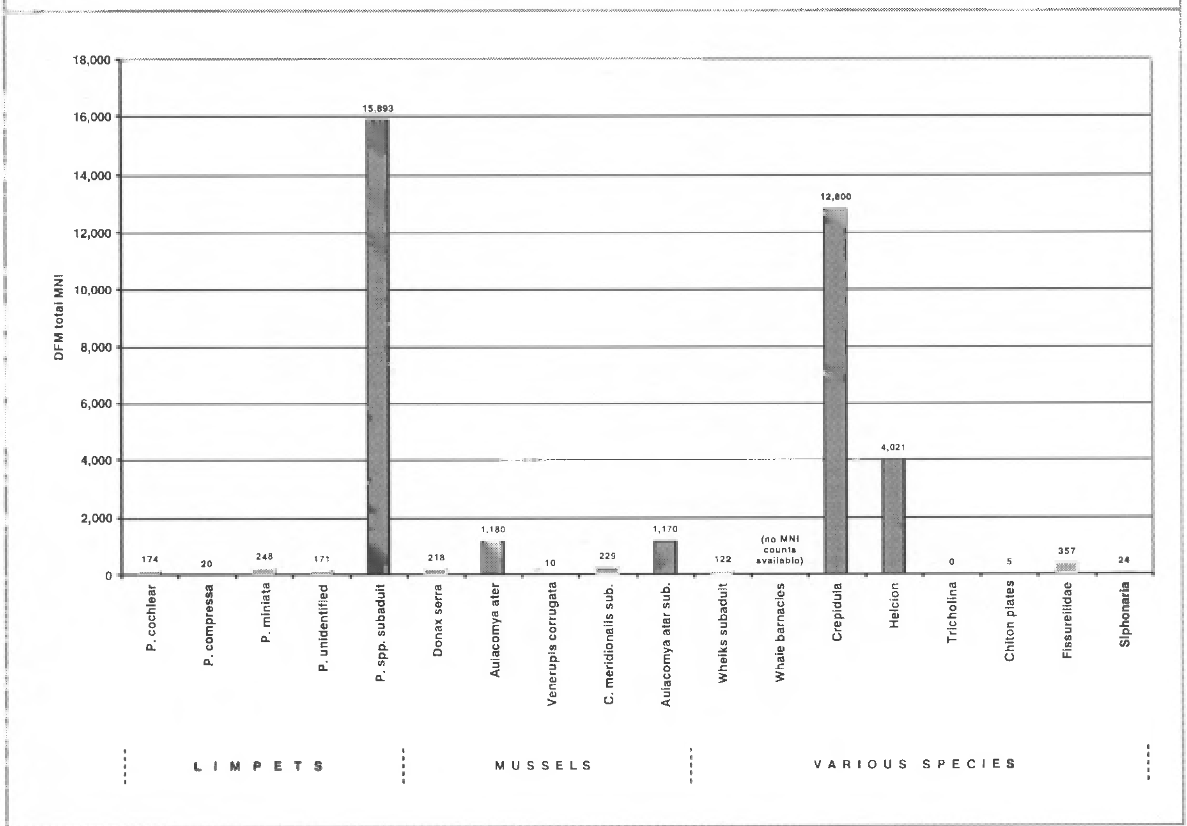


Figure 99: DFM total shellfish MNI counts of the seven most abundant species. (Top)

Figure 100: DFM total shellfish MNI counts of the less frequent species (and species categories). (Bottom)

Species (category)	Total sample in database			Adult specimen				
	n	Mean (mm)	StDev (mm)	n	Mean (mm)	StDev (mm)	Defined minimum (mm)	Observed maximum (mm)
Patella granatina	27914	51.24	8.95	27772	51.40	8.68	25.00	94.92
Patella granularis	26544	37.12	4.18	26451	37.24	4.06	25.00	87.27
Patella barbara	1873	65.67	12.80	1755	68.33	7.69	45.00	94.56
Patella argenvillei	728	65.91	11.79	684	68.13	7.93	45.00	99.60
Patella miniata	134	58.86	16.70	109	66.02	7.51	45.00	85.29
Patella cochlear	128	54.32	16.92	94	64.02	4.90	45.00	74.54
Choromytilus meridionalis (left countable)	13532	8.87	1.47	-	-	-	-	14.88
Choromytilus meridionalis (right countable)	12611	8.89	1.47	-	-	-	-	16.40
Choromytilus meridionalis (left measurable)	2766	8.61	1.40	-	-	-	-	13.25
Choromytilus meridionalis (right measurable)	2783	8.77	1.36	-	-	-	-	13.43

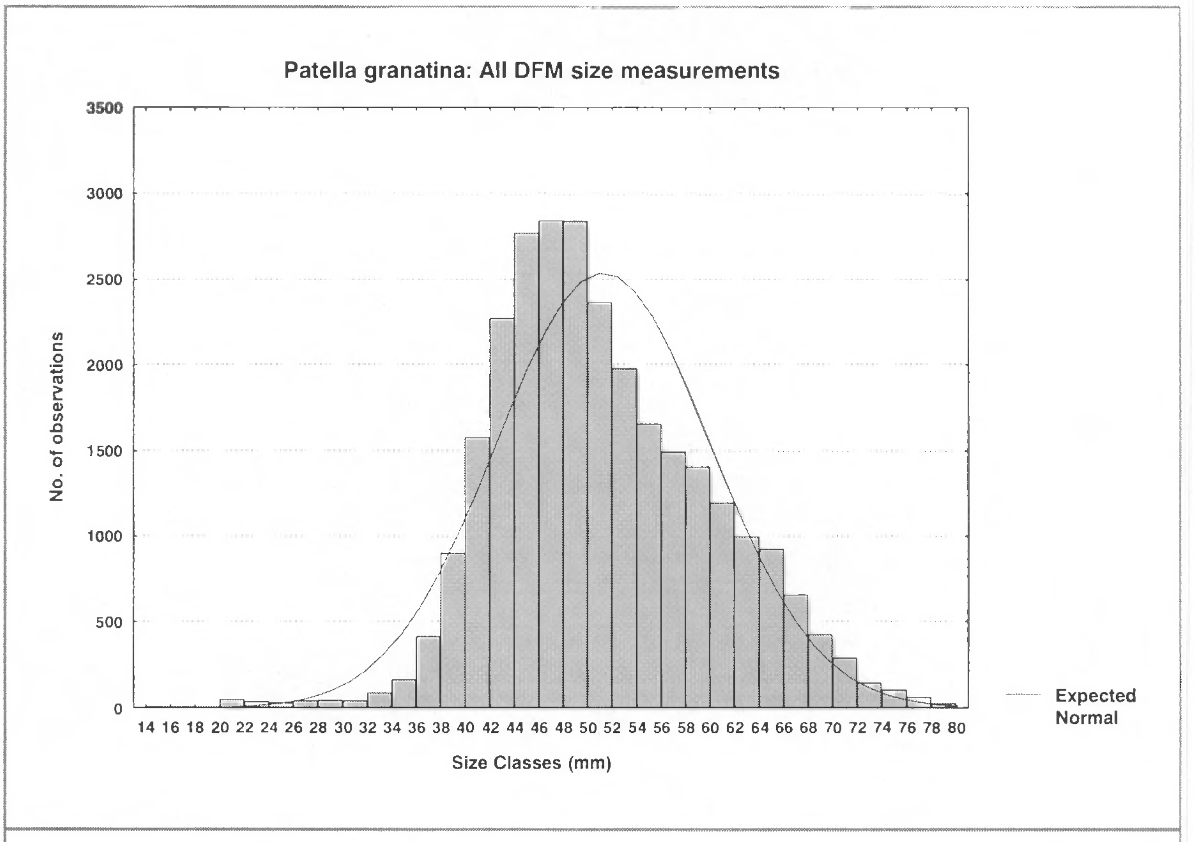
Table 42: Descriptive statistics of all DFM shellfish size measurements.

Species	1-2 years			2-3 years			older than 3 years		
	size (mm)	n	n%	size (mm)	n	n%	size (mm)	n	n%
Patella granatina	30<=x<54	18146	65.0	54<=x<68	8400	30.1	>=68	1131	4.1
Patella granularis	28<=x<40	20574	77.5	40<=x<47	5257	19.8	>=47	509	1.9

Table 43: Population structure of *Patella granatina* and *Patella granularis* at Dunefield Midden (size ranges of age classes from Branch 1974:187 & 172).

Species	Size measurements (mm)		Minimum and maximum dry flesh mass (g)	
	Lower quartile	Upper quartile	Lower quartile	Upper quartile
Patella granatina	45.00	57.06	0.57	1.72
Patella granularis	34.51	39.50	0.40	1.48
Choromytilus meridionalis (left countable)	7.91	9.83	1.32	2.34

Table 44: Calculation of dry flesh mass from the size quartile ranges of the three most important shellfish species at DFM (conversion table and equations from Rebelo 1982:3-1).



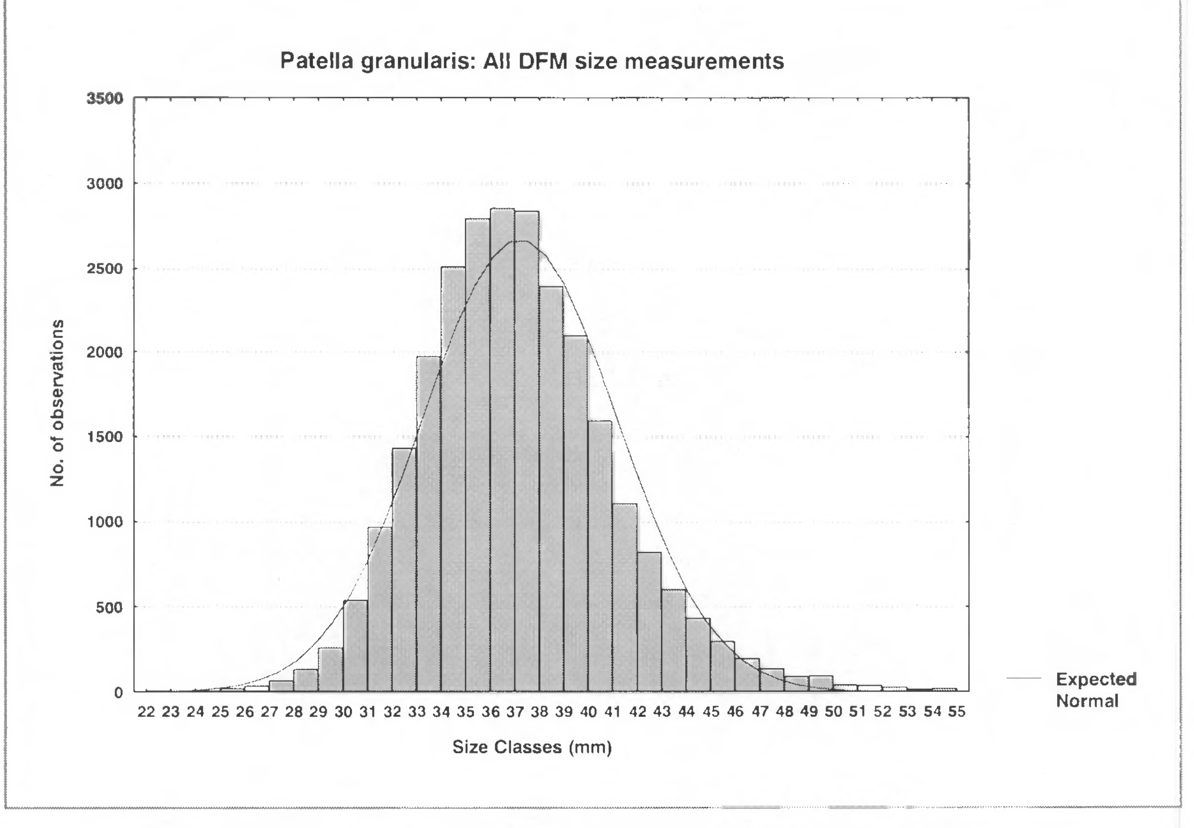
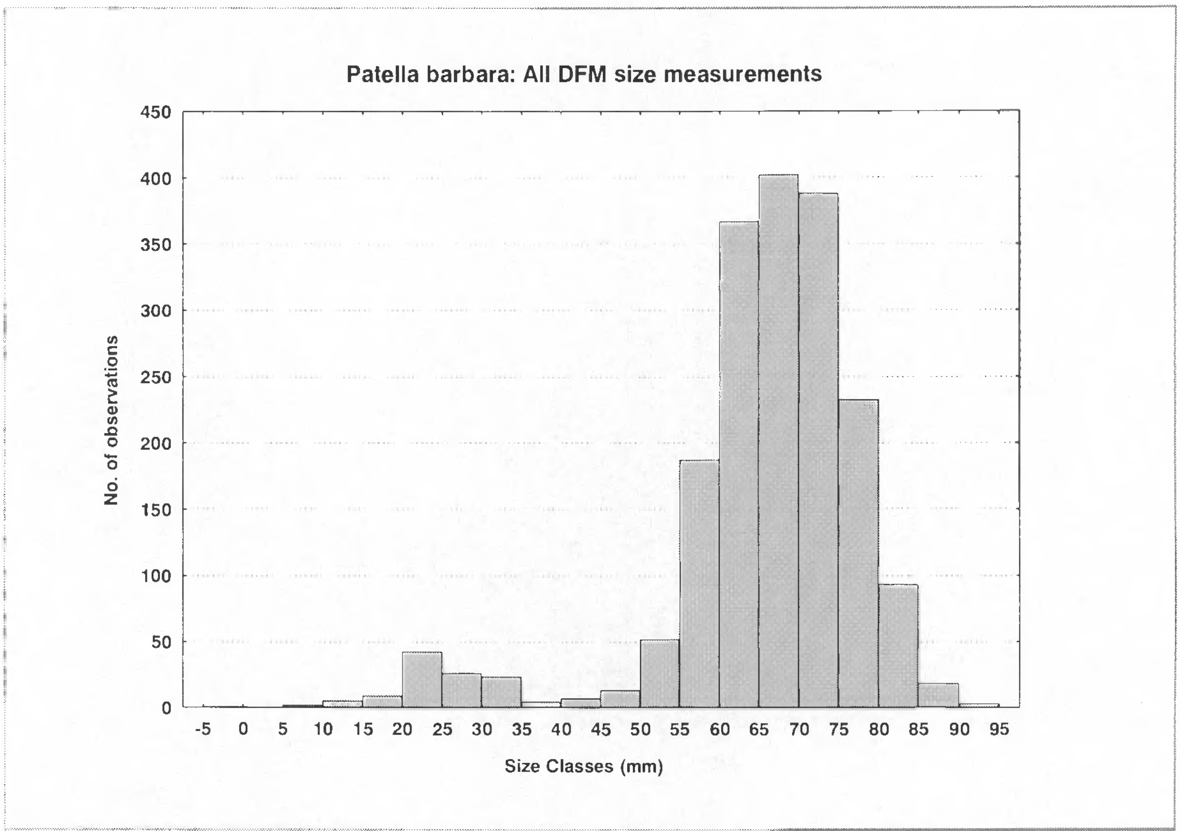


Figure 101: DFM shellfish size measurements histogram: *Patella granatina*. (Top)

Figure 102: DFM shellfish size measurements histogram: *Patella granularis*. (Bottom)



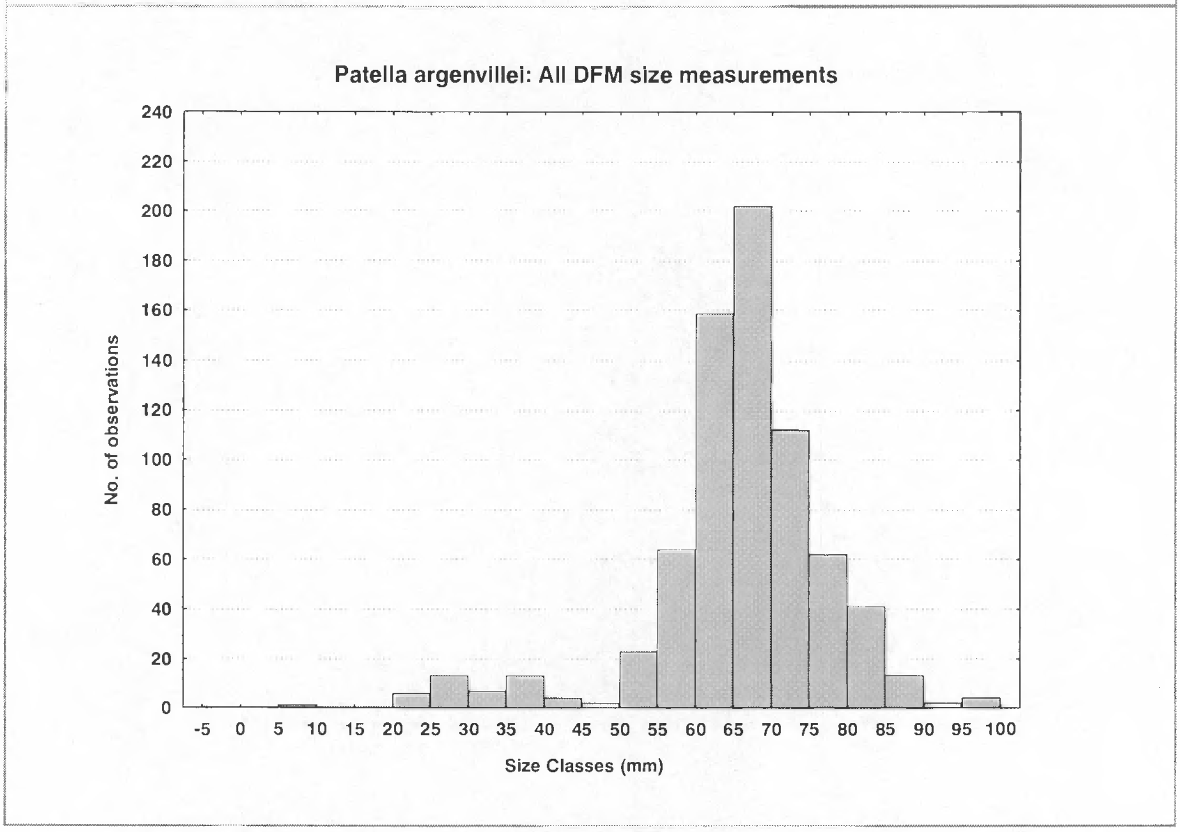
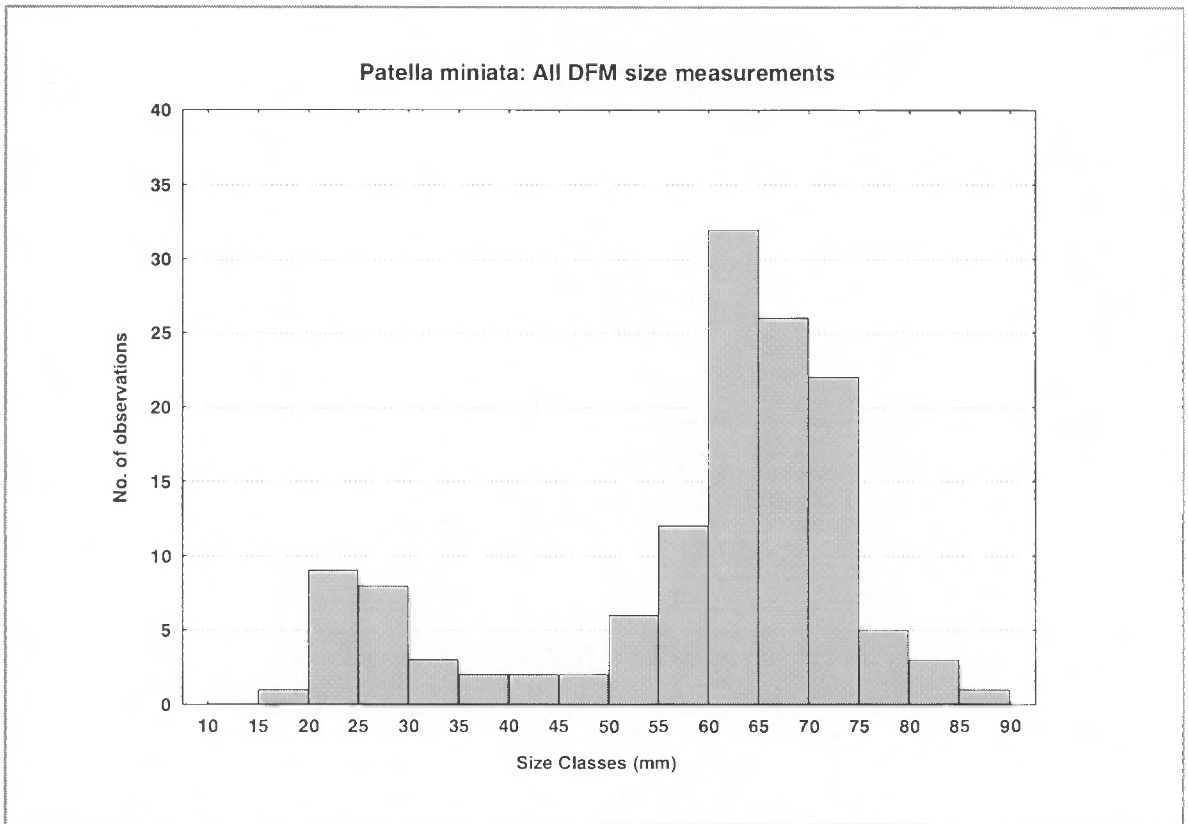


Figure 103: DFM shellfish size measurements histogram: *Patella barbara*. (Top)

Figure 104: DFM shellfish size measurements histogram: *Patella argenvillei*. (Bottom)



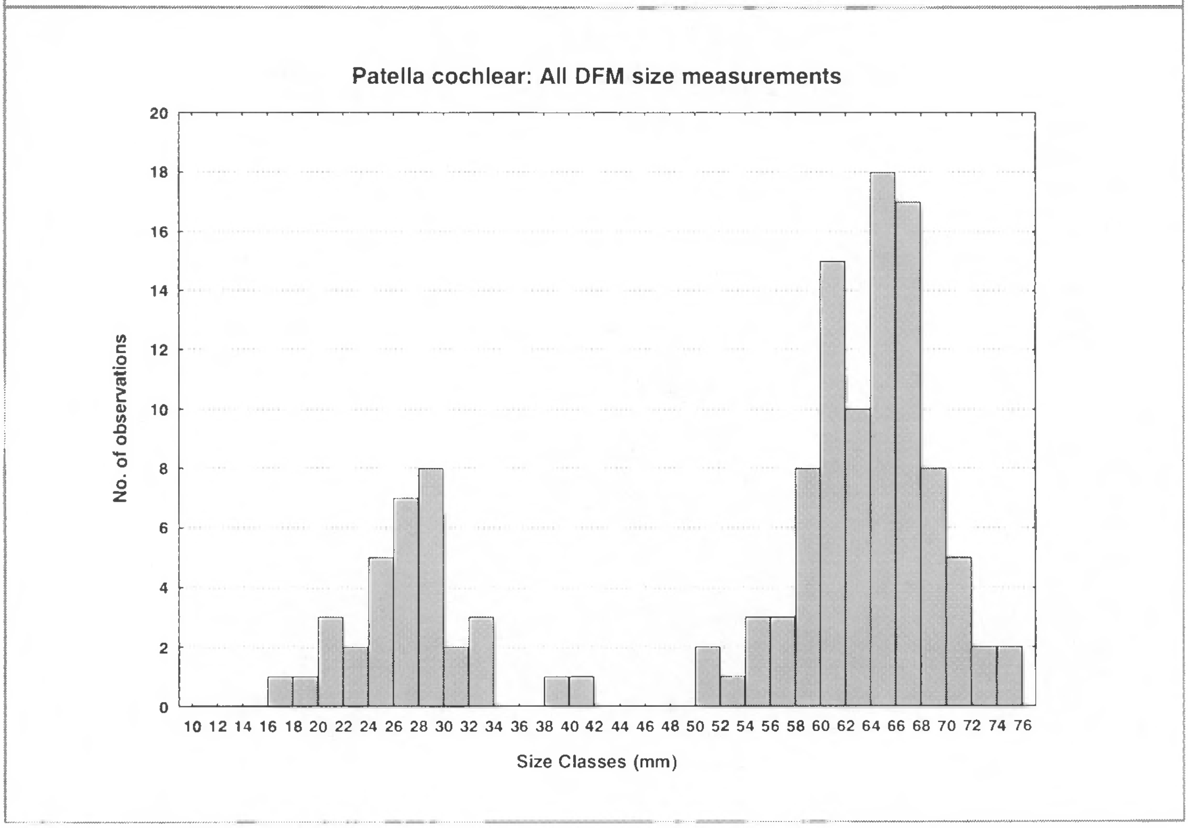
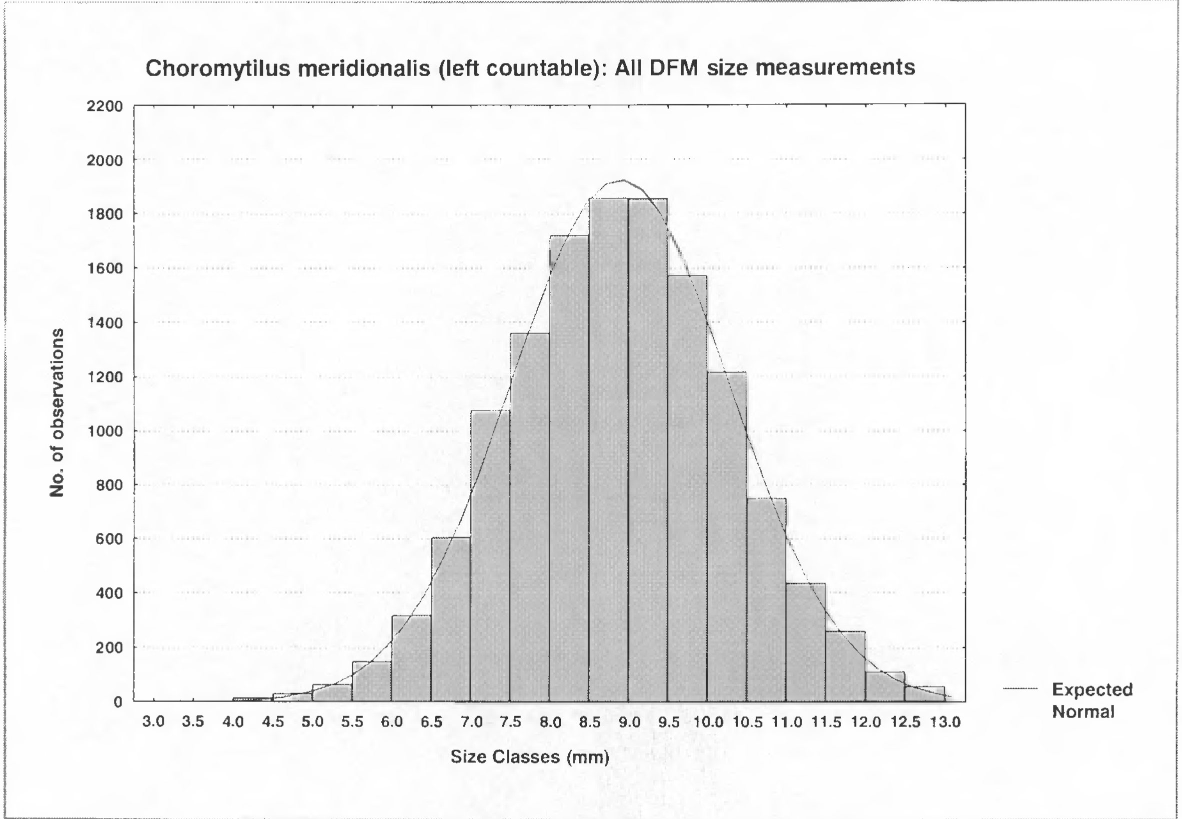


Figure 105: DFM shellfish size measurements histogram: *Patella miniata*. (Top)

Figure 106: DFM shellfish size measurements histogram: *Patella cochlear.* (Bottom)



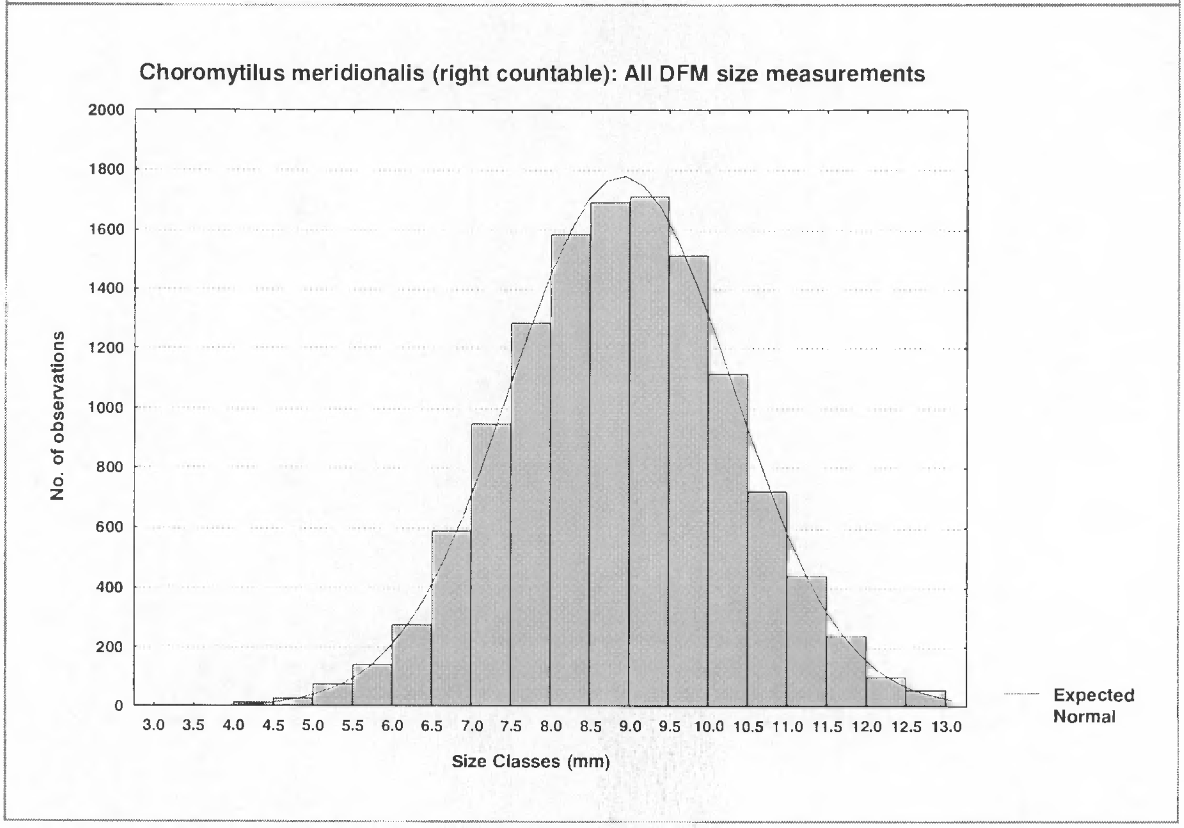
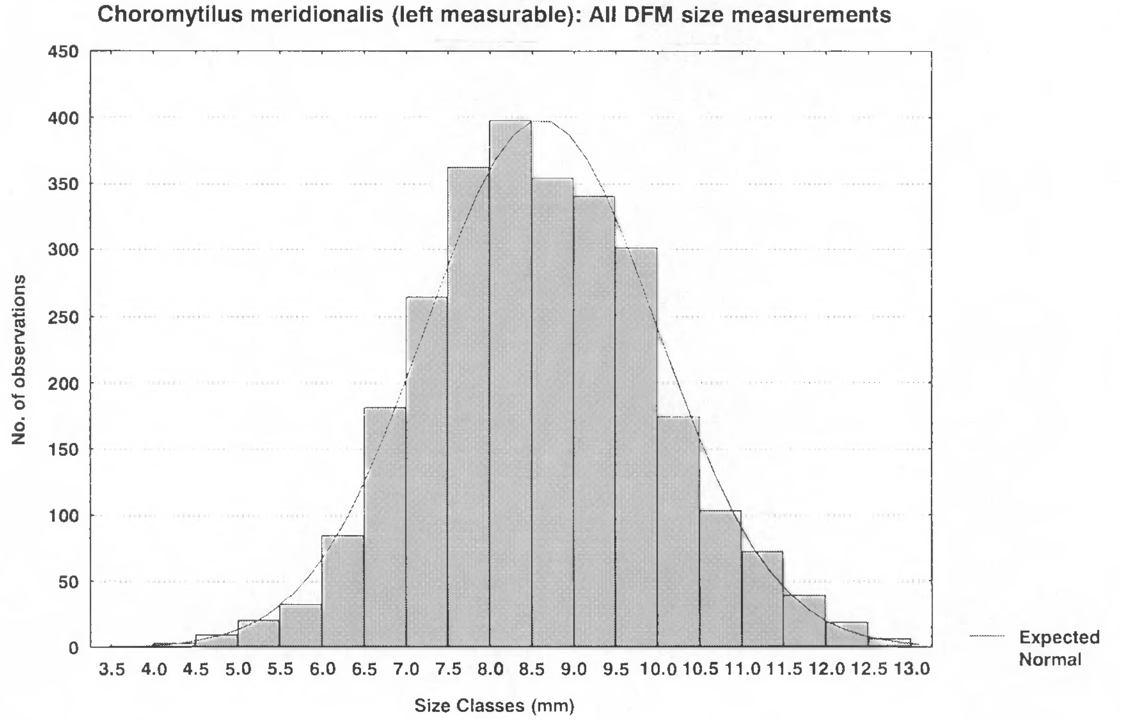


Figure 107: DFM shellfish size measurements histogram: *Choromytilus meridionalis* (left countable). (Top)

Figure 108: DFM shellfish size measurements histogram: *Choromytilus meridionalis* (right countable). (Bottom)



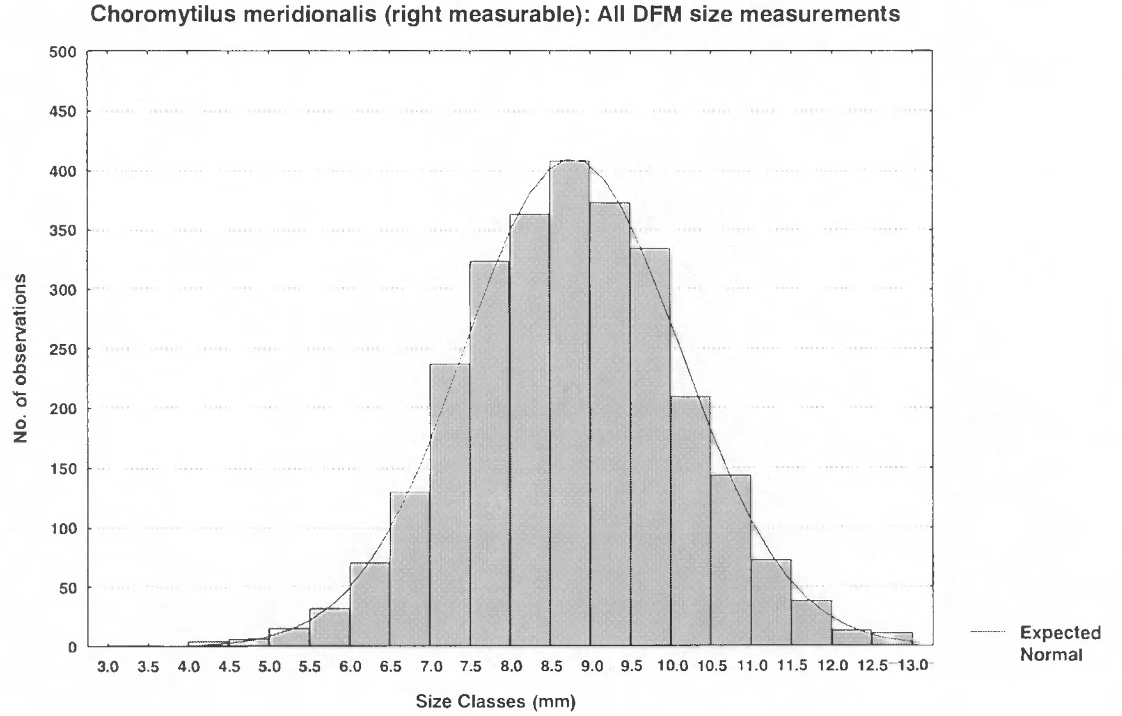
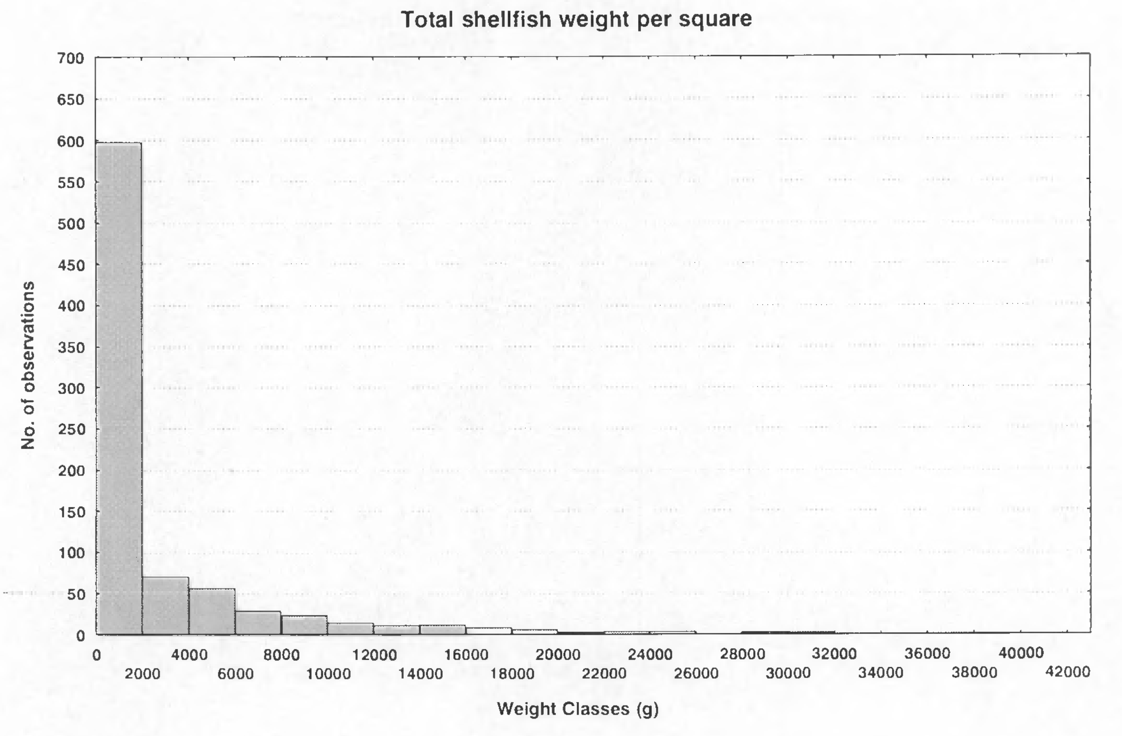


Figure 109: DFM shellfish size measurements histogram: *Choromytilus meridionalis* (left measurable). (Top)

Figure 110: DFM shellfish size measurements histogram: *Choromytilus meridionalis* (right measurable). (Bottom)



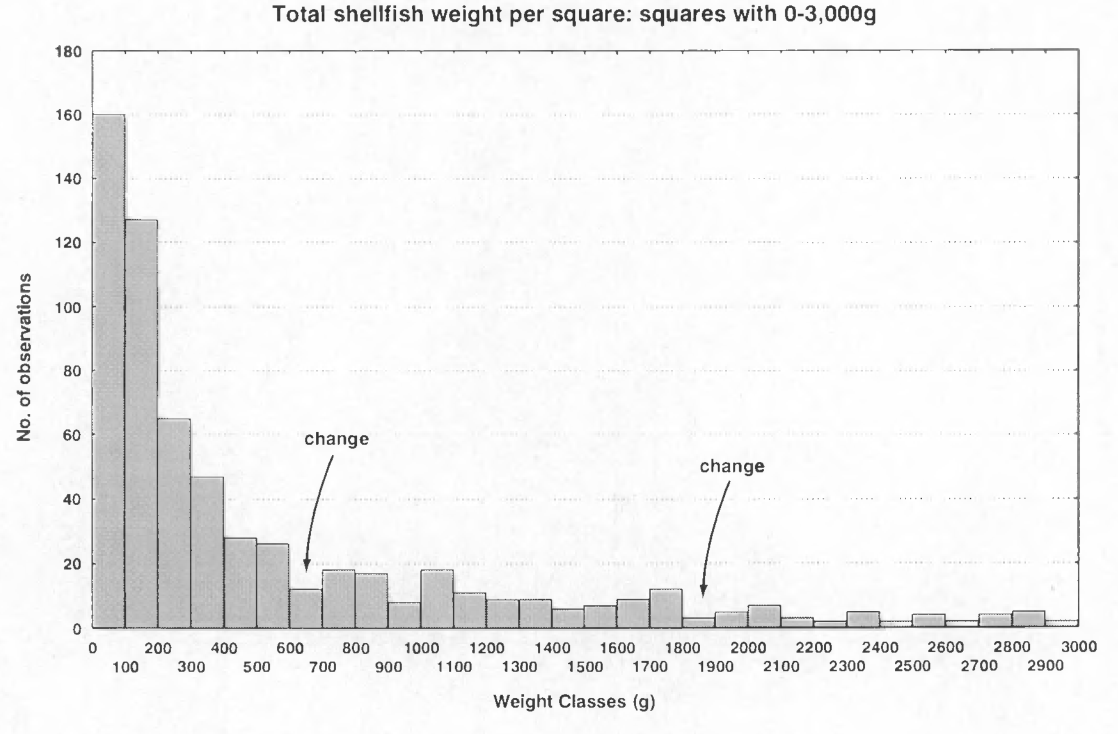
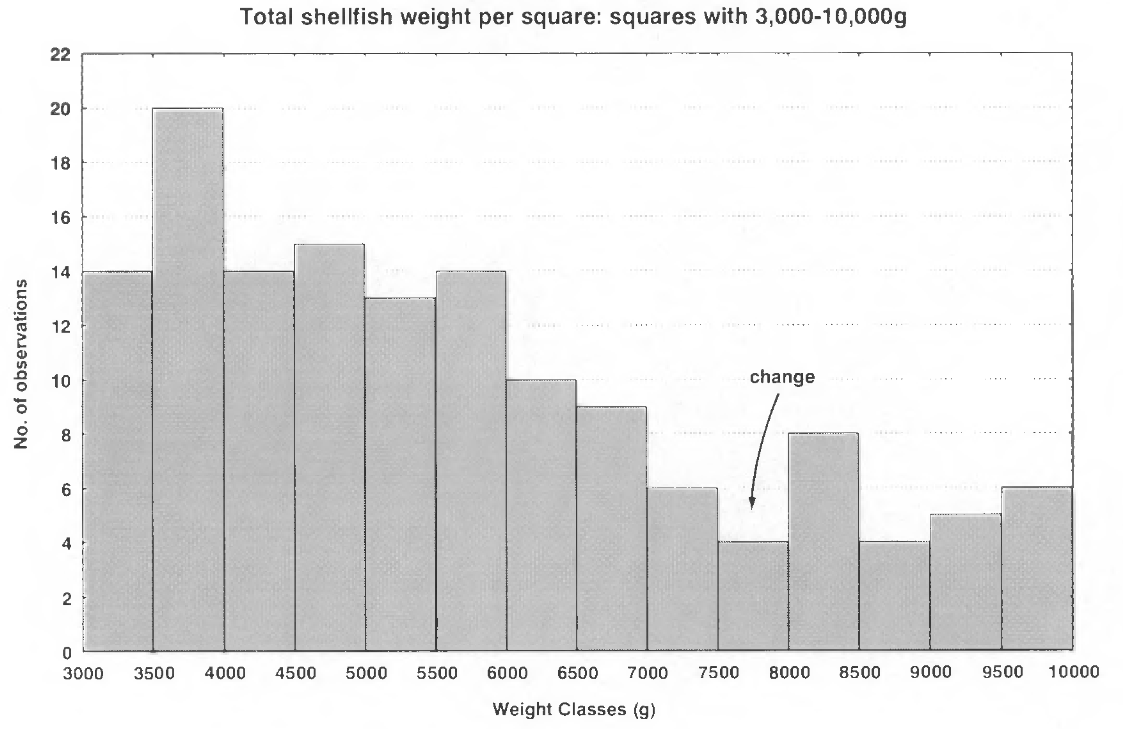


Figure 111: Histogram of total shellfish weight per square: all weight classes. (Top)

Figure 112: Histogram of total shellfish weight per square: squares with 0-3,000g. (Bottom)



