Ancient stonewall fish traps on the south coast of South Africa: Documentation, current use, ecological effects and management implications

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Thesis presented in partial fulfilment for the degree of Master of Science: Applied Marine Science.

March 2006. Zoology Department, University of Cape Town, South Africa.

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This study is dedicated to my parents, with love and gratitude.

DECLARATION

I hereby declare that all the work in this thesis is my own, except where otherwise stated in the text. This thesis has not been submitted in whole or in part for a degree at any other university.

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Lucy Valeska Kemp

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Date

ACKNOWLEDGEMENTS

'favours for *vywers*'

This study would never have been brought to fruition without the conceptualisation, guidance, funding (Andrew Mellon Foundation and National Research Foundation grant-holder bursary and scholarship) and support of Prof. George Branch. I thank him and am yet another loyal one to add to his army of admirers. Dr Colin Attwood is thanked for his insights into the minds of the fishers, the policy makers and the fish. The flights and mapping were generously funded by Jonathan Sharfman and Nikolay Mavrodinov of the South African Heritage Resource Agency. Funding aside, their support and humour as we waited, month in and month out, for that nearly impossible combination of conditions for aerial photography - clear, windless, mist-free skies on a spring tide - is also appreciated.

Dr Julian Smit is thanked for his patience with my endless questions and for his professional approach to getting the *vywers* photographed and mapped despite all the challenges Mother Nature threw our way. Thanks to Guy and Colleen Gardener (Still Bay) and Christo Swanepoel and Ethel Botha (Arniston) for taking in this stranger and giving her board, lodging, stories and beer. To the fishers at Arniston and Still Bay for your patience in teaching me how the *vywers* work, allowing me to tag along and get in the way – 'dank se'. Dr Tamara Robinson and Maya Pfaff are thanked for their efforts in leading me to a calmer appreciation of statistics, and their friendship and support. Andrew Geel is thanked for surveying the *vywers* and making me laugh till I cried.

Also much gratitude to Prof. Heinz Ruther (UCT), Dr Graham Avery (Iziko Museums), Dr Tol Pienaar (Still Bay), Gert Groenewald (for permission to access the OTB sites and much additional information), Dr Judy Sealy, Philip Hine, Thomas Slingsby and Nicholas Lindenberg (GIS at UCT), and Steve Lamberth (MCM) for their professional and patient advice. To my friends Annabelle Wienand and Brendan Maughan-Brown, for their support through both the messy and hilarious times 謝謝您.

ABSTRACT

Ancient intertidal stonewall fish traps are found world-wide and those along the South African south coast are the focus of my thesis. These fish traps, known locally as '*vywers*', have recently enjoyed much media attention as interest increases in both South Africa's cultural heritage and its diminishing fish stocks. Two pioneering studies, by Goodwin (1946) and Avery (1975), provided the only documented knowledge of these *vywers*. My study aimed to locate, survey and document the main concentrations of *vywers* within a 300-km stretch along the south coast. A total of 43 sets of *vywers* was located by aerial surveys, 30 of which are only accessible through private land. This affords them some measure of protection, together with five located off reserves, but diminishes their educational and tourism value. Four sets of *vywers* were mapped in detail using aerial photogrammetry, a method that provided a rapid, extensive, accurate survey record in the form of geo-rectified ortho-images of these sites. The *vywers* are built in both exposed and sheltered environments, constructed from *in situ* rock material built into walls with either angular or curved shapes. These walls may occur singularly or in complexes of up to 25 traps. *Vywers* are prone to decimation by wave action and storm damage and so require maintenance to retain their characteristic form and associated cultural information.

Tensions have, however, arisen between those who maintain and fish the *vywers,* and fisheries managers. Data from a questionnaire survey compared with records from the literature showed that species composition has not changed significantly in the last five decades. The fish are caught most frequently during new-moon spring-tides, especially in the winter months. The *vywer* fishery, currently active at only two sets of *vywers*, targets primarily mullet species (mostly *Liza richardsonii*) but infrequently enjoys 'bonanza' catches of over-exploited linefish stocks such as galjoen *Dichistius capensis*. It is these latter catches that concern managers, in addition to the non-compliance of fishers in terms of catch composition and size, permits and gear. I offer recommendations for ameliorating 'by-catch' of these vulnerable species as part of a research programme that is designed to yield long-term data on the impact of *vywer*-fishing.

The original builders of the *vywers* may also have had an understanding of how *vywers* alter the rocky-shore invertebrate community. Sampling was conducted at four sets of *vywers*, both on the *vywer* walls and at adjacent control sites. I found that the *vywer* walls host a significantly different assemblage when compared to adjacent natural control sites, in addition to the effects of shore-height and wave exposure. This difference appears in terms of biomass, number of species and overall diversity, all of which were greater in *vywer* walls than control sites. When compared with solid natural rock and artificial surfaces such as the walls of tidal pools, *vywers* exhibited higher physical heterogeneity, which was inversely related to stability. With man-made developments in the intertidal zone on the rise, *vywers* offer a greater understanding of how their impacts can be ameliorated to diminish loss of biodiversity.

GENERAL INTRODUCTION

Intertidal fish-traps, consisting of stone walls built by coastal dwellers as long as 3500 years ago (Avery 1975), are becoming an intriguing attraction for visitors to the Western Cape coast of South Africa. Analogous fish traps, built by aboriginal fishing communities, are found worldwide, and relict traps have been found in Australia and Tasmania (Stockton 1982, Bandler 1995, Johannes & Yeeting 2000), Taiwan (Cheng-Hwa 2001, Bender 2004, Chiung-fang 2005), Alaska (Livley 1997) and Wales (Bannerman & Jones 1999).

South Africa has a number of extant fish traps, known locally as '*vis-vywers*' (Afrikaans for 'fish ponds' and referred to hereafter as '*vywers*'), with the majority found along the south-west coast between Danger Point and Mossel Bay, a few scattered on the west coast and reports of some potential examples on the east coast (Anon. 1992, Breetzke 2004, A. Booth pers. comm.). Only two studies have dealt with South African fish traps in any detail. Goodwin (1946) discussed prehistoric fishing techniques whereas Avery (1975) estimated the age of the *vywers* and offered inferences about their original uses based on modern use and techniques.

In his review of the *vywers*, Gribble (2005) stated that for these "ocean baskets", "....very little is known about the extent, precise location, age and archaeological associations of these sites". A nationwide initiative by the South African Heritage Resource Agency (SAHRA), called the National Survey of Underwater Heritage (NSUH) and funded by the National Lottery, started a survey to document all underwater heritage sites, including the *vywers*. The survey and documentation of *vywers* forms the first chapter of this thesis and was conducted in collaboration with SAHRA to ensure that their NSUH goals were met (Anon. 2004).

Some *vywers* have been reported as still being maintained and used, but management of the fishing within these *vywers* is difficult. The fishers see themselves as volunteer preservationists of a valuable cultural heritage resource and so exempt from many of the fishing regulations that apply elsewhere. However, it is unknown whether the 'fishery' is sustainable since occasional large catches of threatened species may damage the viability of local fish populations. The second chapter of this thesis provides details of current fishing practices and offers insights for better management of the *vywers*.

It is thought that *vywers* provide evidence of the earliest constructed coastal walls in southern Africa (J. Sealy pers. comm.). This is of ecological interest since in recent years much has been published on the effects of development in the intertidal zone including the 'hardening' of soft-sediment substrata (Branch et al. in press). I postulate that construction of the walls would have altered the structure and composition of the invertebrate communities within *vywers*. Transformation of the dynamic system of boulder shores to a more stable rocky-shore-like habitat is predicted to have had an effect on overall species diversity and richness. An analysis and discussion of the invertebrate communities at a selection of *vywers,* in comparison with those on adjacent shores unaffected by *vywers,* forms the basis of Chapter 3. Much has been written about the effects of modern artificial sea-walls (Walker 1988, Ambrose & Anderson 1990, Holloway & Connell 2002, Chapman 2002, 2003, Qiu et al. 2003, Bulleri & Chapman 2004) but this is the first research to identify the community effects of equivalent archaeological structures.

My study aims to answer the following questions within each of the chapters described above:

i) Where are and what is the state of repair of the *vywers*?

ii) What is the current harvest from these *vywers* and what, if any, are the conservation implications?

iii) Has the movement and consolidation of boulders and rocks into *vywers* altered intertidal communities?