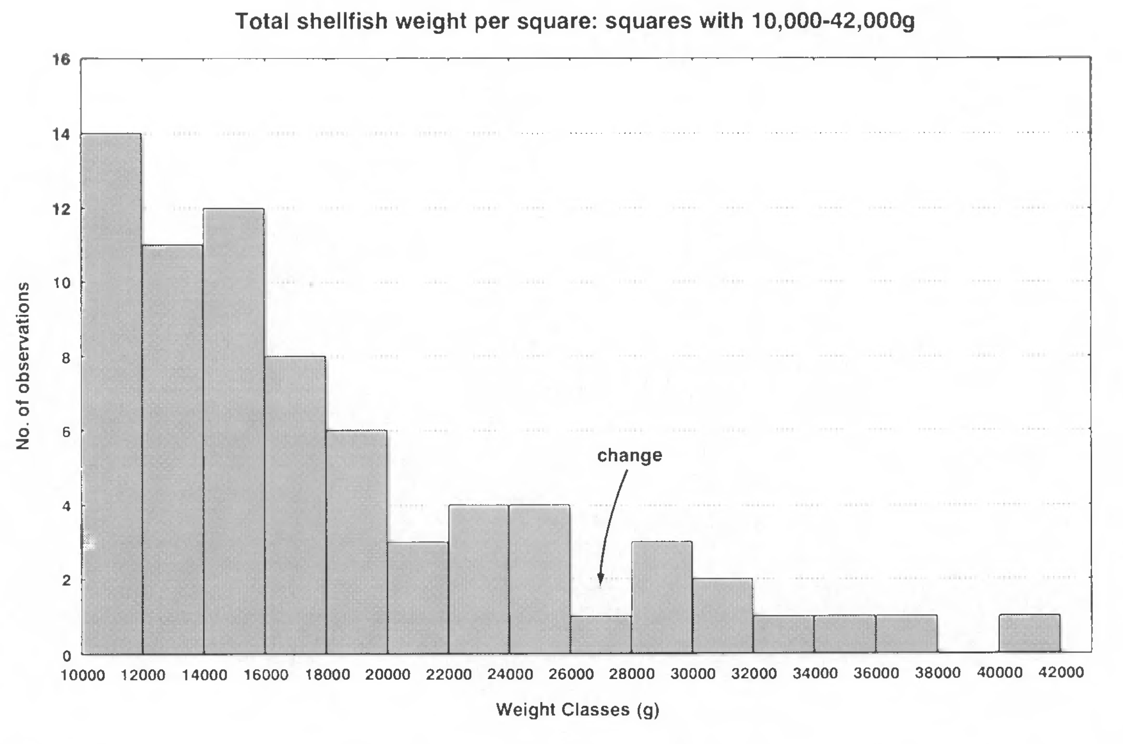
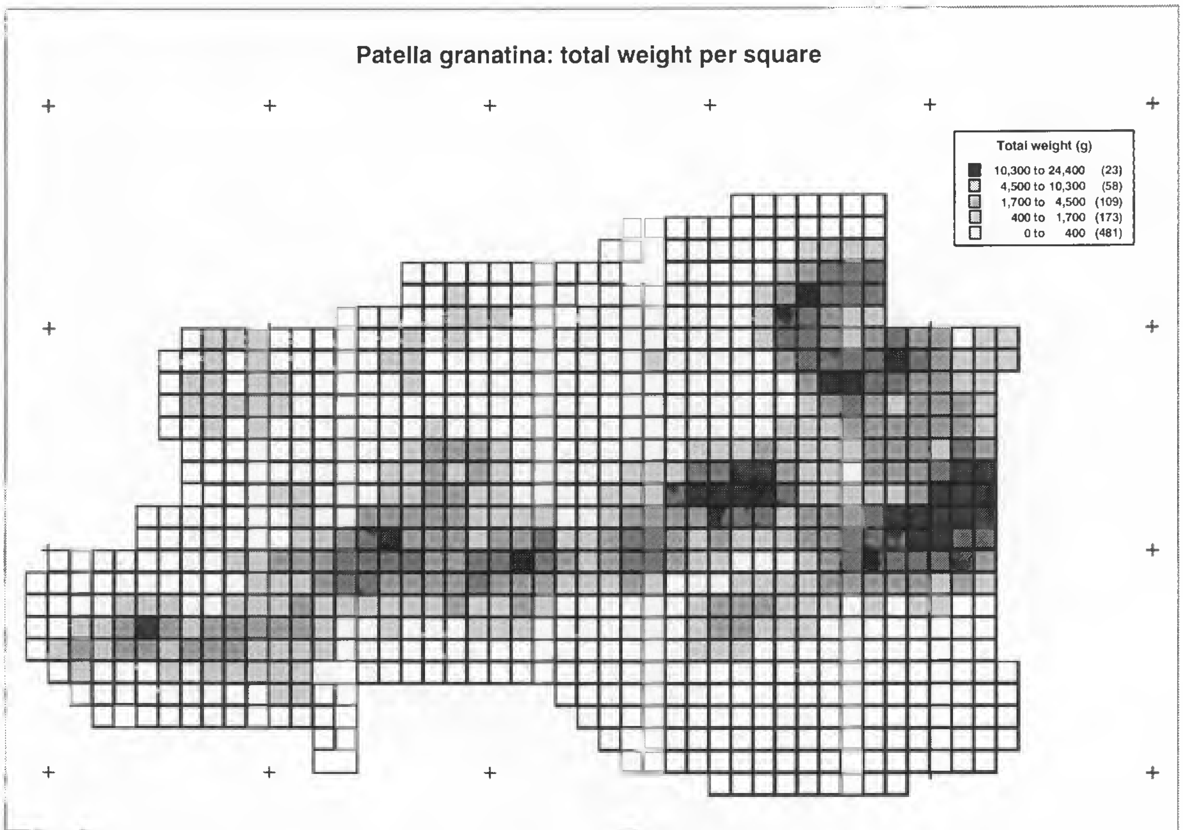


Figure 113: Histogram of total shellfish weight per square: squares with 3,000-10,000g. (Top)

Figure 114: Histogram of total shellfish weight per square: squares with 10,000-42,000g. (Bottom)



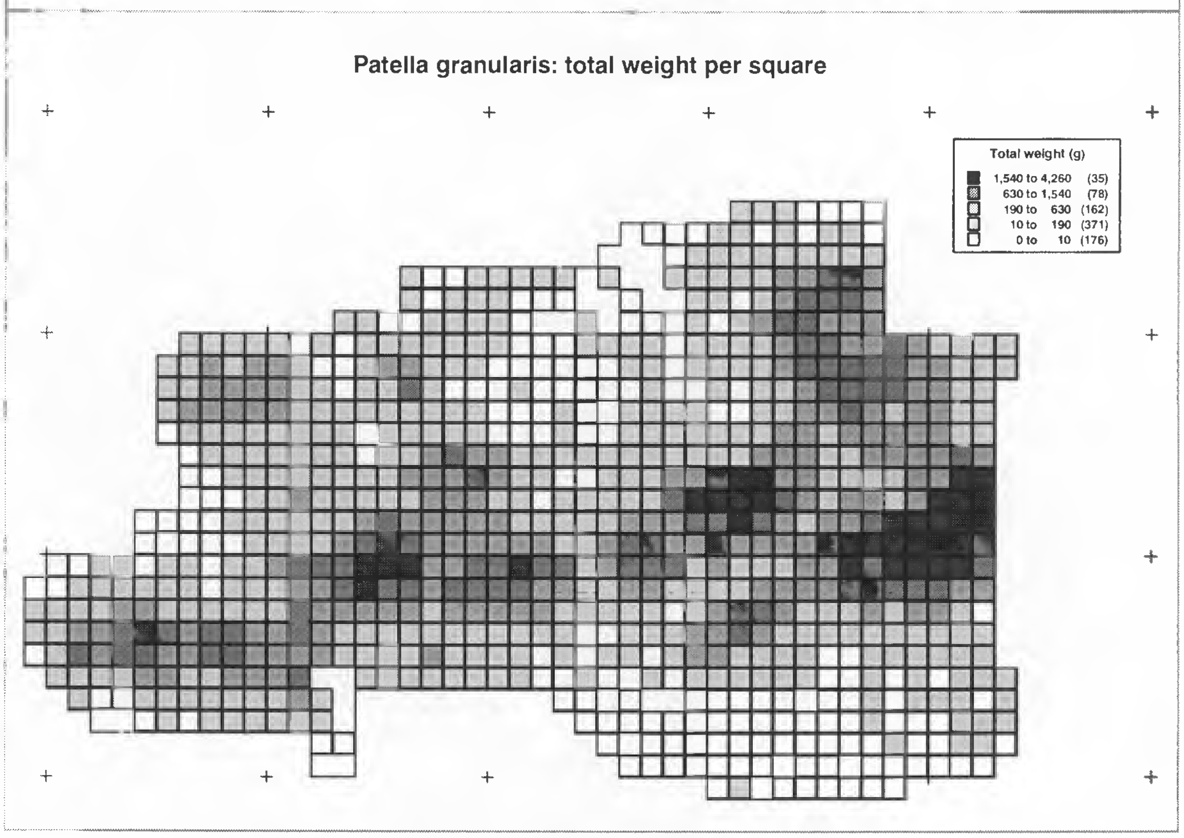
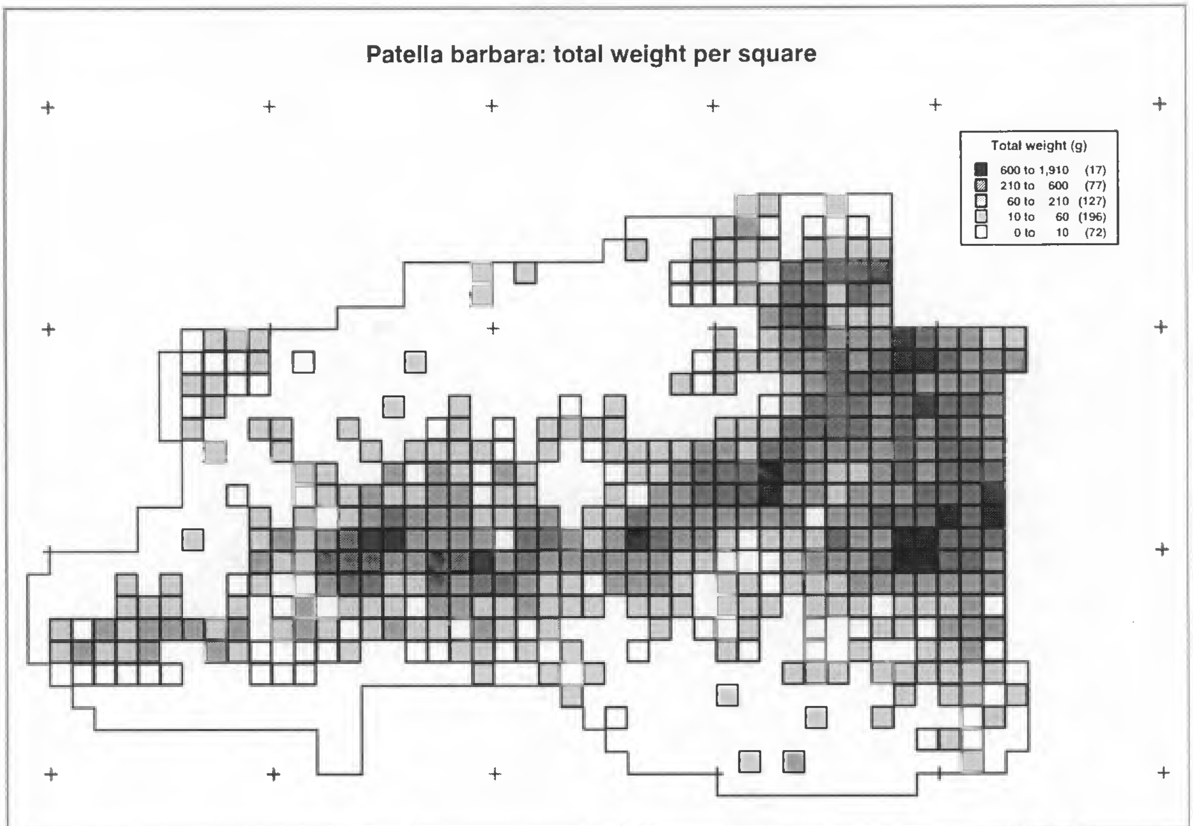


Figure 115: Limpets total weight per square: *Patella granatina*. (Top)

Figure 116: Limpets total weight per square: *Patella granularis*. (Bottom)



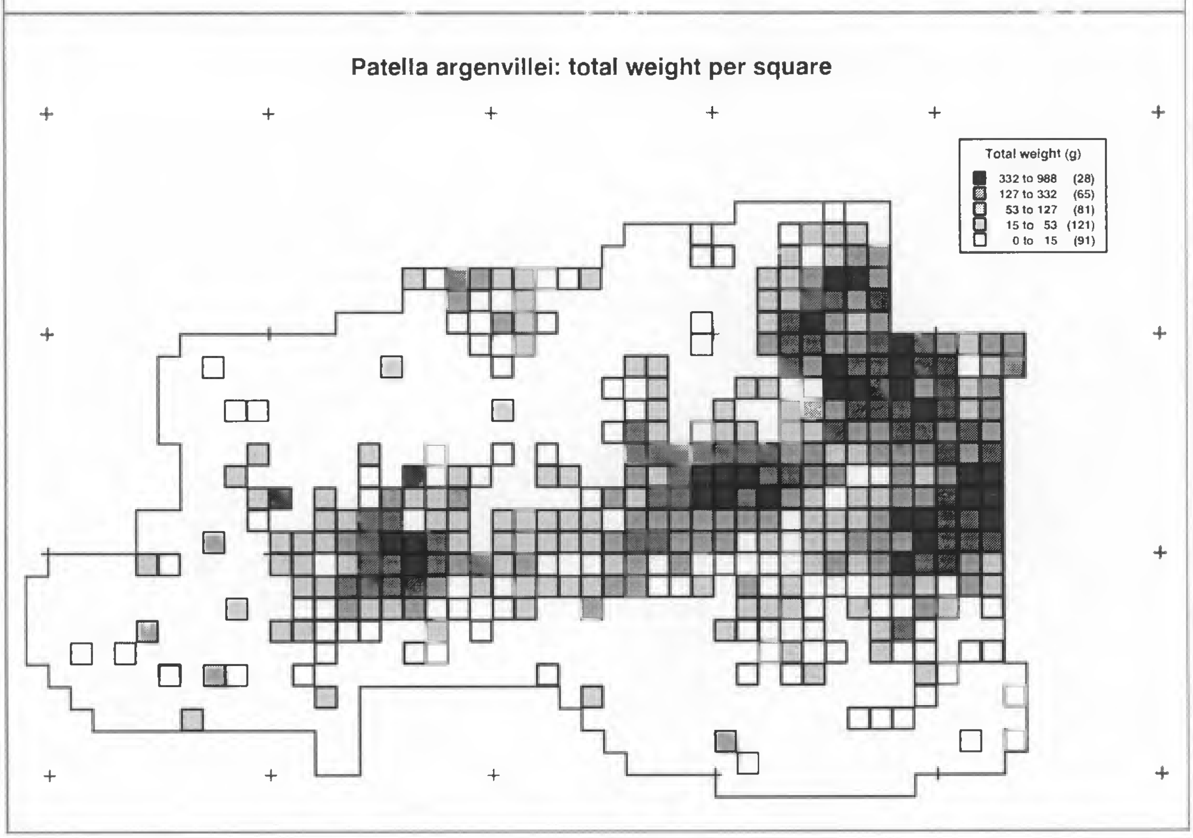


Figure 117: Limpets total weight per square: *Patella barbara*. (Top)

Figure 118: Limpets total weight per square: *Patella argenvillei*. (Bottom)

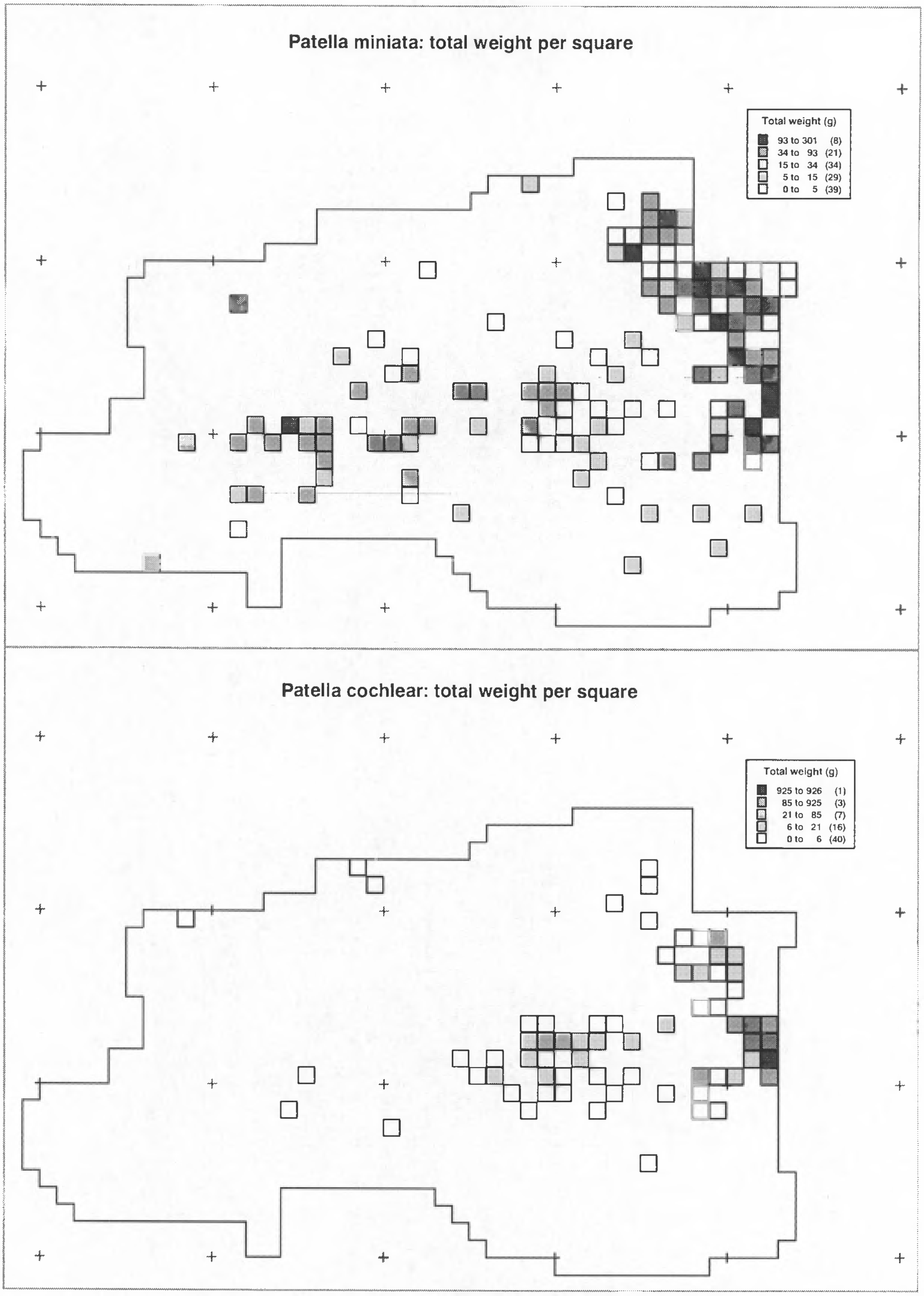
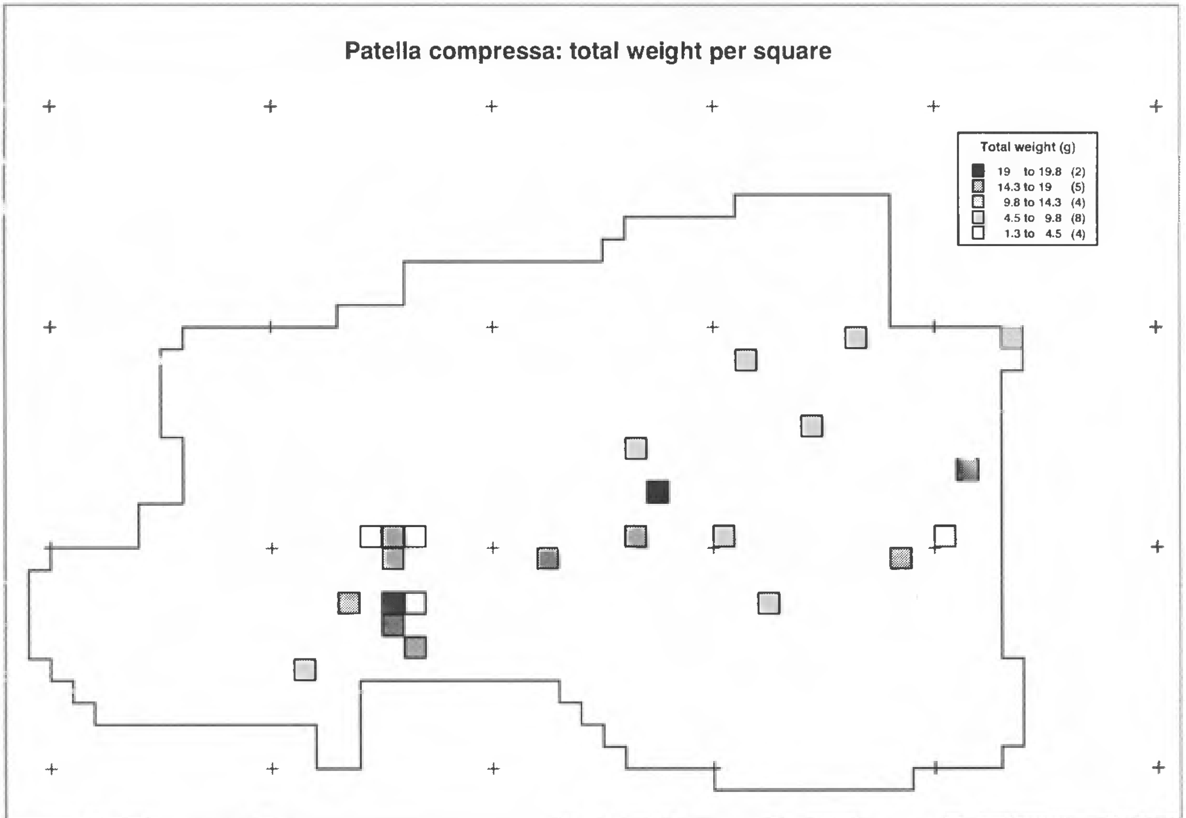


Figure 119: Limpets total weight per square: *Patella miniata*. (Top)

Figure 120: Limpets total weight per square: *Patella cochlear*. (Bottom)



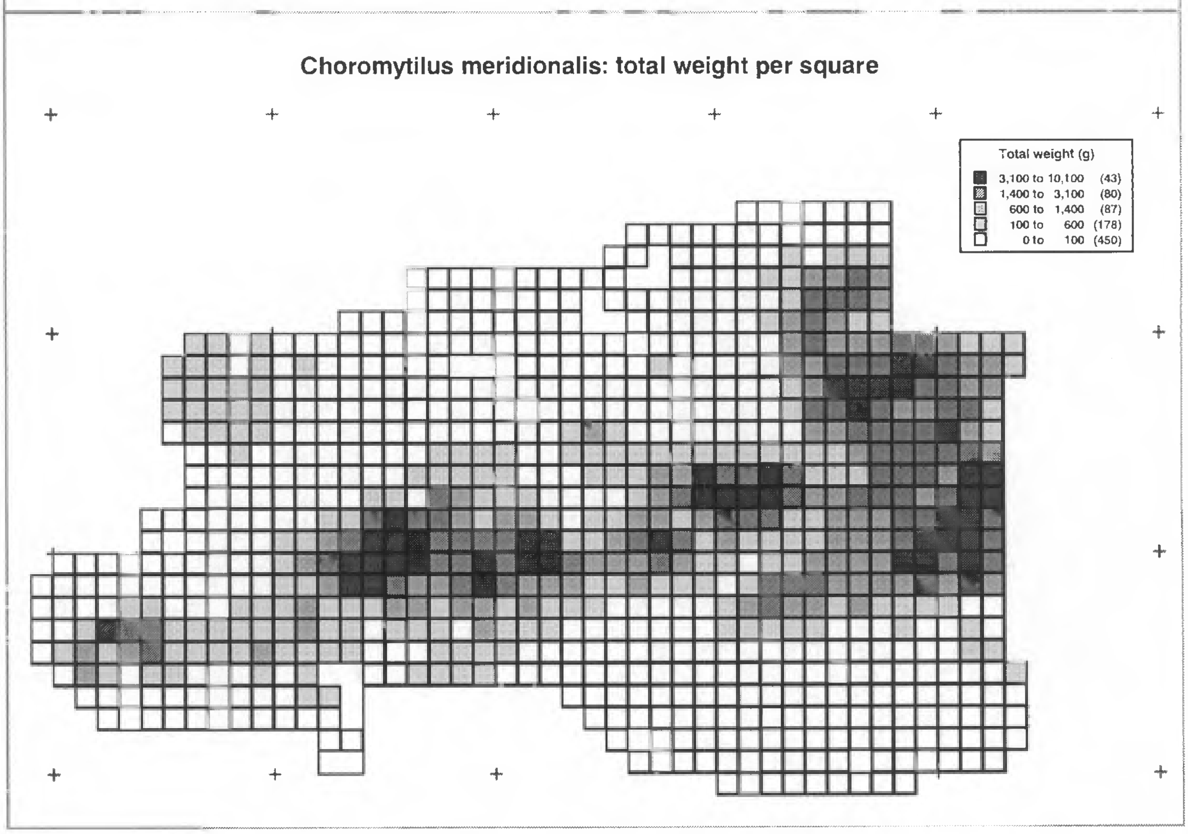
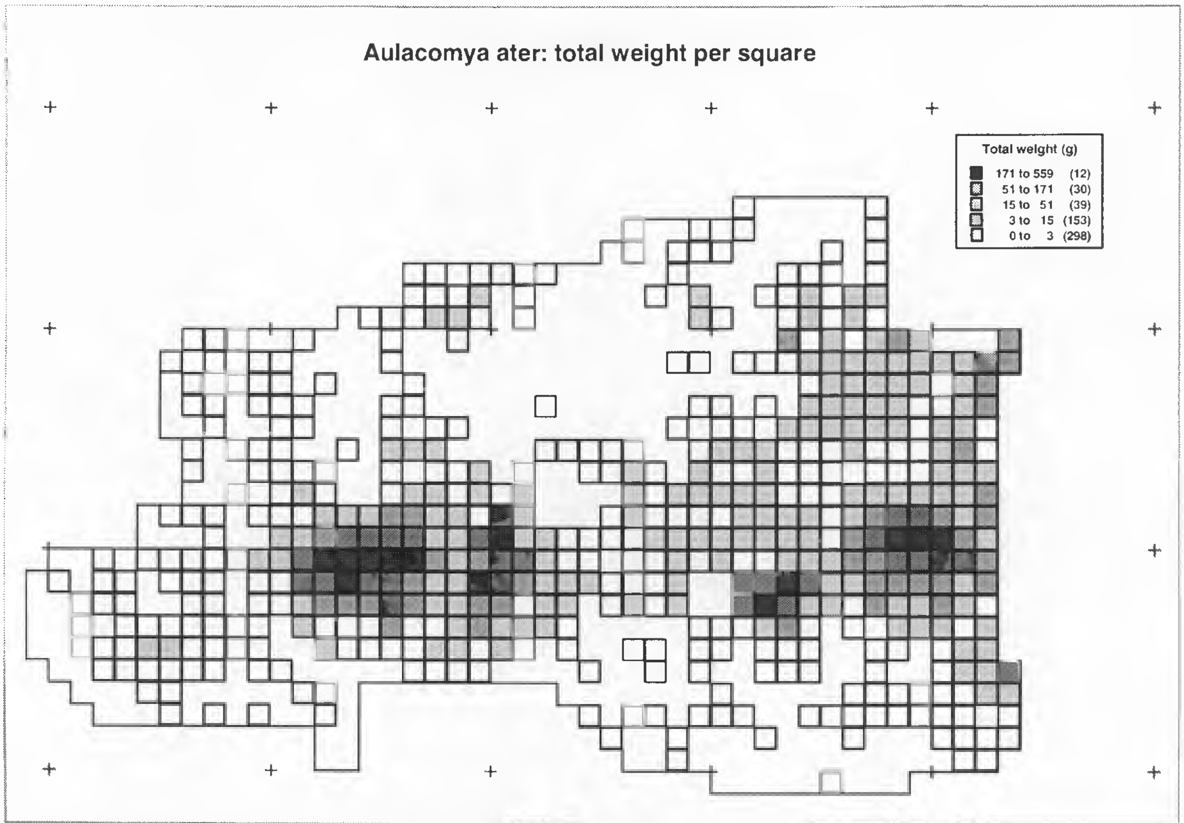


Figure 121: Limpets total weight per square: *Patella compressa*. (Top)

Figure 122: Mussels total weight per square: *Choromytilus meridionalis*. (Bottom)



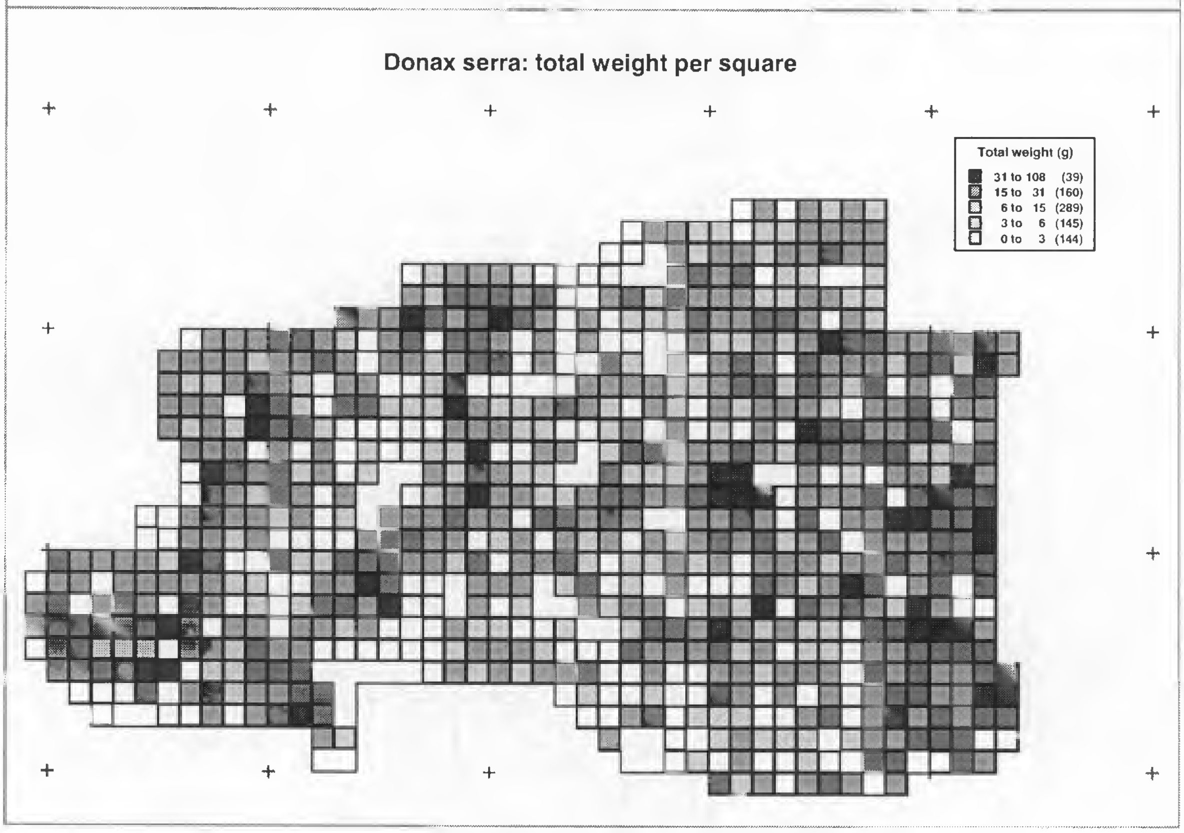
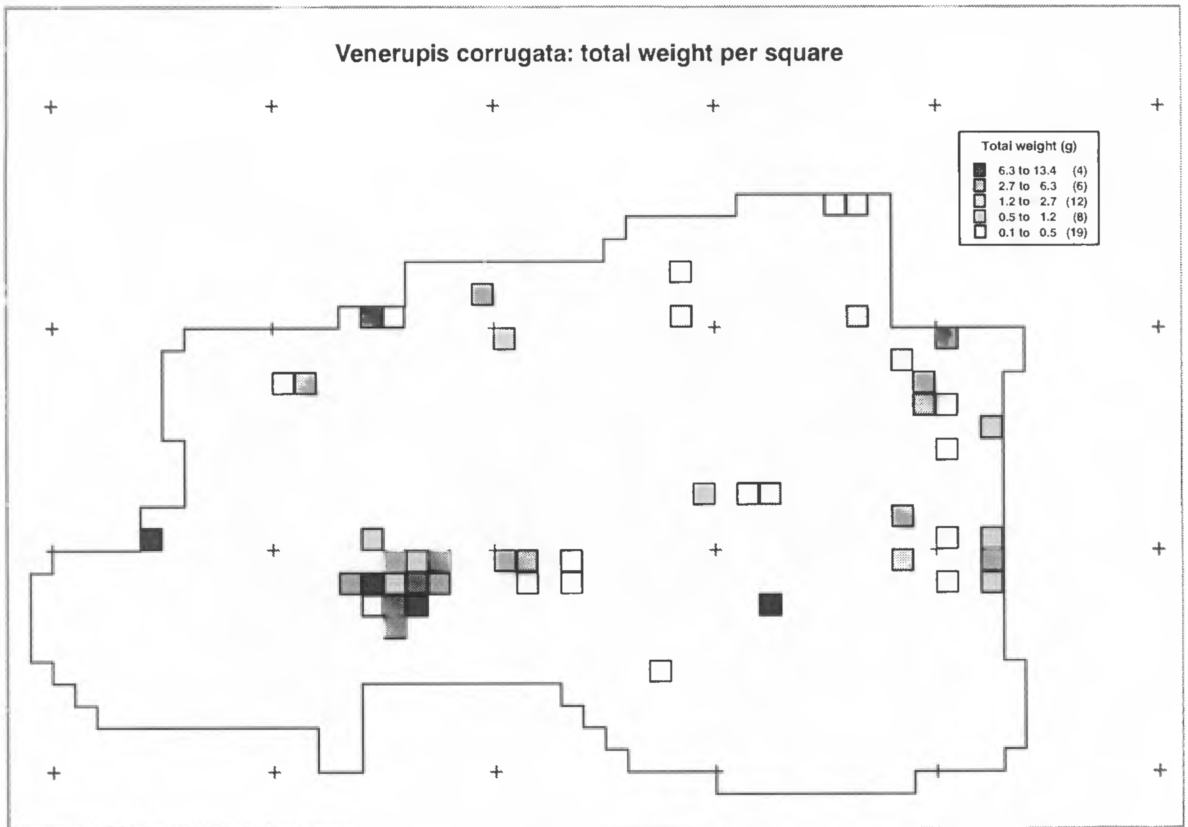


Figure 123: Mussels total weight per square: *Aulacomya ater.* (Top)

Figure 124: Mussels total weight per square: *Donax serra.* (Bottom)



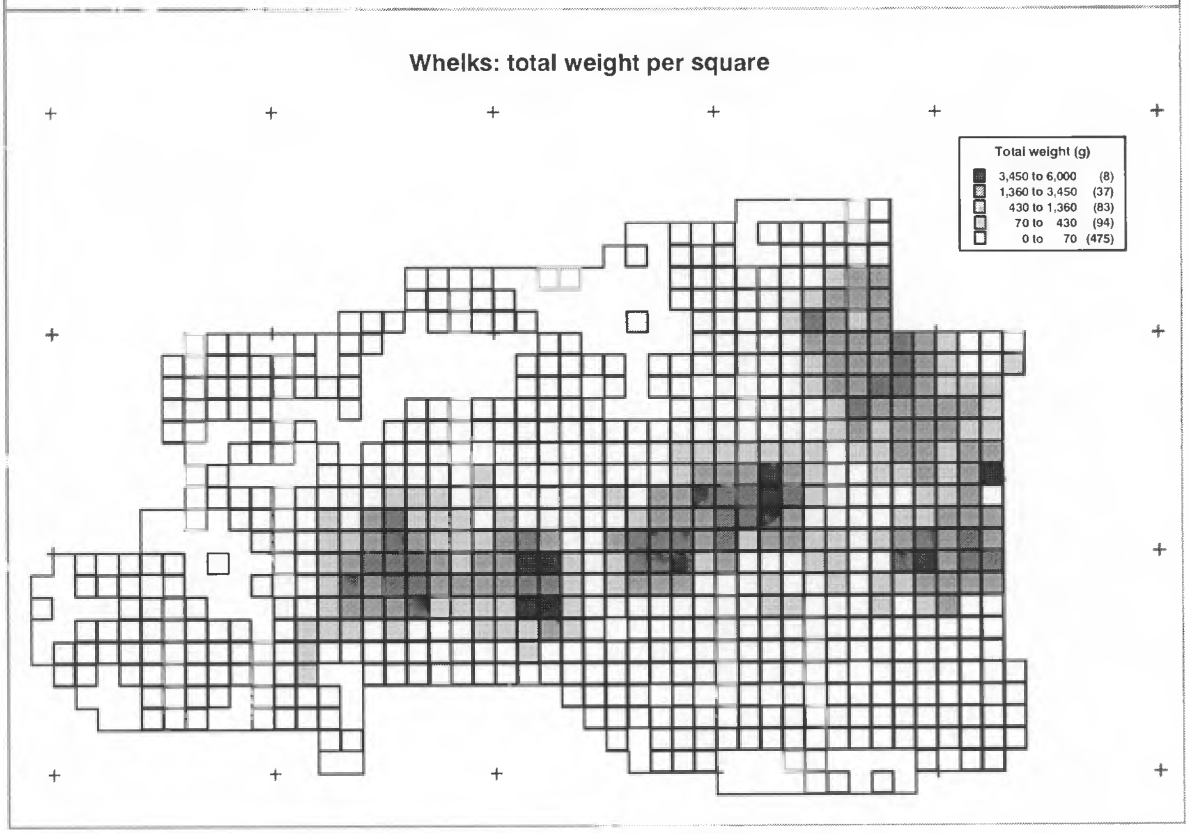
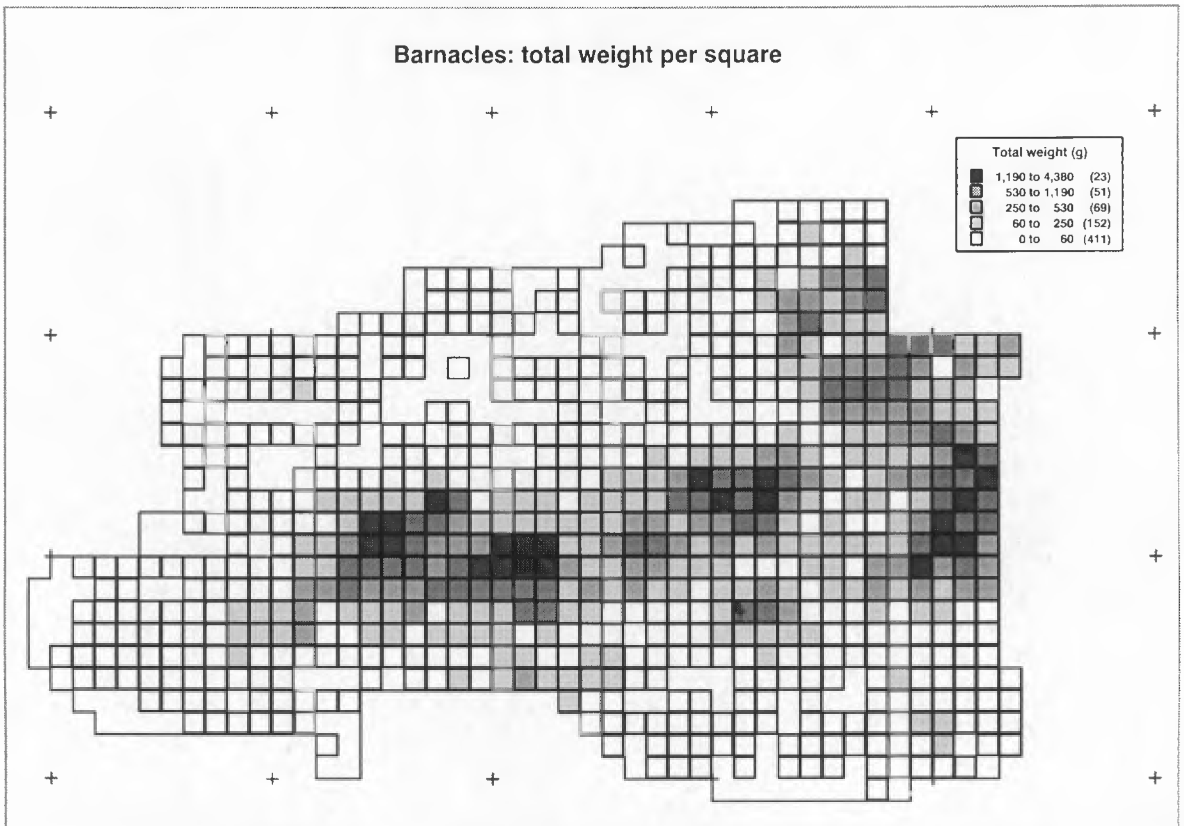


Figure 125: Mussels total weight per square: *Venerupis corrugata.* (Top)

Figure 126: Various total weight per square: Whelks. (Bottom)



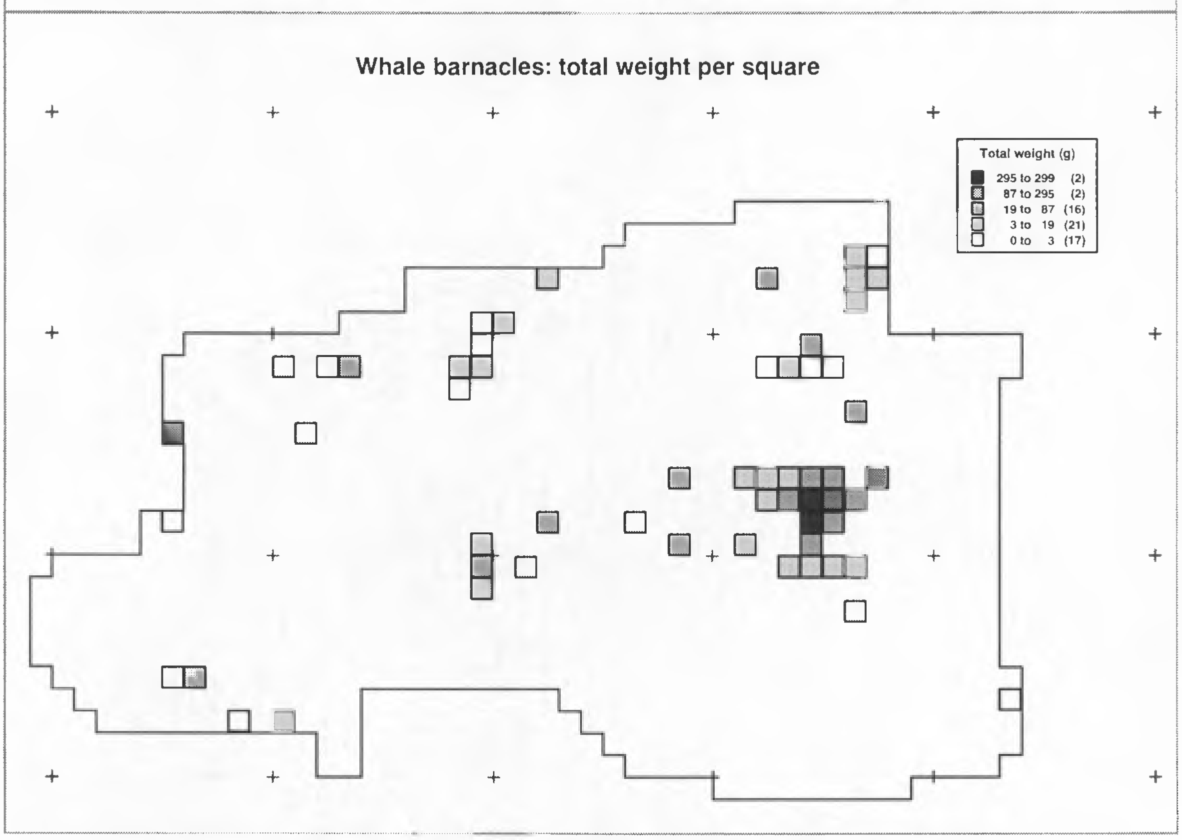
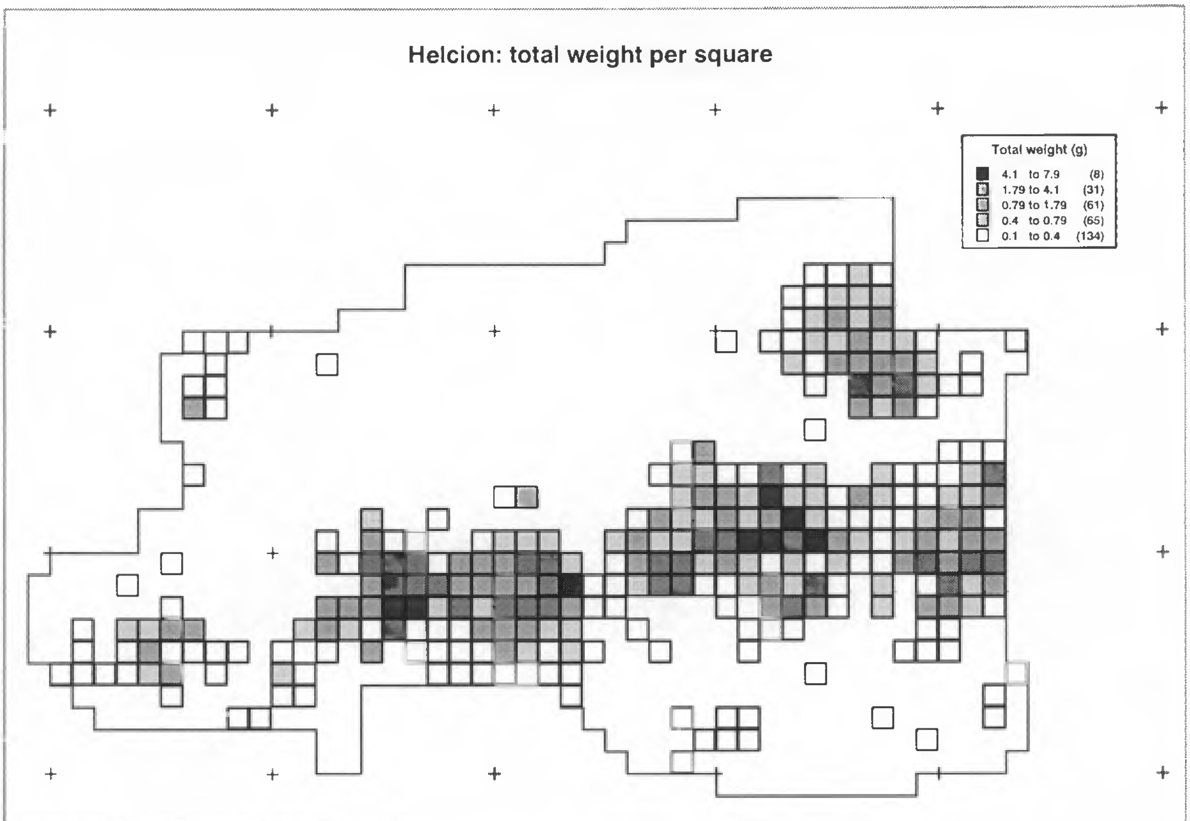


Figure 127: Various total weight per square: Barnacles. (Top)

Figure 128: Various total weight per square: Whale barnacles. (Bottom)