CHAPTER 1

LOCATION AND DOCUMENTATION OF PRECOLONIAL STONEWALL FISH TRAPS ALONG THE SOUTH AFRICAN SOUTH COAST

INTRODUCTION

Intertidal stonewall fish traps ('*vywers*') found along the south coast of South Africa have only recently been legally recognised for their cultural significance, with a set of operational *vywers* at Still Bay being the first to be declared a National Cultural Heritage site, in 1997 (Anon. 1997a). Only two other sites have been registered on the database of the South African Heritage Resource Agency (SAHRA). This low level of formal recognition is curious, considering that *vywers* constitute some of the earliest walled structures in southern Africa, being dated at being between 3500 and 1700 years old (Avery 1975), and that they provide insight into the importance of marine resources in the diet of the region's early inhabitants.

The UNESCO Convention on the Protection of Underwater Cultural Heritage (2001) highlights the importance of accurate documentation and *in situ* preservation of maritime archaeological sites as basic priorities for national conservation authorities. Documentation, monitoring and maintenance of *vywers* are particularly important because they deteriorate in the face of tidal action and waves, with concomitant loss of associated cultural information. V*ywers* are accessible to the public at low tide and UNESCO guidelines encourage public access to sites and education about them, as long as such access is in line with protection and management strategies.

Swell from winter storms along the coast has the potential to destroy the walls of *vywers*. Some *vywers* walls have been cemented together by natural biota and, in the case of some of the easterly *vywers*, limestone rocks used to build the walls have amalgamated over time into a more weather-resilient system. However, this natural preservation may not be enough to secure the future the *vywers*. Reports of bait collectors causing irreparable damage to the *vywers*, by pulling apart the walls with crowbars in search of wonder worms *Eunice aphroditois* for fishing bait, is cause for concern (G. Avery pers. comm.). Part of this problem may be lack of awareness of the cultural significance of the *vywer* sites.

Current knowledge about the distribution of *vywers* is distilled in two pioneering papers, Goodwin (1946) and Avery (1975), but anecdotal reports suggest the existence of many additional undocumented sites and some of those reported in these two papers may since have deteriorated or even disappeared. A prerequisite for the declaration of cultural heritage sites is a detailed survey, but since the Still Bay *vywers* were declared there have been no further official surveys to document other *vywer* sites (Anon. 1997b). My study was designed to locate, map and characterize as many of these other *vywers* sites as possible along the south coast where *vywers* are concentrated. The protocol I developed could be used to extend the work to *vywers* known to occur beyond this area on the west and east coasts (Anon. 1992, T. Booth pers. comm.).

A number of survey methods were considered. Traditional ground surveys were disregarded as being too costly in terms of time, money and man-power. Remote sensing techniques were then investigated. Satellite imagery available was not of a sufficiently fine scale resolution to map *vywers* accurately, particularly those that are less well preserved and thus less distinct on satellite imagery.

Aerial photography has already been used extensively for exploratory purposes in archaeology, generally backed up by ground-truthing surveys. In South Africa, Mapangubwe was investigated in this manner, revealing sites previously not discovered (Meyer 1998). Among others, Maggs (1976) used aerial photography to find and map Iron Age sites across the southern Highveld region. Several methods for obtaining aerial photographs are available, including fixed-wing aircraft, helicopter, model aircraft, blimp, drone and even manned or unmanned hot-air balloons (Clarkson et al.1999). The benefit of such remote sensing is that it is rapid, non-invasive and can also employ infra-red or other geophysical techniques that may yield additional information not available to the human eye without destructive excavations. Many major archaeological sites, such as the Giza pyramids, Machu Pichu, and numerous sites in Jordan have been analysed by aerial surveys (Bewley & Kennedy 1998).

I opted for photogrammetry (aerial stereo photographs taken from a fixed-wing aeroplane that permit three-dimensional imagery) to survey the *vywers*. The method has been used extensively worldwide (reviews by Fussel 1982, Gisinger et al. 1996, Ruther 1996, Redfern 1998, Boehler & Heinz 2001a, b, Georgopoulos & Ioannidis 2004) and in South Africa (Adams 1976). V*ywers* fall at the intermediate spatial scale (~100 m) considered favourable for such surveying (Boehler & Heinz 2001), and the method allows rapid, affordable and long-range coverage. Early coastal orthophotographs available from the South African Chief Directorate of Surveys and Mapping did prove useful in locating some sets of *vywers* and providing a perspective on how they have changed over time, but their resolution and the fact that many of them were taken at high tide diminished their value as a means of accurately mapping all the *vywers*. As a result, I initiated a complete aerial survey of the study area on the grounds that this would be the most efficient, cost effective technique to document the *vywers*.

The final product, a set of high resolution orthophotos, has a number of advantages over simple line drawings yielded by traditional surveying methods. Orthophotos are (a) objective in that they eliminate observer bias, (b) offer a high level of accuracy and homogeneity, especially when assessing many sites over a large area, and (c) can be employed by researchers at a later date if additional analyses are required, without the need to re-survey the region. The imagery and associated data, if catalogued, archived and maintained in digital form by a central host, can also be made available to a wider audience for education, awareness and management purposes, as required by UNESCO.

Time limited the number of sites that I could survey in detail. As a result, I first documented the locations of all *vywers* on the south coast and classified them according to their construction and shape. Then, I selected four sets of *vywers* to span different types of construction and mapped these in detail using aerial orthophotos. The procedures I developed can, however, readily be applied to all other *vywers* to complete their systematic mapping.

METHODS

There were three phases to my study. First, I collated reports of *vywer* localities from the literature, from various anecdotal sources, and from early orthophotos. The majority of records reported *vywers* between Mossel Bay (34°11'0"S, 22°9'0"E) and Hermanus (34°25'30"S, 19°13'30"E) on the south coast of the Western Cape Province, South Africa. Second, I conducted an aerial survey to confirm these records and search for unrecorded sites. Finally, I selected four representative sites for detailed mapping using a combination of orthophotos and ground-truthing.

Study area

The study area falls within the fynbos biome (Rutherford 1997) and the Cape Fold Mountain belt. The western portion of this coastline is dominated by low limestone cliffs of less than 150 m in height, derived from the Bredasdorp formation of shales and sandstones of the Bokkeveld group (Heydorn & Tinley 1980, Lubke et al. 1997). Further east, long stretches of cliffs drop sharply into the sea due to the collapse of remnant planation shelves. Sandy beaches are generally restricted to around the mouths of large rivers (Lubke et al. 1997).

Aerial census and survey

All aerial surveys were conducted around low springtide to ensure maximum exposure of the *vywers*. A reconnaissance flight in a Cessna 210 aeroplane was flown on 17 November 2005 along the entire study area (Fig. 1.1), taking in every bay and point. Coordinates were taken at each set of *vywers* encountered, both with a handheld Geographical Positioning System (GPS; Garmin Etrex Venture) and onboard flight