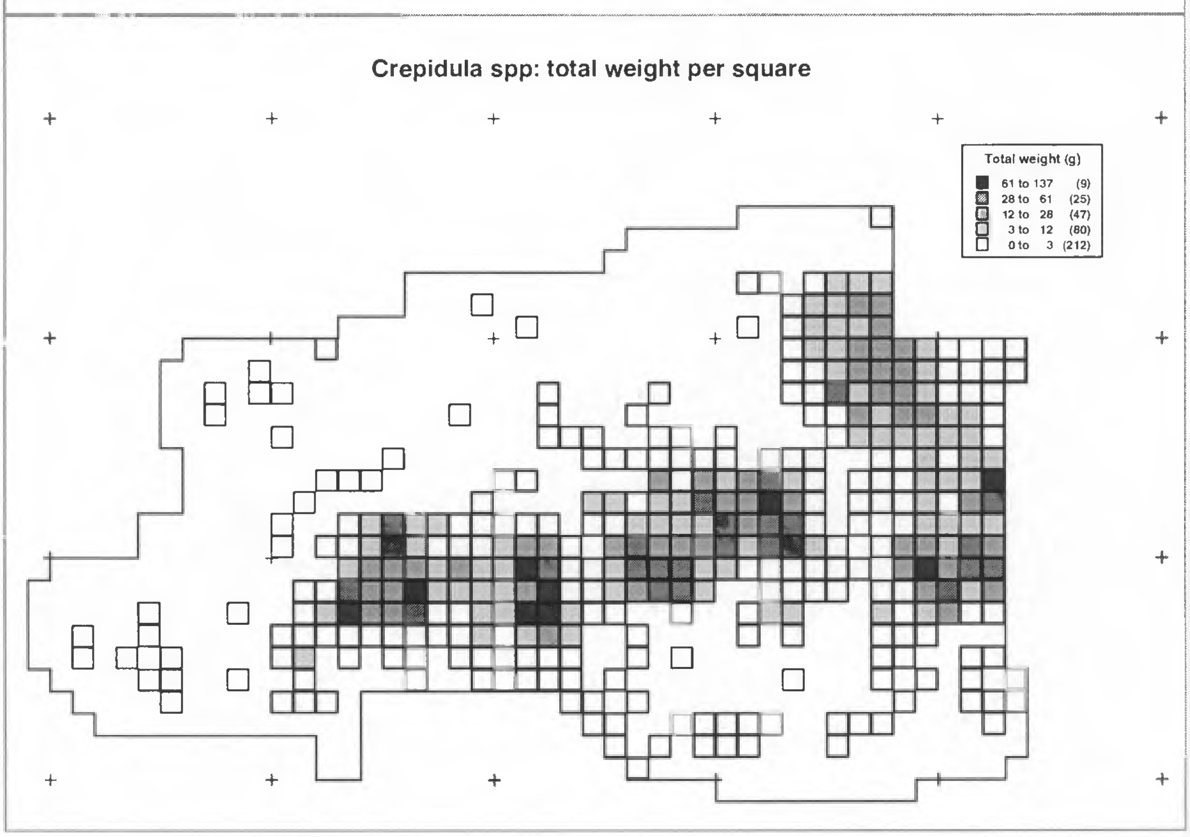
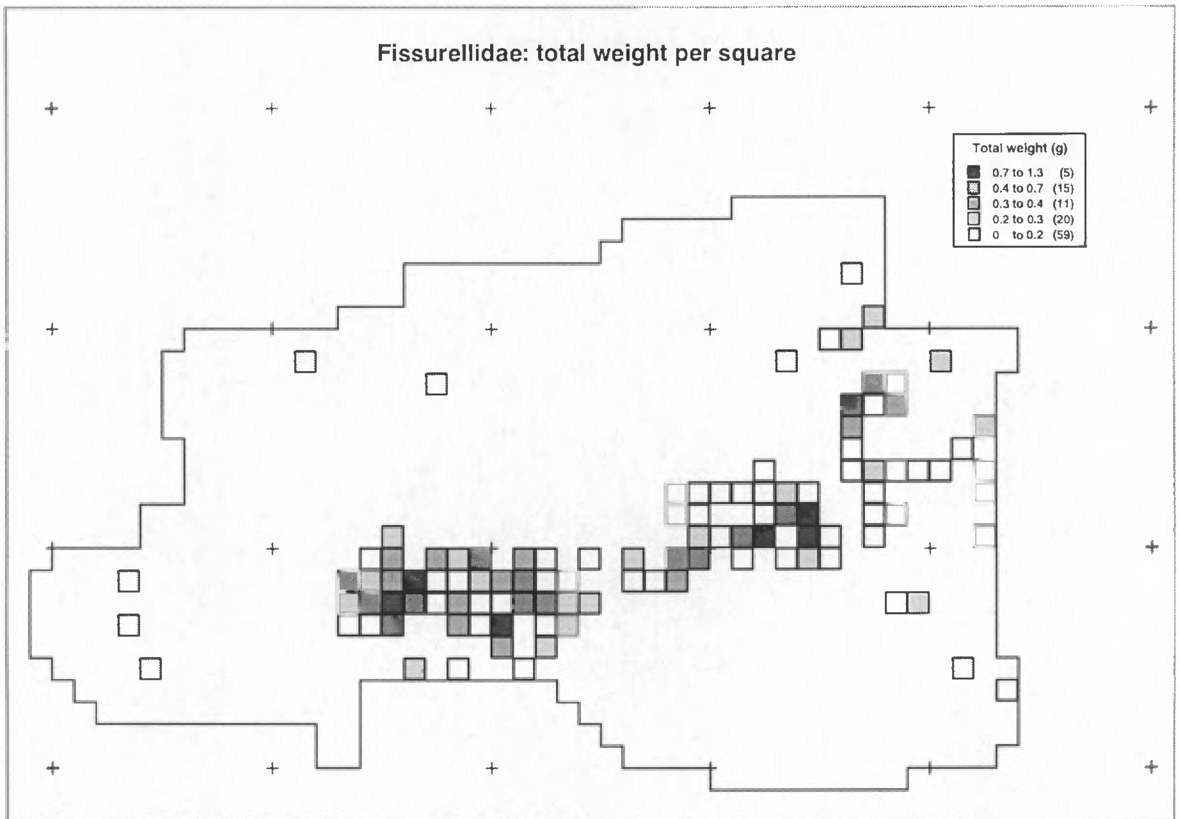


Figure 129: Various total weight per square: *Helcion* spp. (Top)

Figure 130: Various total weight per square: *Crepidula* spp. (Bottom)



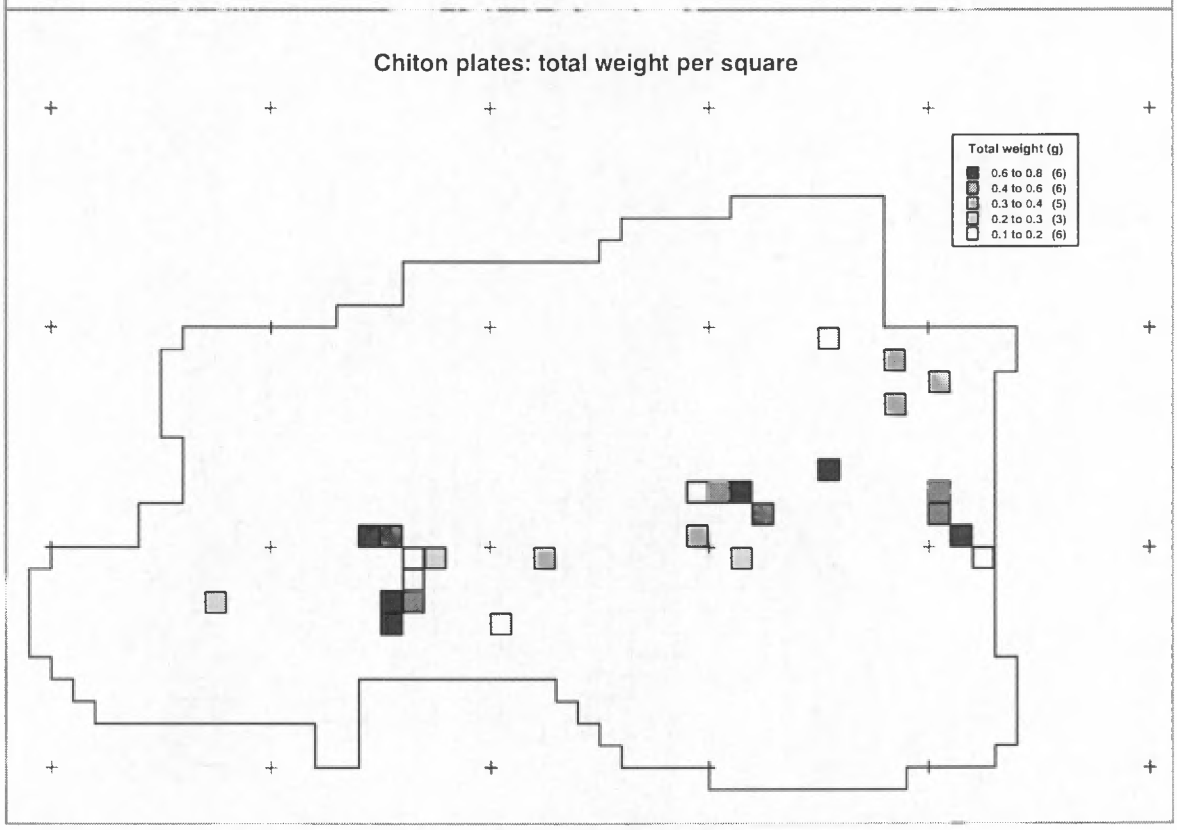


Figure 131: Various total weight per square: Fissurellidae. (Top)

Figure 132: Various total weight per square: Chiton plates. (Bottom)

		Limpets								
		P. granatina	P. granularis	P. barbara	P. argenvillei	P. cochlear	P. compr.	P. miniata	P. unident.	P. spp. sub.
Limpets	P. granatina	1.00	*** 0.92**	* 0.70	* 0.66	0.16	0.18	* 0.28	0.00	*** 0.77**
	P. granularis	*** 0.92**	1.00	* 0.63	* 0.56	* 0.28	0.11	* 0.25	0.02	*** 0.79**
	P. barbara	* 0.70	* 0.63	1.00	* 0.67	* 0.29	0.13	* 0.55	0.00	* 0.63
	P. argenvillei	* 0.66	* 0.56	* 0.67	1.00	* 0.55	0.16	* 0.49	0.05	* 0.61
	P. cochlear	0.16	* 0.28	* 0.29	* 0.55	1.00	0.42	0.33	-0.21	* 0.52
	P. compressa	0.18	0.11	0.13	0.16	0.42	1.00	-0.01	-	0.18
	P. miniata	* 0.28	* 0.25	* 0.55	* 0.49	0.33	-0.01	1.00	-0.03	* 0.35
	P. unidentified	0.00	0.02	0.00	0.05	-0.21	-	-0.03	1.00	0.12
	P. spp. subadult	*** 0.77**	*** 0.79**	* 0.63	* 0.61	* 0.52	0.18	* 0.35	0.12	1.00
Mussels	C. meridionalis	*** 0.81**	*** 0.76**	* 0.70	* 0.61	0.05	0.04	* 0.32	0.30	*** 0.72**
	Donax Serra	* 0.34	* 0.35	* 0.15	* 0.32	0.17	0.04	0.03	0.20	* 0.34
	Aulacomya ater	* 0.32	* 0.43	* 0.35	* 0.13	-0.03	-0.07	-0.02	0.07	* 0.32
	Venerupis corrugata	-0.11	-0.07	-0.13	-0.09	-0.35	-0.09	-0.09	0.24	0.09
	C. meridionalis subadult	0.02	0.08	-0.04	0.00	-0.03	-0.23	0.04	-0.15	0.13
	Aulacomya ater subadult	* 0.37	* 0.32	* 0.33	* 0.23	0.04	-0.11	0.04	-0.14	* 0.41
Various	Whelks	* 0.63	* 0.60	* 0.56	* 0.39	-0.02	0.24	* 0.23	0.03	* 0.63
	Whelks subadult	* 0.46	* 0.46	* 0.60	0.25	-0.26	1.00	-0.14	0.10	* 0.37
	Barnacles	* 0.68	* 0.60	* 0.56	* 0.45	0.07	0.02	0.17	-0.08	* 0.59
	Whale barnacles	-0.08	-0.12	-0.18	-0.17	* 0.69	-	-0.28	-	-0.06
	Crepidula spp.	* 0.38	* 0.41	* 0.29	* 0.20	0.00	0.13	0.07	-0.09	* 0.49
	Helcion	* 0.17	* 0.20	0.07	-0.01	-0.12	0.14	-0.01	-0.10	* 0.38
	Fissurellidae	-0.13	-0.10	-0.17	-0.16	-0.22	0.17	-0.24	-	* 0.31
	Siphonaria	0.26	0.29	0.17	0.30	0.75	-	0.57	-0.56	-0.08

Table 45: Correlations (r-values) of total shellfish species weights per square for limpets; pairwise deletion of missing data (*: significant at the 0.05 level; correlations with r>0.70 or r<-0.70 are highlighted).

		Mussels					
		C. merid.	D. serra	A. ater	V. corrug.	C. merid. sub.	A. ater sub.
Limpets	P. granatina	*** 0.81**	* 0.34	* 0.32	-0.11	0.02	* 0.37
	P. granularis	*** 0.76**	* 0.35	* 0.43	-0.07	0.08	* 0.32
	P. barbara	* 0.70	* 0.15	* 0.35	-0.13	-0.04	* 0.32
	P. argenvillei	* 0.61	* 0.32	* 0.13	-0.09	0.00	* 0.23
	P. cochlear	0.05	0.17	-0.03	-0.35	-0.03	0.04
	P. compressa	0.04	0.04	-0.07	-0.09	-0.23	-0.11
	P. miniata	* 0.32	0.03	-0.02	-0.09	0.04	0.04
	P. unidentified	0.30	0.20	0.07	0.24	-0.15	-0.14
	P. spp. subadult	*** 0.72**	* 0.34	* 0.32	0.09	0.13	* 0.41
Mussels	C. meridionalis	*1.00*	* 0.25	* 0.47	-0.06	0.15	* 0.46
	Donax Serra	* 0.25	*1.00*	0.07	0.13	* 0.25	* 0.16
	Aulacomya ater	* 0.47	0.07	*1.00*	0.20	0.14	0.10
	Venerupis corrugata	-0.06	0.13	0.20	*1.00*	* 0.40	0.05
	C. meridionalis subadult	0.15	* 0.25	0.14	* 0.40	*1.00*	0.06
	Aulacomya ater subadult	* 0.46	* 0.16	0.10	0.05	0.06	*1.00*
Various	Whelks	*** 0.72**	* 0.14	* 0.26	0.10	0.15	* 0.45
	Whelks subadult	0.23	-0.12	*** 0.77**	*** 0.75**	-0.08	* 0.41
	Barnacles	*** 0.82**	* 0.16	* 0.29	0.17	* 0.17	* 0.40
	Whale barnacles	-0.03	-0.02	-0.10	-	*** 0.86**	-0.02
	Crepidula spp.	* 0.42	0.07	* 0.12	0.10	0.12	* 0.30
	Helcion	* 0.23	0.02	0.08	0.25	0.20	* 0.32
	Fissurellidae	-0.06	-0.01	0.10	0.35	* 0.38	0.11
	Siphonaria	0.20	-0.04	0.19	-	0.06	-0.06

Table 46: Correlations (r-values) of total shellfish species weights per square for mussels; pairwise deletion of missing data (*: significant at the 0.05 level; correlations with r>0.70 or r<-0.70 are highlighted).

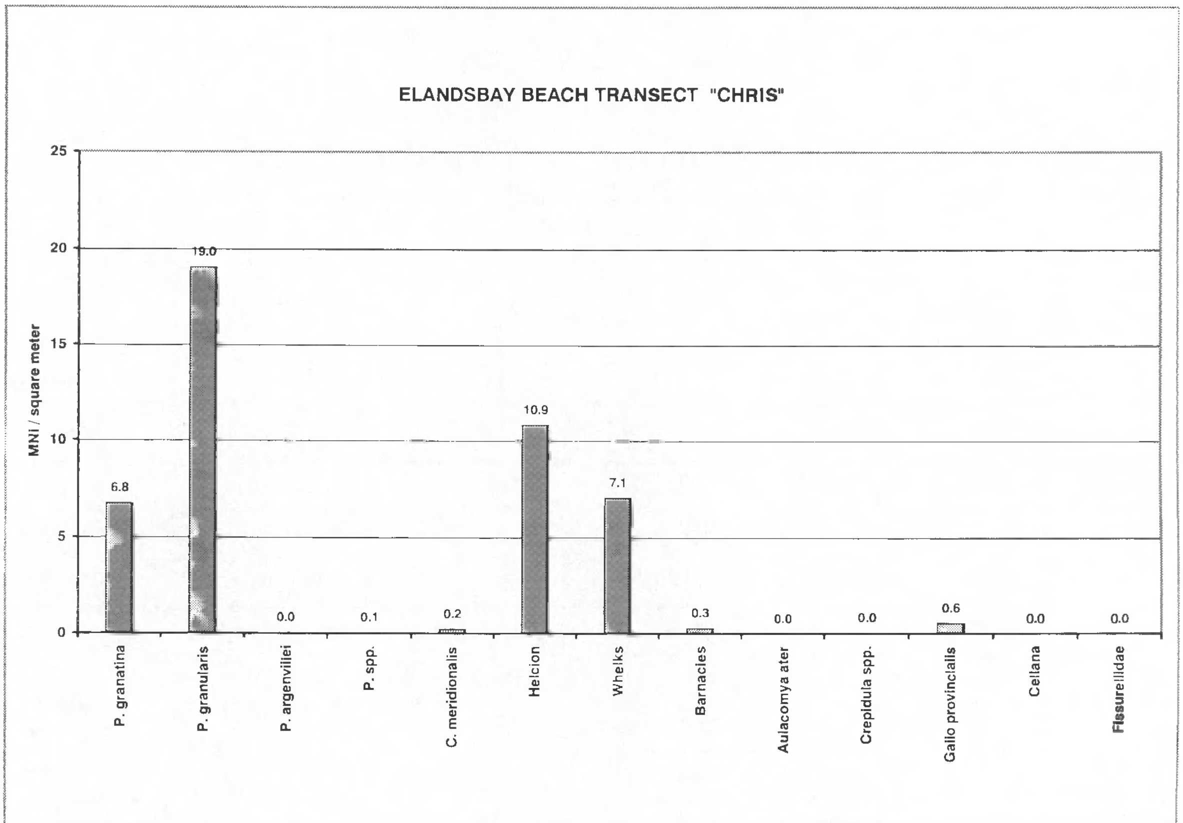
Table 47: Correlations (r-values) of total shellfish species weights per square for various species; pairwise deletion of missing data (*: significant at the 0.05 level; correlations with r>0.70 or r<-0.70 are highlighted).

		Various							
		Whelks	Whelks sub.	Barnacles	W. barnacles	Crep. spp.	Helcion	Fissurellidae	Siphonaria
Limpets	P. granatina	* 0.63	* 0.46	* 0.68	-0.08	* 0.38	* 0.17	-0.13	0.26
	P. granularis	* 0.60	* 0.46	* 0.60	-0.12	* 0.41	* 0.20	-0.10	0.29
	P. barbara	* 0.56	* 0.60	* 0.56	-0.18	* 0.29	0.07	-0.17	0.17
	P. argenvillei	* 0.39	0.25	* 0.45	-0.17	* 0.20	-0.01	-0.16	0.30
	P. cochlear	-0.02	-0.26	0.07	* 0.69	0.00	-0.12	-0.22	0.75
	P. compressa	0.24	1.00	0.02	-	0.13	0.14	0.17	-
	P. miniata	* 0.23	-0.14	0.17	-0.28	0.07	-0.01	-0.24	0.57
	P. unidentified	0.03	0.10	-0.08	-	-0.09	-0.10	-	-0.58
	P. spp. subadult	* 0.63	* 0.37	* 0.59	-0.06	* 0.49	* 0.38	* 0.31	-0.08
Mussels	C. meridionalis	*** 0.72**	0.23	*** 0.82**	-0.03	* 0.42	* 0.23	-0.06	0.20
	Donax Serra	* 0.14	-0.12	* 0.16	-0.02	0.07	0.02	-0.01	-0.04
	Aulacomya ater	* 0.26	*** 0.77**	* 0.29	-0.10	* 0.12	0.08	0.10	0.19
	Venerupis corrugata	0.10	*** 0.75**	0.17	-	0.10	0.25	0.35	-
	C. meridionalis subadult	0.15	-0.08	* 0.17	*** 0.86**	0.12	0.20	* 0.38	0.06
	Aulacomya ater subadult	* 0.45	* 0.41	* 0.40	-0.02	* 0.30	* 0.32	0.11	-0.06
Various	Whelks	1.00	0.13	*** 0.72**	-0.11	*** 0.87**	* 0.51	0.11	0.01
	Whelks subadult	0.13	1.00	0.14	-	0.10	0.02	-0.98	-0.44
	Barnacles	*** 0.72**	0.14	1.00	-0.09	* 0.48	* 0.23	-0.02	0.02
	Whale barnacles	-0.11	-	-0.09	1.00	-0.15	-0.08	0.37	-
	Crepidula spp.	*** 0.87**	0.10	* 0.48	-0.15	1.00	* 0.56	0.18	0.17
	Helcion	* 0.51	0.02	* 0.23	-0.08	* 0.56	1.00	* 0.47	-0.13
	Fissurellidae	0.11	-0.98	-0.02	0.37	0.18	* 0.47	1.00	-
	Siphonaria	0.01	-0.44	0.02	-	0.17	-0.13	-	1.00

APPENDIX II ELANDSBAY BEACH TRANSECTS

Descriptive statistics

Table 48: Index to figures for the quantitative description of the Elandsbay beach transects.



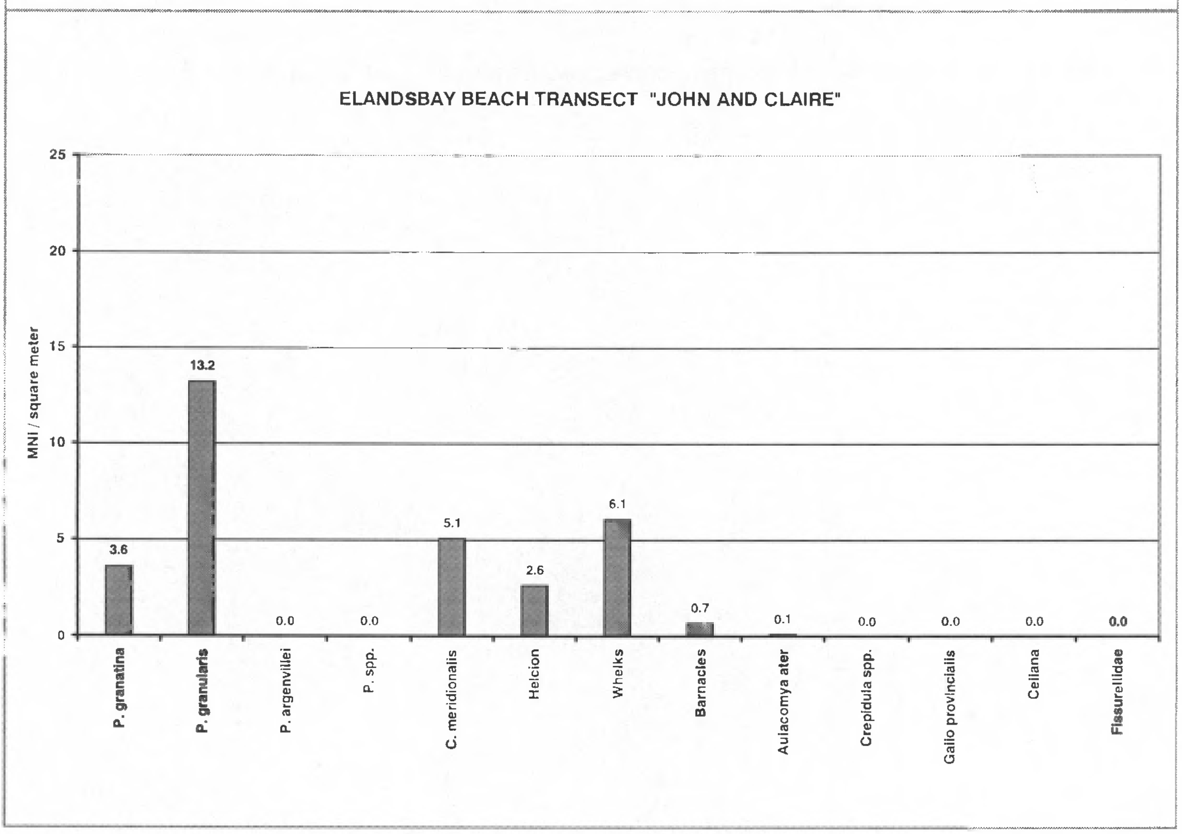
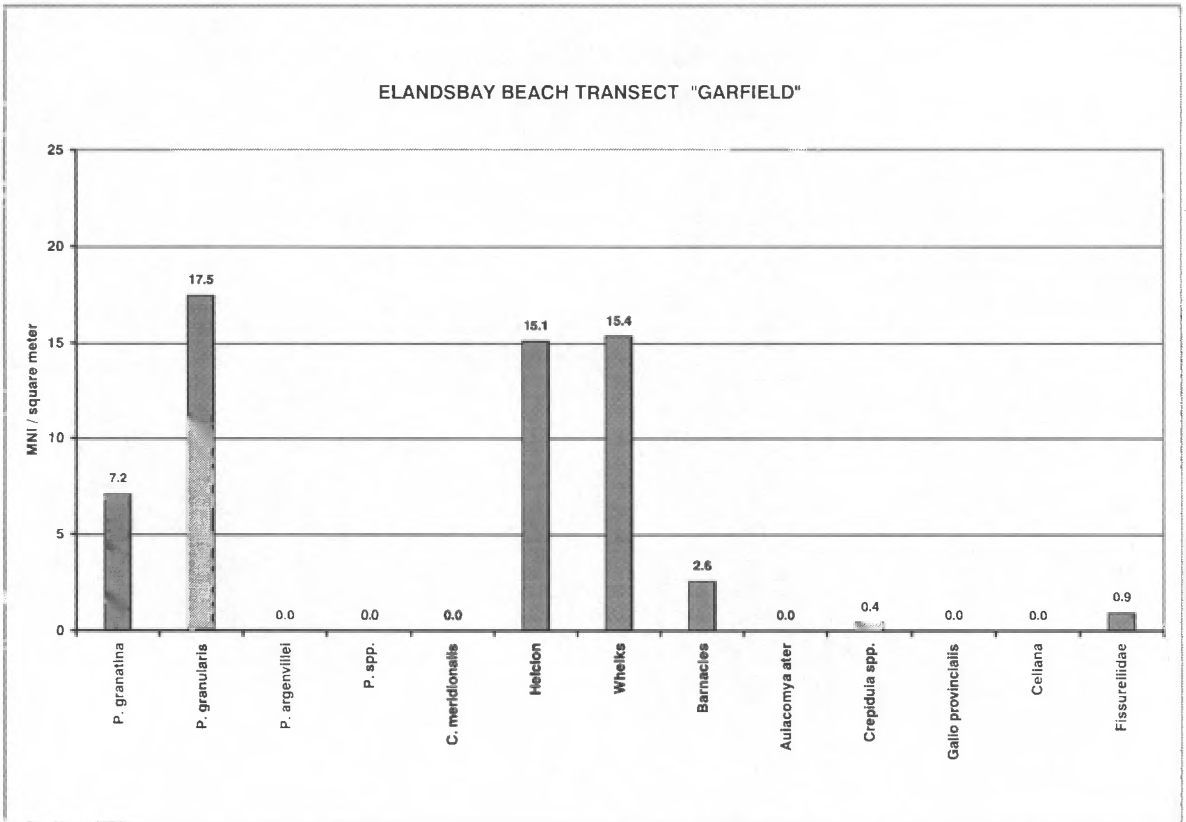


Figure 133: Elandsbay beach transect "Chris": MNI of shellfish species per square meter. (Top)

Figure 134: Elandsbay beach transect "John and Claire": MNI of shellfish species per square meter. (Bottom)



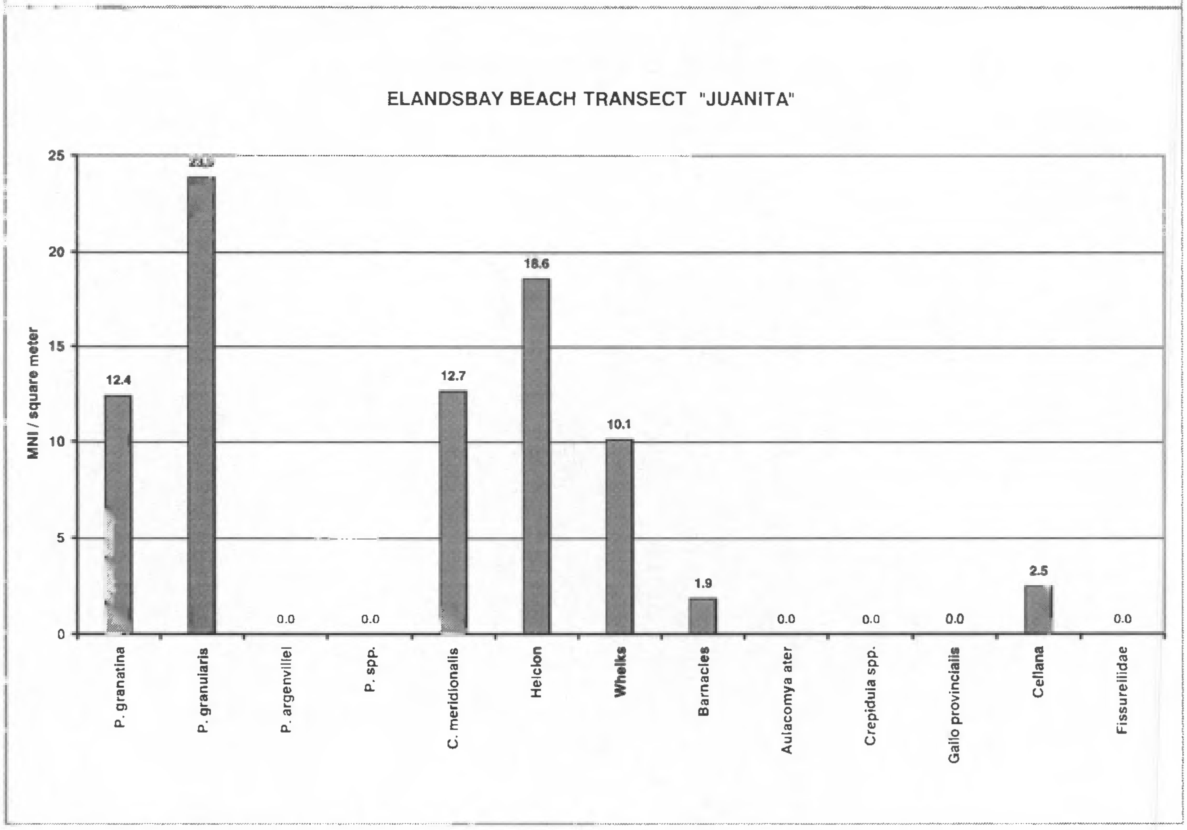


Figure 135: Elandsbay beach transect "Garfield": MNI of shellfish species per square meter. (Top)

Figure 136: Elandsbay beach transect "Juanita": MNI of shellfish species per square meter. (Bottom)

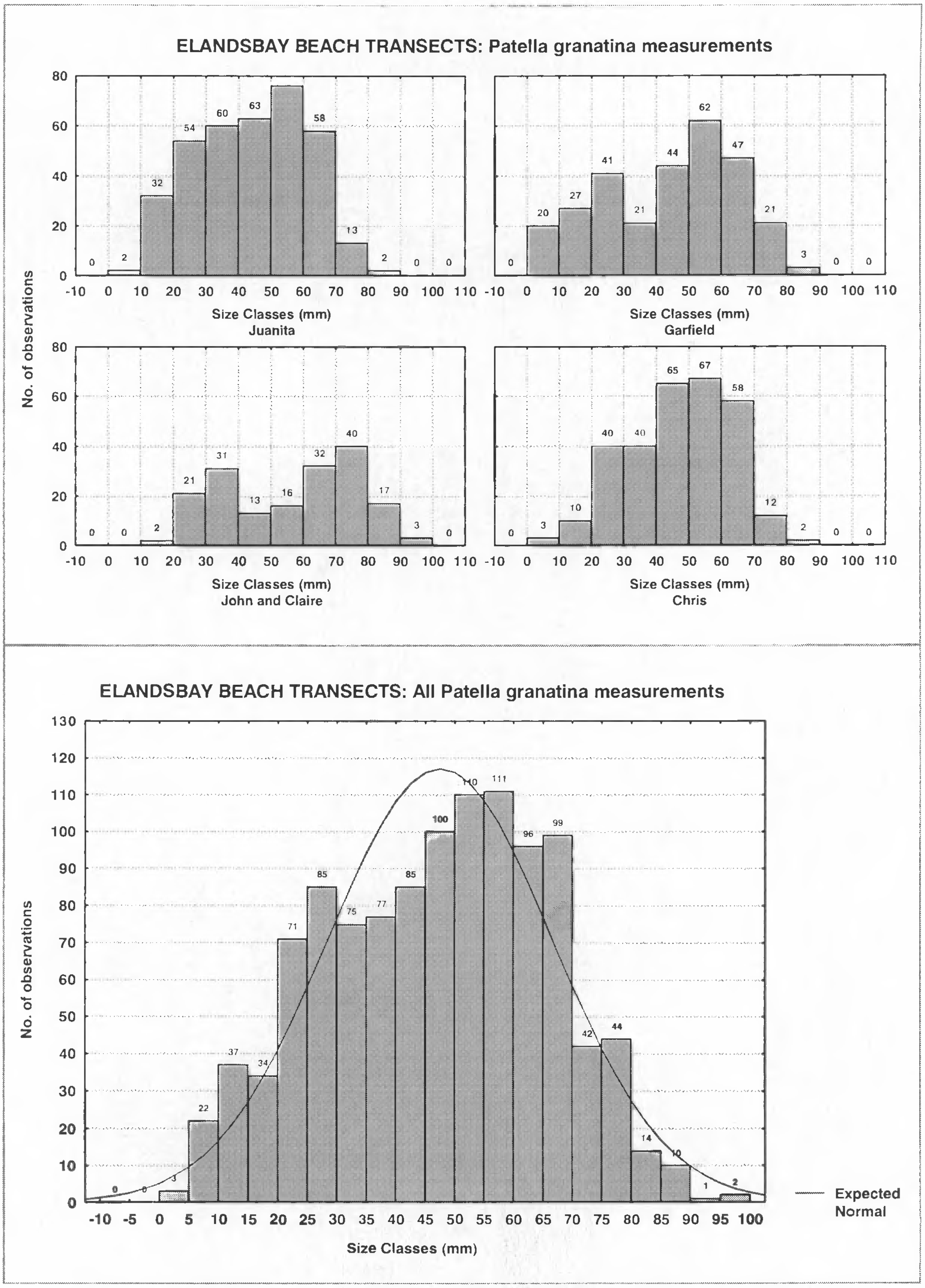
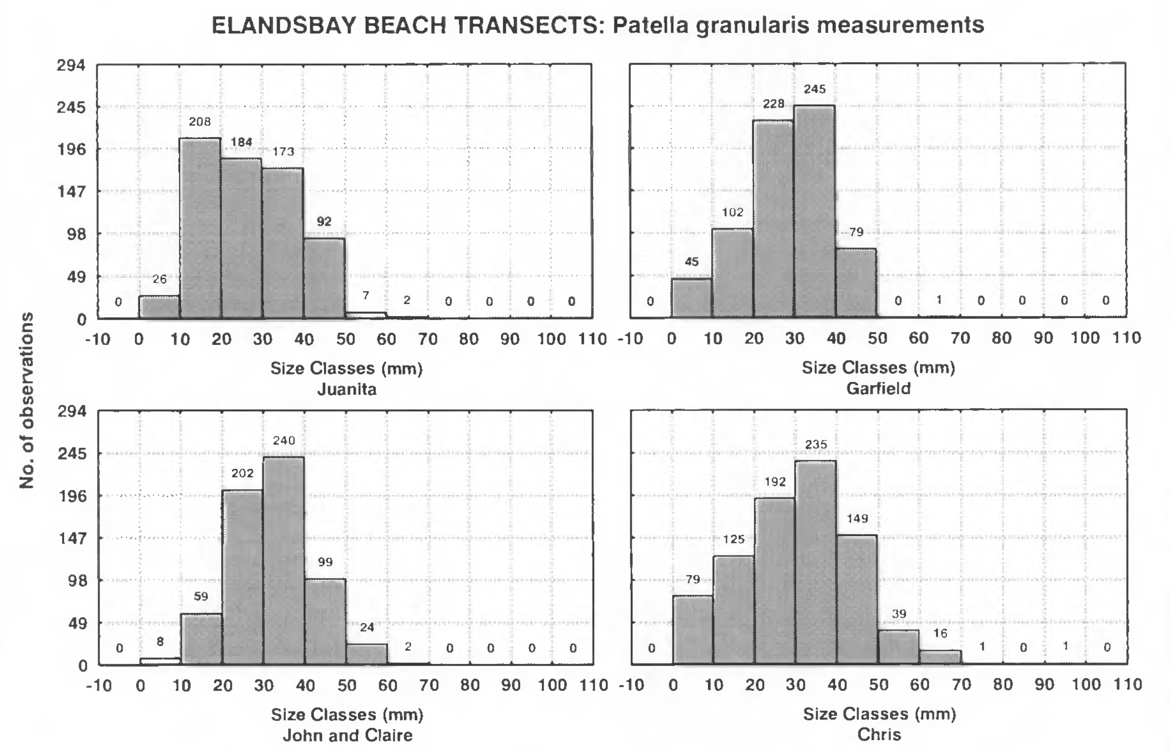


Figure 137: Elandsbay beach transects: Size measurements of *Patella granatina* per transect. (Top)

Figure 138: Elandsbay beach transects: All size measurements of *Patella granatina*. (Bottom)



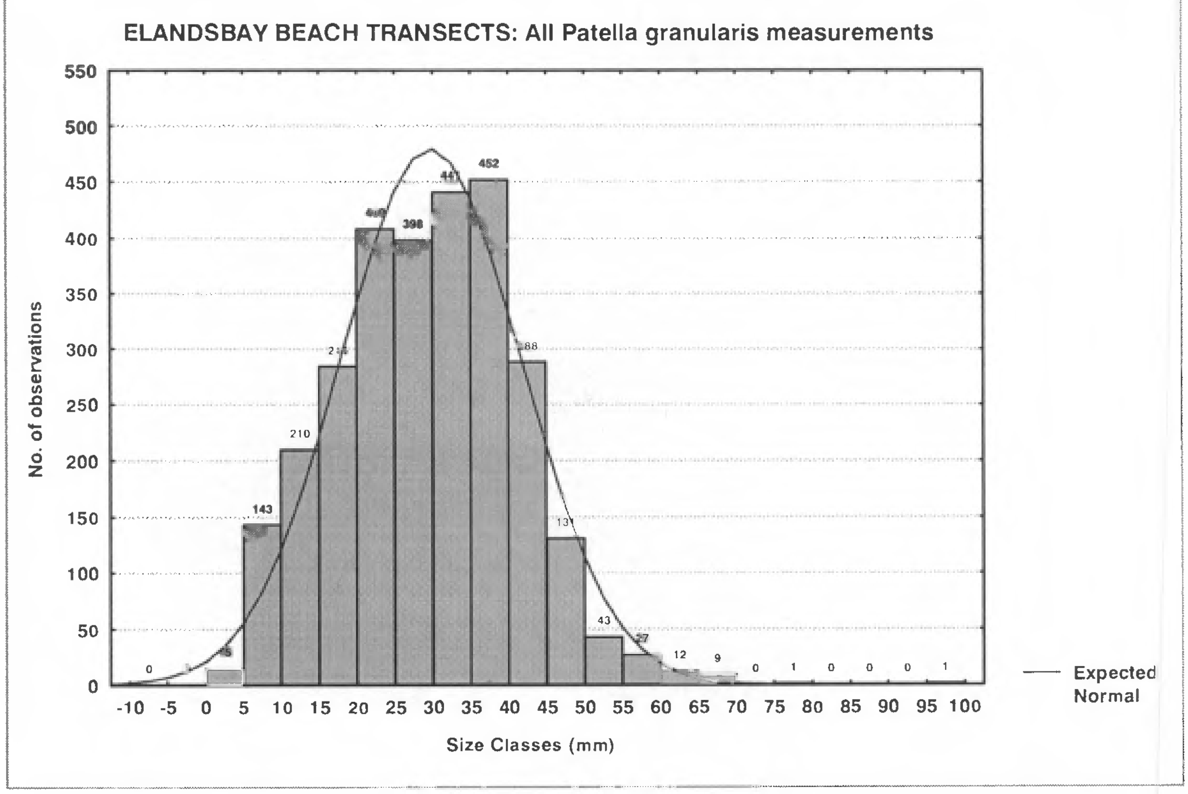


Figure 139: Elandsbay beach transects: Size measurements of *Patella granularis* per transect. (Top)

Figure 140: Elandsbay beach transects: All size measurements of *Patella granularis*. (Bottom)

APPENDIX III SPATIAL AUTOCORRELATION

Join count statistic

The 'Join count statistic' evaluates if joined objects have the same or a different nominal value. In most applications these values are colors, i.e. the black and white squares of a checker board. The calculation of the join type is fairly easy - for the two possible join types, i.e. the same color 'BB' or different colors 'BW', the number of joins is counted using these formulae (Hodder and Orton 1976:177; Cliff and Ord 1981:11):

$$BB = \frac{1}{2} \cdot \sum_{(2)} w_{ij} x_i x_j$$

$$BW = \frac{1}{2} \cdot \sum_{(2)} w_{ij} (x_i - x_j)^2$$

$$\sum_{(2)} = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ i \neq j}}^{n}$$

Note that in these calculations x_i and x_j can only have binary values (1 or 0). *BB* and *BW* do not describe distributions - they merely state the number of same-color joins and different-color joins. Whether their numbers are lower or higher than a random distribution would propose has to be tested with significance tests.

Significance testing

The 'Join count statistic' provide values that are descriptive and the significance of the results has to be evaluated. There are two different ways they can be compared to random distributions with zero spatial autocorrelation (Goodchild 1986:24):

- Resampling null hypothesis (free sampling; denoted 'N'): New values are independently drawn from a normal distribution and randomly redistributed over the objects and then compared to the observed distribution.

- Randomization null hypothesis (nonfree sampling; denoted 'R'): All existing values are randomly redistributed over the objects and compared to the observed distribution.

In the Dunefield Midden context randomization and resampling will be applied to quantify the significance of distributions. For the 'Join count statistic' (*jcs*) the expected random values for joins of two same colors are (Cliff and Ord 1981:19f):

$$E_N(jcs) = \frac{1}{2}S_0 p_r^2$$

$$E_R(jcs) = \frac{S_0 n_r^{(2)}}{2n^{(2)}}$$

And for two different colors (Cliff and Ord 1981:19f):

$$E_N(jcs) = S_0 p_r p_s$$

$$E_R(jcs) = \frac{S_0 n_r n_s}{n^{(2)}}$$

The variances for the 'Join count statistic' of two same colors calculate as (Cliff and Ord 1981:19f):

$$var_N(jcs) = \frac{1}{4}[S_1 p_r^2 + (S_2 - 2S_1)p_r^3 + (S_1 - S_2)p_r^4]$$

$$var_R(jcs) = \frac{1}{4}\left[\frac{S_1 n_r^{(2)}}{n^{(2)}} + \frac{(S_2 - 2S_1)n_r^{(3)}}{n^{(3)}} + \frac{(S_0 + S_1 - S_2)n_r^{(4)}}{n^{(4)}}\right] - \left(\frac{S_0 n_r^{(2)}}{2n^{(2)}}\right)^2$$

And for two different colors (Cliff and Ord 1981:19f):

$$var_N(jcs) = \frac{1}{4}[2S_1 p_r p_s + (S_2 - 2S_1)p_r p_s(p_r + p_s) + 4(S_1 - S_2)p_r^2 p_s^2]$$

$$var_R(jcs) = \frac{1}{4}\left[\frac{S_1 n_r n_s}{n^{(2)}} + \frac{(S_2 - 2S_1)n_r n_s(n_r + n_s - 2)}{n^{(3)}} + \frac{4(S_0^2 + S_1 - S_2)n_r^{(2)} n_s^{(2)}}{n^{(4)}}\right] - \left(\frac{S_0 n_r n_s}{n^{(2)}}\right)^2$$

Table 49 list the variables used in the previous equations and describes them (Goodchild 1986:37)

Variable	Description
n	total number of objects
r, s	color r or color s
n_r n_s	observed number of objects with color r or color s
p_r p_s	probability that a cell has color r ($p_r = n_r/n$) or color s ($p_s = n_s/n$)
S_0	$2A$ where A is the count of all unique joins
S_1	$S_1 = 2S_0 = 4A$
S_2	$S_2 = 4 \cdot \sum_i B_i^2$ where B_i denotes the number of objects adjacent to object i.
$n^{(b)}$	denotes the product n (n-1) (n-2) (n-3) ... (n-b+1)

Table 49: Description of variables used in the calculation of the expected values for random distributions and their variance for the 'Join count statistic'.

The z-score of a normal distribution can be calculated from the observed spatial autocorrelation value (s), the expected value (*E*) and the variance (*var*) of the random distributions using the equation (Goodchild 1986:26):

$$z = \frac{(s - E)}{\sqrt{var}}$$

From the z-score the significance can be derived (one-tailed test on normal distribution with mean = 0 and one standard deviation):

- z-values between -1.645 and +1.645: not significant at 0.05 level;
- z-values lower than -1.645 and higher than +1.645: significant at the 0.05 level;
- z-values lower than -3.090 and higher than +3.090: significant at the 0.001 level.

Method of calculation

As the author was unfamiliar with computer programming techniques, a Microsoft Access database was used to provide the values of the variables needed for the calculation of the 'Join Count Statistic'. Any data that was intended to be analyzed for spatial autocorrelation was loaded into the database and had to contain at least three columns: Unit, Square and Cluster (equivalent with the color of a square). Queries were used to calculate the number of all joins, the number of joins of specific color combinations, etc. The values from the database were copied into an Microsoft Excel spreadsheet which contained the formulae for the calculation of the 'Join count statistic' and the significance tests. Although this process seems to be quite complicated it was the easiest way for an non-programmer to use spatial autocorrelation. Calculation by hand was impossible as the number of objects and possible color combinations was extremely high.

APPENDIX IV DATABASE STRUCTURE

1 INTRODUCTION

Objective

As database systems are usually developed to make information accessible for many persons, not only to the creator, it has to provide explanations of its structure. In computer-jargon this is called 'metadata', as it is information about data (Schlader 2002). In chapter four the basic functions of the DFM Spatial Database were briefly outlined. This appendix provides the metadata for the major database parts.

The objective is to summarize the database structure to a degree of detail that every computer-skilled person can get an overview on the DFM Spatial Database. This is an important aspect as this thesis is intended to create the core of a research database on DFM.

Appendix layout

Two access objects are discussed in detail: tables and queries. Forms are seen to be self-explanatory and as an example the data input forms of the shellfish database are presented. Excluded are the Visual Basic instructions that were incorporated in the forms; their in-depth explanation would exceed the scope of this thesis. It was decided to illustrate the metadata with figures and tables. Flow charts are explain database structure and tables summarize the descriptive information.

2 ACCESS TABLES

Contents

- OES database in Table 54 on page 219,
- Ceramics database in Table 55 on page 220,
- Refits database in Table 56 on page 220,
- Charcoal database in Table 57 on page 221,
- Features database in Table 58 on page 222 and
- Transect database in Table 59 on page 223.