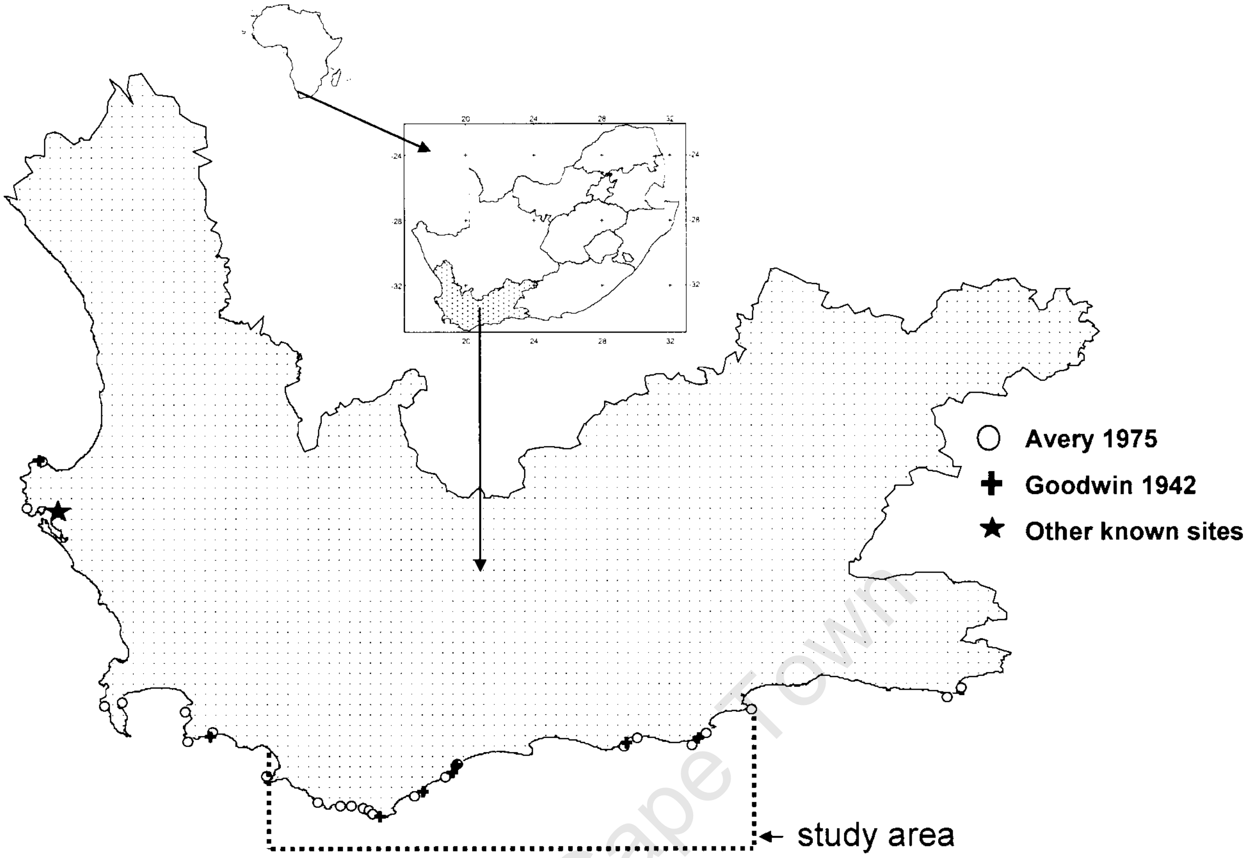


Figure 1.1 Map of locality of *vywers* along the South African coast from Avery (1975) and Goodwin (1946) and the area of focus for this study.

equipment (Garmin III). Digital video and still photographs were taken for use in explicit planning of further surveys and photography.

A second flight was undertaken so that GPS-controlled stereo-aerial photographs could be taken of each set of *vywers* that had been identified, including the four selected for detailed mapping. An image resolution of 25 cm was chosen as best for identifying and locating *vywers*, in particular older, less defined ones. This resulted in a nominal photo scale of 1/32,000 (given the image pixel size of 7.8μm on the camera sensor). The images were taken using a Canon 10D digital camera (3072 x 2048 effective image pixels) fitted with a Sigma 14 mm lens. The rear door of the plane (a Piper Cherokee Six) was removed in order for a camera housing to be fitted. This allowed the camera to be mounted vertically outside the plane when over the *vywers*. An explicit flight plan was followed, based on the initial exploratory flight data, 1:10 000 orthophotos and 1:30 000 colour aerial photographs obtainable from the Chief Directorate of Surveys and Mapping.

Subsequently, *vywers* were visited on the ground to provide photo-control for the photogrammetric mapping process. This was done by means of a GPS (Leica 120) and theodolite survey of selected control points identified from aerial photos taken during the reconnaissance flight. The scope of this study allowed for four sites to be completely ground-controlled.

Once ground-control was completed, ortho-images were produced using the digital photogrammetric software package 'PhotoNet'. This process involved:

1. Aerial triangulation to "tie" together the stereo images and determine their position and orientation at the time of exposure
2. Digital terrain model (DTM) generation
3. Orthophoto mosaic production.

The high-resolution digital ortho-images of the four selected sets of *vywer* sites that were produced provided a means for further spatial analysis. The four sets were mapped using Global Information Systems software (Arc View 3.3). A number of overlays from the Environmental Potential Atlas for South Africa (ENPAT; 1998) were analysed for each set of *vywers* to determine various underlying geological and vegetation parameters that may impact at their locality Each data set was then entered into a database, linking maps with relevant orthophotos and other spatial data, together with information on the categorisation and detailed descriptions of size, depth, building materials and style of construction. The intention is to expand the survey to cover all *vywers* at a later date.

RESULTS

Location

Earlier surveys by Goodwin (1946) and Avery (1975) documented 24 vywer sites on the south coast and southern west coast (Fig. 1.1). Following my surveys a total of 43 sets of *vywers* were located along the 300-km study area (Fig. 1.2, Table 1.1), with 12 in areas previously unrecorded as having *vywers*. No *vywers* were found west of Suiderstrand, despite reports of sites existing there in Avery (1975) and Goodwin (1946). The majority of *vywer* sets consisted of two to six traps, but there were eight sites with only one trap and five sets that consisted of complexes of over 10 traps. The *vywer* complex at Noordkappershoek was the largest, with a total of 25 traps stretching along almost a kilometre of coast. Only eight sets of *vywers* are accessible via common-use public land, five fall adjacent to established reserves, while 30 could

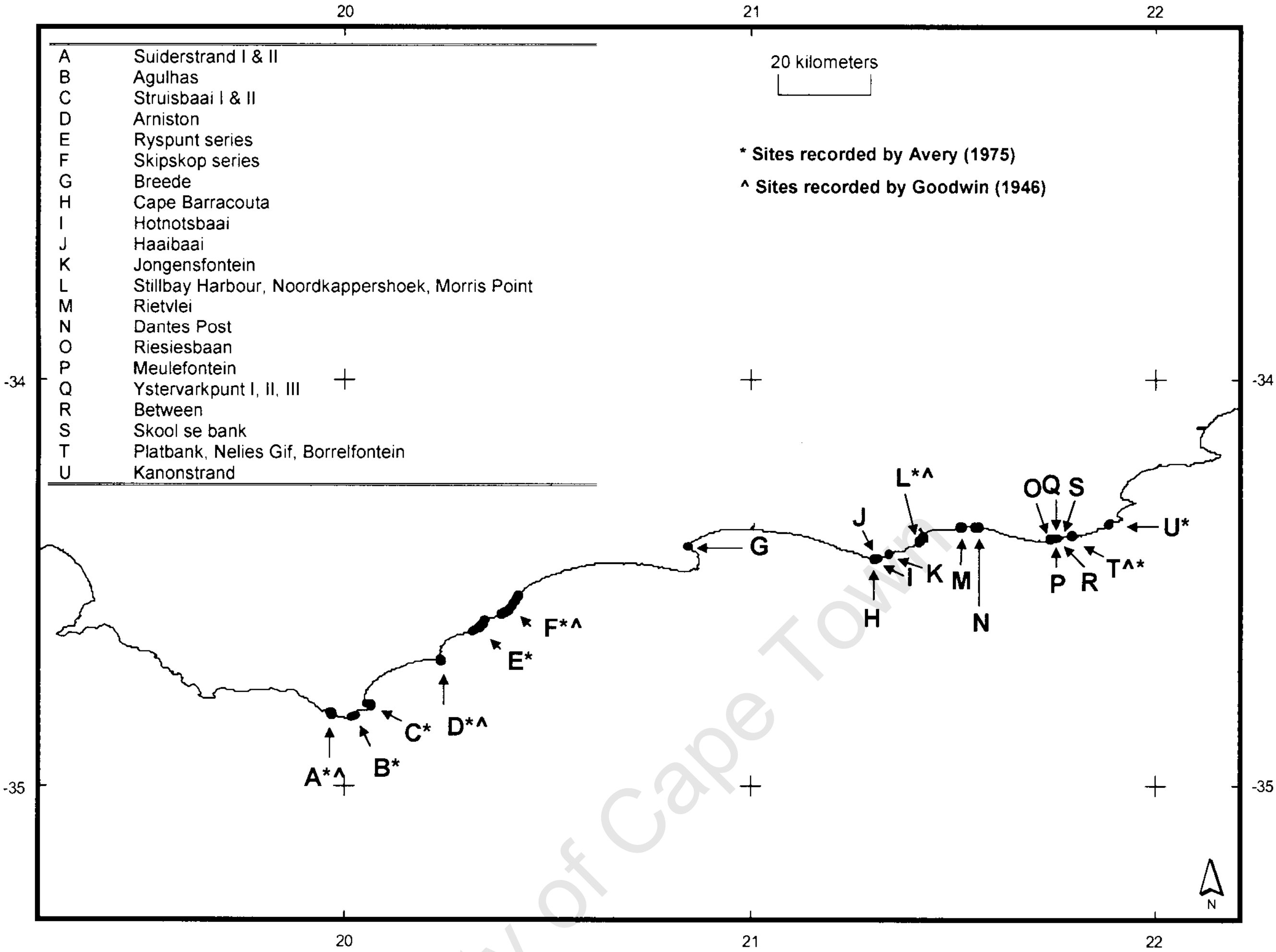


Figure 1.2. Map of sets and series of sets of *vywers* located along the South African south coast during this study.