Relationships

- Spatial Reference database flow chart in Figure 143 on page 224,
- Shellfish database limpets flow chart in Figure 144 on page 225,
- Shellfish database mussels flow chart in Figure 145 on page 226,
- Shellfish database whelks flow chart in Figure 146 on page 227,
- Shellfish database others flow chart in Figure 147 on page 228,
- Lithics database non rounded lithics flow chart in Figure 148 on page 229,
- Lithics database rounded lithics flow chart in Plate 149 on page 230,
- Bones database large bones flow chart in Figure 150 on page 231,
- Bones database large teeth flow chart in Plate 151 on page 231,
- Bones database microfauna flow chart in Plate 152 on page 231,
- Bones database crayfish mandibles flow chart in Figure 153 on page 232,
- Ostrich Eggshell database flow chart in Figure 154 on page 232,
- Refits database flow chart in Figure 155 on page 232,
- Features database features flow chart in Figure 156 on page 233,
- Features database feature buffer flow chart in Figure 157 on page 233,
- Ceramics database flow chart in Figure 158 on page 233,
- Charcoal database flow chart in Figure 159 on page 234 and
- Transect database flow chart in Figure 160 on page 234.

3 ACCESS QUERIES

Contents

4 SHELLFISH DATABASE FORMS

Introduction

This section serves as an example for the usage of Access forms in the DFM Spatial Database. The shellfish database is relatively complex and includes most of the functions that can be found in all other databases. Thus it was chosen to illustrate and briefly explain the two main functions that forms can serve for: data input and data management.

In most cases databases are meant to expand and change during their lifetimes and thus need interfaces that allow the users to add and to change data. In the DFM Spatial Database, 'input areas' were individually designed for each database part facilitating this need.

In the shellfish database the input area was created in order to replicate the structure of the standard shellfish analysis sheet. The input window is composed of three parts (Figure 141 on page 206):

(1) the form header at the top, containing the information about the sheet (e.g. unit, square, sheetnumber, etc.)

(2) the form details in the middle, containing the shellfish data and

(3) the form footer at the bottom, containing the tools for data management.

Three main grouping levels exist that help to navigate through the records:

(a) the sheet definition (e.g. unit: ELA, square: 1, sheet: 1, etc.)

(b) shellfish families (e.g. limpets, mussels, whelks, others)

(c) shellfish species (e.g. *Patella granatina*, *Patella granularis*, etc.)

On the third and lowest level, information can be added and changed if it conforms to the shellfish categorization of Dunefield Midden (see Table 24 on page 111).

Data input

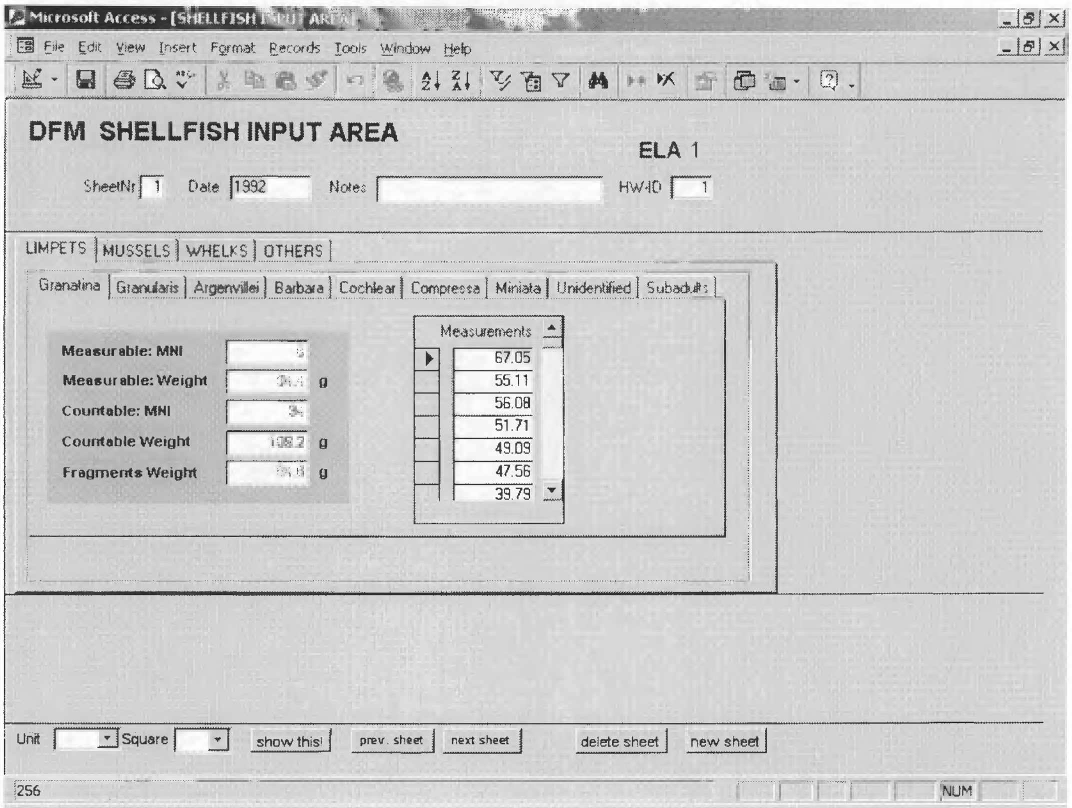
In this example it is assumed that a new shellfish data sheet was produced and has to be added to the database. First, the new sheet has to be defined by clicking the 'new sheet' button (lower right corner of input window, Figure 141). The 'shellfish input area' form is minimized and the 'new sheet definition' form is opened (Figure 142 on page 206). Three fields have to contain values for a valid new sheet definition: 'Unit', 'Square' and 'DataSheetNr'. Whereas 'Date' and 'Notes' can be left empty and/or added later. Values for the former three fields are restricted to the listings of the 'combo boxes'. After the three obligatory entries are made, the new definition can be created by clicking on 'OK' or rejected by 'Cancel'. The latter will result in the return to the 'shellfish input area' without performing any changes. If the 'OK' button is pressed, the new definition is checked for a duplicate in the existing definitions as the entries for 'Unit', 'Square' and 'DataSheetNr.' have to be unique identifier for the sheet. If the result of this check is negative the new definition will be created and added to the database. If it is positive a message appears on the screen suggesting to change the definition in order to make it unique and therefore valid.

Having defined a new sheet, data entry can be done into the relevant fields. Different shellfish families can be selected by clicking onto the tab control at the top of the form detail area and shellfish species can be chosen by clicking onto the desired shellfish species name. For shellfish measurements separate subforms exist that are generally situated next to the fields of 'MNI' and 'Weights'. Validation rules have to be followed to create a valid entry in the measurement list. Invalid measurements are rejected with displaying an error message window.

Data management

Adding new records to the database is one of the main tasks of the shellfish input form. Another is the facilitation of changing and deleting existing records. Several tools located in the form footer area allow to navigate through all the information stored in the shellfish database. The combo boxes on the left are a search-tool that filters the total recordset. For example all information on DFM square 'PET45' (i.e. unit=PET and square=45) can be displayed if the unit field is set to 'PET', the square field to '45' and the 'show this!'-button is pressed. As there can be several sheets for one square, the navigation buttons 'prev. sheet' and 'next sheet' can be used to swap between them.

Sometimes it might be necessary not only to change entries of an existing sheet definition but to delete it completely from the database. Therefore a 'delete sheet' button exists; it that has to be handled with much care as the deletion of a whole sheet cannot be made undone! Two warnings are displayed if the 'delete sheet' button is clicked - in case that the sheet is not supposed to be removed from the database, the command can be canceled in these warning windows.



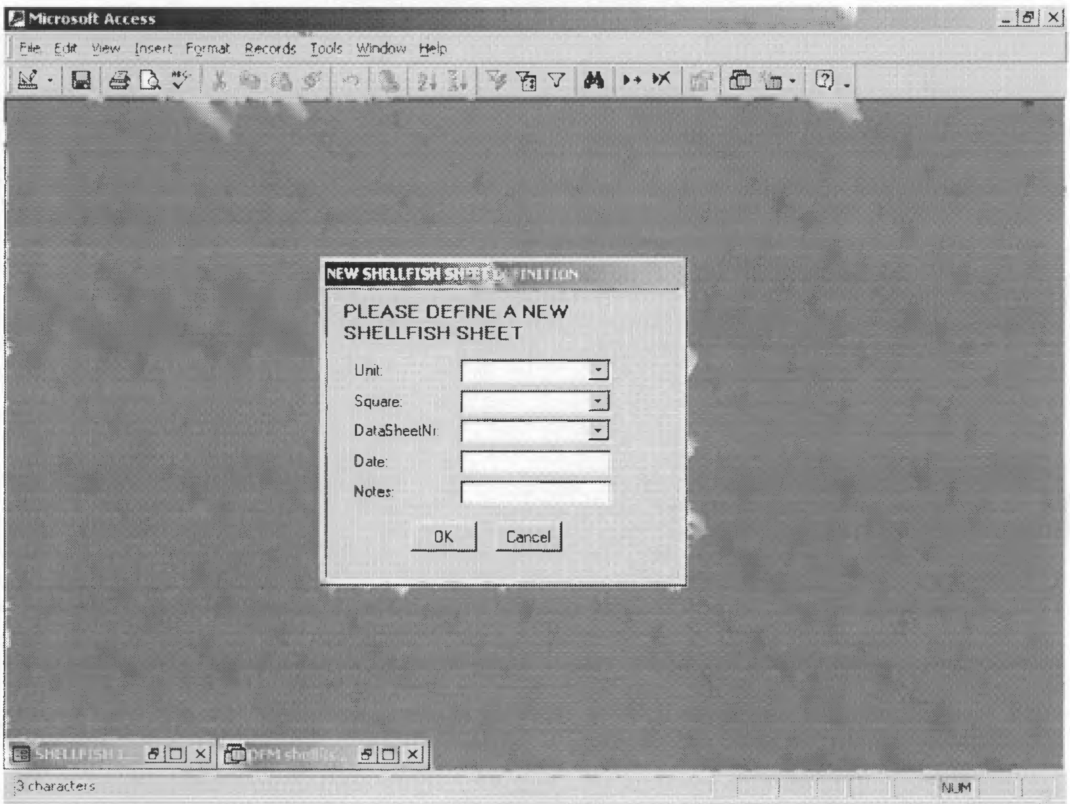


Figure 141: Screenshot shellfish database input area. (Top)

Figure 142: Screenshot shellfish database new sheet definition. (Bottom)

Table(s)	Field	Data Type	Validation	Description
C14-Dates	Date-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Reference	Text	-	10 characters
	C14-Date	Integer	-	years BP
	C14-StdDev	Integer	-	years
	Material	Text	-	8 characters
	Calib-Date	Integer	-	years AD
	-1Sigma	Integer	-	years AD
	+1Sigma	Integer	-	years AD
	-2Sigma	Integer	-	years AD
	+2Sigma	Integer	-	years AD
	FeatureType	Text	-	20 characters
DFM occupation layer survey data	Unit	Text	-	3 characters
	Square	Byte	-	-
	Section	Text	Lookup	5 characters
	Material	Text	-	30 characters
	Depth below E datum	Integer	-	in mm (0 decimals)
Excavated Squares	ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Year	Integer	-	-
MAPINFO-MAPCATALOG	-	-	-	MapInfo generated table holding spatial information of tables
Section coordinates	Section	Text	-	5 charcters
	X	Single	-	in m (1 decimal)
	Y	Single	-	n m (1 decimal)
Spatial reference catalogue 1988-1999	FindID	AutoNumber	-	-
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Serialnumber	Text	-	10 characters
	X	Single	-	in centimeter
	Y	Single	-	in centimeter

Table 50: DFM Spatial Reference database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
Spatial reference squares	Square	Byte	-	-
	SquareX	Byte	-	-
	SquareY	Byte	-	-
Spatial reference units	Unit	Text	-	3 characters
	UnitX	Byte	-	-
	UnitY	Byte	-	-

Table 50: (Continued) DFM Spatial Reference database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• Argobuccinum pustulosum	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
• Oxystele spp	apicesMNI	Integer	-	-
	apicesG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
• Aulacomya ater	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
• Donax serra	leftvalvesMNI	Integer	-	-
	leftvalvesG	Single	-	in grams (1 decimal)
	rightvalvesMNI	Integer	-	-
	rightvalvesG	Single	-	in grams (1 decimal)
	hingesMNI	Integer	-	-
	hingesG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
• Aulacomya ater subadult	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
• Bullia spp subadult	MNI	Integer	-	-
• Choromytilus meridionalis subadult • Crepidula spp • Helcion spp • Patella spp subadult • Whelks subadult	weight	Single	-	in grams (1 decimal)
Barnacles	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	BarnaclesWeight	Single	-	in grams (1 decimal)
	WhaleBarnacles-Weight	Single	-	in grams (1 decimal)

Table 51: DFM Shellfish database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• Bullia spp • Burnupena and Nucella	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	apicesMNI	Integer	-	-
	apicesG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
Choromytilus meridionalis	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	measurableMNIleft	Integer	-	-
	measurableMNIright	Integer	-	-
	measurableGleft	Single	-	in grams (1 decimal)
	measurableGright	Single	-	in grams (1 decimal)
	countableMNIleft	Integer	-	-
	countableMNIright	Integer	-	-
	countableGleft	Single	-	in grams (1 decimal)
	countableGright	Single	-	in grams (1 decimal)
	notmeasurableMNIleft	Integer	-	-
	notmeasurableM-NIright	Integer	-	-
	notmeasurableGleft	Single	-	in grams (1 decimal)
	notmeasurableGright	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
Choromytilus meridionalis measurements CL	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	countableLeft	Single	<20	in mm (2 decimals)
Choromytilus meridionalis measurements CR	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	countableRight	Single	<20	in mm (2 decimals)
Choromytilus meridionalis measurements ML	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	measurableLeft	Single	<20	in mm (2 decimals)
Choromytilus meridionalis measurements MR	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	measurableRight	Single	<20	in mm (2 decimals)
Excavated squares	-	-	-	linked table from Spatial Reference database
MAPINFO_MAPCATALOG	-	-	-	MapInfo generated table holding spatial information of tables

Table 51: (Continued) DFM Shellfish database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• Patella argenvillei • Patella barbara • Patella cochlear • Patella compressa • Patella granatina • Patella granularis • Patella miniata • Patella unidentified	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	measurableMNI	Integer	-	-
	measurableG	Single	-	in grams (1 decimal)
	countableMNI	Integer	-	-
	countableG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
• Patella argenvillei measurements • Patella barbara measurements • Patella cochlear measurements • Patella compressa measurements • Patella granatina measurements • Patella granularis measurements • Patella miniata measurements • Patella unidentified measurements	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	Measurement	Single	<100	in mm (2 decimals)
Reanalyzed squares	Unit	Text	-	3 characters
	Square	Byte	-	-
	OldDataSheetNr	Byte	-	-
	NowOnDataSheetNr	Byte	-	-
	Notes	Text	-	50 characters
	Date	Text	-	15 characters
Sheetdefinition	Reference-ID	AutoNumber	-	primary key
	Unit	Text	Lookup	3 characters
	Square	Byte	Lookup	-
	DataSheetNr	Byte	Lookup	-
	Notes	Text	-	50 characters
	Date	Text	-	15 characters
	Handwriting-ID	Byte	-	-
SheetHWinformation	Handwriting-ID	Byte	-	-
	Initials	Text	-	4 characters
	Notes	Text	-	100 characters
Sheetnumbers	sheetnumber	Byte	-	-

Table 51: (Continued) DFM Shellfish database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database
Various others	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	tricholiaMNI	Integer	-	-
	tricholiaG	Single	-	in grams (1 decimal)
	littorinaMNI	Integer	-	-
	littorinaG	Single	-	in grams (1 decimal)
	chitonMNI	Integer	-	-
	chitonG	Single	-	in grams (1 decimal)
	fissurellidaeMNI	Integer	-	-
	fissurellidaeG	Single	-	in grams (1 decimal)
	siphonariaMNI	Integer	-	-
	siphonariaG	Single	-	in grams (1 decimal)
Venerupis corrugata	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	leftvalvesMNI	Integer	-	-
	leftvalvesG	Single	-	in grams (1 decimal)
	rightvalvesMNI	Integer	-	-
	rightvalvesG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
Whelks	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	countableMNI	Integer	-	-
	countableG	Single	-	in grams (1 decimal)
	fragments	Single	-	in grams (1 decimal)
• WWSP	Reference-ID	Long Integer	-	unique ID linked to sheetdefinition
	WWSNo	Integer	-	-
	WWSweight	Single	-	in grams (1 decimal)
	WWPNo	Integer	-	-
	WWPweight	Single	-	in grams (1 decimal)

Table 51: (Continued) DFM Shellfish database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
Excavated squares	Square-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Year	Integer	-	-
MiscellaneaousStones	Square-ID	Long Integer	-	unique ID linked to 'excavated squares'
	OCHRE	Byte	-	-
	OCHREnotes	Text	-	20 characters
	PIGMENT	Byte	-	-
	PIGMENTnotes	Text	-	20 characters
• NonRoundedCCSFormalTools • NonRoundedFGBRFormalTools • NonRoundedIndetMatFormal-Tools • NonRoundedQuartzFormalTools • NonRoundedQuartziteFormal-Tools • NonRoundedSandstoneFormal-Tools • NonRoundedSilcreteFormal-Tools • RoundedCCSFormalTools • RoundedFGBRFormalTools • RoundedIndetMatFormalTools • RoundedQuartziteFormalTools • RoundedSandstoneFormalTools • RoundedSilcreteFormalTools	Square-ID	Long Integer	-	unique ID linked to 'excavated squares'
	SCRAPER	Byte	-	-
	SCRAPERnotes	Text	-	20 characters
	BACKEDSCRAPER	Byte	-	-
	BACKEDSCRAPER-notes	Text	-	20 characters
	BACKEDPIECE	Byte	-	-
	BACKEDPIECEnotes	Text	-	20 characters
	BORER	Byte	-	-
	BORERnotes	Text	-	20 characters
	DRILL	Byte	-	-
	DRILLnotes	Text	-	20 characters
	MRP	Byte	-	-
	MRPnotes	Text	-	20 characters

Table 52: DFM Lithics database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• NonRoundedCCSOther • NonRoundedFGBROther • NonRoundedIndetMatOther • NonRoundedQuartzOther • NonRoundedQuartziteOther • NonRoundedSandstoneOther • NonRoundedSilcreteOther • RoundedCCSOther • RoundedFGBROther • RoundedIndetMatOther • RoundedQuartzOther • RoundedQuartziteOther • RoundedSandstoneOther • RoundedSilcreteOther	Square-ID	Long Integer	-	unique ID linked to 'excavated squares'
	MANUPORTS	Byte	-	-
	MANUPORTSnotes	Text	-	20 characters
• NonRoundedCCSMatUtilized-Pieces • NonRoundedFGBRUtilized-Pieces • NonRoundedIndetMatUtilized-Pieces • NonRoundedQuartzUtilized-Pieces • NonRoundedQuartziteUtilized-Pieces • NonRoundedSandstoneUtilized-Pieces • NonRoundedSilcreteUtilized-Pieces • RoundedCCSMatUtilizedPieces • RoundedFGBRUtilizedPieces • RoundedIndetMatUtilizedPieces • RoundedQuartzUtilizedPieces • RoundedQuartziteUtilizedPieces • RoundedSandstoneUtilized-Pieces • RoundedSilcreteUtilizedPieces	Square-ID	Long Integer	-	unique ID linked to 'excavated squares'
	FLAKES	Integer	-	-
	FLAKESnotes	Text	-	20 characters
	CHUNKS	Integer	-	-
	CHUNKSnotes	Text	-	20 characters
	CHIPS	Integer	-	-
	CHIPSnotes	Text	-	20 characters
	HAMMERSTONE	Integer	-	-
	HAMMER-STONEnotes	Text	-	20 characters
	GRINDSTONE	Integer	-	-
	GRINDSTONEnotes	Text	-	20 characters
	ANVIL	Integer	-	-
	ANVILnotes	Text	-	20 characters
	PEBBLE	Integer	-	-
	PEBBLEnotes	Text	-	20 characters

Table 52: (Continued) DFM Lithics database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• NonRoundedCCSWaste • NonRoundedFGBRWaste • NonRoundedIndetMatWaste • NonRoundedQuartzWaste • NonRoundedQuartziteWaste • NonRoundedSandstoneWaste • NonRoundedSilcreteWaste • RoundedCCSWaste • RoundedFGBRWaste • RoundedIndetMatWaste • RoundedQuartzWaste • RoundedQuartziteWaste • RoundedSandstoneWaste • RoundedSilcreteWaste	Square-ID	Long Integer	-	unique ID linked to 'excavated squares'
	FLAKES	Integer	-	-
	FLAKESnotes	Text	-	20 characters
	CHUNKS	Integer	-	-
	CHUNKSnotes	Text	-	20 characters
	CHIPS	Integer	-	-
	CHIPSnotes	Text	-	20 characters
	BIPOLARCORE	Integer	-	-
	BIPOLARCOREnotes	Text	-	20 characters
	SINGLEPLATFORM-CORE	Integer	-	-
	SINGLEPLATFORM-COREnotes	Text	-	20 characters
	IRREGULARCORE	Integer	-	-
	IRREGULAR-COREnotes	Text	-	20 characters
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database

Table 52: (Continued) DFM Lithics database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
Bones distal fractions list	Distal Fraction	Single	-	-
Bones distal fusions list	Distal Fusion	Single	-	-

Table 53: DFM Bones database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
BONES MODIFICATIONS	Bone-ID	Long Integer	-	unique ID linked to 'Bones taxonomy'
	Burnt	Yes/No	-	-
	Carnivore chewed	Yes/No	-	-
	Cut	Yes/No	-	-
	Acid etched	Yes/No	-	-
	Porcupine gnawed	Yes/No	-	-
	Small rodent gnawed	Yes/No	-	-
	Abraded	Yes/No	-	-
	Weathered	Yes/No	-	-
	Notes	Text	-	50 characters
Bones portions list	Portion	Text	-	1 character
Bones proximal fractions list	Proximal Fraction	Single	-	-
Bones proximal fusions list	Proximal Fusion	Single	-	-
Bones sides list	Side	Text	-	1 character
Bones skeletal parts list	Part	Text	-	2 characters
	Description	Text	-	30 characters
Bones taxa list	Taxon	Text	-	30 characters
BONES TAXONOMY	Bone-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Serialnumber	Text	-	10 characters
	Site	Text	-	20 characters
	Taxon	Text	Lookup	30 characters
	Skeletal Part	Text	Lookup	2 characters
	Side	Text	Lookup	1 character
	Portion	Text	Lookup	1 character
	Proximal Fusion	Text	Lookup	2 characters
	Proximal Fraction	Single	Lookup	-
	Distal Fusion	Text	Lookup	2 characters
	Distal Fraction	Single	Lookup	-

Table 53: (Continued) DFM Bones database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
CRAYFISHMANDIBLEMeasure-mentsLeft	Square-ID	Long Integer	-	unique ID linked to 'Excavated squares'
	SerialNumber	Integer	-	-
	MeasurementsLeft	Single	>=0 and <20	in millimeter (2 decimals)
	Comments	Text	-	10 characters
CRAYFISHMANDIBLEMeasure-mentsRight	Square-ID	Long Integer	-	unique ID linked to 'Excavated squares'
	SerialNumber	Integer	-	-
	MeasurementsRight	Single	>=0 and <20	in millimeter (2 decimals)
	Comments	Text	-	10 characters
CrayfishMandibleUnmeasureable	Square-ID	Long Integer	-	unique ID linked to 'Excavated squares'
	UnmeasureableLeft	Integer	-	-
	UnmeasureableRight	Integer	-	-
	Fragments	Integer	-	-
	Comments	Text	-	10 characters
Excavated squares	-	-	-	linked table from Spatial Reference database
MAPINFO_MAPCATALOG	-	-	-	MapInfo generated table holding spatial information of tables
Microfauna BodyPart list	BodyPartID	Byte	-	-
	BodyPart	Text	-	40 characters
Microfauna BoneType list	BoneType	Text	-	40 characters
Microfauna Feature list	FeatureID	Byte	-	-
	Feature	Text	-	40 characters
MICROFAUNA features	BoneID	Long Integer	-	unique ID linked to 'Microfauna main'
	Feature	Byte	-	-

Table 53: (Continued) DFM Bones database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
MICROFAUNA main	Unit	Text	-	3 characters
	Square	Byte	-	-
	Suffix	Text	-	5 characters
	SerialNumber	Integer	-	-
	BoneID	AutoNumber	-	primary key
	BoneType	Text	Lookup	40 character
	Species	Byte	-	-
	BodyPart	Byte	-	-
	Comments	Text	-	100 characters
Microfauna segment list	SegmentID	Byte	-	unique ID linked to 'Microfauna segments'
	Segmente	Text	-	40 characters
MICROFAUNA segments	BoneID	Long Integer	-	unique ID linked to 'Microfauna main'
	Segment	Byte	-	-
Microfauna Species list	SpeciesID	Byte	-	unique ID linked to 'Microfauna segments'
	Species	Text	-	40 characters
Spatial reference catalogue 1988-1999	-	-	-	linked table from Spatial Reference database
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database
TEETH MODIFICATIONS	Tooth-ID	Long Integer	-	unique ID linked to 'Teeth taxonomy'
	Burnt	Yes/No	-	-
	Carnivore chewed	Yes/No	-	-
	Cut	Yes/No	-	-
	Acid etched	Yes/No	-	-
	Porcupine gnawed	Yes/No	-	-
	Small rodent gnawed	Yes/No	-	-
	Abraded	Yes/No	-	-
	Weathered	Yes/No	-	-
	Notes	Text	-	50 characters

Table 53: (Continued) DFM Bones database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
TEETH TAXONOMY	Tooth-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Serialnumber	Text	-	10 characters
	Site	Text	-	20 characters
	Taxon	Text	Lookup	30 characters
	Jaw	Text	Lookup	1 character
	Side	Text	Lookup	4 characters
	I1	Text	-	2 characters
	I2	Text	-	2 characters
	I3	Text	-	2 characters
	C	Text	-	2 characters
	P1	Text	-	2 characters
	P2	Text	-	2 characters
	P3	Text	-	2 characters
	P4	Text	-	2 characters
	M1	Text	-	2 characters
	M2	Text	-	2 characters
	M3	Text	-	2 characters
Tooth list	category	Text	-	2 characters

Table 53: (Continued) DFM Bones database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
OES BEADS Square content	OES-Beads-ID	Long Integer	-	unique ID linked to 'Oes Beads Square reference'
	Serialnumber	Integer	-	-
	Diameter	Single	-	in millimeter (2 decimals)
	Aperture	Single	-	in millimeter (2 decimals)
	Comments	Text	-	50 characters
	Whole	Yes/No	-	-
	Broken	Yes/No	-	-
	Burnt	Yes/No	-	-
	Chipped	Yes/No	-	-
	Irregular	Yes/No	-	-
	IrregularAperture	Yes/No	-	-
	Unmeasurable	Yes/No	-	-
	Unfinished	Yes/No	-	-
OES BEADS Square reference	OES-Beads-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
OES Square content	OES-ID	Long Integer	-	unique ID linked to 'Oes Square reference'
	Serialnumber	Integer	-	-
	Set	Integer	-	-
OES Square reference	OES-Beads-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
Spatial reference catalogue 1988-1999	-	-	-	linked table from Spatial Reference database
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database

Table 54: DFM OES database: contents of tables.

Table(s)	*Field*	*Data Type*	*Validation*	*Description*
CERAMICS Refits	Refit-ID	AutoNumber	-	primary key
	Setnumber	Integer	-	-
	C1Unit	Text	Lookup	3 character
	C1Square	Byte	>0 and <=100	-
	C1SerialNo	Integer	-	-
	C1Comments	Text	-	20 characters
	C2Unit	Text	Lookup	3 character
	C2Square	Byte	>0 and <=100	-
	C2SerialNo	Integer	-	-
	C2Comments	Text	-	20 characters
CERAMICS Square content	Ceramics-ID	Long Integer	-	unique ID linked to 'Ceramics Square reference'
	Serialnumber	Integer	-	-
	Notes	Text	-	50 characters
	Sherds	Integer	-	-
	Setnumber	Integer	-	-
	Existing	Yes/No	-	-
CERAMICS Square reference	Ceramics-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database

Table 55: DFM Ceramics database: contents of tables.

Table(s)	*Field*	*Data Type*	*Validation*	*Description*
Material list	Material	Text	-	10 characters

Table 56: DFM Refits database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
REFIT DATA	Misc-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Serialnumber	Integer	-	-
	Material	Text	Lookup	10 characters
	Set	Byte	-	-
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database

Table 56: (Continued) DFM Refits database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
CHARCOAL Family list	charcoalfamily	Text	-	25 characters
CHARCOAL Sample information	Sample-ID	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	featuretype	Text	-	20 characters
	featurenotes	Text	-	50 characters
	sampleweight	Single	-	in grams (1decimal)
CHARCOAL Species list	charcoalspecies	Text	-	25 characters
CHARCOAL Taxa of sample	Samlpe-ID	Long Integer	-	unique ID linked to 'Charcoal sample information'
	charcoalspecies	Text	Lookup	25 characters
	charcoalfamily	Text	Lookup	25 characters
	charcoalweight	Single	-	in grams (1 decimal)
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database

Table 57: DFM Charcoal database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
• 0cm buffer square areas • 100cm buffer square areas • 125cm buffer square areas • 150cm buffer square areas • 175cm buffer square areas • 200cm buffer square areas • 25cm buffer square areas • 50cm buffer square areas • 75cm buffer square areas	FeatureNo	Byte	-	-
	Unit	Text	Lookup	3 characters
	Square	Byte	Lookup	-
	Area	Single	-	in squaremeter (3 decimals)
Excavated squares	-	-	-	linked table from Spatial Reference database
feature center coords	FeatureNo	Byte	-	-
	X	Single	-	in meter (2 decimals)
	Y	Single	-	in meter (2 decimals)
Feature list	FeatureNo	Integer	-	primary key
	FeatureType	Text	Lookup	35 characters
FEATURES	id	AutoNumber	-	primary key
	Unit	Text	-	3 characters
	Square	Byte	-	-
	Year	Text	Lookup	20 characters
	FNS	Text	Lookup	20 characters
	all units	Text	-	50 characters
	c14	Text	-	50 characters
	feat no	Integer	-	-
	datenote	Date/Time	-	-
	shortnote	Text	-	50 characters
	longnote	Memo	-	-
	feat type	Text	-	50 characters
	confidence	Text	-	50 characters
	comments	Memo	-	-
	JP Notes	Yes/No	-	-
	Student Notes	Yes/No	-	-
	plan map	Yes/No	-	-
	cross sect	Yes/No	-	-

Table 58: DFM Features database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
FeatureTypesList	FeatureType	Text	-	35 characters
FieldNoteSource	FNS	Text	-	5 charcters
MAPINFO_MAPCATALOG	-	-	-	MapInfo generated table holding spatial information of tables
Spatial reference squares	-	-	-	linked table from Spatial Reference database
Spatial reference units	-	-	-	linked table from Spatial Reference database
Years	Year	Integer	-	-

Table 58: (Continued) DFM Features database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
Patella granatina measurements	AreaID	Long Integer	-	-
	Measurements	Single	<100	in millimeter (1 decimal)
Patella granularis measurements	AreaID	Long Integer	-	-
	Measurements	Single	<100	in millimeter (1 decimal)
TransectAreaCodesList	AreaCode	Text	-	5 characters

Table 59: Transect database: contents of tables.

Table(s)	Field	Data Type	Validation	Description
TransectAreas	TransectID	Long Integer	-	-
	AreaID	AutoNumber	-	primary key
	AreaCode	Text	Lookup	5 characters
	AreaDescription	Text	-	200 characters
	Choromytilus	Integer	-	-
	Mussel	Integer	-	-
	Helcion	Integer	-	-
	Oxystele	Integer	-	-
	Burnapena	Integer	-	-
	Barnacle	Integer	-	-
	Aulacomya	Integer	-	-
	Crepidula	Integer	-	-
	GalloProvincialis	Integer	-	-
	Cellana	Integer	-	-
	PatArgenvillei	Integer	-	-
	Patella spp	Integer	-	-
	Whelk	Integer	-	-
	Fissurellidae spp	Integer	-	-
TransectDefinition	TransectID	AutoNumber	-	primary key
	Name	Text	-	50 characters
	Dates	Text	-	50 characters
	Notes	Text	-	200 characters

Table 59: (Continued) Transect database: contents of tables.

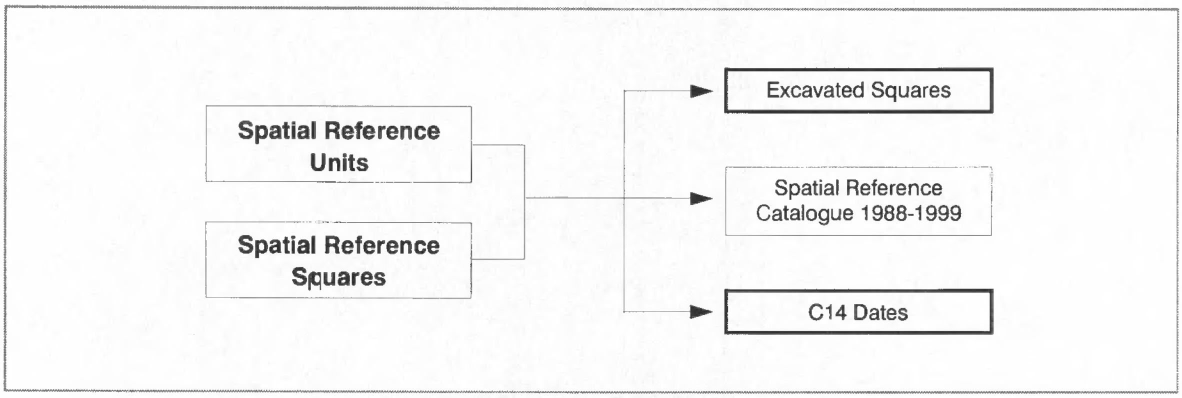


Figure 143: Spatial Reference database: flow chart.

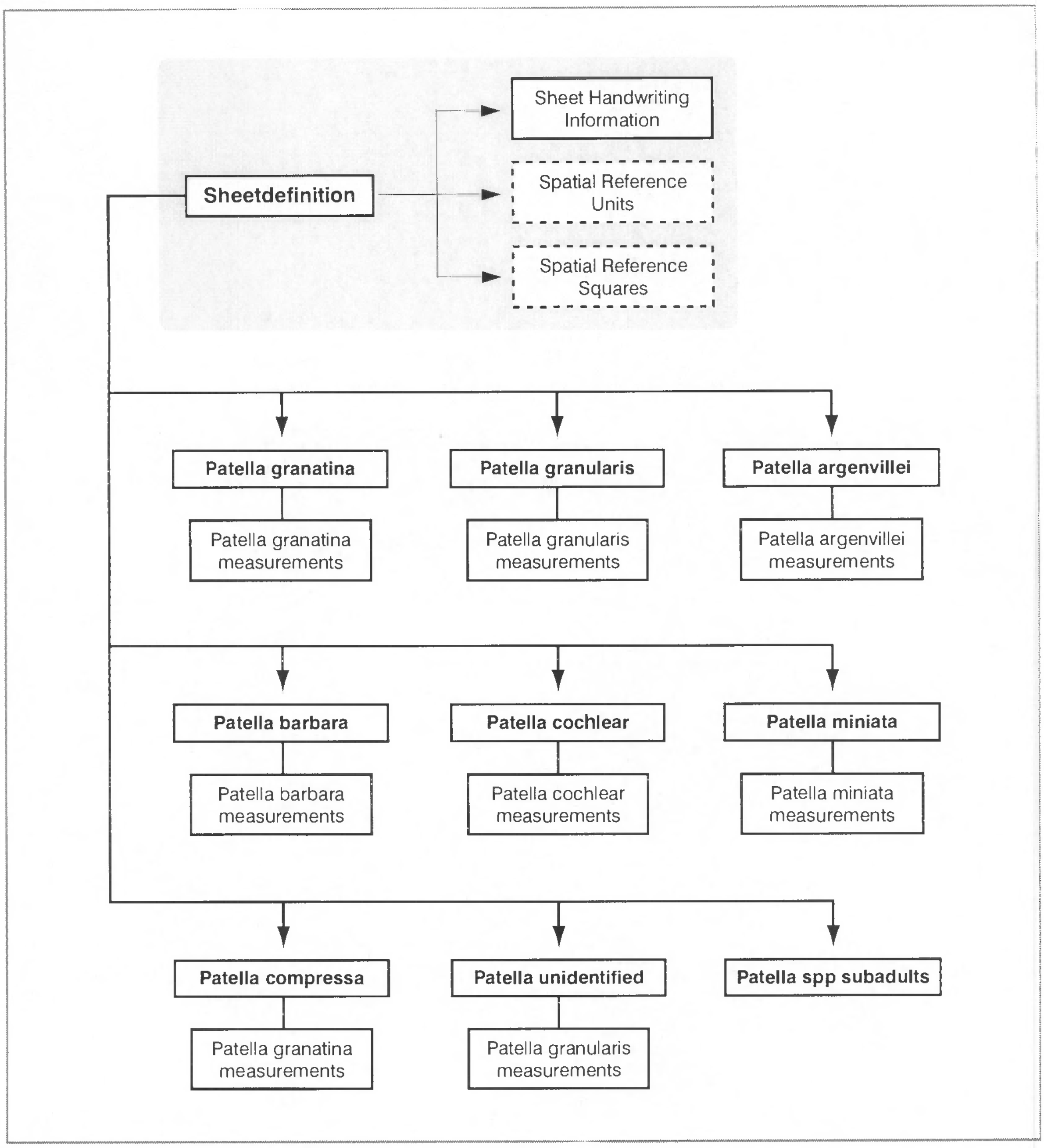


Figure 144: Shellfish database: limpets flow chart.

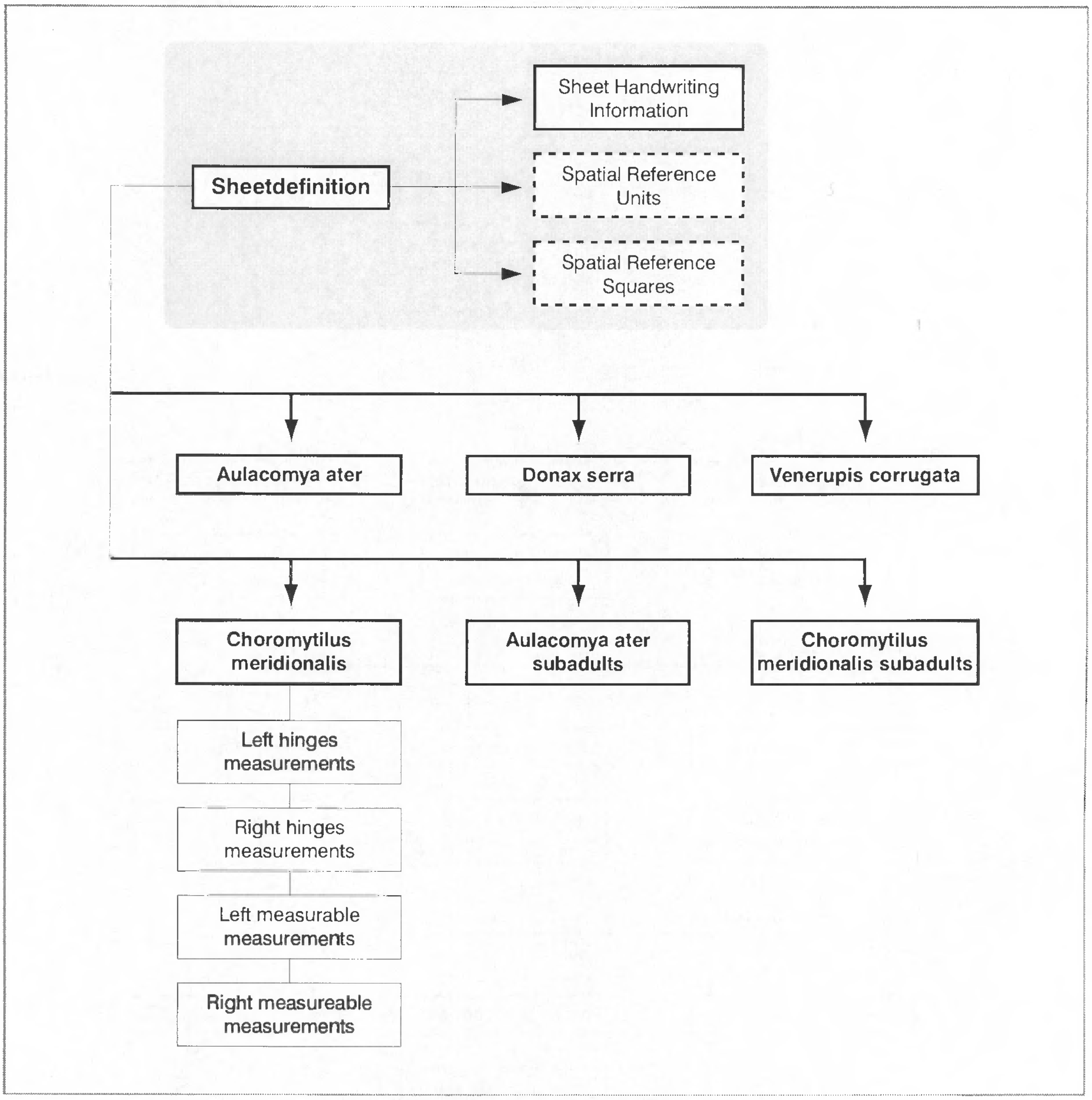


Figure 145: Shellfish database: mussels flow chart.

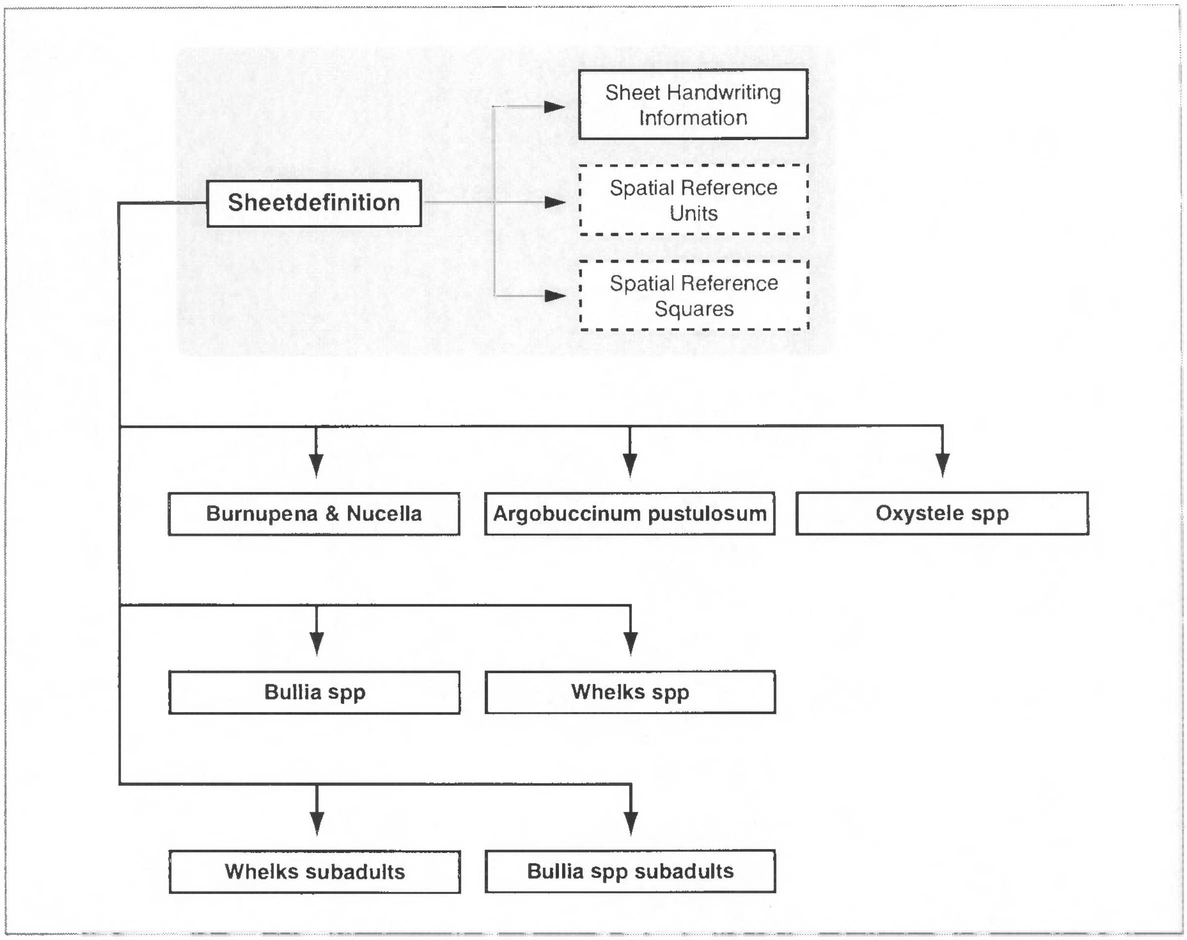


Figure 146: Shellfish database: whelks flow chart

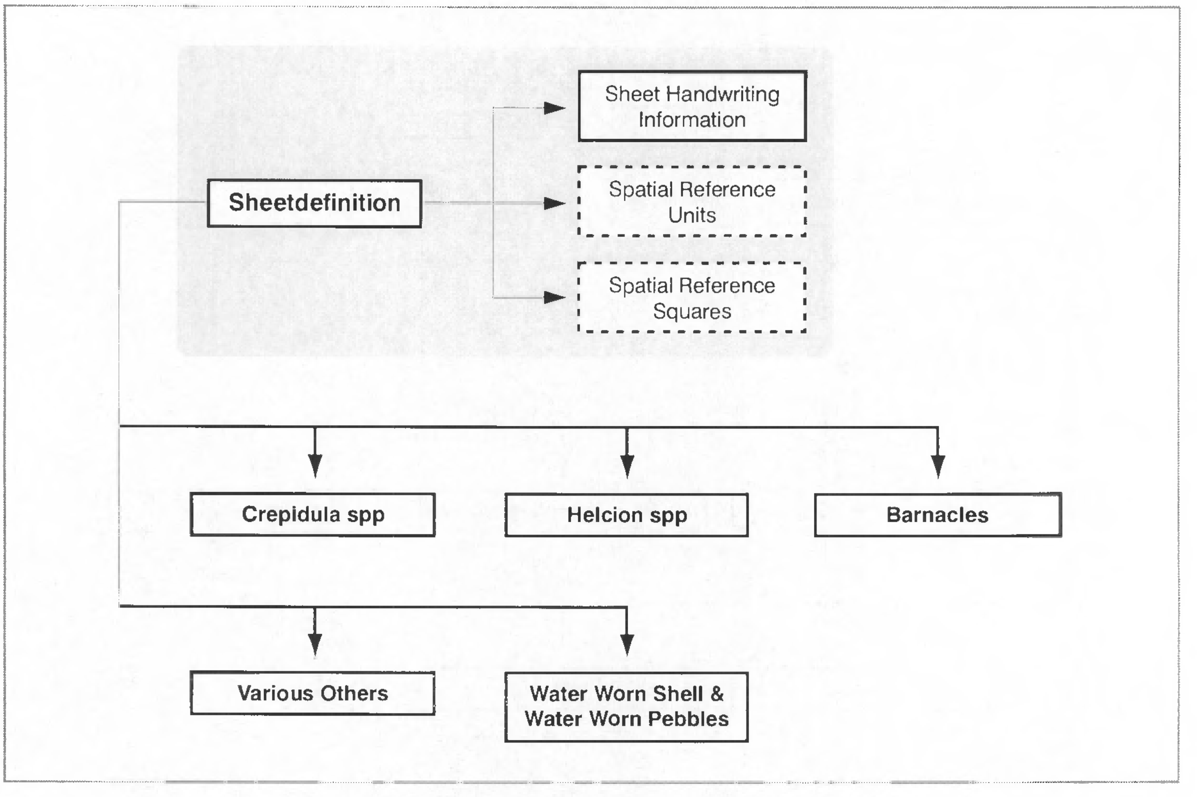


Figure 147: Shellfish database: others flow chart.