Table 1.1. Location and access to sets of vywers identified along the south coast of South Africa. OTB = Overberg Test Range

Name of set of *vywers*	Number of traps	GPS co-ordinates		Land access
Agulhas	3	20.0211	-34.8285	Public
Arniston	19	20.2358	-34.6908	Reserve
Between	~15	21.752	-34.3887	Private
Borrelfontein	~5	21.7915	-34.3831	Private
Breede	1	20.8426	-34.4077	Public
Cape Barracouta	1	21.3016	-34.4389	Private
Dantes Post	~1	21.5556	-34.3618	Private
Haaibaai	~3	21.3168	-34.4338	Private
Hotnotsbaai	~4	21.3105	-34.439	Private
Jongensfontein	3	21.3388	-34.4271	Public
Kanonstrand	2	21.9075	-34.334	Public
Morris Point	~3	21.7147	-34.3953	Reserve
Meulefontein	2	21.4315	-34.3947	Private
Nelies Gif	~5	21.7886	-34.3839	Private
Noordkappershoek	25	21.3388	-34.4271	Public
Riesiesbaan	~5	21.7806	-34.3847	Private
Platbank	1	21.687	-34.3926	Private
Rietvlei	6	21.5171	-34.3623	Private
Ryspunt 1	3	20.3113	-34.6199	OTB
Ryspunt 2	3	↓	↓	OTB
Ryspunt 3	5			OTB
Ryspunt 4	2	20.3437	-34.5929	OTB
Skipskop 1	1	20.3826	34.5771	OTB
Skipskop 2	1			OTB
Skipskop 3	2	↓	↓	OTB
Skipskop 4	4			OTB
Skipskop 5	1			OTB
Skipskop 6	1			OTB
Skipskop 7	1			OTB
Skipskop 8	4			OTB
Skipskop 9	2			OTB
Skipskop 10	3			OTB
Skipskop 11	2			OTB
Skipskop 12	5	20.4267	-34.5294	OTB
Skool se bank	2	21.7618	-34.3862	Reserve
Still Bay Harbour	9	21.4237	-34.3836	Public
Struisbay 1	5	20.0639	-34.8285	Public
Struisbay 2	6	20.0563	-34.7972	Public
Suiderstrand 1	7	19.9645	-34.8198	Reserve
Suiderstrand 2	6	19.9682	-34.8242	Reserve
Ystervarkpunt I	~2	21.7358	-34.3933	Private
Ystervarkpunt II	4	21.7394	-34.3917	Private
Ystervarkpunt III	~10	21.7429	-34.3891	Private

only be accessed on private land, either farms or military land (Overberg Testing Range: OTB).

Description and characterisation

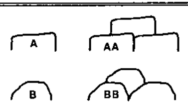
The *vywers* are built both within sheltered bays and on exposed headlands (Roussouw 1989, R. Branch pers. comm.), in situations where boulders or shale-like rocks accumulate and are accessible as building material, and they appear to be of one or a combination of three types (Table 1.2). Some *vywers* are constructed entirely from material available *in situ* (Fig 1.3), some are constructed using beneficial natural features, such as boulder spits or natural gullies where a wall is simply built to close off a natural feature (Fig. 1.4), and a few are simply ponds where boulders have been removed to form a depression in a boulder field (Fig. 1.5, and see also Fig. 1.13). Their shapes are either angular, such as the majority within the OTB area, or curved as in most other *vywers* and are either singular or a number of traps built in a complex interlaced fashion (Table 1.2).

The building material used is site–dependant (J. Malan pers. comm.). The most common material is boulders derived from the upper geological unit of the Cape Supergroup (CS), which forms the boulder fields used (as at Arniston and Still Bay: Fig. 1.6). In the stretch of coast occupied by the OTB and covering the Skipskop and Ryspunt *vywers*, flat, shale-like sheets, derived from the Rietvlei unit of the CS, are packed upright to form walls (Fig. 1.7) The limestone-like rocks used at the Rietvlei *vywers* are derived from the coastal cliffs belonging to the Bredasdorp group, which has an aeolian history (Fig. 1.8).