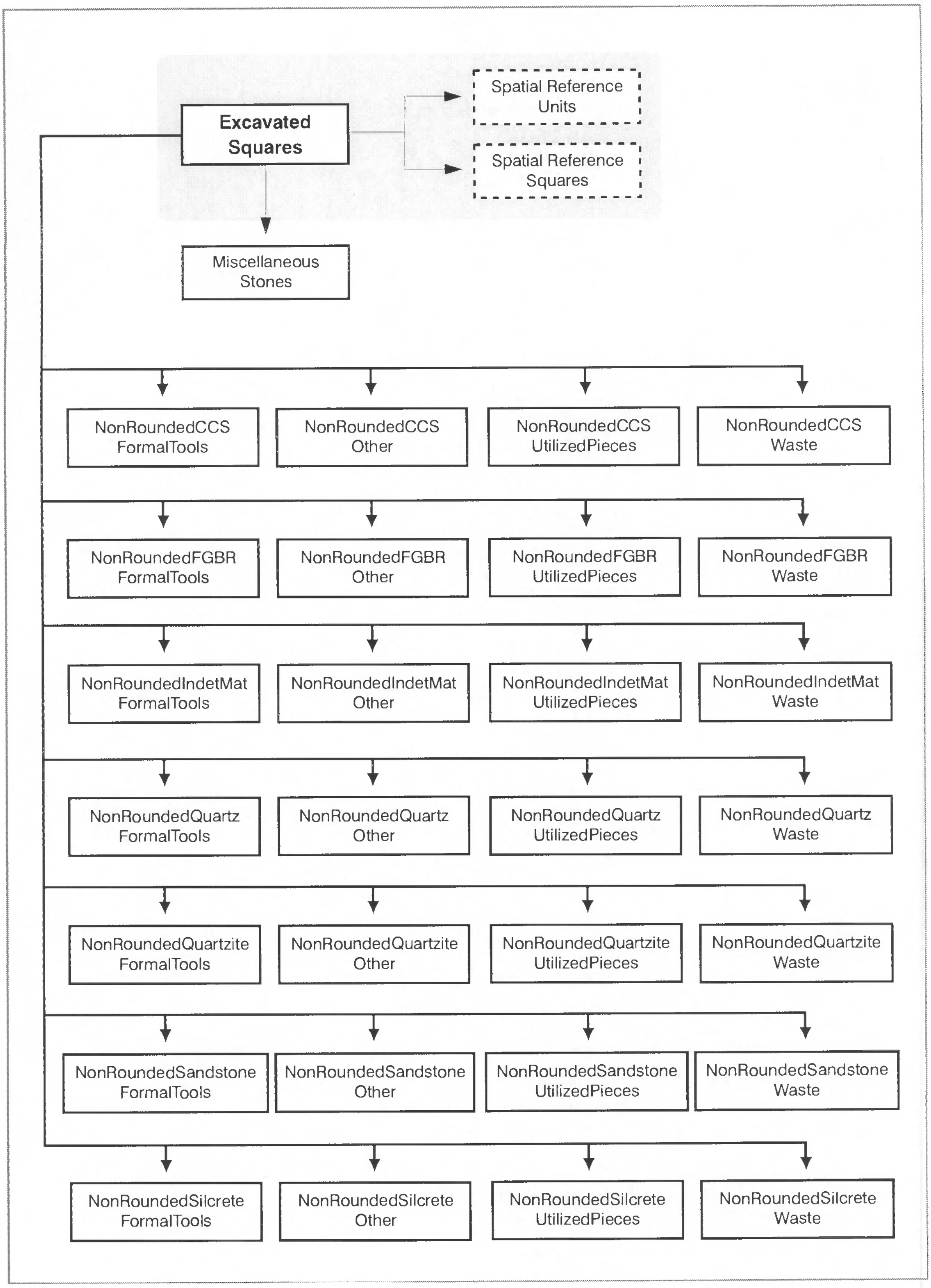


Figure 148: Lithics database: non rounded lithics flow chart.

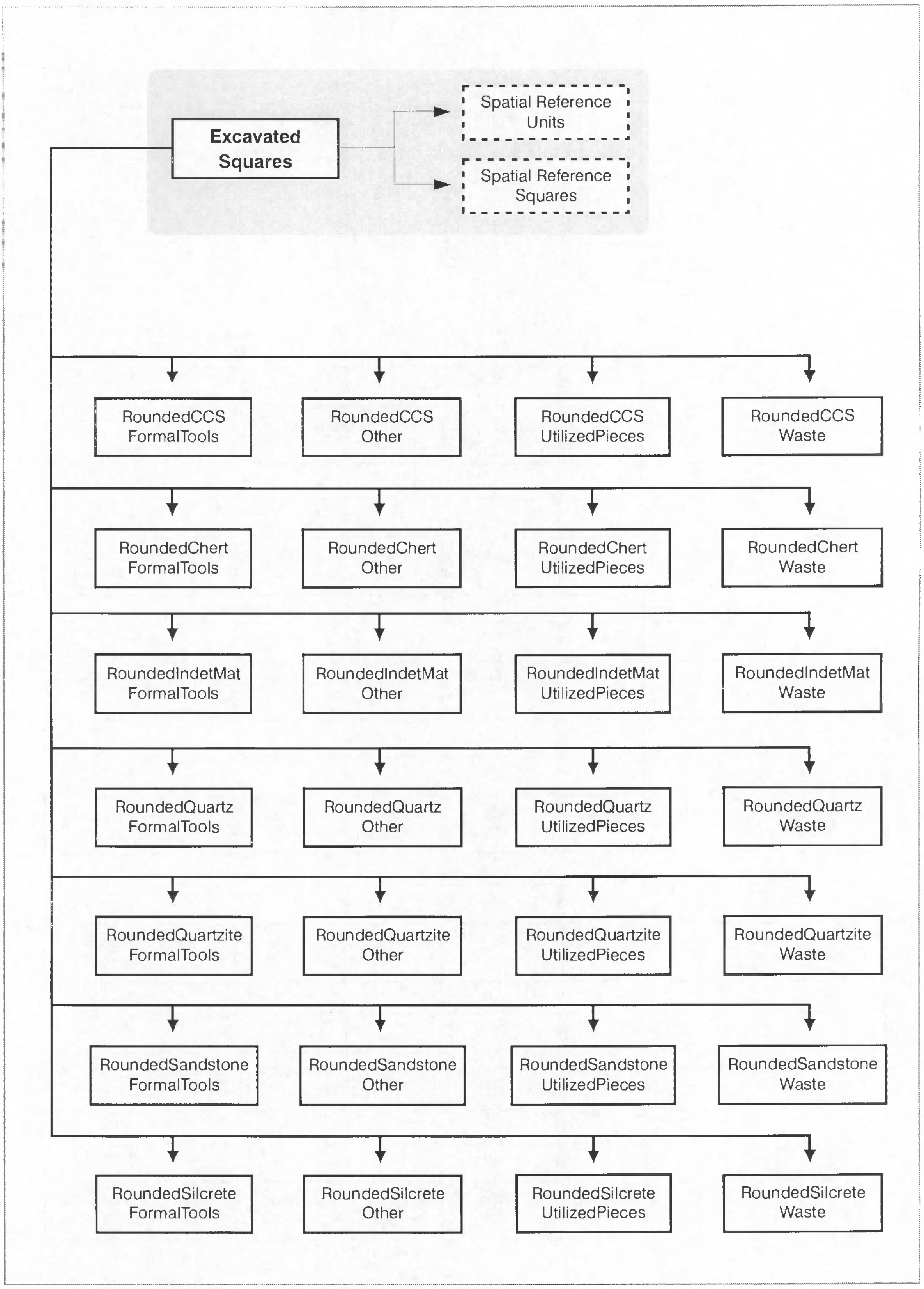
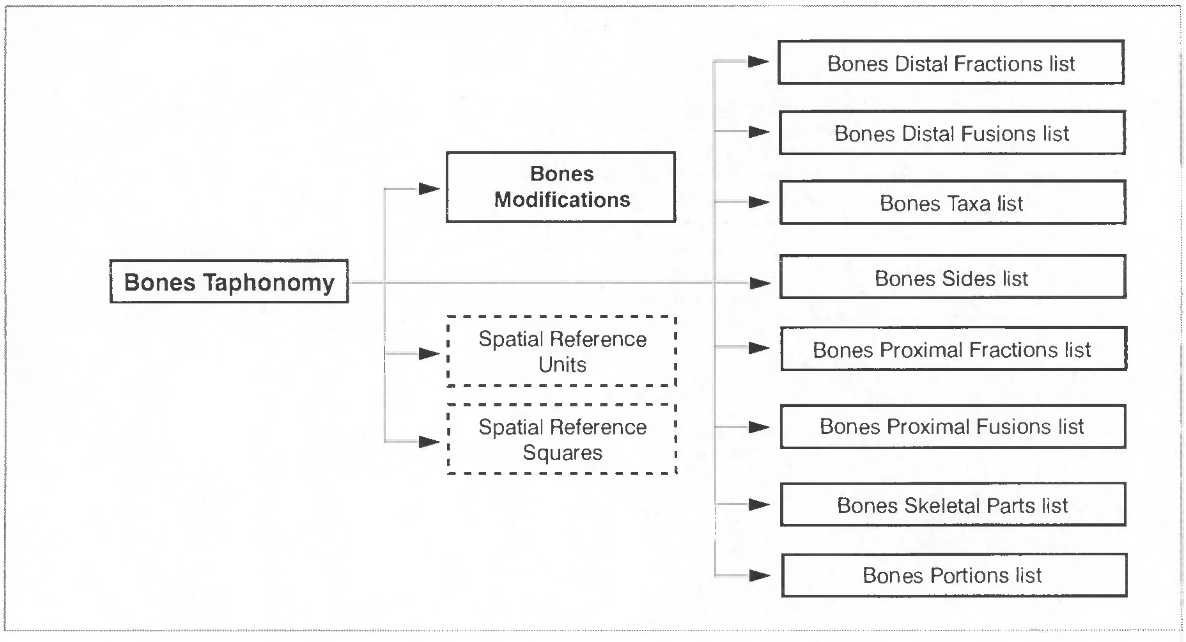
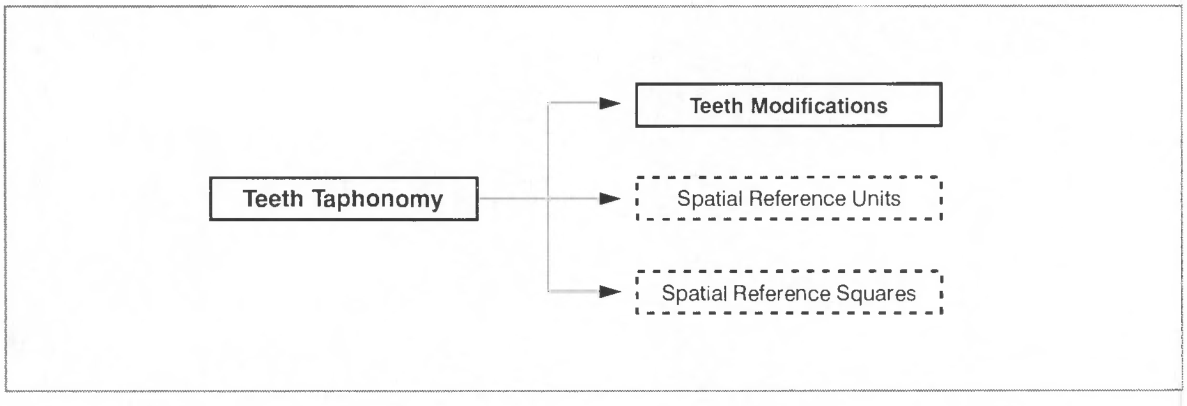


Figure 149: Lithics database: rounded lithics flow chart.





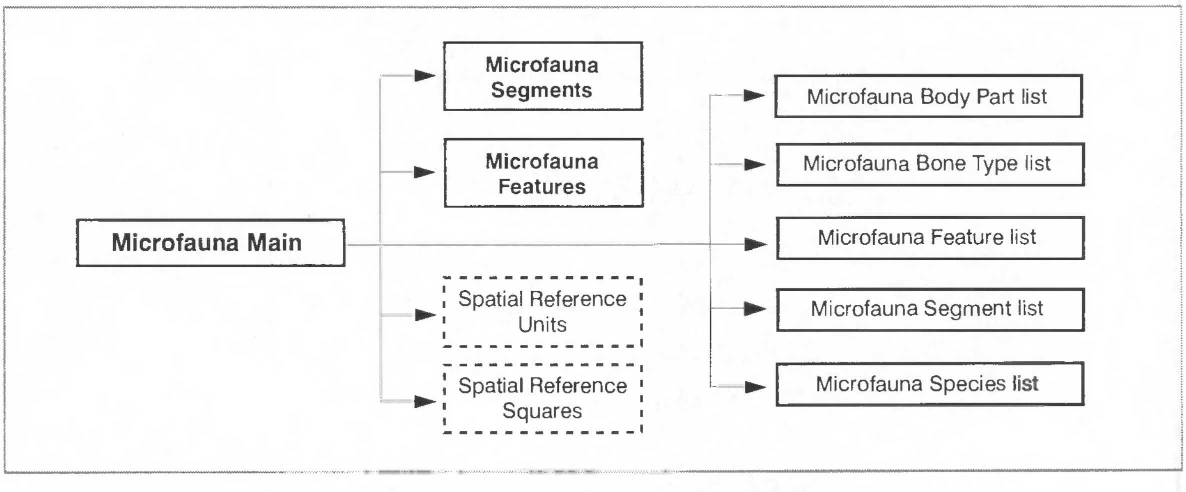
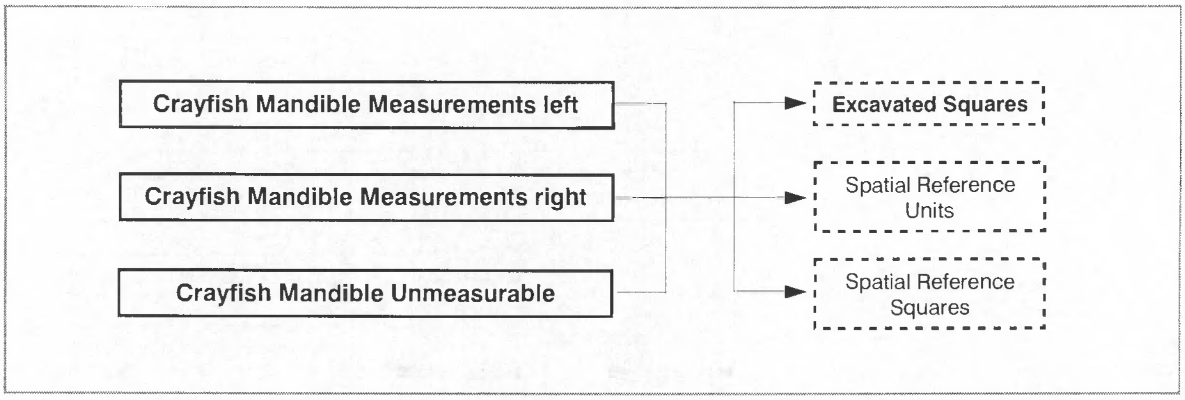
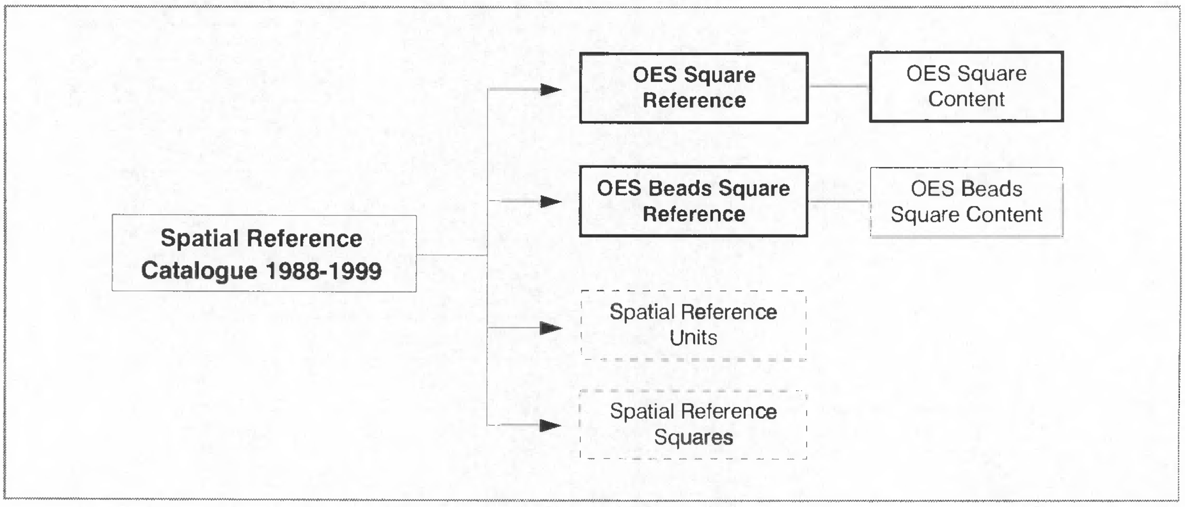


Figure 150: Bones database: large bones flow chart. (Top)

Figure 151: Bones database: large teeth flow chart. (Middle)

Figure 152: Bones database: microfauna flow chart. (Bottom)





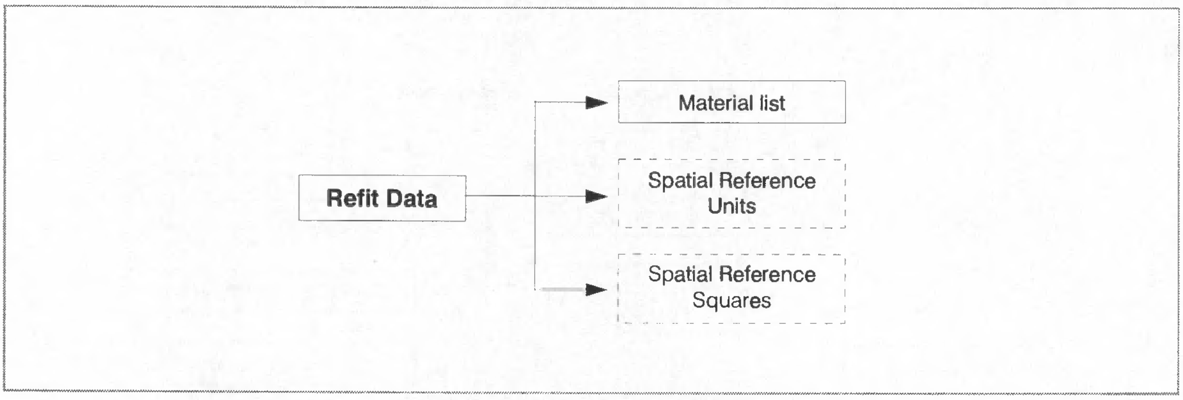
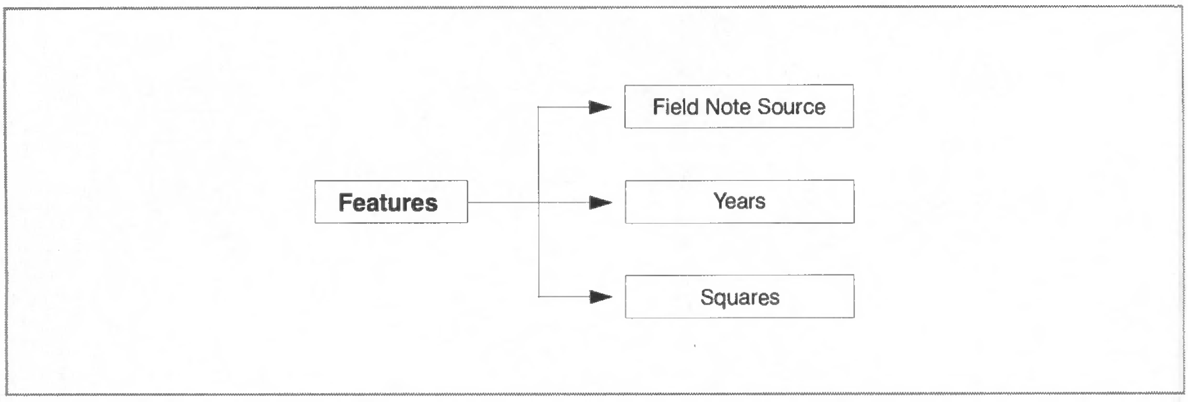
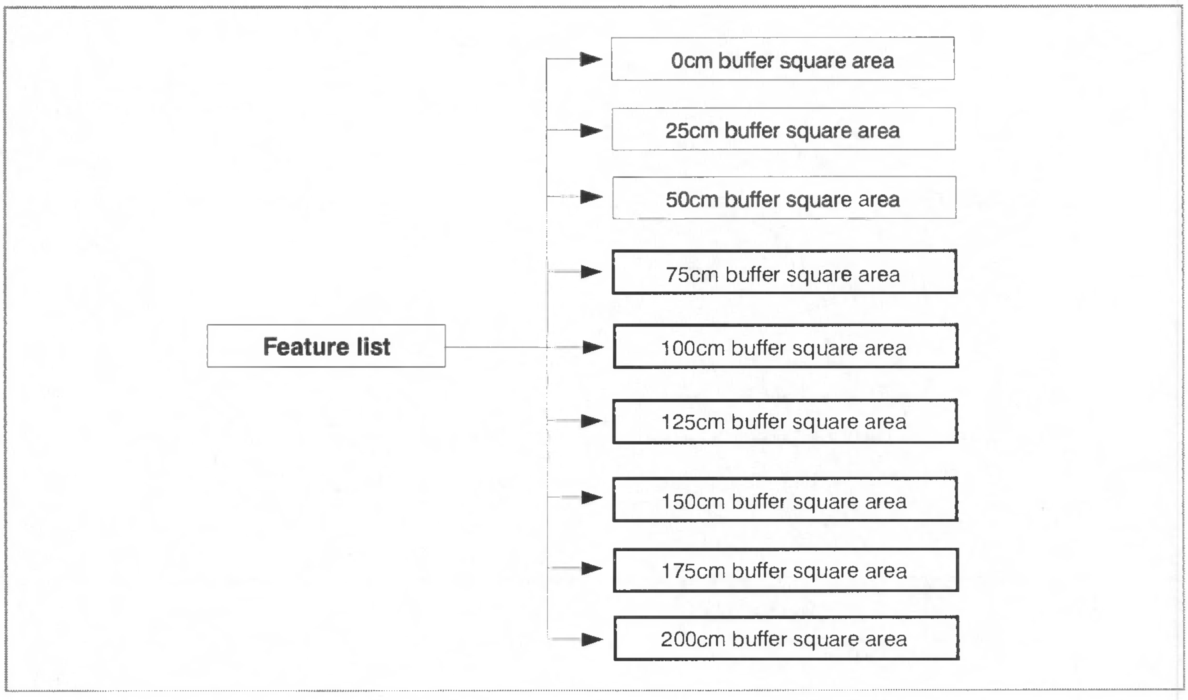


Figure 153: Bones database: crayfish mandibles flow chart. (Top)

Figure 154: Ostrich Eggshell database: flow chart. (Middle)

Figure 155: Refits database: flow chart. (Bottom)





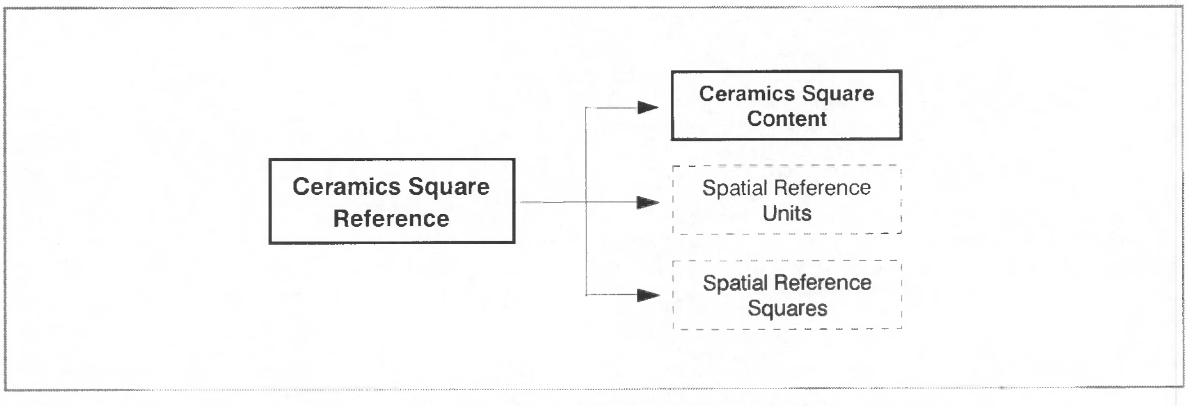
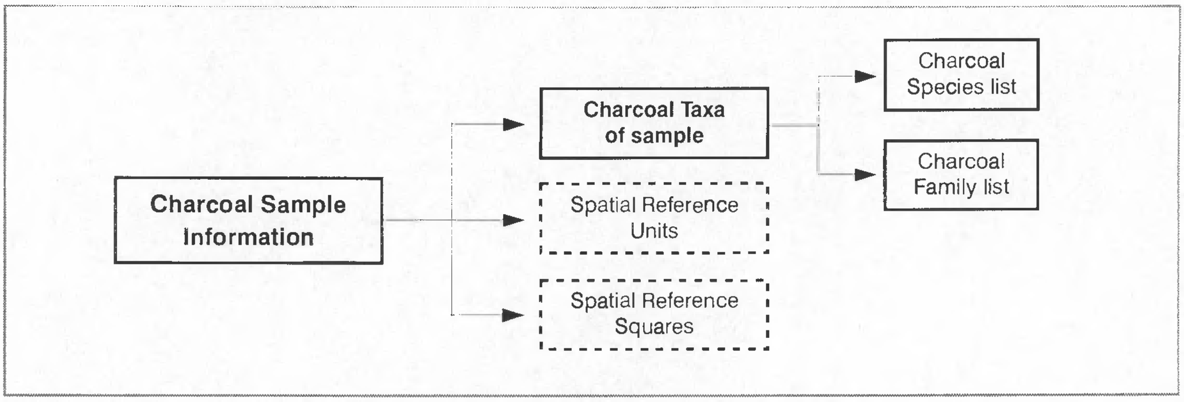


Figure 156: Features database: features flow chart. (Top)

Figure 157: Features database: feature buffer flow chart. (Middle)

Figure 158: Ceramics database: flow chart. (Bottom)



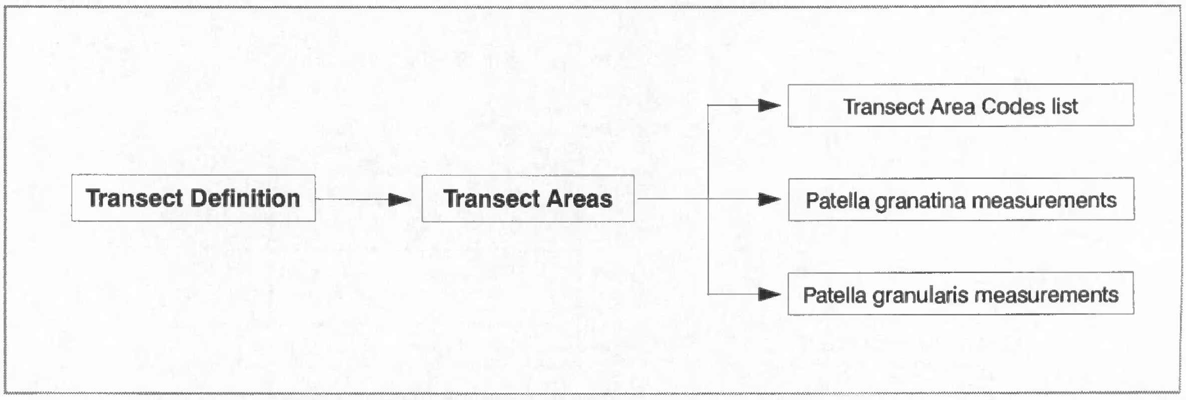


Figure 159: Charcoal database: flow chart. (Top)

Figure 160: Transect database: flow chart. (Bottom)

Query	*Tables used*	*Queries used*	*Description*
Average plane of DFM occupation layer	• DFM occupation layer survey data • Spatial reference squares • Spatial reference units	-	Calculates the average DFM occupation plane from the survey data by adding the spatial coordinates of elevation measurements.
Catalogue 1988-1999 with abscoord	• Spatial reference catalogue 1988-1999 • Spatial reference squares • Spatial reference units	-	Adds to each dataset (plotted find) of 'Spatial reference catalogue 1988-1999' its absolute coordinates in the DFM grid.
Catalogue summary	Spatial reference catalogue 1988-1999	-	Counts the number of datasets (plotted finds) in 'Spatial reference catalogue 1988-1999'
Excavated squares with abscoord	• Excavated squares • Spatial reference squares • Spatial reference units	-	Adds to each dataset (excavated square) of 'Excavated squares' its center coordinates in the DFM grid.

Table 60: DFM Spatial Reference database: contents of queries.

Query	Tables used	Queries used	Description
Squares of catalogue	Spatial reference catalogue 1988-1999	-	Creates a list of squares occuring in 'Spatial reference catalogue 1988-1999'
Squares of catalogue with abscoord	-	Squares of catalogue	Adds the central coordinates of each square listed in 'Squares of catalogue' in the DFM grid.
Summary plotted finds per square	Spatial reference catalogue 1988-1999	-	Counts the number of finds plotted for each square.
Unit and Square names combined	Excavated squares	-	Adds a column to 'Excavated squares' containing both, unit name and square number.

Table 60: (Continued) DFM Spatial Reference database: contents of queries.

Query	Tables used	Queries used	Description
Analyzed squares	• Sheetdefinition • Spatial reference squares • Spatial reference units	-	Generates a list of DFM squares from 'Sheetdefinition' where results of shellfish analysis have been inputted for and adds their central coordinates in the DFM grid.
Preparation Whelks summary	• Sheetdefinition • Argobuccinum pustulosum • Burnupena and Nucella • Whelks • Oxystele spp • Bullia spp	-	Summarizes the information on these shellfish species grouped by DFM square in preparation for the query 'Summary Whelks'.
Spatial Analysis Pgranatina and Pgranularis avg measurements n20	-	• Summary Patella granatina measurements • Summary Patella granularis measurements	Creates a list of squares with average measurements of P. granatina and P. granularis with the criterion that at least 20 measurements per limpet have to exist in a square.
Spatial Analysis Pgranatina individuals between 1 and 2 years	• Sheetdefinition • Patella granatina measurements	-	Counts measurements per square that lie between 30mm and 54mm.
Spatial Analysis Pgranatina individuals between 1 and 2 years %	-	• Spatial analysis Pgranatina individuals between 1 and 2 years • Summary Patella granatina measurements	Calculates the % of measurements per square from the total that lie between 30mm and 54mm.

Table 61: DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Spatial Analysis Pgranatina individuals between 2 and 3 years	• Sheetdefinition • Patella granatina measurements	-	Counts measurements per square that lie between 54mm and 68mm.
Spatial Analysis Pgranatina individuals between 2 and 3 years %	-	• Spatial analysis Pgranatina individuals between 2 and 3 years • Summary Patella granatina measurements	Calculates the % of measurements per square from the total that lie between 54mm and 68mm.
Spatial Analysis Pgranatina squares with 1_2 and 2_3%	-	• Spatial Analysis Pgranatina individuals between 1 and 2 years % • Spatial Analysis Pgranatina individuals between 2 and 3 years %	Combines the two queries into one list that contains only squares that had results for both size classes.
Spatial Analysis Pgranularis individuals between 1 and 2 years	• Sheetdefinition • Patella granularis measurements	-	Counts measurements per square that lie between 28mm and 40mm.
Spatial Analysis Pgranularis individuals between 1 and 2 years %	-	• Spatial analysis Pgranularis individuals between 1 and 2 years • Summary Patella granularis measurements	Calculates the % of measurements per square from the total that lie between 28mm and 40mm.
Spatial Analysis Pgranularis individuals between 2 and 3 years	• Sheetdefinition • Patella granularis measurements	-	Counts measurements per square that lie between 40mm and 47mm.
Spatial Analysis Pgranularis individuals between 2 and 3 years %	-	• Spatial analysis Pgranularis individuals between 2 and 3 years • Summary Patella granularis measurements	Calculates the % of measurements per square from the total that lie between 40mm and 47mm.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Spatial Analysis Pgranularis squares with 1_2 and 2_3%	-	• Spatial Analysis Pgranularis individuals between 1 and 2 years % • Spatial Analysis Pgranularis individuals between 2 and 3 years %	Combines the two queries into one list that contains only squares that had results for both size classes.
Summary All Shellfish Weights	-	• Summary Mussel Weights • Summary Patella Weights • Summary Various Weights	Combines these three queries into one list with all shellfish information per square available for DFM and calculates the totals.
Summary All Shellfish Weights in %		Summary All Shellfish Weights	Transforms all absolute weights per square into relative percentages by dividing them with the total weight per square.
Summary All Shellfish Weights in % squares with more 600g total		Summary All Shellfish Weights	Transforms all absolute weights per square into relative percentages by dividing them with the total weight per square. Additionally the list is limited to squares that have at least a total of 600g shellfish weight.
Summary Aulacomya ater	• Sheetdefinition • Aulacomya ater	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Aulacomya ater subadults	• Sheetdefinition • Aulacomya ater subadult	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Barnacles	• Sheetdefinition • Barnacles	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Choromytilus meridionalis	• Sheetdefinition • Choromytilus meridionalis	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Choromytilus meridionalis measurements left countable	• Sheetdefinition • Choromytilus meridionalis measurements CL	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Choromytilus meridionalis measurements left measurable	• Sheetdefinition • Choromytilus meridionalis measurements CR	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Choromytilus meridionalis measurements right countable	• Sheetdefinition • Choromytilus meridionalis measurements ML	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Summary Choromytilus meridionalis measurements right measurable	• Sheetdefinition • Choromytilus meridionalis measurements MR	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Choromytilus meridionalis subadults	• Sheetdefinition • Choromytilus meridionalis	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Crepidula spp	• Sheetdefinition • Crepidula spp	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Donax serra	• Sheetdefinition • Donax serra	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Helcion spp	• Sheetdefinition • Helcion spp	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Mussel Weights	-	• Summary Choromytilus meridionalis • Summary Donax serra • Summary Aulacomya ater • Summary Venerupis corrugata • Summary Choromytilus meridionalis subadults • Summary Aulacomya ater subadults	Combines the results of these queries into one list containing all available information on mussels at DFM.
Summary Patella argenvillei	• Sheetdefinition • Patella argenvillei	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella argenvillei measurements	• Sheetdefinition • Patella argenvillei measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella barbara	• Sheetdefinition • Patella barbara	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella barbara measurements	• Sheetdefinition • Patella barbara measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella cochlear	• Sheetdefinition • Patella cochlear	-	Summarizes the information on this shellfish species grouped by DFM square.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Summary Patella cochlear measurements	• Sheetdefinition • Patella cochlear measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella compressa	• Sheetdefinition • Patella compressa	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella compressa measurements	• Sheetdefinition • Patella compressa measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella granatina	• Sheetdefinition • Patella granatina	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella granatina measurements	• Sheetdefinition • Patella granatina measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella granularis	• Sheetdefinition • Patella granularis	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella granularis measurements	• Sheetdefinition • Patella granularis measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella miniata	• Sheetdefinition • Patella miniata	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella miniata measurements	• Sheetdefinition • Patella miniata measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.
Summary Patella spp subadults	• Sheetdefinition • Patella subadults	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella unidentified	• Sheetdefinition • Patella unidentified	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Patella unidentified measurements	• Sheetdefinition • Patella unidentified measurements	-	Calculates number of measurements, average measurement and standard deviation of these shellfish measurements grouped by DFM square.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Summary Patella Weights	-	• Summary Patella granatina • Summary Patella granularis • Summary Patella barbara • Summary Patella argenvillei • Summary Patella cochlear • Summary Patella compressa • Summary Patella miniata • Summary Patella unidentified • Summary Patella spp subadults	Combines the results of these queries into one list containing all available information on pattella spp at DFM.
Summary Pgranatina and Pgranularis average measurements	-	• Summary Patella granatina measurements • Summary Patella granularis measurements	Combines the average size measurements of P. granatina and P. granularis into one list including only squares that have measurements for both limpets.
Summary Various	• Sheetdefinition • Various	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Various Weights	-	• Summary Whelks • Summary Whelks subadults • Summary Barnacles • Summary Crepidula spp • Summary Helcion spp • Summary Various	Combines the results of these queries into one list containing all available information on various other species at DFM including Barnacles and Whelks.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
Summary Venerupis corrugata	• Sheetdefinition • Venerupis corrugata	-	Summarizes the information on this shellfish species grouped by DFM square.
Summary Whelks	-	Preparation Whelks summary	Summarizes the information on Whelks grouped by DFM square.
Summary Whelks subadults	• Sheetdefinition • Whelks subadults	-	Summarizes the information on this shellfish species grouped by DFM square.

Table 61: (Continued) DFM Shellfish database: contents of queries.

Query	Tables used	Queries used	Description
NonRoundedCCSFormalTools summary	NonRoundedCCSFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedCCSOther summary	NonRoundedCCSOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedCCSUtilizedPieces summary	NonRoundedCCSUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedCCSWaste summary	NonRoundedCCSWaste	-	Calculates the total number of specimens for each category in this table.
NonRoundedFGBRFormalTools summary	NonRoundedFGBRFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedFGBROther summary	NonRoundedFGBROther	-	Calculates the total number of specimens for each category in this table.
NonRoundedFGBRUtilizedPieces summary	NonRoundedFGBRUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedFGBRWaste summary	NonRoundedFGBRWaste	-	Calculates the total number of specimens for each category in this table.
NonRoundedIndetMatFormalTools summary	NonRoundedIndetMatFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedIndetMatOther summary	NonRoundedIndetMatOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedIndetMatUtilizedPieces summary	NonRoundedIndetMatUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedIndetMatWaste summary	NonRoundedIndetMatWaste	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartzFormalTools squaredata	• Excavated squares • NonRoundedQuartzFormalTools	-	Summarizes the information of the categories in this table grouped by DFM square.
NonRoundedQuartzFormalTools summary	NonRoundedQuartzFormalTools	-	Calculates the total number of specimens for each category in this table.

Table 62: DFM Lithics database: contents of queries.

Query	Tables used	Queries used	Description
NonRoundedQuartzOther summary	NonRoundedQuartzOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartzUtilizedPieces summary	NonRoundedQuartzUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartzWaste squaredata	• Excavated squares • NonRoundedQuartzWaste	-	Summarizes the information of the categories in this table grouped by DFM square.
NonRoundedQuartzWaste summary	NonRoundedQuartzWaste	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartziteFormalTools summary	NonRoundedQuartziteFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedCCSOther summary	NonRoundedQuartziteOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartziteUtilizedPieces summary	NonRoundedQuartziteUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedQuartzite-Waste summary	NonRoundedQuartziteWaste	-	Calculates the total number of specimens for each category in this table.
NonRoundedSandstone-FormalTools summary	NonRoundedSandstoneFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedSandstoneOther summary	NonRoundedSandstoneOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedSandstoneUtilizedPieces summary	NonRoundedSandstoneUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedSandstone-Waste summary	NonRoundedSandstone-Waste	-	Calculates the total number of specimens for each category in this table.
NonRoundedSilcreteFormalTools summary	NonRoundedSilcreteFormalTools	-	Calculates the total number of specimens for each category in this table.
NonRoundedSilcreteOther summary	NonRoundedSilcreteOther	-	Calculates the total number of specimens for each category in this table.
NonRoundedSilcreteUtilizedPieces summary	NonRoundedSilcreteUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
NonRoundedSilcreteWaste summary	NonRoundedSilcreteWaste	-	Calculates the total number of specimens for each category in this table.
RoundedCCSFormalTools summary	RoundedCCSFormalTools	-	Calculates the total number of specimens for each category in this table.
RoundedCCSOther summary	RoundedCCSOther	-	Calculates the total number of specimens for each category in this table.
RoundedCCSUtilized-Pieces summary	RoundedCCSUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedCCSWaste summary	RoundedCCSWaste	-	Calculates the total number of specimens for each category in this table.
RoundedFGBRFormalTools summary	RoundedFGBRFormalTools	-	Calculates the total number of specimens for each category in this table.

Table 62: (Continued) DFM Lithics database: contents of queries.

Query	Tables used	Queries used	Description
RoundedFGBROther summary	RoundedFGBROther	-	Calculates the total number of specimens for each category in this table.
RoundedFGBRUtilizedPieces summary	RoundedFGBRUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedFGBRWaste summary	RoundedFGBRWaste	-	Calculates the total number of specimens for each category in this table.
RoundedIndetMatFormalTools summary	RoundedIndetMatFormalTools	-	Calculates the total number of specimens for each category in this table.
RoundedIndetMatOther summary	RoundedIndetMatOther	-	Calculates the total number of specimens for each category in this table.
RoundedIndetMatUtilizedPieces summary	RoundedIndetMatUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedIndetMatWaste summary	RoundedIndetMatWaste	-	Calculates the total number of specimens for each category in this table.
RoundedQuartzFormalTools summary	RoundedQuartzFormalTools	-	Calculates the total number of specimens for each category in this table.
RoundedQuartzOther summary	RoundedQuartzOther	-	Calculates the total number of specimens for each category in this table.
RoundedQuartzUtilizedPieces summary	RoundedQuartzUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedQuartzWaste squaredata	• Excavated squares • RoundedQuartzWaste	-	Summarizes the information of the categories in this table grouped by DFM square.
RoundedQuartzWaste summary	RoundedQuartzWaste	-	Calculates the total number of specimens for each category in this table.
RoundedQuartziteFormalTools summary	RoundedQuartziteFormalTools	-	Calculates the total number of specimens for each category in this table.
RoundedCCSOther summary	RoundedQuartziteOther	-	Calculates the total number of specimens for each category in this table.
RoundedQuartziteUtilizedPieces summary	RoundedQuartziteUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedQuartziteWaste summary	RoundedQuartziteWaste	-	Calculates the total number of specimens for each category in this table.
RoundedSandstoneFormalTools summary	RoundedSandstoneFormalTools	-	Calculates the total number of specimens for each category in this table.
RoundedSandstoneOther summary	RoundedSandstoneOther	-	Calculates the total number of specimens for each category in this table.
RoundedSandstoneUtilizedPieces summary	RoundedSandstoneUtilizedPieces	-	Calculates the total number of specimens for each category in this table.
RoundedSandstoneWaste summary	RoundedSandstoneWaste	-	Calculates the total number of specimens for each category in this table.
RoundedSilcreteFormalTools summary	RoundedSilcreteFormalTools	-	Calculates the total number of specimens for each category in this table.

Table 62: (Continued) DFM Lithics database: contents of queries.

Query	Tables used	Queries used	Description
RoundedSilcreteOther summary	RoundedSilcreteOther	-	Calculates the total number of specimens for each category in this table.
RoundedSilcreteUtilized-Pieces summary	RoundedSilcreteUtilized-Pieces	-	Calculates the total number of specimens for each category in this table.
RoundedSilcreteWaste summary	RoundedSilcreteWaste	-	Calculates the total number of specimens for each category in this table.
Squares with Rounded and NonRounded QuartzWaste	-	• NonRounded-QuartzWaste • Rounded-QuartzWaste	Combines the two queries into one, listing only the DFM squares where there are datasets existing for in both queries.

Table 62: (Continued) DFM Lithics database: contents of queries.

Query	Tables used	Queries used	Description
Bones analyzed squares	• Bones taxonomy • Spatial reference squares • Spatial reference units	-	Generates a list of DFM squares from 'Bones taxonomy' on which a large bones analysis has been performed on and adds their center coordinates in the DFM grid.
Bones counts per species per squares	Bones taxonomy	-	Creates a summary of identified large bones from 'Bones taxonomy' grouped by square and taxa.
Bones counts per square	• Bones taxonomy • Spatial reference squares • Spatial reference unit	-	Counts the identified large bones from 'Bones taxonomy' grouped by square and adds the squares center coordinates in the DFM grid.
Bones with coordinates	• Bones taxonomy • Spatial reference squares • Spatial reference unit	-	Lists all identified large bones from 'Bones taxonomy' that have been plotted and adds their absolute coordinates in the DFM grid.
Crayfish mandibles analyzed squares	• CrayfishMandibleMeasure-mentsLeft • CrayfishMandibleMeasure-mentsRight • CrayfishMandibleUnmea-surable • Excavated squares	-	Generates a list of DFM squares on which a crayfish mandible analysis has been performed on.
LargeBonesSquareData	Bones taxonomy	-	Counts all large bone specimens from 'Bones taxonomy' grouped by DFM square.
LargeTeethSquareData	Teeth taxonomy	-	Counts all large teeth specimens from 'Teeth taxonomy' grouped by DFM square.
Microfauna analyzed squares	• Microfauna main • Spatial reference squares • Spatial reference unit	-	Generates a list of DFM squares from 'Microfauna main' on which a microfauna analysis has been performed on and adds their center coordinates in the DFM grid.

Table 63: DFM Bones database: contents of queries.

Query	Tables used	Queries used	Description
Microfauna summary	Microfanua main	-	Creates a total specimen count from 'Microfauna main' grouped by 'BoneType'.
Richard's Bones summary	Bones taxonomy	-	Creates a total specimen count from 'Bones taxonomy' grouped by 'Taxon'.
Richard's Teeth summary	Teeth taxonomy	-	Creates a total specimen count from 'Teeth taxonomy' grouped by 'Taxon'.
Summary Crayfish Mandible Measurements Left	• CrayfishMandibleMeasurementsLeft • Excavated squares	-	Summarizes the information on left crayfish mandible measurements by calculating the number of measurements, their average and the standard deviation.
Summary Crayfish Mandible Measurements Right	• CrayfishMandibleMeasurementsRight • Excavated squares		Summarizes the information on right crayfish mandible measurements by calculating the number of measurements, their average and the standard deviation.
Teeth analyzed squares	• Teeth taxonomy • Spatial reference squares • Spatial reference units	-	Generates a list of DFM squares from 'Teeth taxonomy' on which a large teeth analysis has been performed on and adds their center coordinates in the DFM grid.
Teeth counts per species per square	Teeth taxonomy	-	Creates a summary of identified large teeth from 'Teeth taxonomy' grouped by square and taxa.
Teeth with coordinates	• Teeth taxonomy • Spatial reference squares • Spatial reference unit	-	Lists all identified large teeth from 'Teeth taxonomy' that have been plotted and adds their absolute coordinates in the DFM grid.

Table 63: (Continued) DFM Bones database: contents of queries.

Query	Tables used	Queries used	Description
OES Beads all information	• OES Beads Square content • OES Beads Square reference	-	Generates a list of all OES Beads information.
OES Beads diameter not null	• OES Beads Square content • OES Beads Square reference	-	Generates a list of all OES Beads information where 'Diameter' was measured.
OES Beads Inputted squares	OES Beads Square content	-	Generates a list of DFM squares from 'OES Beads Square content' on which a OES beads analysis has been performed on.
OES Beads squaredata	-	OES Beads diameter not null	Calculates the number and average of OES beads diameters grouped by DFM square.
OES Beads summary	OES Beads Square content	-	Creates a total specimen count of OES beads.

Table 64: DFM OES database: contents of queries.

Query	Tables used	Queries used	Description
OES Pieces all information	• OES Square content • OES Square reference	-	Generates a list of all OES Pieces information.
OES Pieces Inputted Squares	OES Square content	-	Generates a list of DFM squares from 'OES Square content' on which a OES pieces analysis has been performed on.
OES Pieces summary	OES Square content	-	Creates a total specimen count of OES pieces.

Table 64: (Continued) DFM OES database: contents of queries.

Query	Tables used	Queries used	Description
Ceramics all information	• CERAMICS Square content • CERAMICS Square reference	-	Generates a list of all Ceramics information.
Ceramics analyzed squares	• CERAMICS Square reference • Spatial reference squares • Spatial reference unit	-	Generates a list of DFM squares from 'Ceramics Square reference' on which a ceramics analysis has been performed on and adds their center coordinates in the DFM grid.
Ceramics refit sets	CERAMICS Square content	-	Compiles a list of existing ceramics refit sets.
Ceramics refits all information	CERAMICS Refits	-	Generates a list of all Ceramics Refits information.
Ceramics refits summary	CERAMICS Refits	-	Counts the total number of Ceramics Refits.
Ceramics squaredata	• CERAMICS Square content • CERAMICS Square reference	-	Summarizes the Ceramics information by counting the number of sherds grouped by DFM square.
Ceramics summary	CERAMICS Square content	-	Counts the total number of sherds of 'CERAMICS Square content'.

Table 65: DFM Ceramics database: contents of queries.

Query	Tables used	Queries used	Description
Refits summary	REFIT DATA	-	Summarizes the Refit information by counting the refitted specimen grouped by material.

Table 66: DFM Refits database: contents of queries.

Query	Tables used	Queries used	Description
Analyzed squares	CHARCOAL Sample information	-	Generates a list of DFM squares from 'CHARCOAL Sample information' on which a charcoal analysis has been performed on.

Table 67: DFM Charcoal database: contents of queries.

Query	Tables used	Queries used	Description
0cm-25cm buffer matching	• 0cm buffer square areas • 25cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
100cm-125cm buffer matching	• 100cm buffer square areas • 125cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
125cm-150cm buffer matching	• 125cm buffer square areas • 150cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
150cm-175cm buffer matching	• 150cm buffer square areas • 175cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
175cm-200cm buffer matching	• 175cm buffer square areas • 200cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
25cm-50cm buffer matching	• 25cm buffer square areas • 50cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
50cm-75cm buffer matching	• 50cm buffer square areas • 75cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
75cm-100cm buffer matching	• 75cm buffer square areas • 100cm buffer square areas	-	Prepares the buffer data for Inter-Buffer-Area calculation.
Excavated squares with abs center coord	• Excavated squares • Spatial reference squares • Spatial reference units	-	Creates a list of all excavated DFM squares with their center coordinates in the DFM grid.
Feature Coordinate Deltas	-	FeatureWithCoordinates	Calculates the x- and y-deltas of all DFM features to each other.
Feature to Square distances	• Excavated squares • feature center coords	-	Calculates the squared distances and relative orientation of all DFM features to all DFM squares.
Feature to Square distances smaller 4m	-	Feature to Square distances	Restricts the 'Feature to Square distances' query to distances that are smaller than 4m.
Feature to Square ENE	-	Feature to Square distances	Filters the relative orientations of 'Feature to Square distances' that match an east-north-eastern direction.

Table 68: DFM Features database: contents of queries.

Query	Tables used	Queries used	Description
Feature to Square ESE	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an east-south-eastern direction.
Feature to Square NNE	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an north-north-eastern direction.
Feature to Square NNW	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an north-north-western direction.
Feature to Square SSE	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an south-southeastern direction.
Feature to Square SSW	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an south-southwestern direction.
Feature to Square WNW	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an west-north-western direction.
Feature to Square WSW	-	Feature to Square dis-tances	Filters the relative orientations of 'Feature to Square distances' that match an west-south-western direction.
FeaturesWithCoordinates	• feature center coords • Feature list	-	Generates a list of all DFM features with their absolute center coordinates in the DFM grid.
Hearth features coordinate deltas	-	2x FeatureWith-Coordinates	Calculates the x- and y-deltas of all DFM hearth features to each other.
InterBufferArea0cm-25cm	-	0cm-25cm buffer matching	Calculates the area of the buffer between 0cm and 25cm for each feature grouped by DFM square
InterBufferArea100cm-125cm	-	100cm-125cm buffer matching	Calculates the area of the buffer between 100cm and 125cm for each feature grouped by DFM square
InterBufferArea125cm-150cm	-	125cm-150cm buffer matching	Calculates the area of the buffer between 125cm and 150cm for each feature grouped by DFM square
InterBufferArea150cm-175cm	-	150cm-175cm buffer matching	Calculates the area of the buffer between 150cm and 175cm for each feature grouped by DFM square
InterBufferArea175cm-200cm	-	175cm-200cm buffer matching	Calculates the area of the buffer between 175cm and 200cm for each feature grouped by DFM square
InterBufferArea25cm-50cm	-	25cm-50cm buffer matching	Calculates the area of the buffer between 25cm and 50cm for each feature grouped by DFM square

Table 68: (Continued) DFM Features database: contents of queries.

Query	Tables used	Queries used	Description
InterBufferArea50cm-75cm	-	50cm-75cm buffer matching	Calculates the area of the buffer between 50cm and 75cm for each feature grouped by DFM square
InterBufferArea75cm-100cm	-	75cm-100cm buffer matching	Calculates the area of the buffer between 75cm and 100cm for each feature grouped by DFM square

Table 68: (Continued) DFM Features database: contents of queries.

Query	Tables used	Queries used	Description
Summary MNI all species per transect	-	• Summary MNI Patella granatina per transect • Summary MNI Patella granularis per transect • Summary MNI per species per transect	Combines these three queries into one list of all MNI counts per species grouped by transect name
Summary MNI Patella granatina per transect	• Patella granatina measurements • TransectAreas • TransectDefinition	-	Counts number of measurements of Patella granatina grouped by transect name.
Summary MNI Patella granularis per transect	• Patella granularis measurements • TransectAreas • TransectDefinition	-	Counts number of measurements of Patella granularis grouped by transect name.
Summary MNI per species per transect	• TransectAreas • TransectDefinition	-	Counts number MNI per identified species grouped by transect name.
Summary number of squaremeters per transect	• TransectAreas • TransectDefinition	-	Calculates the number of analyzed square meters of each transect.
Summary Patella granatina measurements per transect	• Patella granatina measurements • TransectAreas • TransectDefinition	-	Generates a list of all Patella granatina measurements from the transects including their transect source.
Summary Patella granularis measurements per transect	• Patella granularis measurements • TransectAreas • TransectDefinition	-	Generates a list of all Patella granularis measurements from the transects including their transect source.

Table 69: Transect database: contents of queries.

APPENDIX V SHELLFISH ANALYSIS VARIABILITY

Results

Species	Category	Intra-group experiment		Inter-group experiment	
		Table	Figure	Table	Figure(s)
Patella granatina	MNI: Measurable, Countable, Total	72, page 253	161, page 260	78, page 256	179, page 269
	Weight: Measurable, Countable	73, page 253	162, page 260	79, page 257	180, page 269
	Weight: Fragments	73, page 253	162, page 260	79, page 257	183, page 271
	Weight: Total	71, page 252	162, page 260	77, page 256	183, page 271
	Size Measurements	76, page 255	167, page 263	82, page 259	185, page 272 186, page 272
Patella granularis	MNI: Measurable, Countable, Total	72, page 253	163, page 261	78, page 256	181, page 270
	Weight: Measurable, Countable	73, page 253	164, page 261	79, page 257	182, page 270
	Weight: Fragments	73, page 253	164, page 261	79, page 257	184, page 271
	Weight: Total	71, page 252	164, page 261	77, page 256	184, page 271
	Size Measurements	76, page 255	168, page 263	82, page 259	187, page 273 188, page 273
Patella barbara	MNI: Measurable, Countable, Total	72, page 253	165, page 262	-	-
	Weight: Measurable, Countable	73, page 253	166, page 262	-	-
	Weight: Fragments	73, page 253	166, page 262	-	-
	Weight: Total	71, page 252	166, page 262	-	-
	Size Measurements	76, page 255	169, page 264	-	-

Table 70: Index to tables and figures of the shellfish analysis variability experiments.

Species	***Category***	***Intra-group experiment***		***Inter-group experiment***	
		Table	***Figure***	***Table***	***Figure(s)***
Choromytilus meridionalis	MNI (left): Countable, Measurable, Total	74, page 254	171, page 265	80, Tage 257	189, page 274
	MNI (right): Countable, Measurable, Total	74, page 254	172, page 265	80, page 257	190, page 274
	Weight (left): Countable, Measurable, Meas.+Count.	75, page 254	173, page 266	81, page 258	191, page 275
	Weight (right): Countable, Measurable, Meas.+Count.	75, page 254	174, page 266	81, page 258	192, page 275
	Weight: Fragments	-	170, page 264	-	193, page 276
	Weight: Total	71, page 252	170, page 264	77, page 256	193, page 276
	Size Measurements (left countable)	76, page 255	175, page 267	82, page 259	194, page 277 195, page 277
	Size Measurements (right countable)	76, page 255	176, page 267	82, page 259	196, page 278 197, page 278
	Size Measurements (left measurable)	76, page 255	177, page 268	82, page 259	198, page 279 199, page 279
	Size Measurements (right measurable)	76, page 255	178, page 268	82, page 259	200, page 280 201, page 280

Table 70: Index to tables and figures of the shellfish analysis variability experiments.

Species	***Analyst 1/2: total weight (g)***			***Analyst 1/3: total weight (g)***			***Analyst 2/3: total weight (g)***			***Av. rel. var.***
	Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.	
Patella granatina	2376.35	3.1	0.001	2391.15	32.7	0.014	2392.7	29.6	0.012	***0.009***
Patella granularis	991.85	6.7	0.007	979.75	17.5	0.018	983.1	24.2	0.025	***0.017***
Patella barbara	105.1	0.2	0.002	105.45	0.9	0.009	105.55	0.7	0.007	***0.006***
Choromytilus meridionalis	1470.2	2.2	0.002	1474.0	9.8	0.007	1475.1	7.6	0.005	***0.005***

Table 71: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: All species total weight averages, ranges and relative variations.

Species	Analyst	Measurable MNI			Countable MNI			Total MNI		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	1/2	103.5	9.0	0.087	458.0	36.0	0.079	561.5	27.0	0.048
	1/3	115.0	14.0	0.122	442.0	4.0	0.009	557.0	18.0	0.032
	2/3	110.5	23.0	0.208	460.0	32.0	0.070	570.5	9.0	0.016
	Av.			***0.139***			***0.053***			***0.032***
Patella granu-laris	1/2	161.0	16.0	0.099	181.0	32.0	0.177	342.0	16.0	0.047
	1/3	166.5	5.0	0.030	166.0	2.0	0.012	332.5	3.0	0.009
	2/3	158.5	11.0	0.069	182.0	30.0	0.165	340.5	19.0	0.056
	Av.			***0.066***			***0.118***			***0.037***
Patella barbara	1/2	4.0	2.0	0.500	2.0	2.0	1.000	6.0	0.0	0.000
	1/3	5.0	0.0	0.000	1.0	0.0	0.000	6.0	0.0	0.000
	2/3	4.0	2.0	0.500	2.0	2.0	1.000	6.0	0.0	0.000
	Av.			***0.333***			***0.667***			***0.000***

Table 72: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: Patella species MNI averages, ranges and relative variations.

Species	Analyst	Measurable weight (g)			Countable weight (g)			Fragments weight (g)		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	1/2	556.5	46.6	0.084	1109.6	53.6	0.048	710.25	3.9	0.005
	1/3	598.9	38.2	0.064	1071.75	22.1	0.021	720.5	16.6	0.023
	2/3	575.6	84.8	0.147	1098.55	75.7	0.069	718.55	20.5	0.029
	Av.			***0.098***			***0.046***			***0.019***
Patella granularis	1/2	494.1	61.0	0.123	326.75	63.3	0.194	171.0	4.4	0.026
	1/3	513.25	22.7	0.044	308.7	27.2	0.088	157.8	22.0	0.139
	2/3	482.75	38.3	0.079	340.35	36.1	0.106	160.0	26.4	0.165
	Av.			***0.082***			***0.129***			***0.110***
Patella barbara	1/2	87.45	14.7	0.168	15.9	14.8	0.931	1.75	0.1	0.057
	1/3	95.4	1.2	0.013	8.5	0.0	0.000	1.55	0.3	0.194
	2/3	88.05	15.9	0.181	15.9	14.8	0.931	1.6	0.4	0.250
	Av.			***0.121***			***0.621***			***0.167***

Table 73: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: Patella species weight averages, ranges and relative variations.

Species	Analyst	Countable MNI			Measurable MNI			Count. + meas. MNI		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
C. meridionalis left valves	1/2	72.0	4.0	0.056	14.0	2.0	0.143	86.0	6.0	0.070
	1/3	78.0	16.0	0.205	11.0	4.0	0.364	89.0	12.0	0.135
	2/3	80.0	12.0	0.150	12.0	6.0	0.500	92.0	6.0	0.065
	Av.			***0.137***			***0.336***			***0.090***
C. meridionalis right valves	1/2	63.0	2.0	0.032	14.5	3.0	0.207	77.5	5.0	0.065
	1/3	67.5	11.0	0.163	12.5	1.0	0.080	80.0	10.0	0.125
	2/3	68.5	9.0	0.131	14.0	4.0	0.286	82.5	5.0	0.061
	Av.			***0.109***			***0.191***			***0.084***

Table 74: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: *Choromytilus meridionalis* MNI averages, ranges and relative variations.

Species	Analyst	Countable weight (g)			Measurable weight (g)			Countable + measurable weight (g)		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
C. meridionalis left valves	1/2	188.8	2.0	0.011	26.7	0.8	0.030	215.5	2.8	0.013
	1/3	196.1	16.6	0.085	22.05	8.5	0.385	218.15	8.1	0.037
	2/3	197.1	14.6	0.074	22.45	9.3	0.414	219.55	5.3	0.024
	Av.			***0.057***			***0.276***			***0.025***
C. meridionalis right valves	1/2	130.95	8.7	0.066	20.85	4.9	0.235	151.8	3.8	0.025
	1/3	133.8	14.4	0.108	22.35	1.9	0.085	156.15	12.5	0.080
	2/3	138.15	5.7	0.041	19.9	3.0	0.151	158.05	8.7	0.055
	Av.			***0.072***			***0.157***			***0.053***

Table 75: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: *Choromytilus meridionalis* weight averages, ranges and relative variations.

Species (sub-category)	Analyst	Average size (mm)			Median size (mm)		
		Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	1/2	47.805	0.21	0.004	46.5975	0.225	0.005
	1/3	47.015	1.37	0.029	45.7325	1.505	0.033
	2/3	47.12	1.58	0.034	45.845	1.73	0.038
	Av.			**0.022**			**0.025**
Patella granularis	1/2	36.13	0.2	0.006	35.795	0.27	0.008
	1/3	36.14	0.18	0.005	35.8425	0.175	0.005
	2/3	36.04	0.02	0.001	35.7075	0.095	0.003
	Av.			**0.004**			**0.005**
Patella barbara	1/2	67.7	9.18	0.136	69.855	2.79	0.040
	1/3	63.135	0.05	0.001	68.37	0.18	0.003
	2/3	67.725	9.13	0.135	69.765	2.97	0.043
	Av.			**0.091**			**0.029**
Choromytilus meridionalis (left countable)	1/2	8.055	0.29	0.036	7.94	0.38	0.048
	1/3	8.04	0.32	0.040	7.885	0.49	0.062
	2/3	7.895	0.03	0.004	7.695	0.11	0.014
	Av.			**0.027**			**0.041**
Choromytilus meridionalis (right countable)	1/2	8.055	0.39	0.048	7.9175	0.405	0.051
	1/3	8.035	0.43	0.054	7.9375	0.365	0.046
	2/3	7.84	0.04	0.005	7.735	0.04	0.005
	Av.			**0.036**			**0.034**
Choromytilus meridionalis (left meas. not count.)	1/2	7.73	0.52	0.067	7.515	0.81	0.108
	1/3	7.855	0.27	0.034	7.725	0.39	0.050
	2/3	7.595	0.25	0.033	7.32	0.42	0.057
	Av.			**0.045**			**0.072**
Choromytilus meridionalis (right meas. not count.)	1/2	7.77	0.92	0.118	7.72	1.06	0.137
	1/3	7.935	0.59	0.074	7.955	0.59	0.074
	2/3	7.475	0.33	0.044	7.425	0.47	0.063
	Av.			**0.079**			**0.091**

Table 76: Intra-group shellfish analysis - Analysts 1, 2 & 3 compared to each other: Average/median sizes, ranges and relative variations for shellfish frequency distributions per species.

Species	Group A/P: total weight (g)			Group B/P: total weight (g)			Group C/P: total weight (g)			Av. rel. var.
	Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.	
Patella granatina	1858.5	43.6	0.023	2391.7	33.8	0.014	3340.2	4.2	0.001	***0.038***
Patella granularis	651.9	26.0	0.040	982.9	11.2	0.011	417.1	5.3	0.013	***0.064***
Choromytilus meridionalis	467.2	140.9	0.302	1495.2	52.2	0.035	3438.6	45.3	0.013	***0.117***

Table 77: Inter-group shellfish analysis - Group A, B & C compared to Present Group: All species total weight averages, ranges and relative variations.

Species	Group	Measurable MNI			Countable MNI			Total MNI		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	A/P	21.5	1.0	0.047	215.5	3.0	0.014	237.0	2.0	0.008
	B/P	93.0	30.0	0.323	455.5	31.0	0.068	548.5	1.0	0.002
	C/P	186.5	7.0	0.038	417.5	19.0	0.046	604.0	26.0	0.043
	Av.			***0.136***			***0.043***			***0.018***
Patella granularis	A/P	66.0	14.0	0.212	122.5	13.0	0.106	188.5	1.0	0.005
	B/P	159.0	20.0	0.126	177.5	25.0	0.141	336.5	5.0	0.015
	C/P	70.0	0.0	0.000	72.0	0.0	0.000	142.0	0.0	0.000
	Av.			***0.113***			***0.082***			***0.007***

Table 78: Inter-group shellfish analysis - Group A, B & C compared to Present Group: Patella species MNI averages, ranges and relative variations.

Species	Group	Measurable weight (g)			Countable weight (g)			Fragments weight (g)		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	A/P	224.4	16.2	0.072	840.8	0.0	0.000	793.3	27.4	0.035
	B/P	516.8	126.0	0.244	1158.5	151.4	0.131	716.4	8.4	0.012
	C/P	1141.5	80.4	0.070	1518.2	108.1	0.071	680.6	23.5	0.035
	Av.			***0.129***			***0.067***			***0.027***
Patella granularis	A/P	271.0	48.0	0.177	274.0	33.5	0.122	107.0	11.5	0.108
	B/P	489.1	71.0	0.145	335.6	80.9	0.241	158.3	21.1	0.133
	C/P	221.1	6.4	0.029	148.7	6.4	0.043	47.3	5.3	0.112
	Av.			***0.117***			***0.135***			***0.118***

Table 79: Inter-group shellfish analysis - Group A, B & C compared to Present Group: Patella species weight averages, ranges and relative variations.

Species	Group	Countable MNI			Measurable MNI			Count. + meas. MNI		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
C. meridionalis left valves	A/P	14.0	4.0	0.286	2.0	4.0	2.000	16.0	0.0	0.000
	B/P	65.0	10.0	0.154	16.5	7.0	0.424	81.5	3.0	0.037
	C/P	93.5	3.0	0.032	7.0	0.0	0.000	100.5	3.0	0.030
	Av.			***0.157***			***0.808***			***0.022***
C. meridionalis right valves	A/P	17.0	0.0	0.000	0.5	1.0	2.000	17.5	1.0	0.057
	B/P	57.5	9.0	0.157	17.0	8.0	0.471	74.5	1.0	0.013
	C/P	95.5	13.0	0.136	10.5	3.0	0.286	106.0	10.0	0.094
	Av.			***0.098***			***0.919***			***0.055***

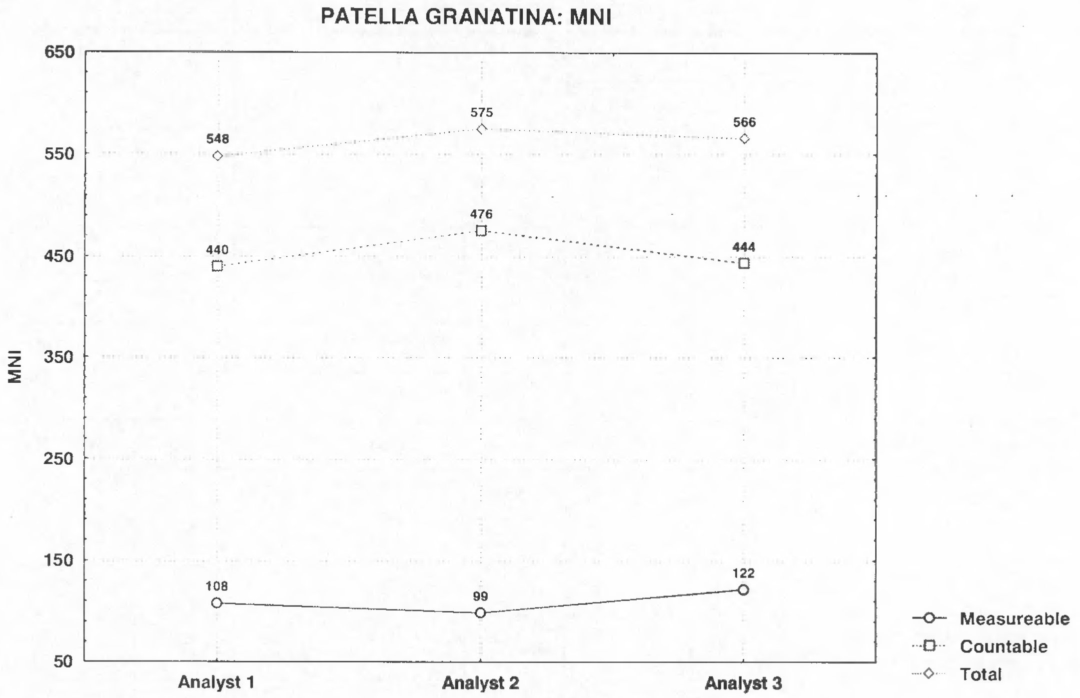
Table 80: Inter-group shellfish analysis - Group A, B & C compared to Present Group: *Choromytilus meridionalis* MNI averages, ranges and relative variations.

Species	Group	Countable weight (g)			Measurable weight (g)			Countable + measurable weight (g)		
		Average	Range	Rel. var.	Average	Range	Rel. var.	Average	Range	Rel. var.
C. meridionalis left valves	A/P	36.6	1.0	0.027	4.85	9.7	2.000	41.5	10.7	0.258
	B/P	189.6	3.6	0.019	30.6	8.6	0.281	220.2	12.2	0.055
	C/P	542.0	25.0	0.046	13.6	0.4	0.029	555.6	24.6	0.044
	Av.			***0.031***			***0.770***			***0.119***
C. meridionalis right valves	A/P	42.5	3.5	0.082	0.95	1.9	2.000	43.4	1.6	0.037
	B/P	128.5	3.7	0.029	26.4	6.2	0.235	154.9	9.9	0.064
	C/P	611.2	5.9	0.010	31.5	12.2	0.387	642.7	6.3	0.010
	Av.			***0.040***			***0.874***			***0.037***

Table 81: Intra-group shellfish analysis - Group A, B & C compared to Present Group: *Choromytilus meridionalis* weight averages, ranges and relative variations.

Species (sub-category)	Group	Average size (mm)			Median size (mm)		
		Average	Range	Rel. var.	Average	Range	Rel. var.
Patella granatina	A/P	57.35	0.66	0.012	58.65	0.19	0.003
	B/P	48.60	1.65	0.034	47.25	1.54	0.033
	C/P	47.54	5.30	0.111	48.36	1.72	0.036
	Av.			***0.052***			***0.024***
Patella granularis	A/P	38.78	0.48	0.012	37.89	0.72	0.019
	B/P	36.08	0.40	0.011	35.79	0.24	0.007
	C/P	36.26	0.42	0.012	35.58	0.16	0.004
	Av.			***0.012***			***0.010***
Choromytilus meridionalis (left countable)	A/P	9.52	1.27	0.133	9.62	0.76	0.079
	B/P	8.43	0.45	0.053	8.31	0.37	0.045
	C/P	9.68	0.75	0.077	9.68	0.56	0.058
	Av.			***0.088***			***0.061***
Choromytilus meridionalis (right countable)	A/P	9.72	0.11	0.011	9.40	0.80	0.085
	B/P	8.39	0.28	0.033	8.29	0.33	0.040
	C/P	9.93	0.68	0.068	10.05	0.49	0.049
	Av.			***0.037***			***0.058***
Choromytilus meridionalis (left meas. not count.)	A/P	-	-	-	-	-	-
	B/P	8.44	0.90	0.107	8.37	0.90	0.108
	C/P	9.40	0.31	0.033	9.61	0.01	0.001
	Av.			***0.047***			***0.055***
Choromytilus meridionalis (right meas. not count.)	A/P	-	-	-	-	-	-
	B/P	8.59	0.71	0.083	8.58	0.65	0.076
	C/P	9.70	0.35	0.036	9.73	0.25	0.026
	Av.			***0.060***			***0.051***

Table 82: Inter-group shellfish analysis - Group A, B & C compared to Present Group: Average/median sizes, ranges and relative variations for shellfish frequency distributions per species.



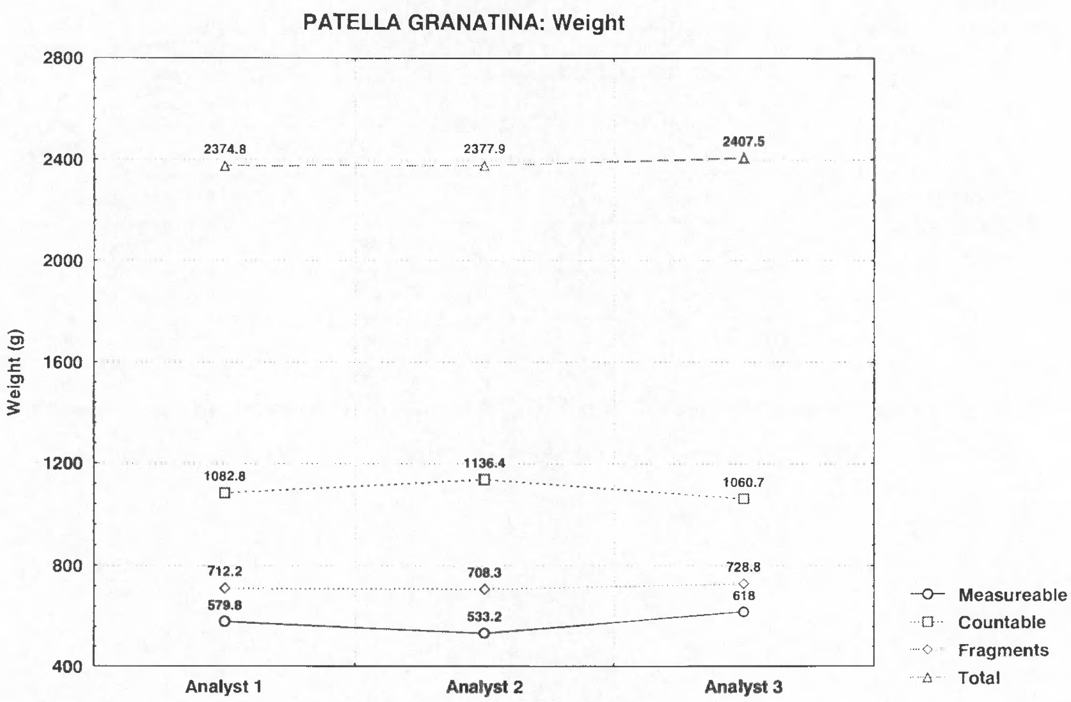


Figure 161: Intra-group shellfish analysis: *Patella granatina* MNI. (Top)

Figure 162: Intra-group shellfish analysis: *Patella granatina* weight. (Bottom)

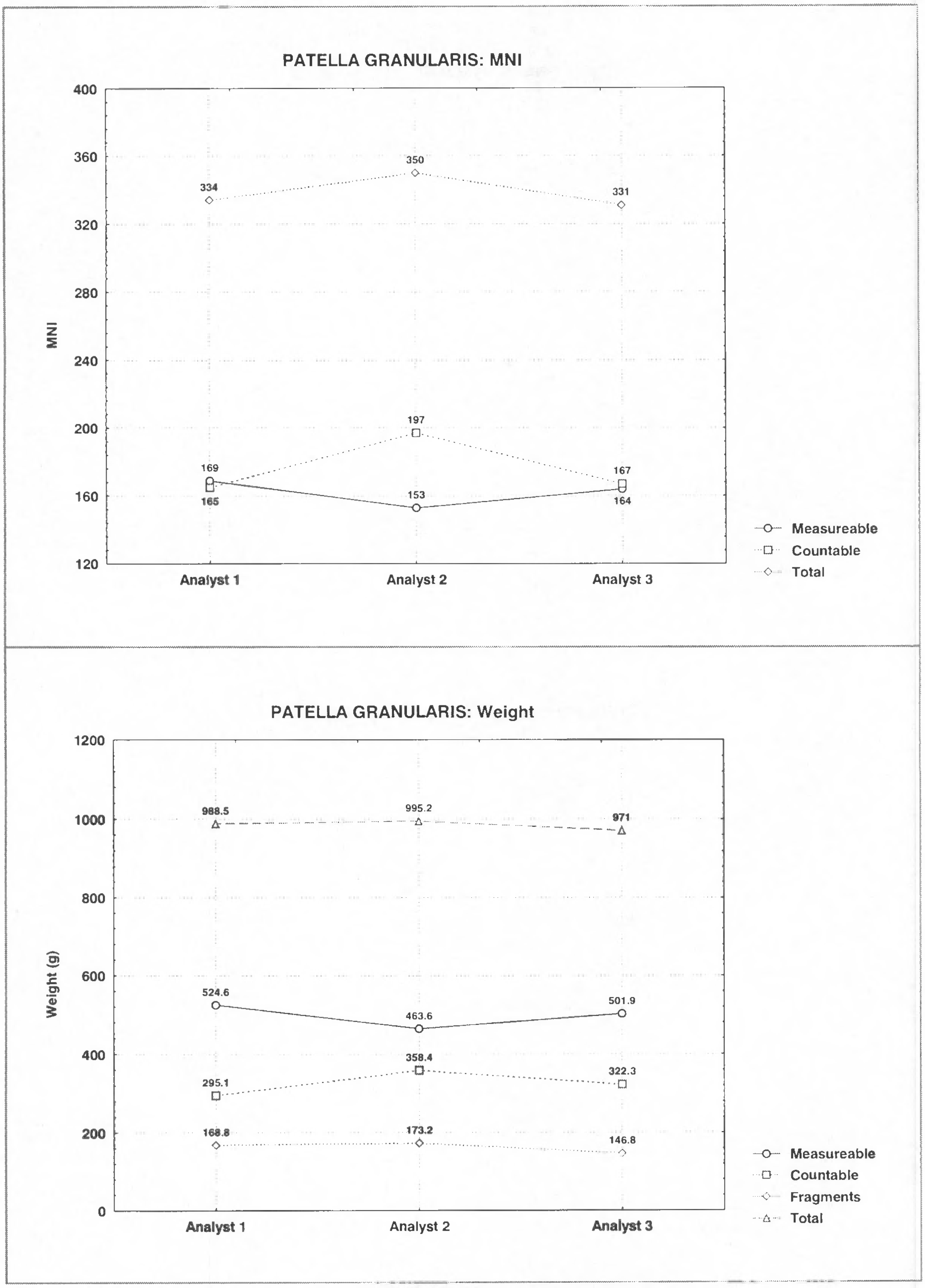
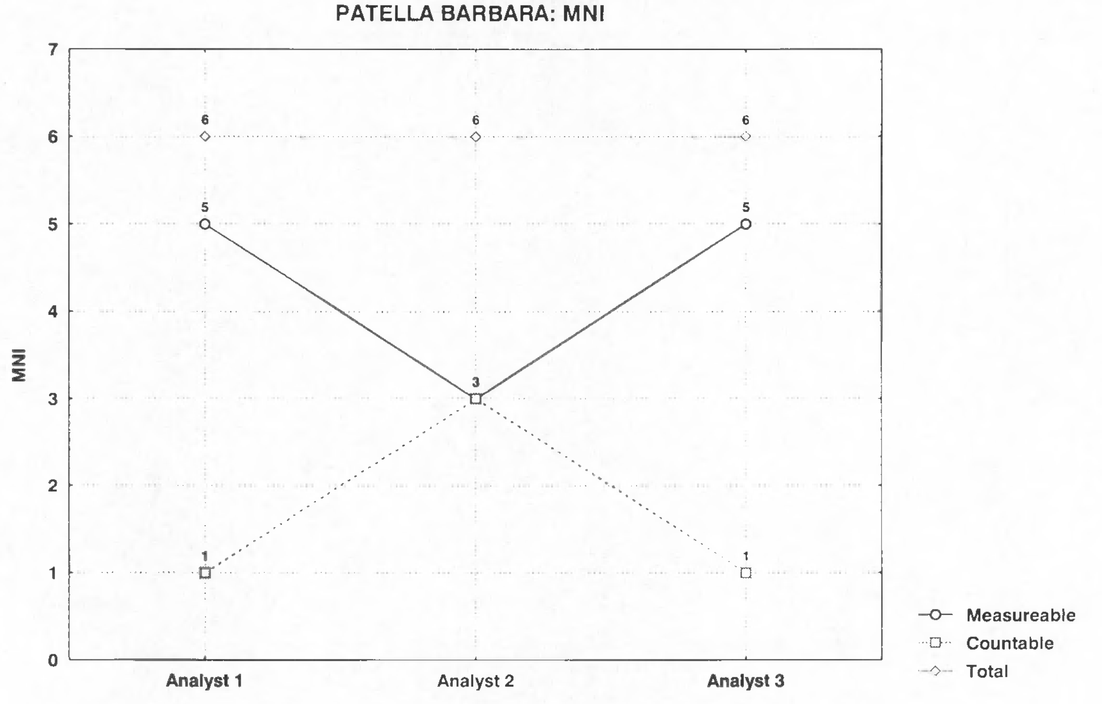


Figure 163: Intra-group shellfish analysis: *Patella granularis* MNI. (Top)

Figure 164: Intra-group shellfish analysis: *Patella granularis* weight. (Bottom)



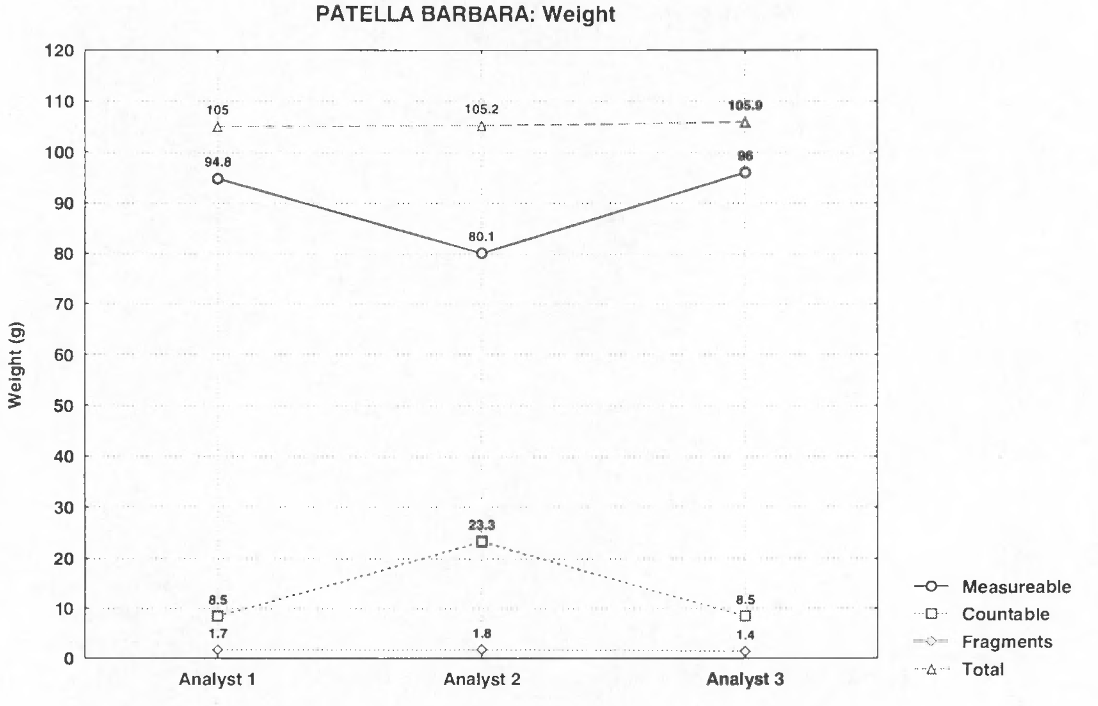
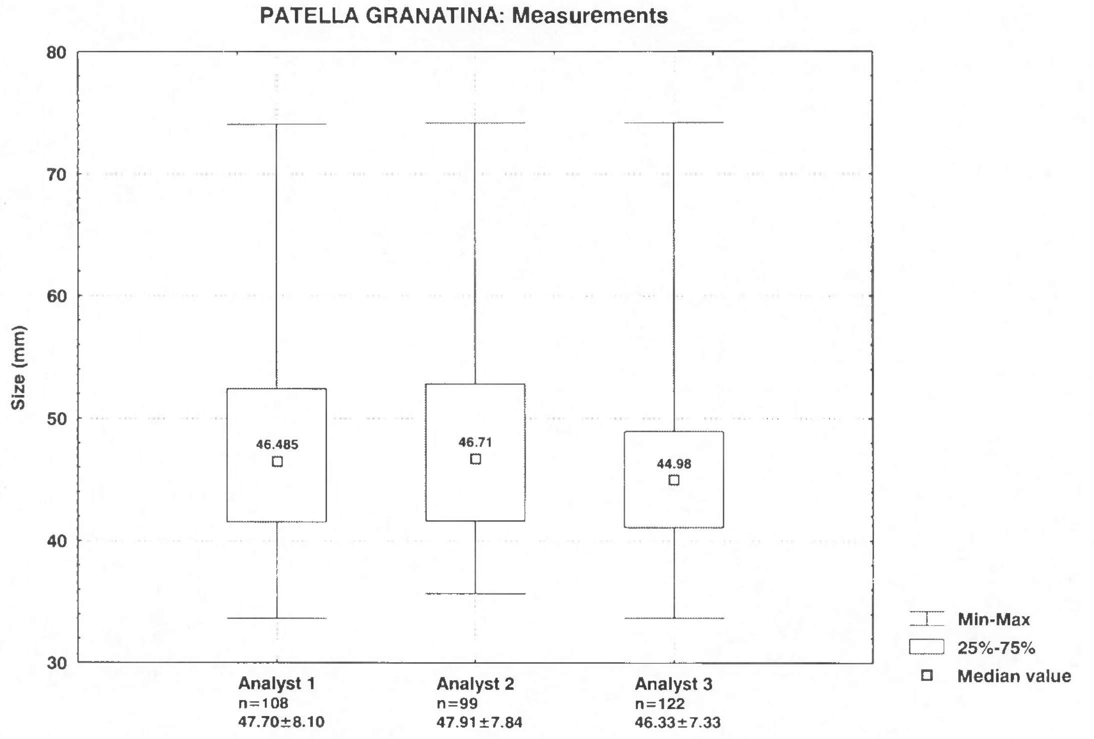


Figure 165: Intra-group shellfish analysis: *Patella barbara* MNI. (Top)

Figure 166: Intra-group shellfish analysis: *Patella barbara* weight. (Bottom)



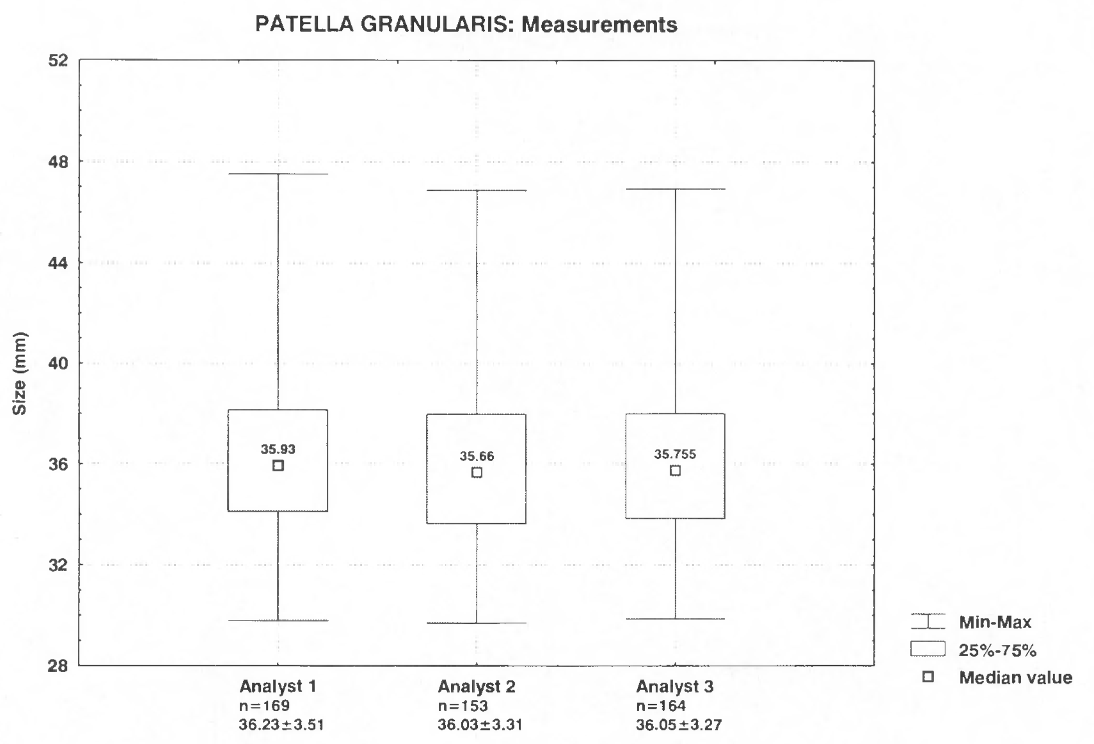
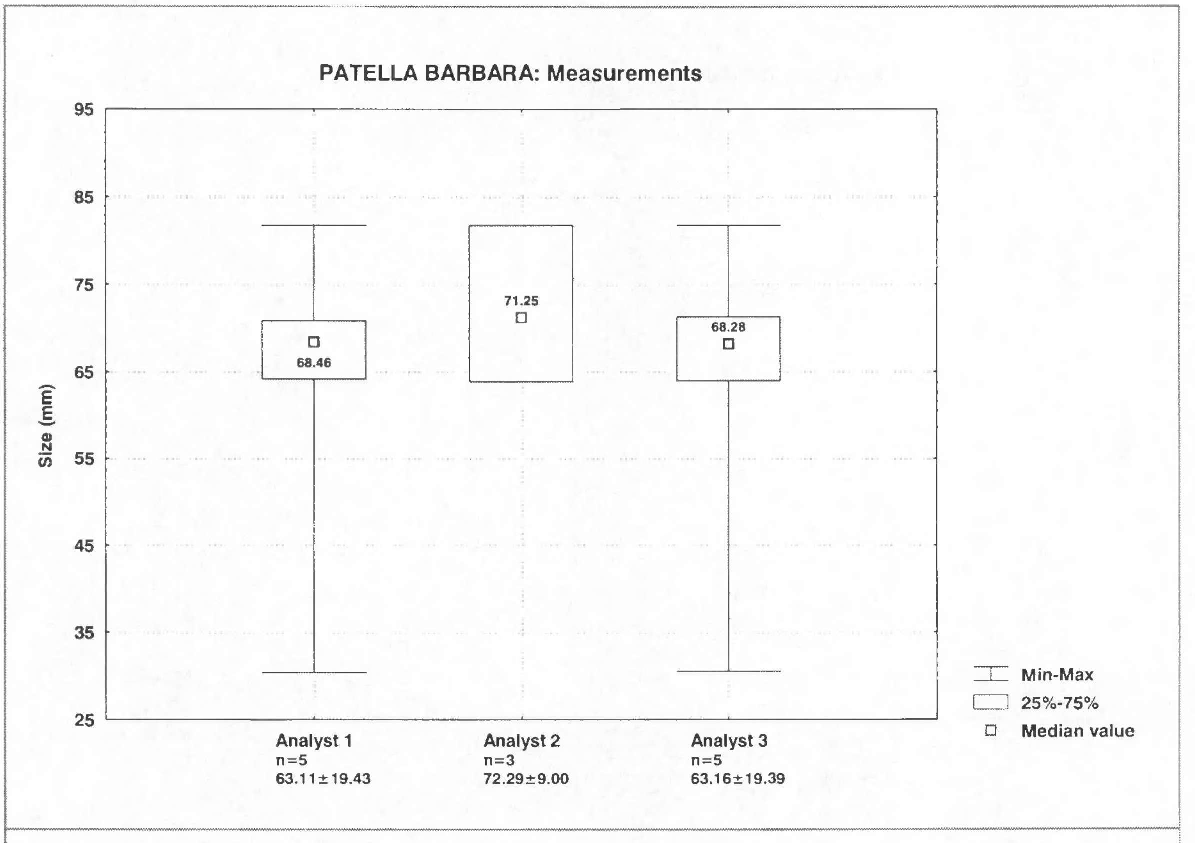


Figure 167: Intra-group shellfish analysis: *Patella granatina* measurements. (Top)

Figure 168: Intra-group shellfish analysis: *Patella granularis* measurements. (Bottom)



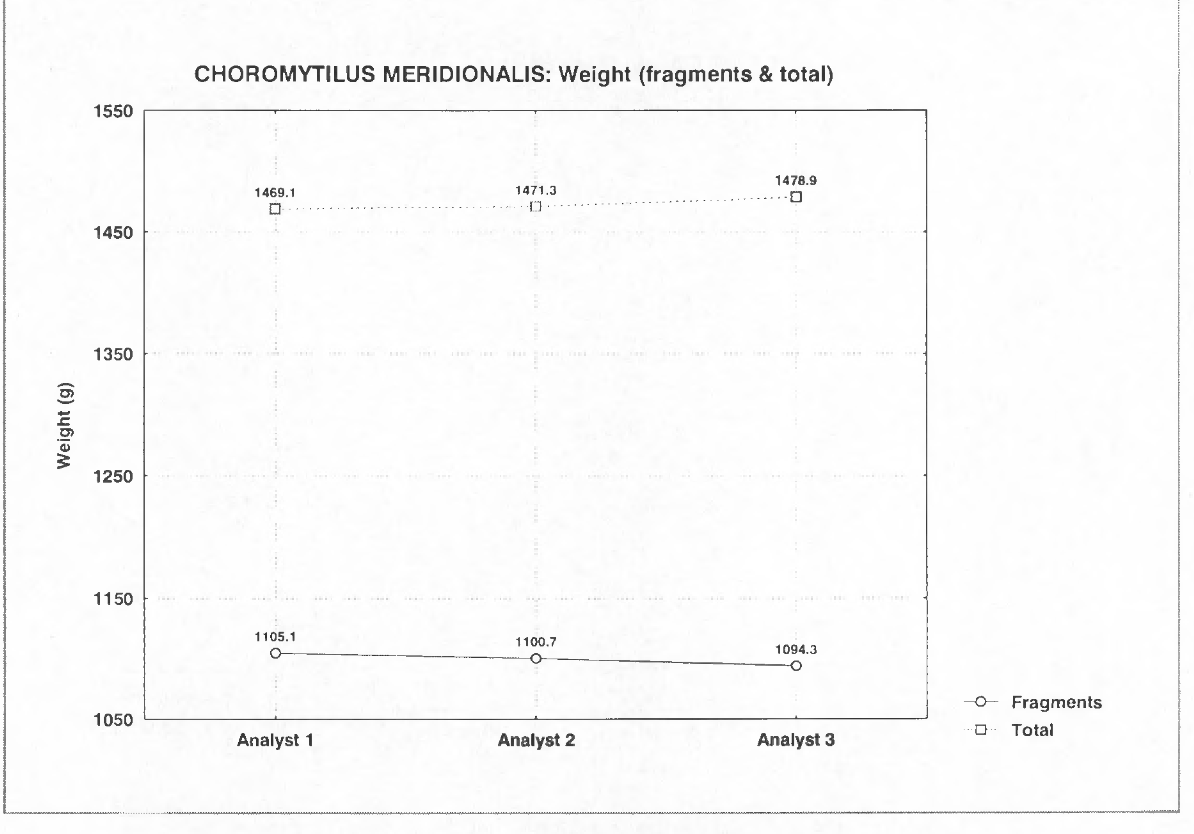
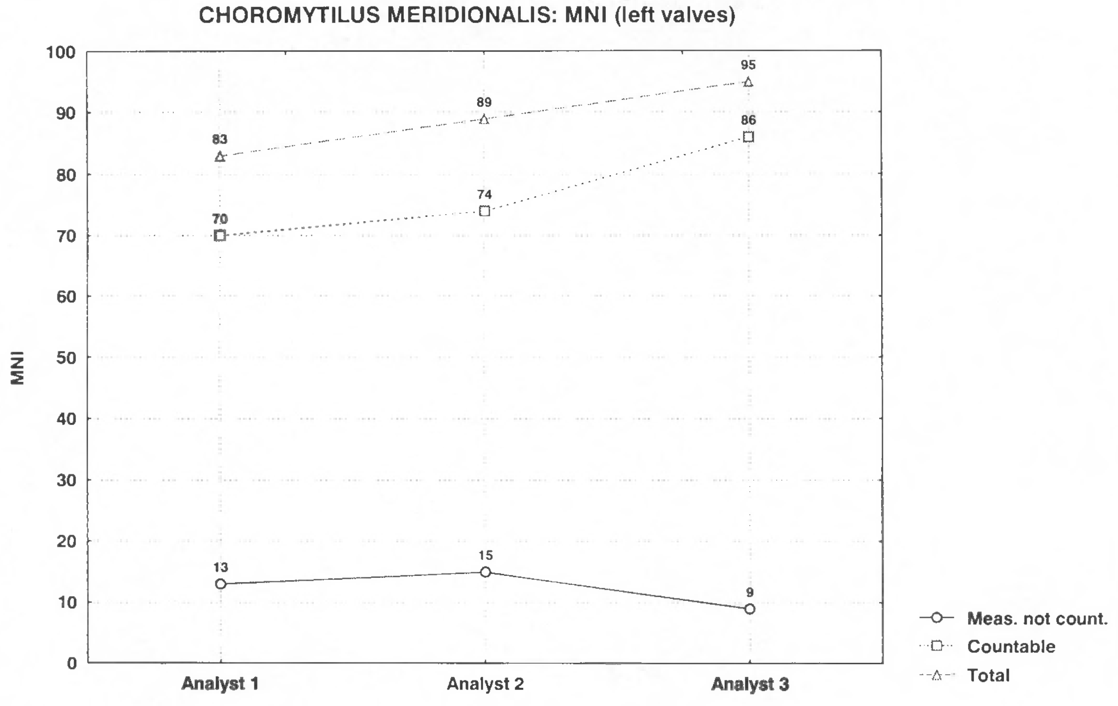


Figure 169: Intra-group shellfish analysis: *Patella barbara* measurements. (Top)

Figure 170: Intra-group shellfish analysis: *Choromytilus meridionalis* weight (fragments and total). (Bottom)



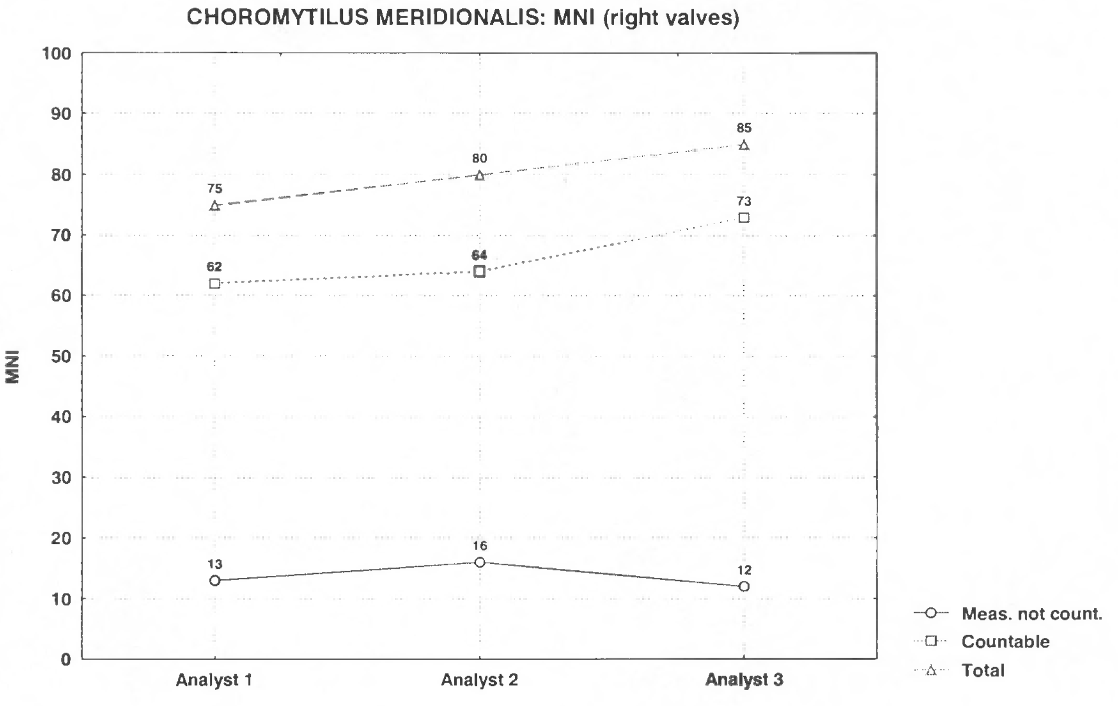
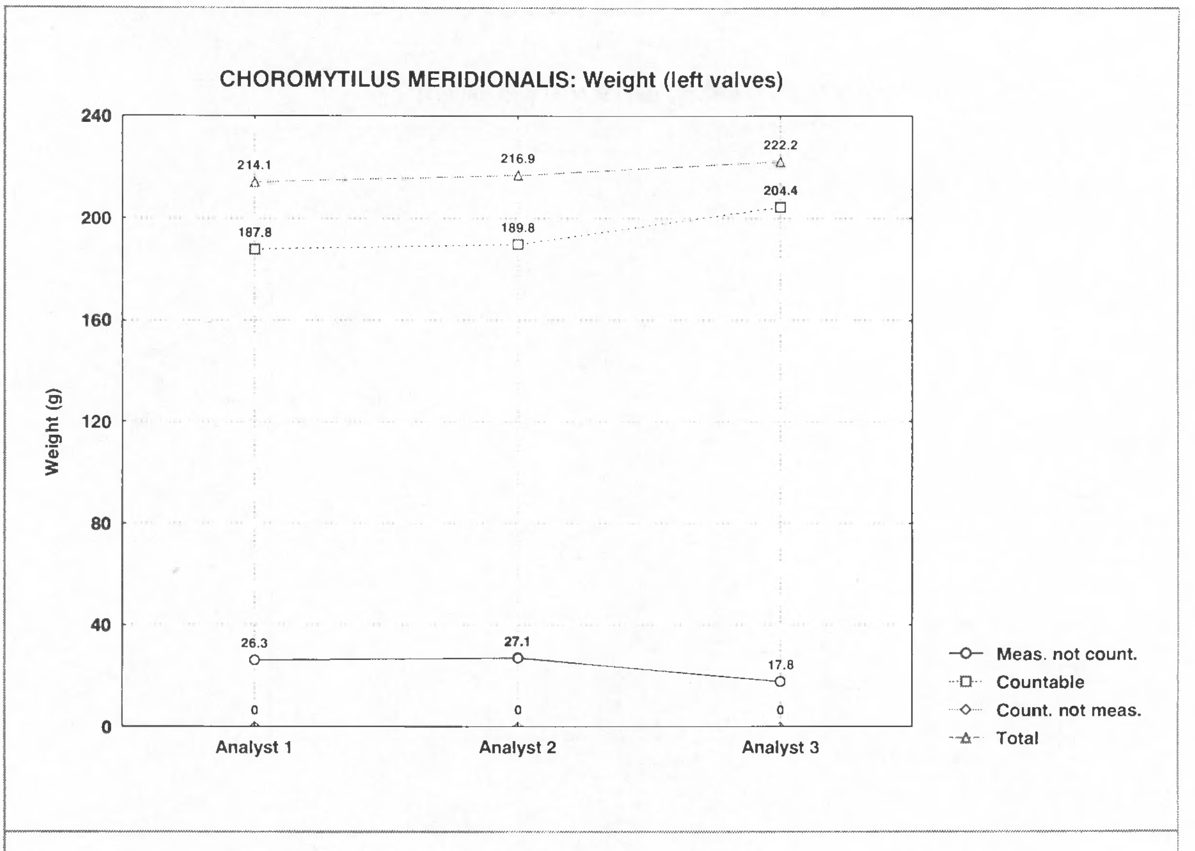


Figure 171: Intra-group shellfish analysis: *Choromytilus meridionalis* MNI (left valves and total). (Top)

Figure 172: Intra-group shellfish analysis: *Choromytilus meridionalis* MNI (right valves and total). (Bottom)



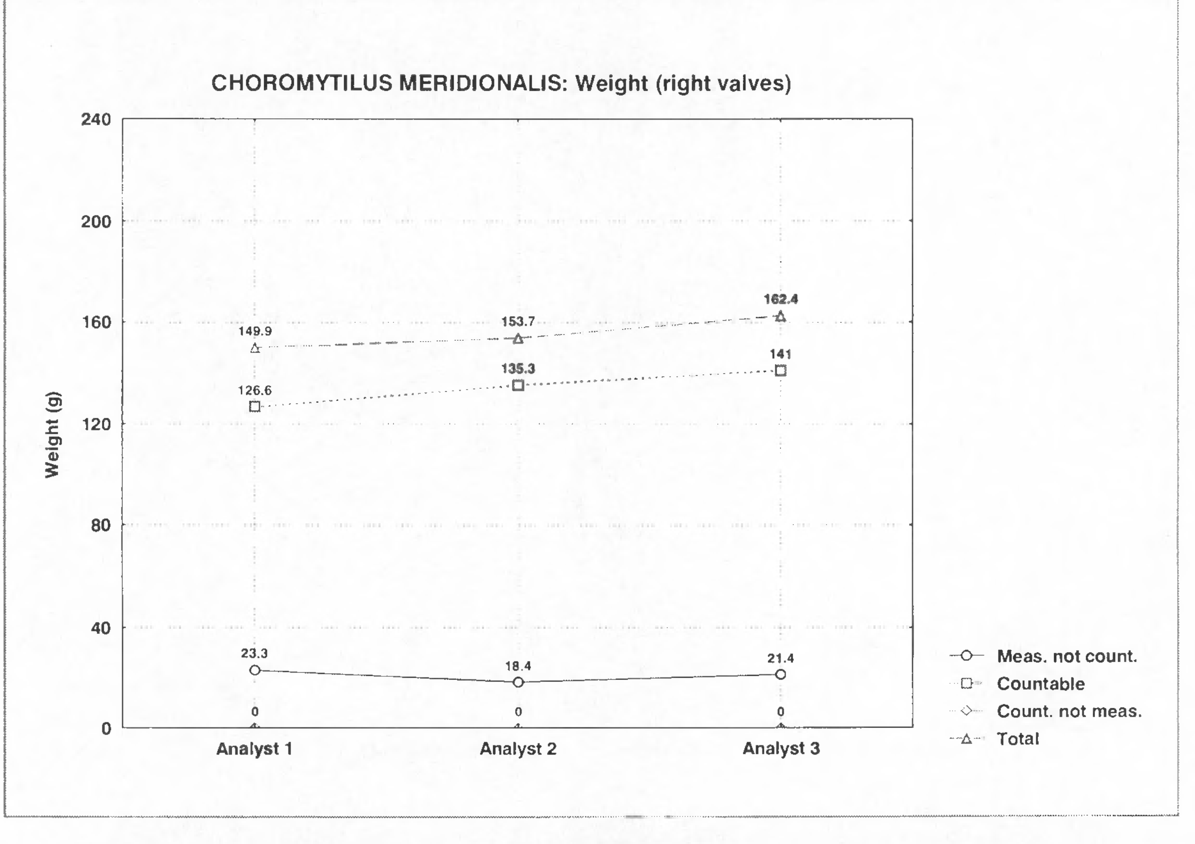
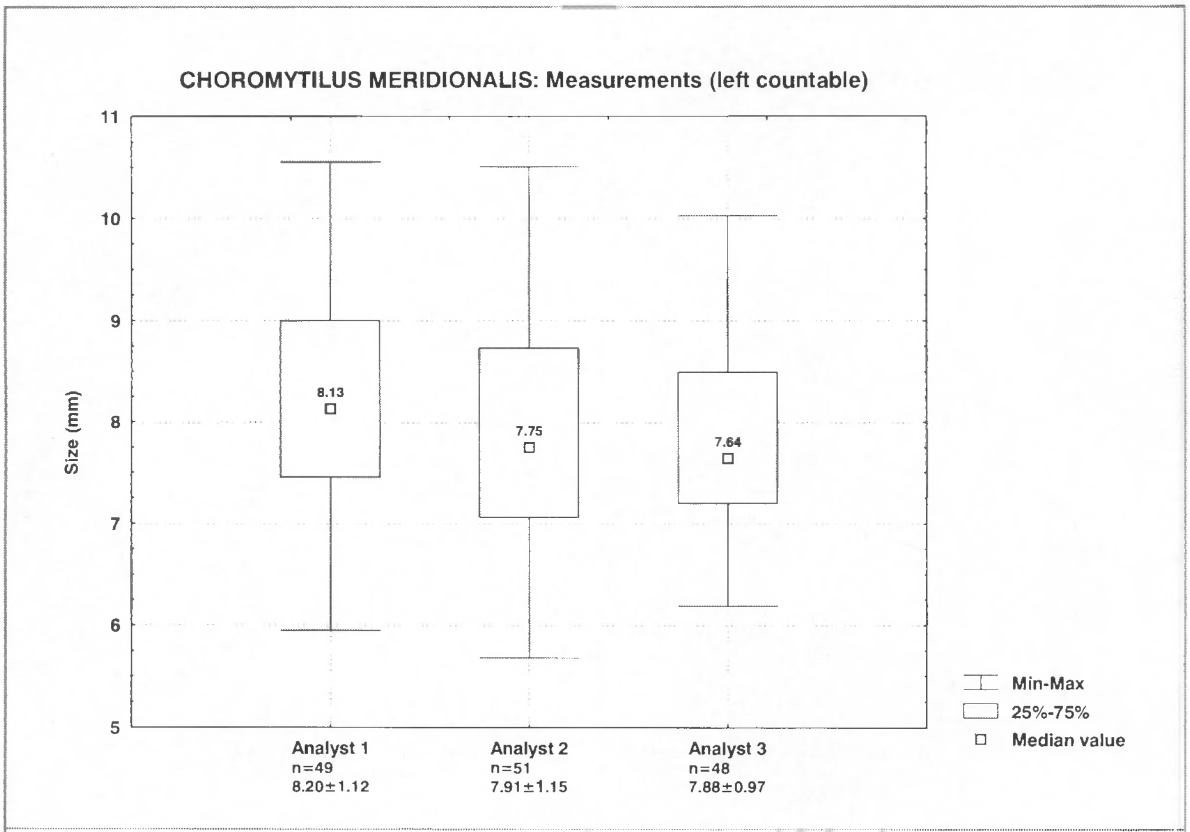


Figure 173: Intra-group shellfish analysis: *Choromytilus meridionalis* weight (left valves). (Top)

Figure 174: Intra-group shellfish analysis: *Choromytilus meridionalis* weight (right valves). (Bottom)



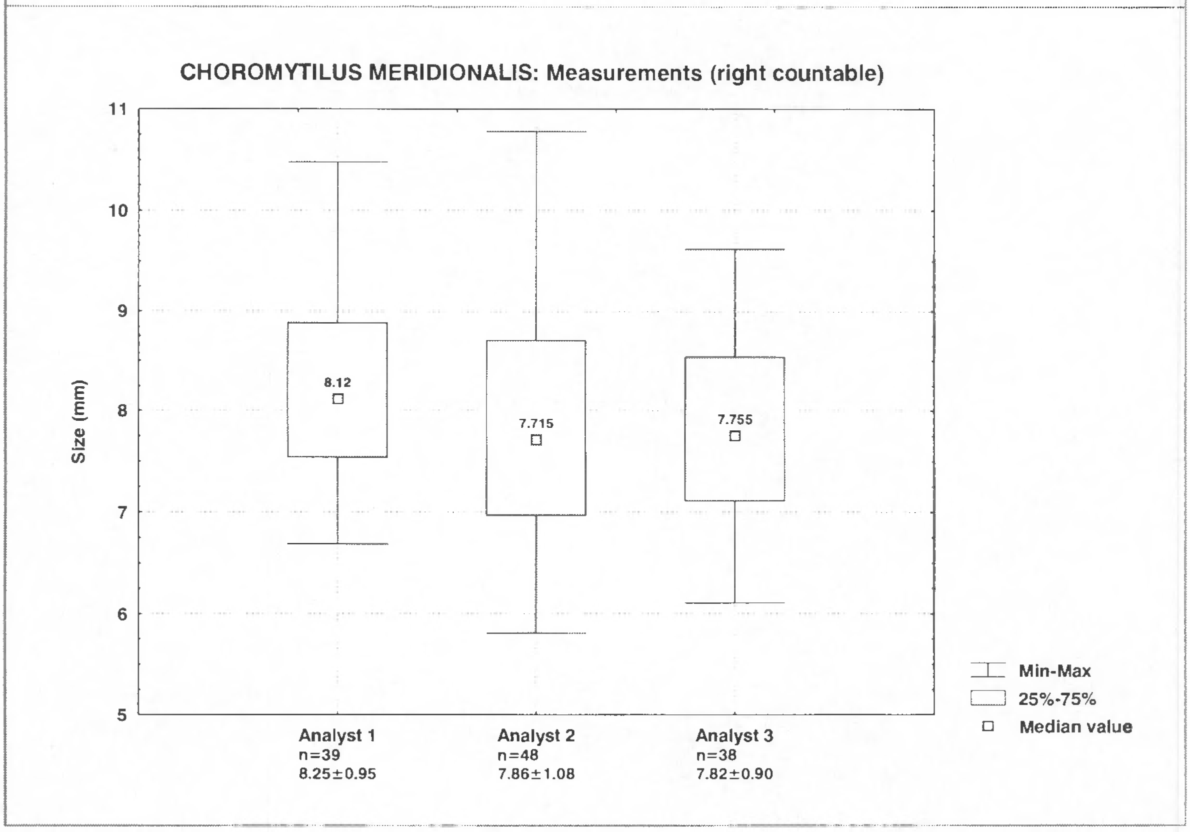
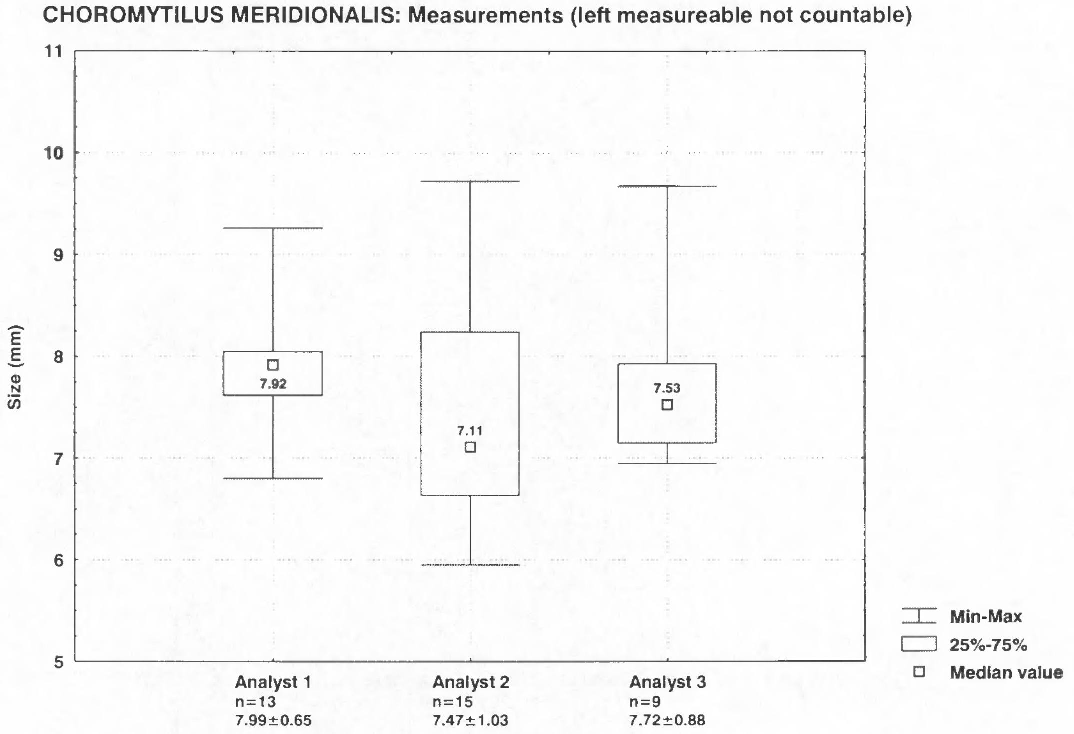


Figure 175: Intra-group shellfish analysis: *C. meridionalis* measurements (left countable). (Top)

Figure 176: Intra-group shellfish analysis: *C. meridionalis* measurements (right countable). (Bottom)



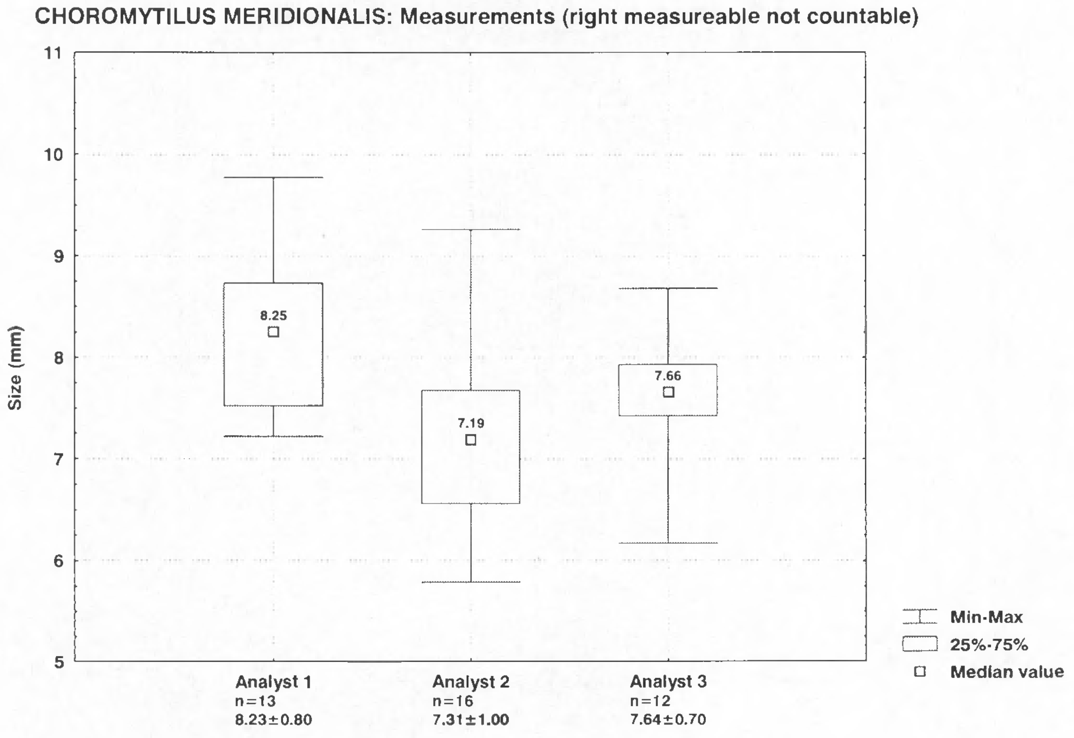
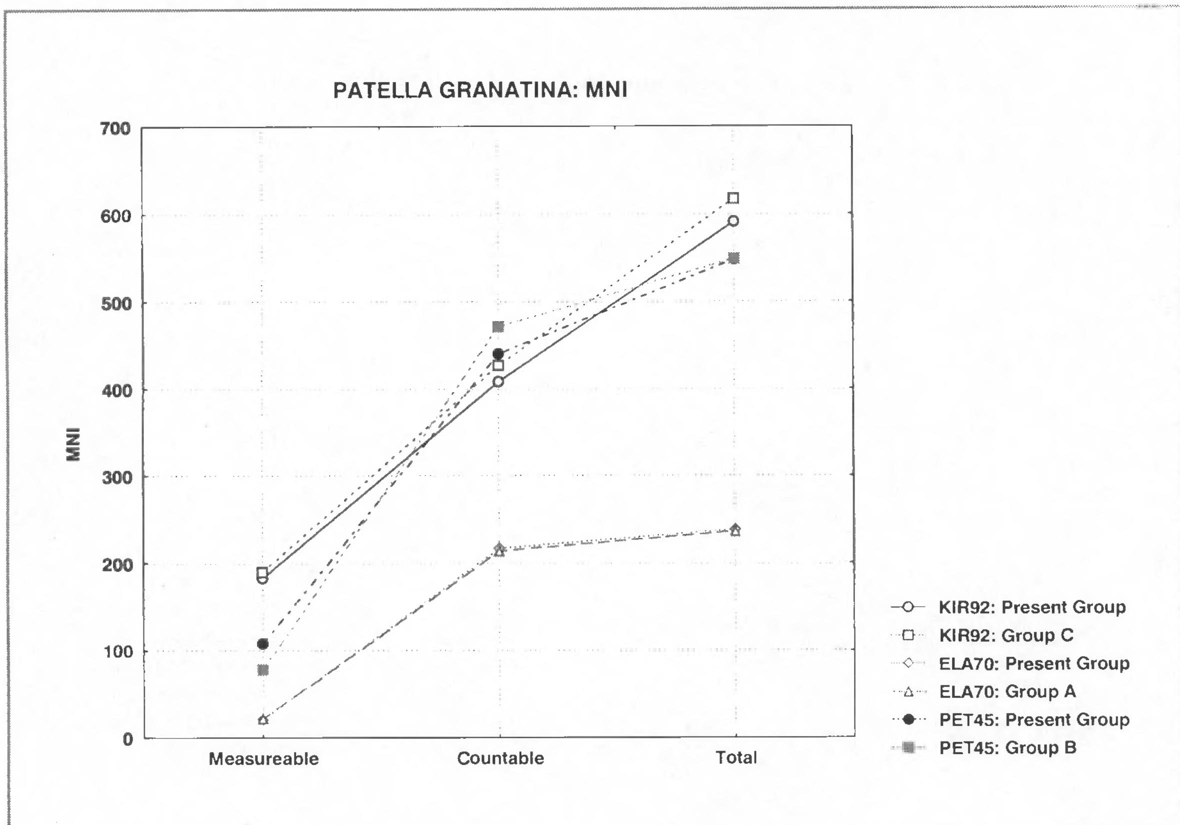


Figure 177: Intra-group shellfish analysis: *C. meridionalis* measurements (left meas. not count.). (Top)

Figure 178: Intra-group shellfish analysis: *C. meridionalis* measurements (right meas. not count.). (Bottom)



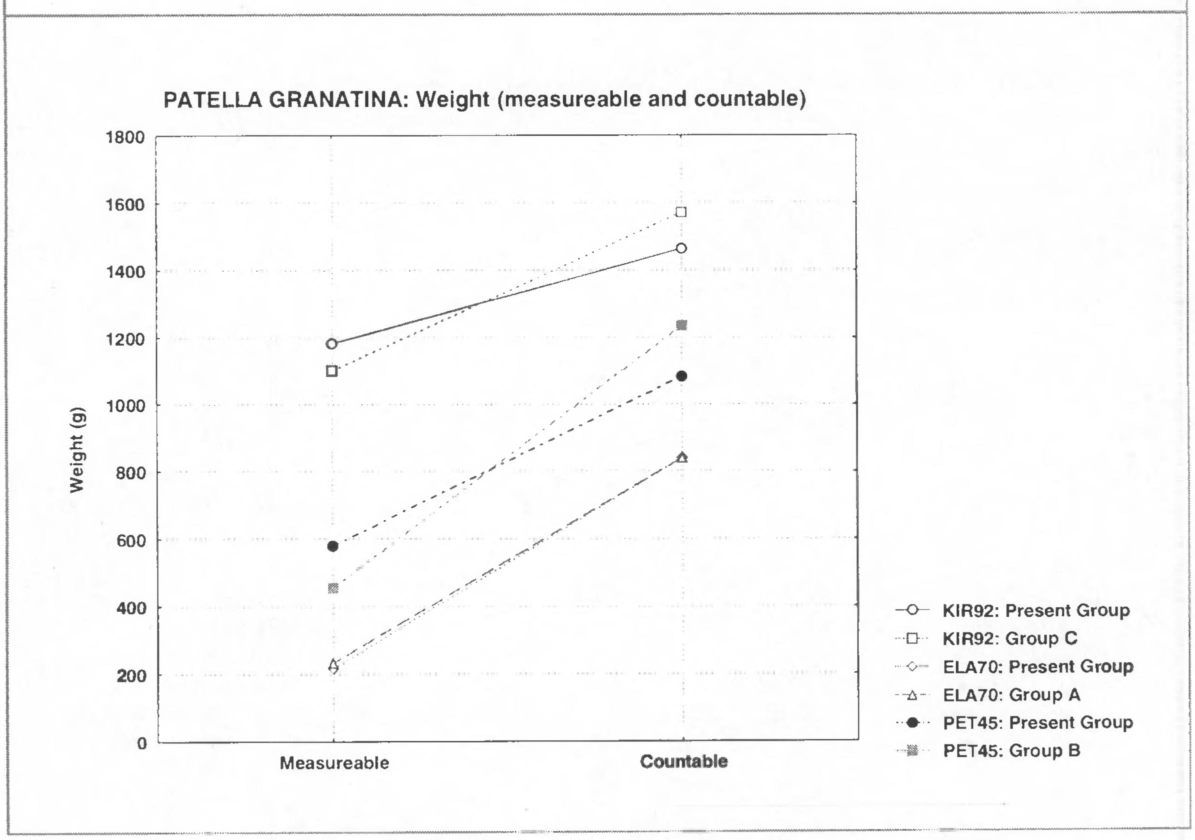
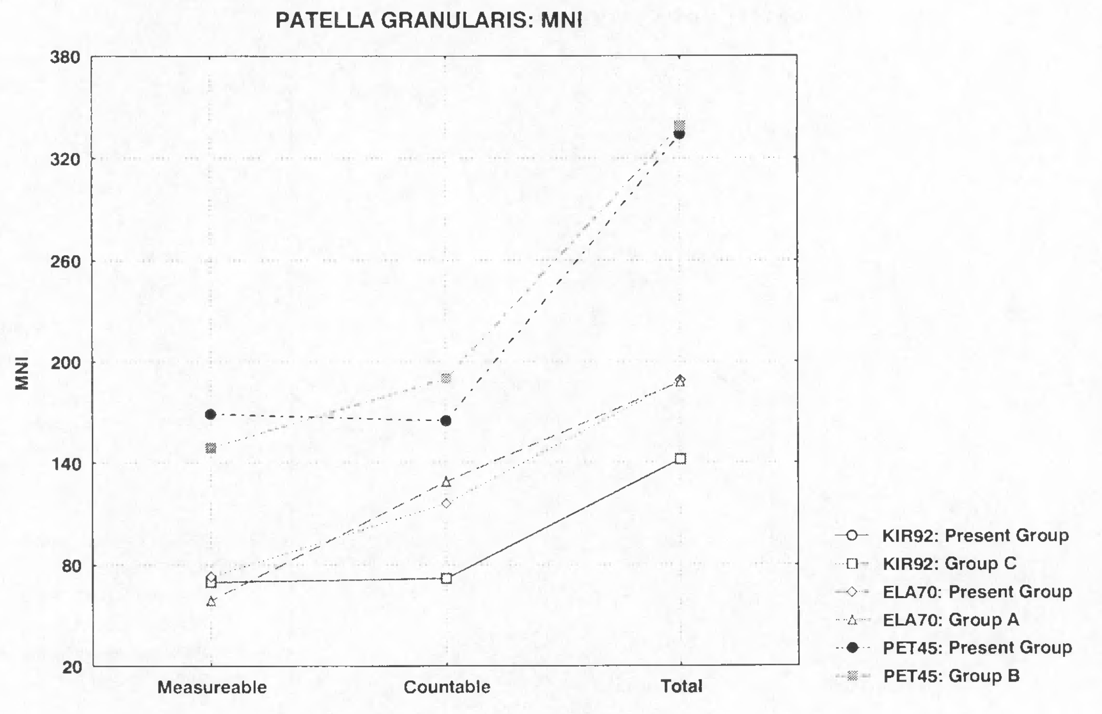


Figure 179: Inter-group shellfish analysis: *Patella granatina* MNI. (Top)

Figure 180: Inter-group shellfish analysis: *Patella granatina* weight (meas. and count.). (Bottom)



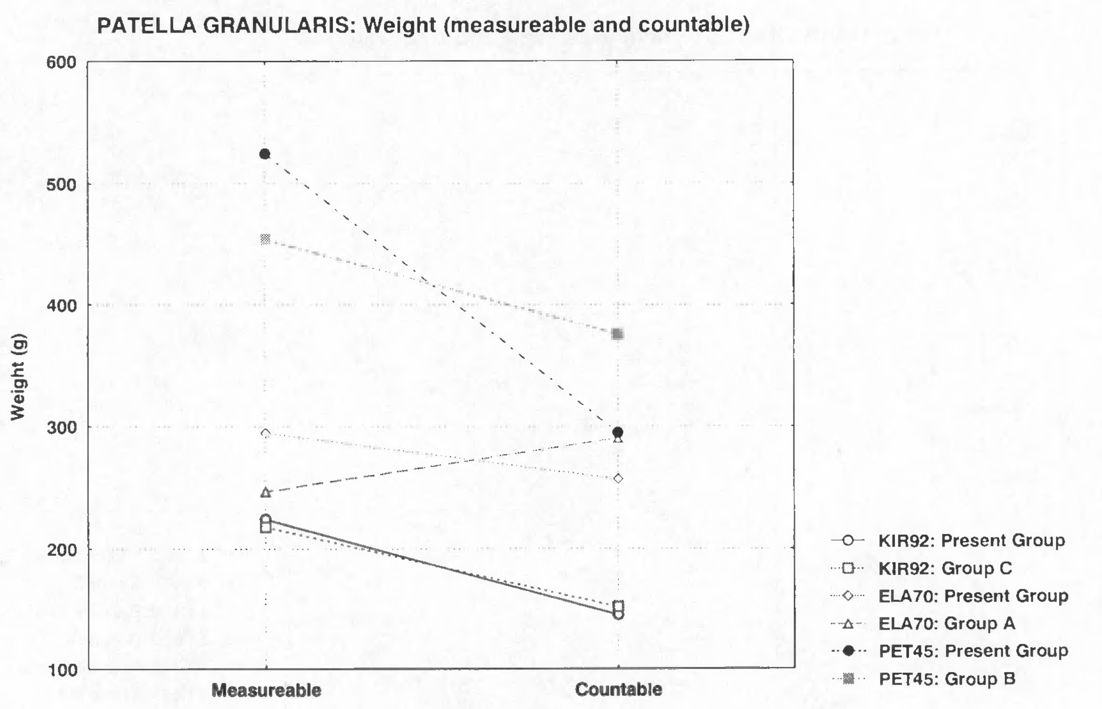
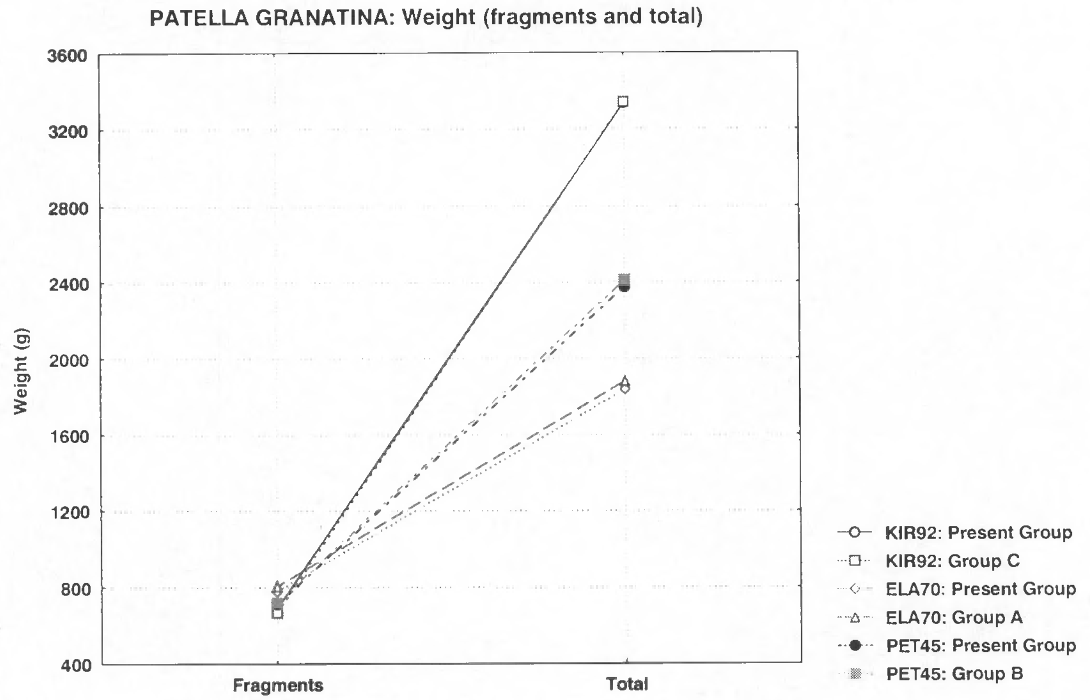


Figure 181: Inter-group shellfish analysis: *Patella granularis* MNI. (Top)

Figure 182: Inter-group shellfish analysis: *Patella granularis* weight (meas. and count.). (Bottom)



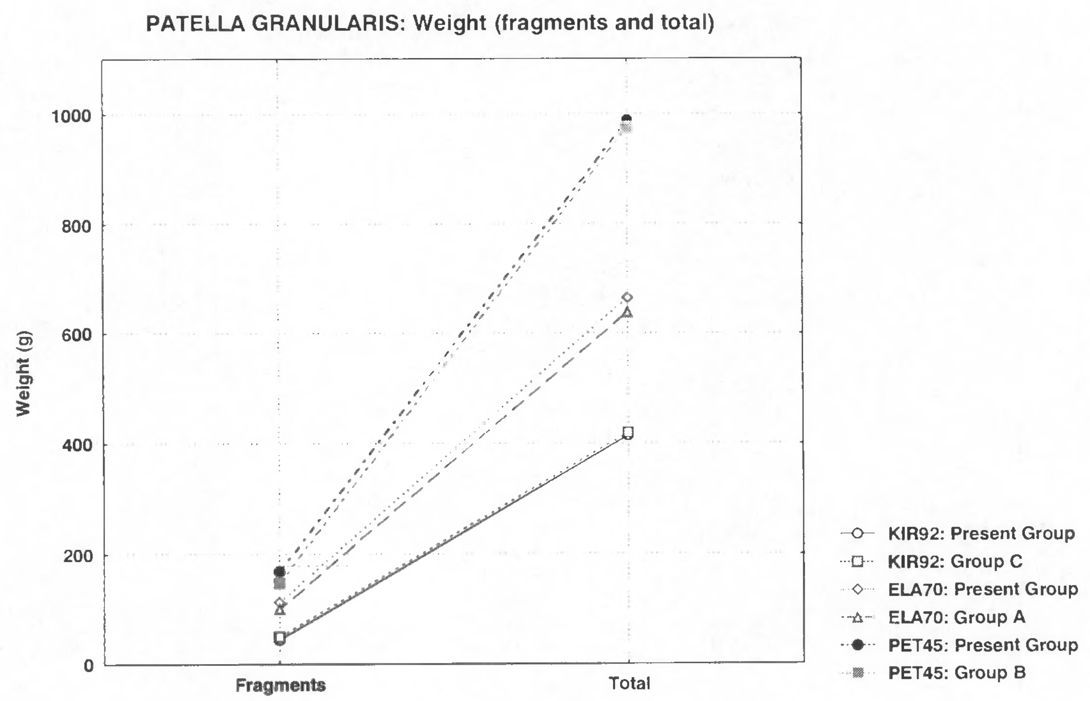
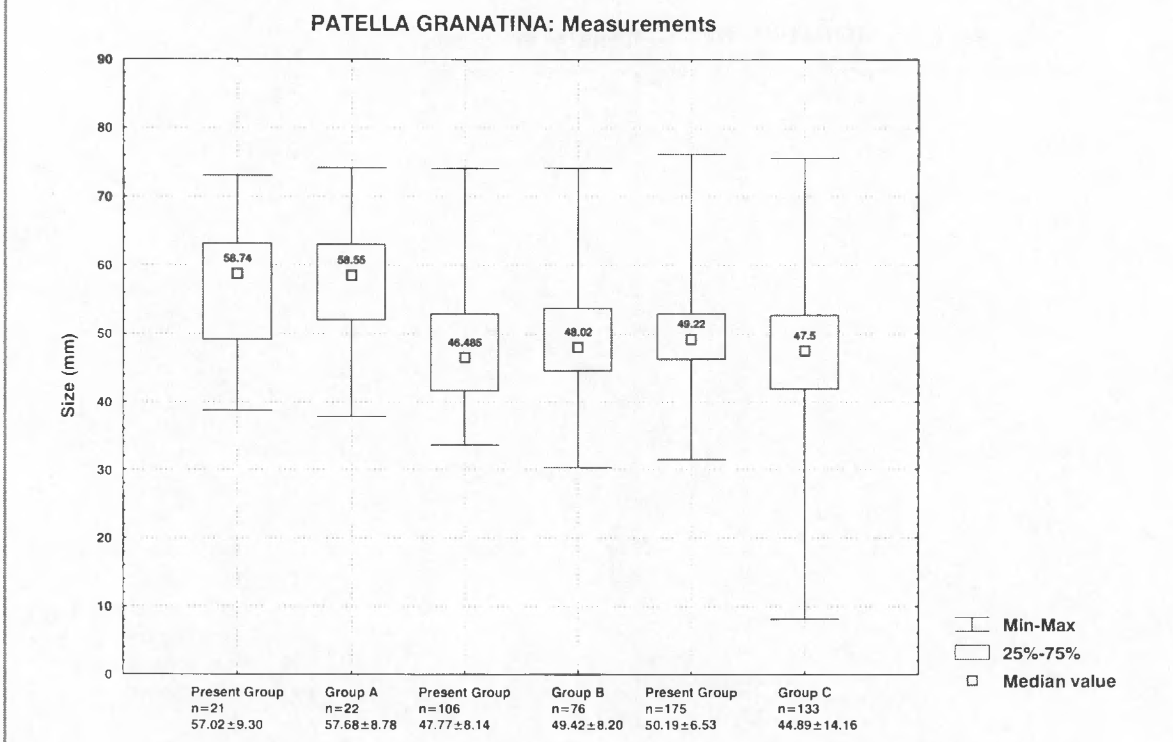


Figure 183: Inter-group shellfish analysis: *Patella granatina* weight (fragments and total). (Top)

Figure 184: Inter-group shellfish analysis: *Patella granularis* weight (fragments and total). (Bottom)



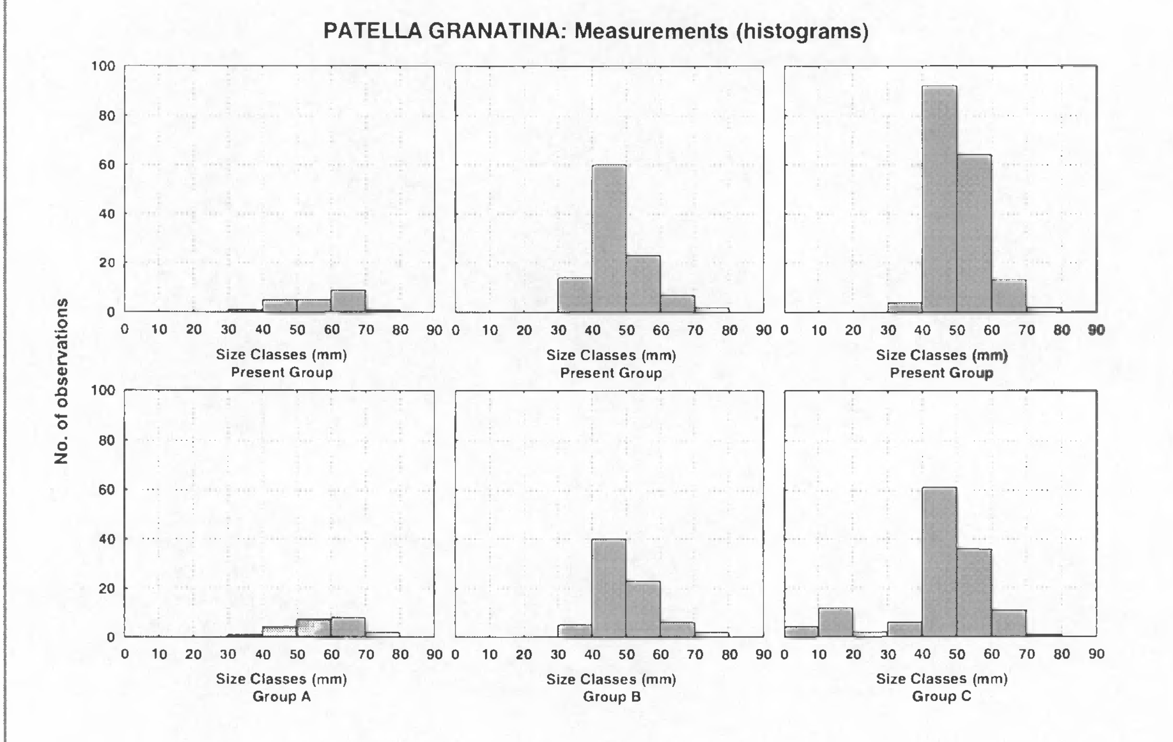
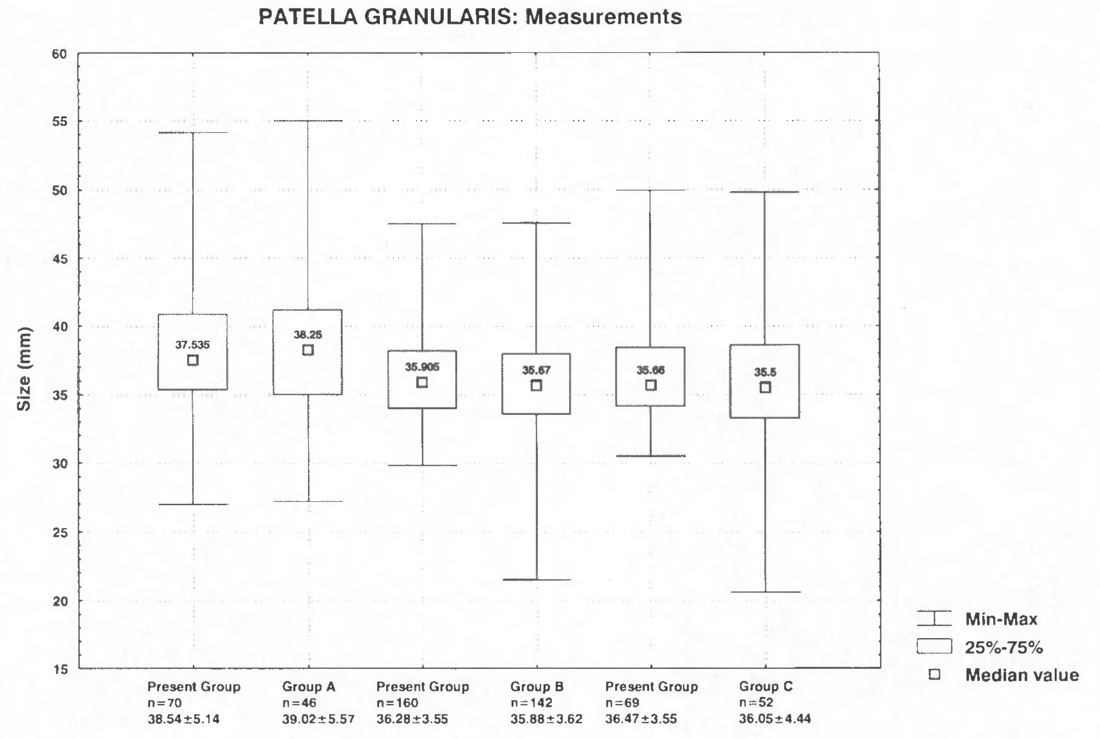


Figure 185: Inter-group shellfish analysis: *Patella granatina* measurements (box plot). (Top)

Figure 186: Inter-group shellfish analysis: *Patella granatina* measurements (histograms). (Bottom)



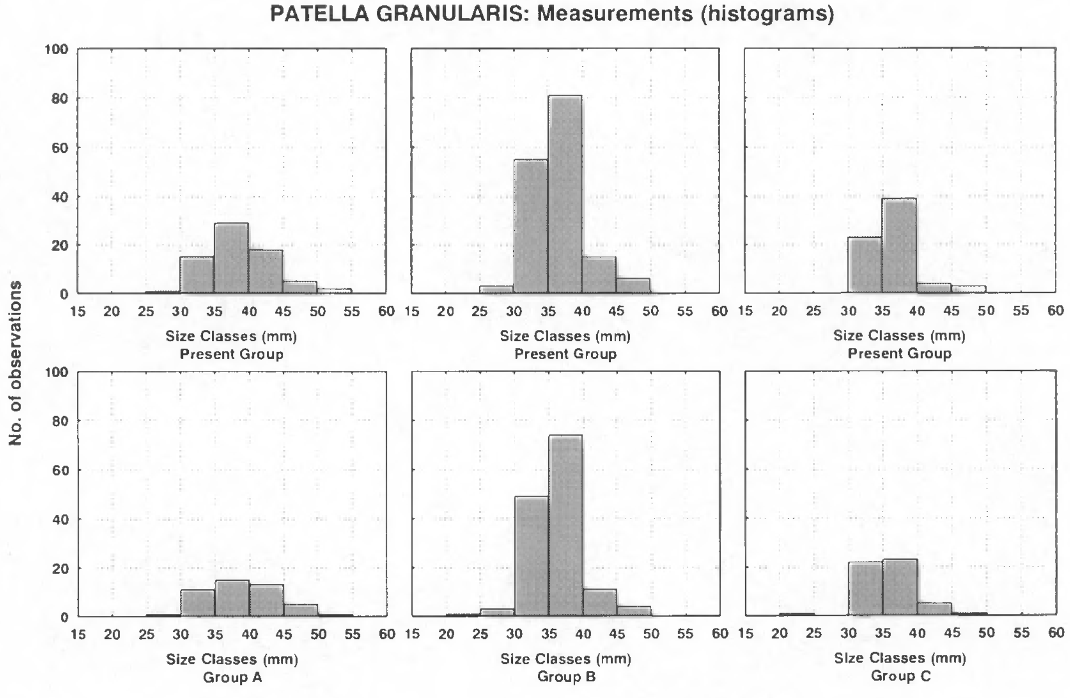
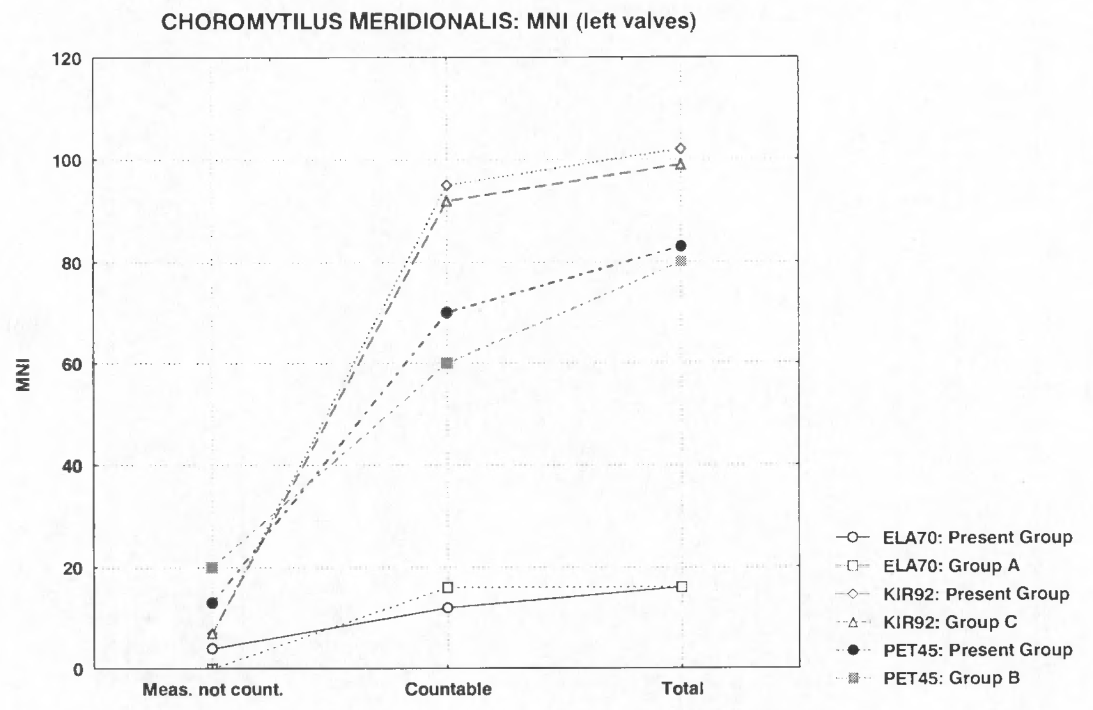


Figure 187: Inter-group shellfish analysis: *Patella granularis* measurements (box plot). (Top)

Figure 188: Inter-group shellfish analysis: *Patella granularis* measurements (histograms). (Bottom)



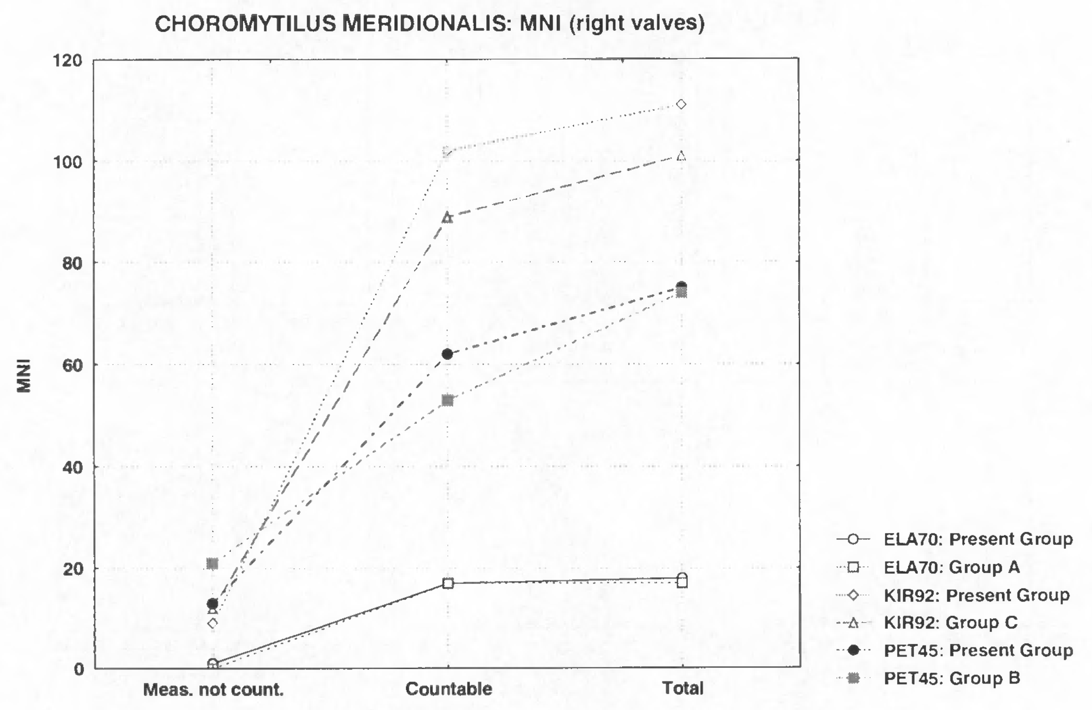
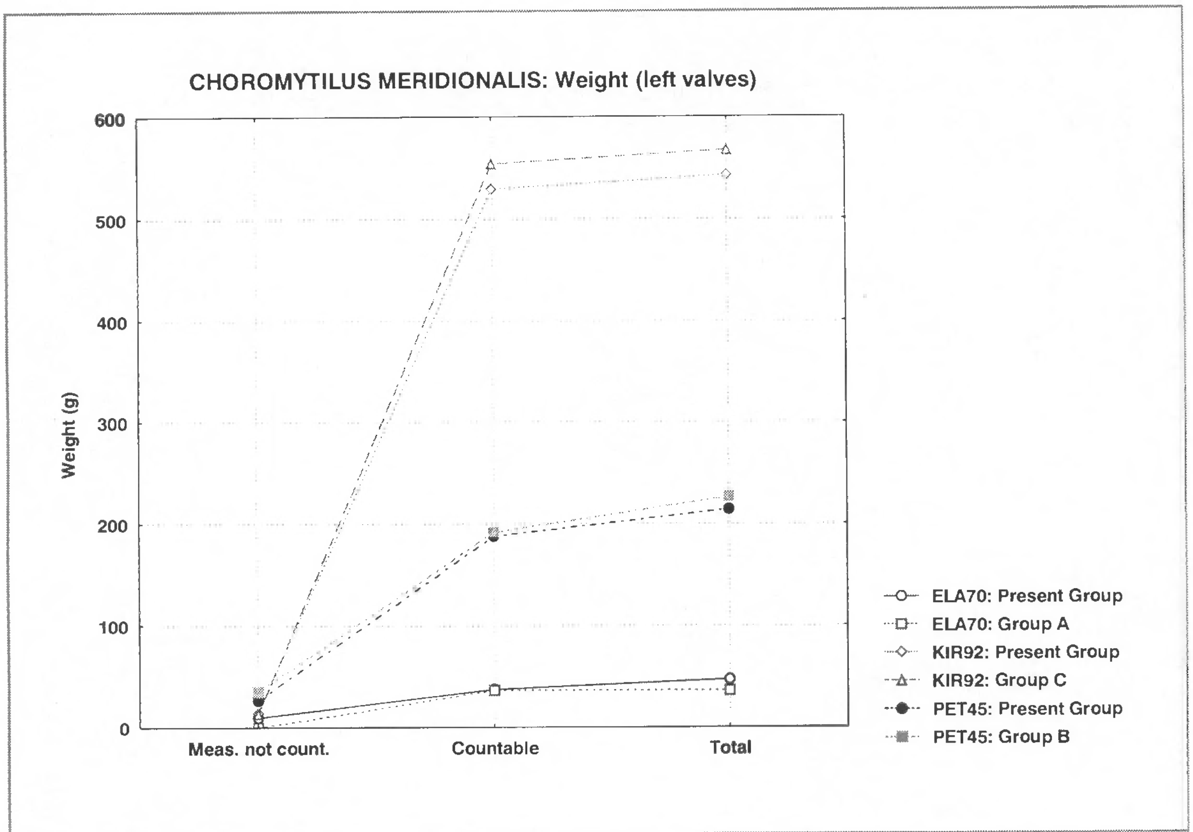


Figure 189: Inter-group shellfish analysis: *Choromytilus meridionalis* MNI (left valves). (Top)

Figure 190: Inter-group shellfish analysis: *Choromytilus meridionalis* MNI (right valves). (Bottom)



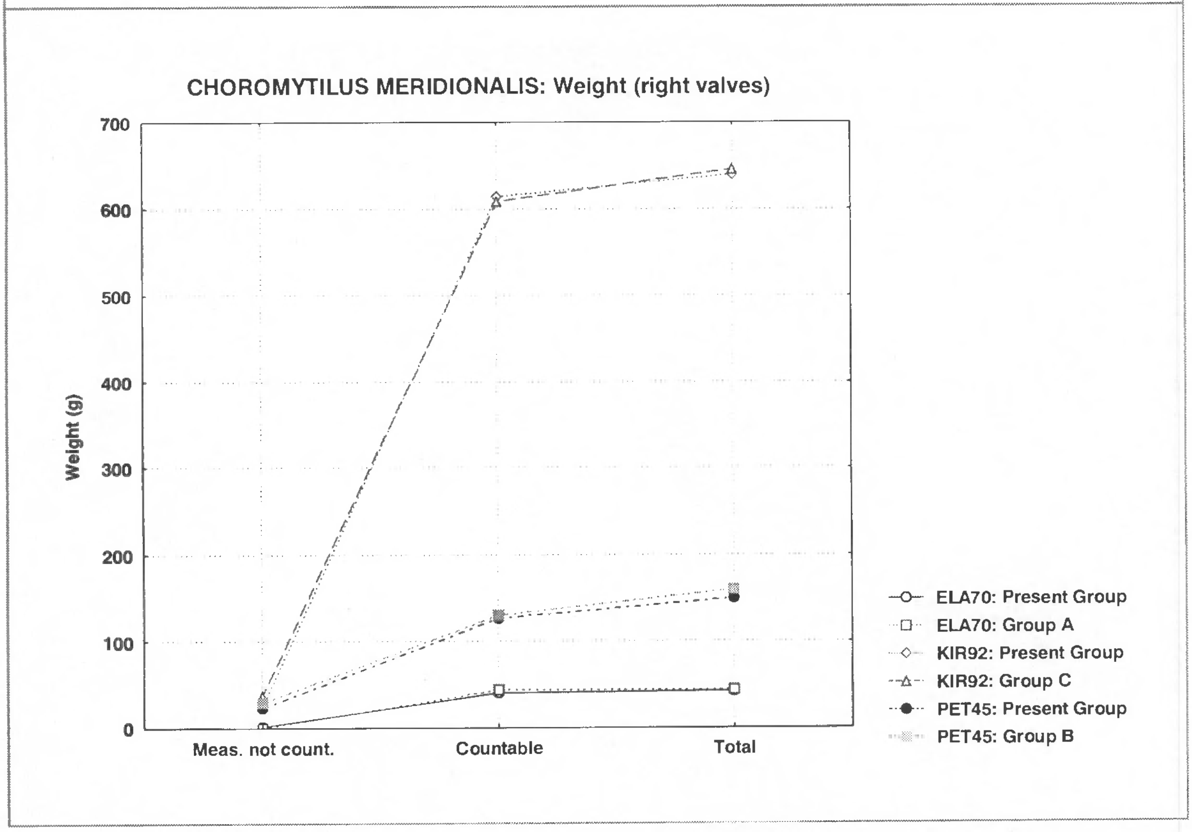


Figure 191: Inter-group shellfish analysis: *Choromytilus meridionalis* weight (left valves). (Top)

Figure 192: Inter-group shellfish analysis: *Choromytilus meridionalis* weight (right valves). (Bottom)

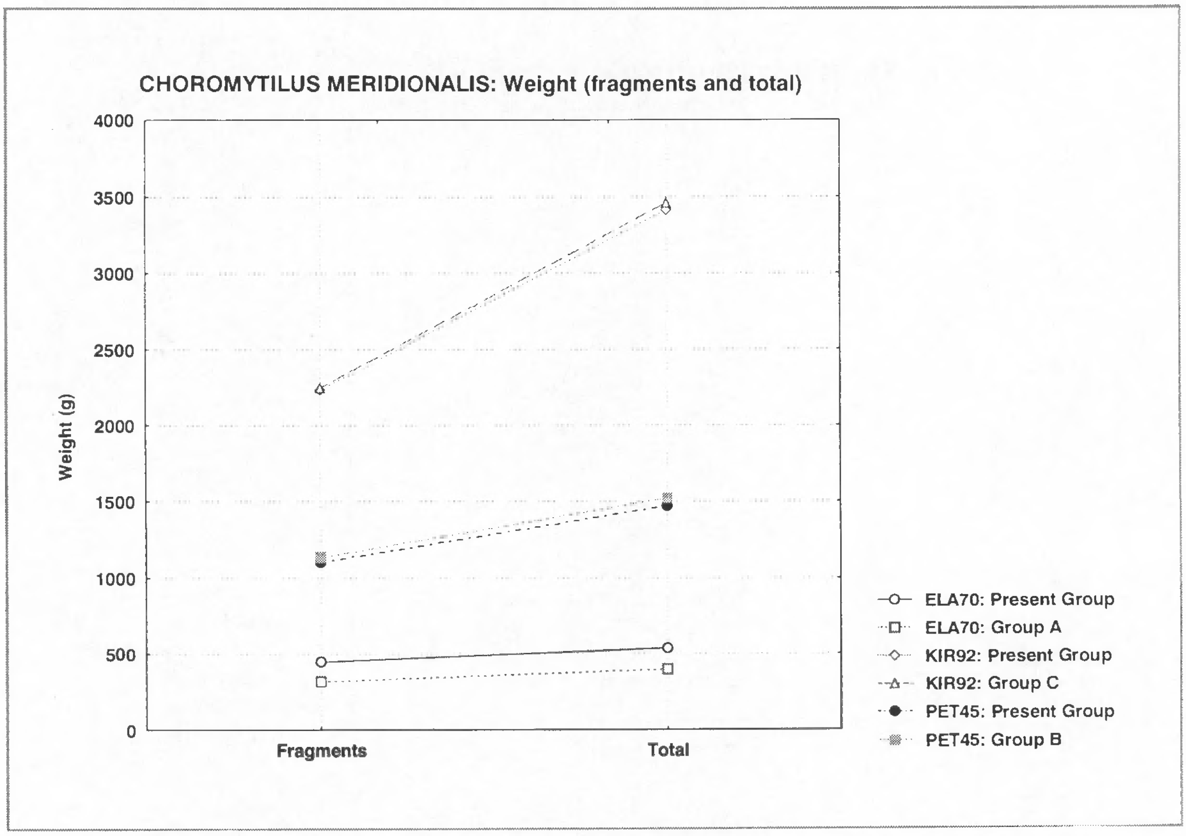
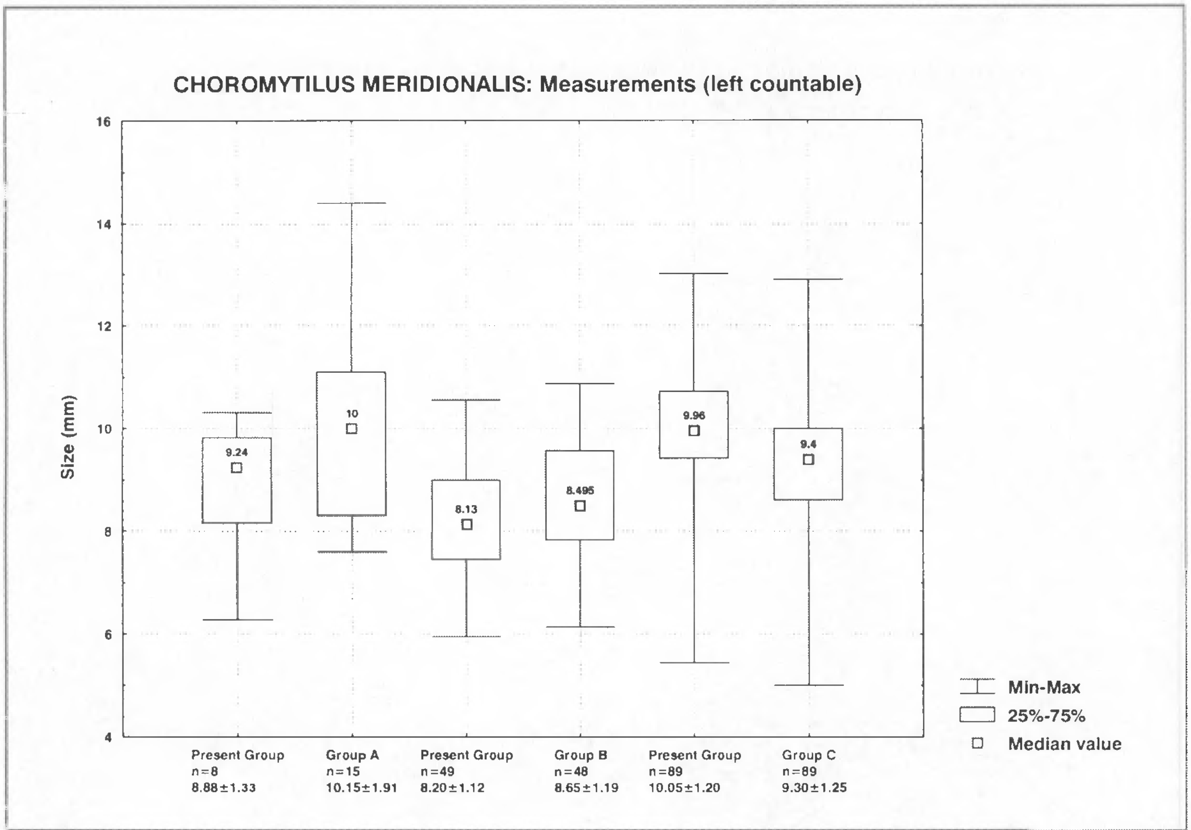


Figure 193: Inter-group shellfish analysis: *Choromytilus meridionalis* weight (fragments and total).



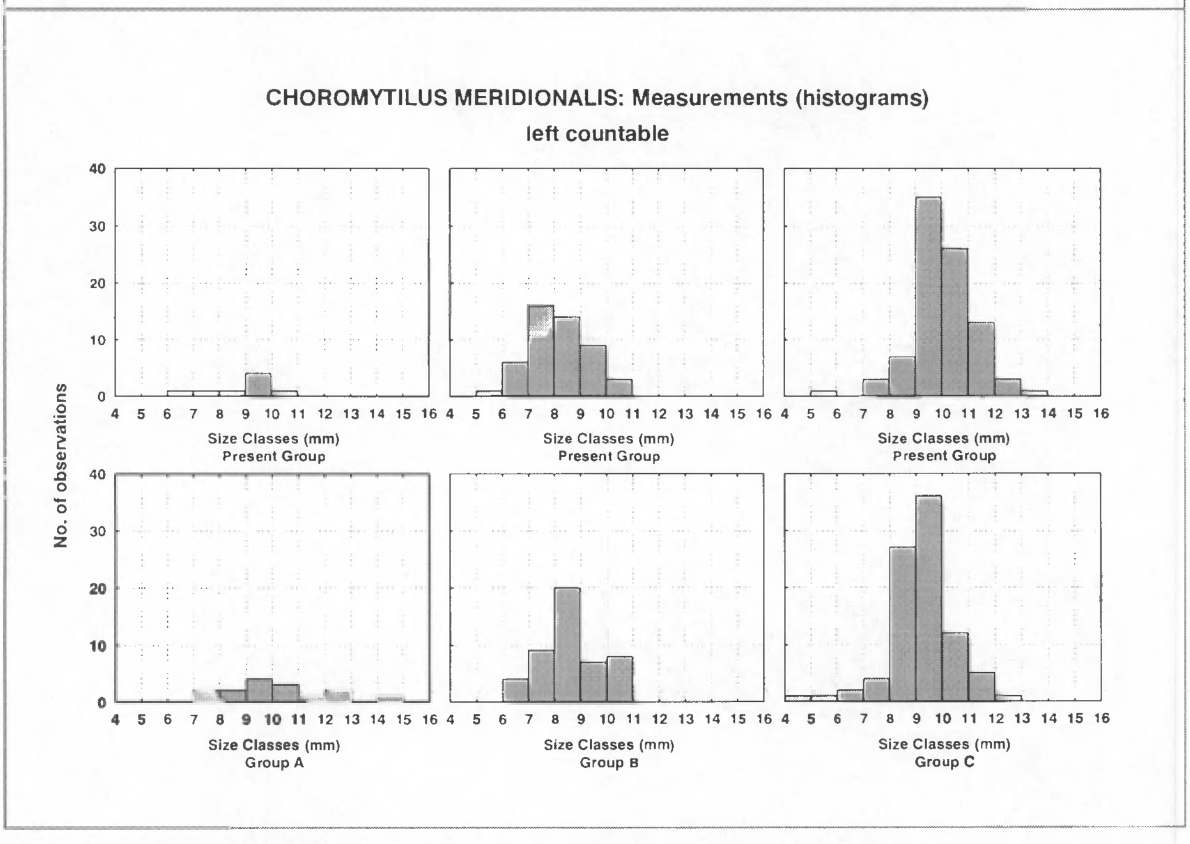
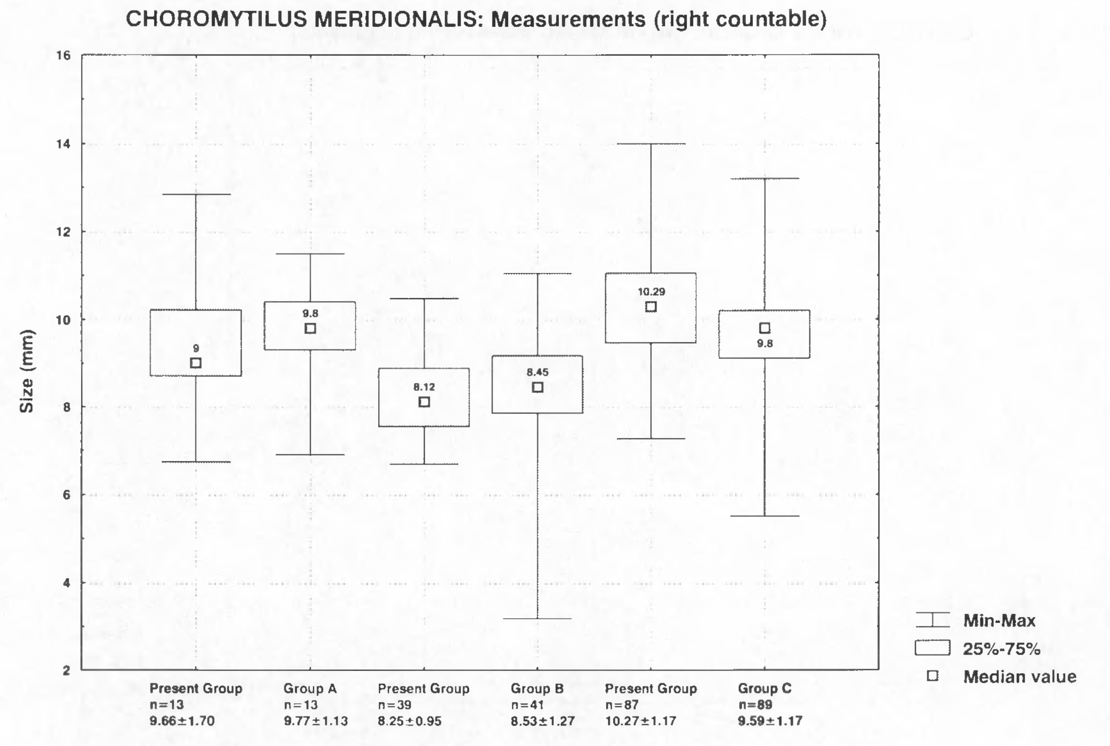


Figure 194: Inter-group shellfish analysis: *C. meridionalis* (left countable) measurements (box plot). (Top)

Figure 195: Inter-group shellfish analysis: *Choromytilus meridionalis* (left countable) measurements (histograms). (Bottom)



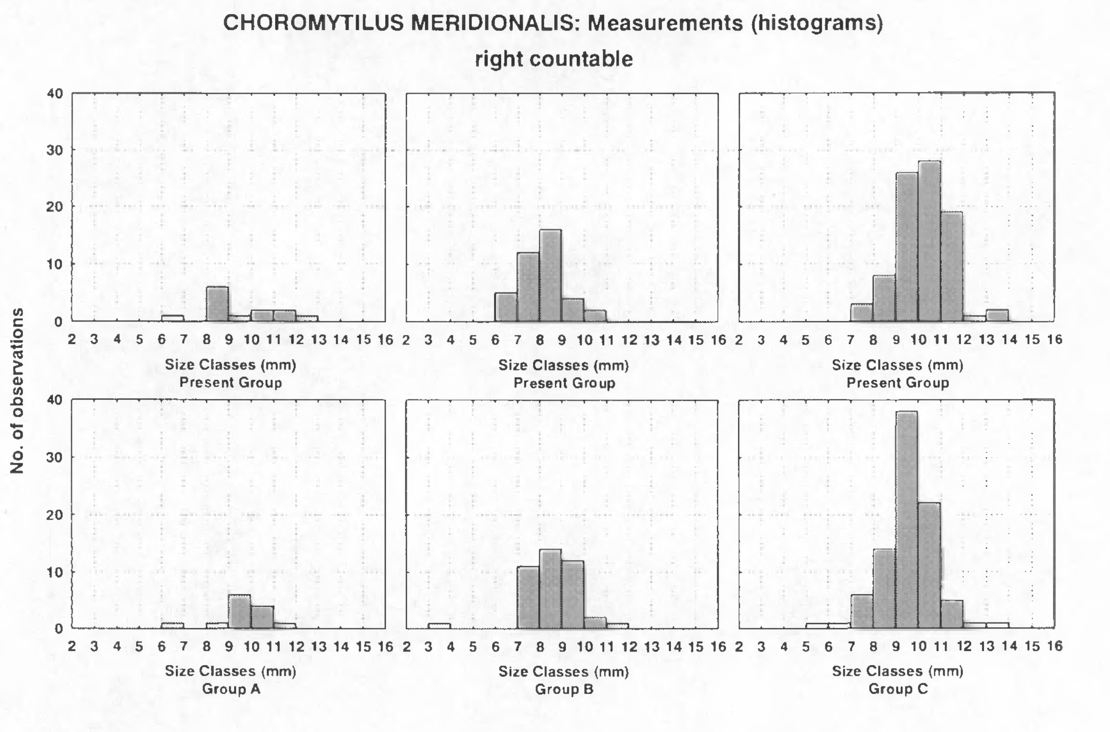
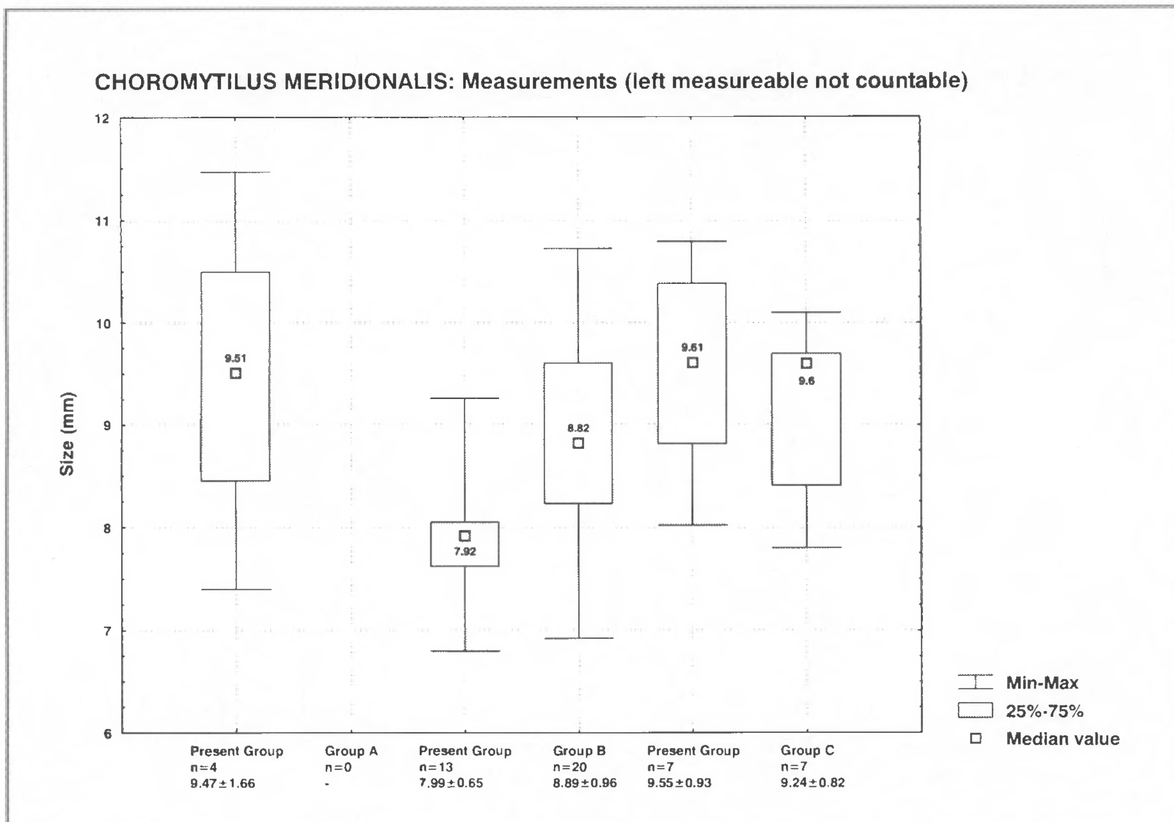


Figure 196: Inter-group shellfish analysis: *C. meridionalis* (right countable) measurements (box plot). (Top)

Figure 197: Inter-group shellfish analysis: *Choromytilus meridionalis* (right countable) measurements (histograms). (Bottom)



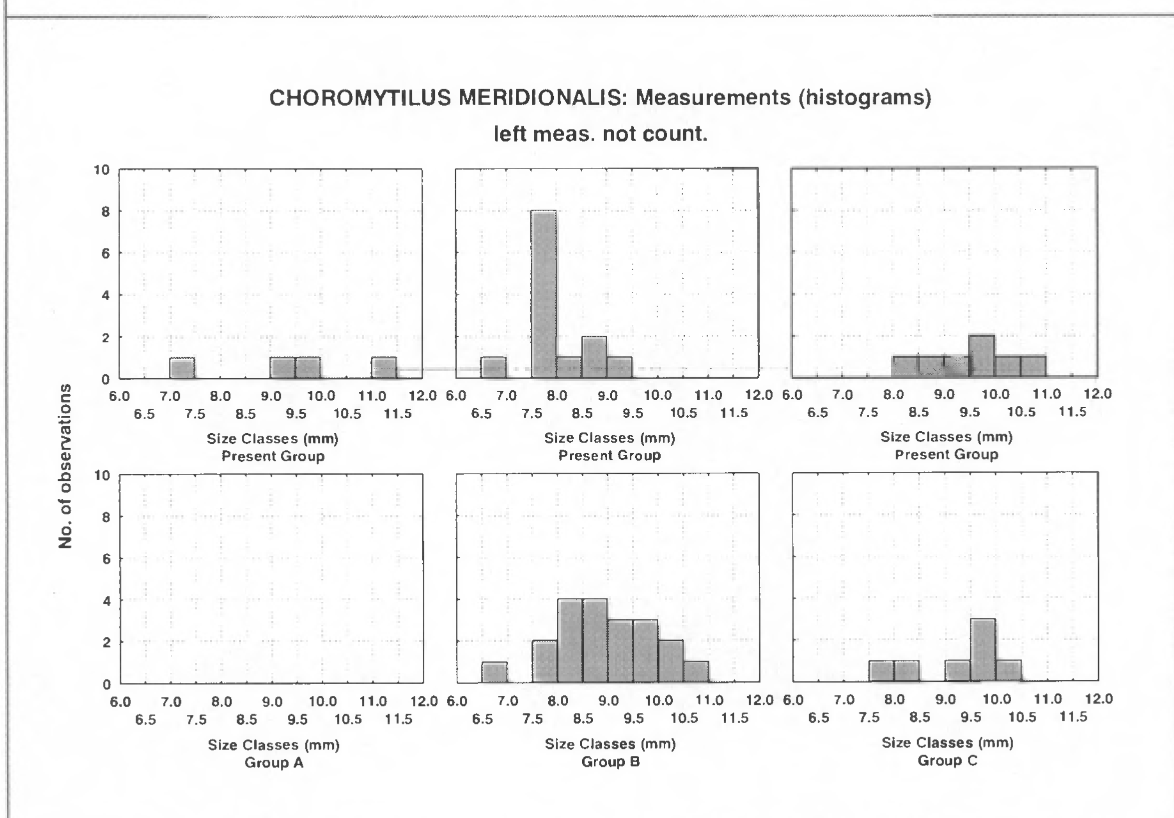
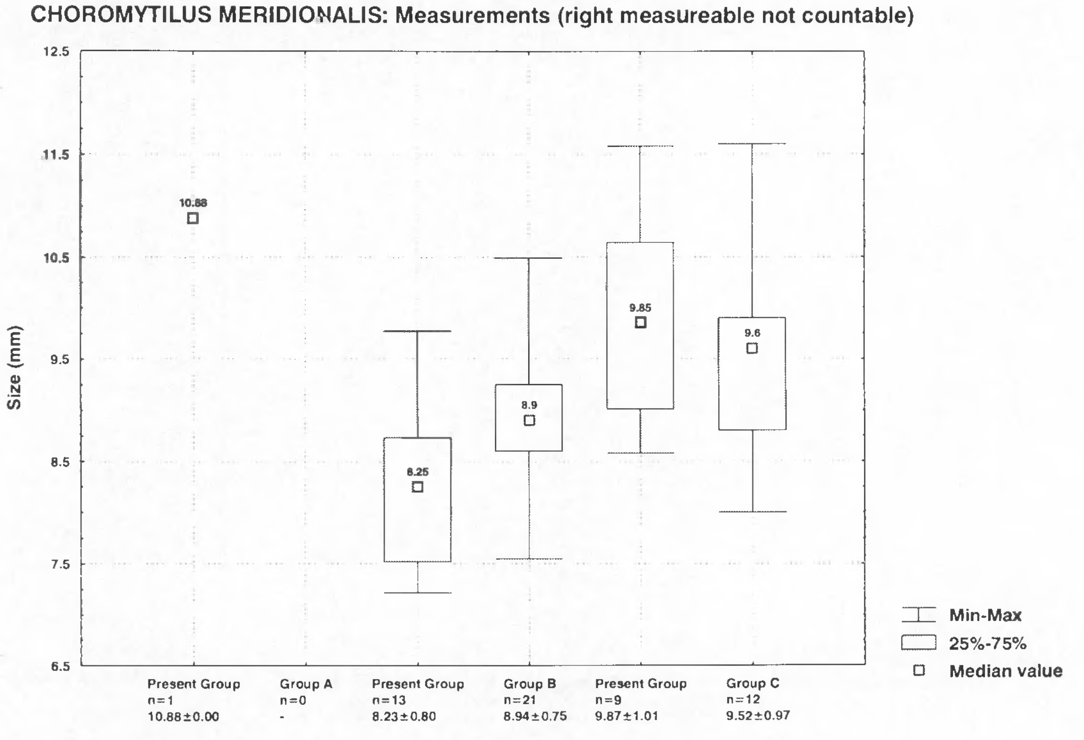


Figure 198: Inter-group shellfish analysis: *C. meridionalis* (left meas. not count.) meas. (box plot). (Top)

Figure 199: Inter-group shellfish analysis: *Choromytilus meridionalis* (left meas. not count.) measurements (histograms). (Bottom)



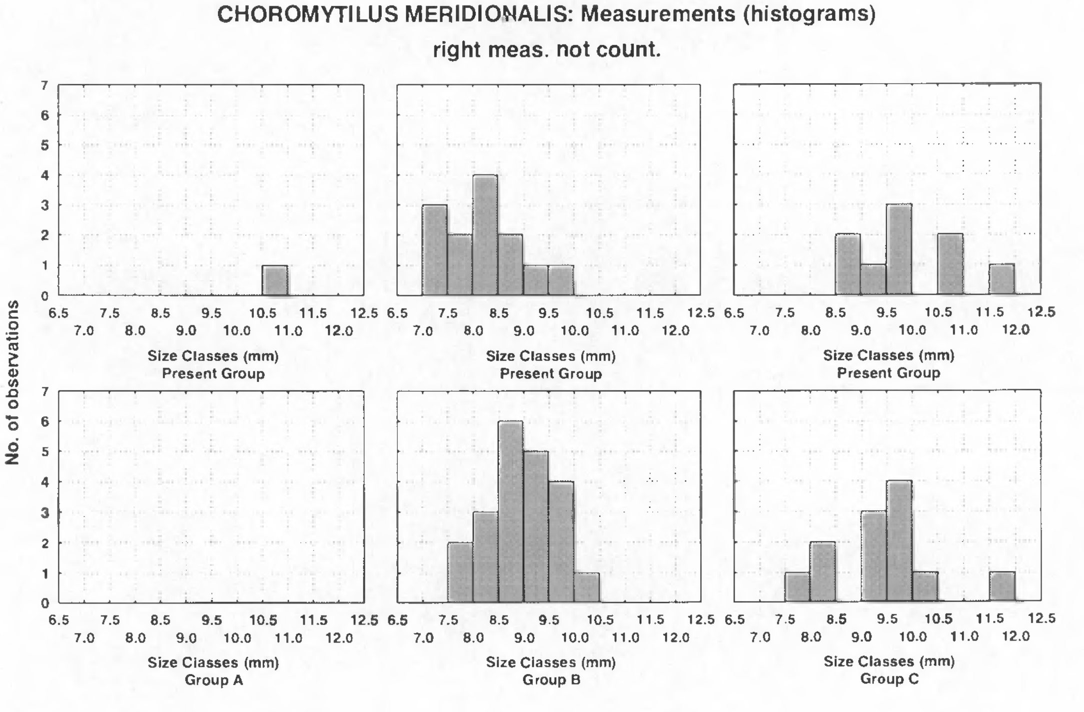


Figure 200: Inter-group shellfish analysis: *C. meridionalis* (right meas. not count.) meas. (box plot). (Top)

Figure 201: Inter-group shellfish analysis: *Choromytilus meridionalis* (right meas. not count.) measurements (histograms). (Bottom)

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