From analyses conducted using ENPAT overlays, the underlying geology was predominantly of the Kalahari group with a section of the Table Mountain formation

Table 1.2. Summary of the shape, building material, construction type and geomorphology along the south coast.

Name of set of *vywers*	Shape	Type	Sensitivity Atlas
Agulhas	AA	C/N	exposed rocky headland
Arniston	AA/BB	N/C	exposed rocky headland
Between	BB	N	wavecut rocky platform
Borrelfontein	AA	N	pebble/shingle beach
Breede	A	C	estuarine environment
Cape Barracouta	B: natural?	N	exposed rocky headland
Dantes Post	B: natural?	N	wavecut rocky platform
Haaibaai	AA	N	fine grained sandy beach intruded by rock platform
Hotnotsbaai	BB	N	fine grained sandy beach/exposed rocky headland
Jongensfontein	AA	N	exposed rocky headland/wavecut rocky platform
Kanonstrand	BB	P	pebble/shingle beach
Morris Point	BB	N	exposed rocky headland
Meulefontein	BB	N	pebble/shingle beach
Nelies Gif	BB	N	pebble/shingle beach
Noordkappershoek	BB	N/C	exposed rocky headland
Riesiesbaan	BB	N	wavecut rocky platform
Platbank	BB	N	pebble/shingle beach
Rietvlei	AA	N	pebble/shingle beach
Ryspunt 1	AA	C	fine grained sandy beach intruded by rock platform
Ryspunt 2	AA	C	fine grained sandy beach intruded by rock platform
Ryspunt 3	AA	C	fine grained sandy beach/wavecut rocky platform
Ryspunt 4	A	C	fine grained sandy beach intruded by rock platform
Skipskop 1	AA	C	fine grained sandy beach intruded by rock platform
Skipskop 2	AA	C	fine grained sandy beach intruded by rock platform
Skipskop 3	AA	N	fine grained sandy beach intruded by rock platform
Skipskop 4	A	C	fine grained sandy beach intruded by rock platform
Skipskop 5	AA	C	fine grained sandy beach intruded by rock platform
Skipskop 6	AA	C	fine grained sandy beach/wavecut rocky platform
Skipskop 7	A	C	fine grained sandy beach/wavecut rocky platform
Skipskop 8	A	N	fine grained sandy beach intruded by rock platform
Skipskop 9	A	N	fine grained sandy beach intruded by rock platform
Skipskop 10	AA	C	fine grained sandy beach intruded by rock platform
Skipskop 11	AA	C	fine grained sandy beach/wavecut rocky platform
Skipskop 12	AA	C	fine grained sandy beach intruded by rock platform
Skool se bank	BB	N	exposed rocky headland
Still Bay Harbour	BB	C	estuarine environment
Struisbay 1	BB	C	fine grained sandy beach intruded by rock platform
Struisbay 2	BB	C	fine grained sandy beach/exposed rocky headland
Suiderstrand 1	AA	C/N	exposed rocky headland/fine grained sandy beach
Suiderstrand 2	AA	C/N	exposed rocky headland/fine grained sandy beach
Ystervarkpunt I	B	N	pebble/shingle beach
Ystervarkpunt II	BB	N	pebble/shingle beach
Ystervarkpunt III	BB	N	pebble/shingle beach

Trap Shape : 

Trap Type:
N: relies on natural structures for some of its form
C: entirely constructed **P:** pond-like with boulders removed

Figure 1.3. Photograph of a vywer set in the OTB stretch of coastline showing the fully constructed walls on a sandy/pebble intertidal zone.

Figure 1.4 Photographs showing the use of natural features in the construction of *vywers*.

Figure 1.5. Photograph of a *vywer* where boulders have simply been removed from the boulder field to create a depression and no walls are evident.

a)

b)

Figure 1.6. Boulders used in the construction of *vywers* within the intertidal at (a) Arniston and (b) Still Bay at Noordkappershoek. Note the extensive natural cementation by marine life on the boulders that form the walls of the Arniston *vywers*.

Figure 1.7. Slate-like rock used for the construction of the angular *vywers* at Skipskop and Ryspunt. The natural rock that is broken to create the walls is seen on the right.

Figure 1.8. Rock derived from coastal cliffs at the Rietvlei *vywers*.

(Fig. 1.9). The corresponding vegetation was coastal macchia (fynbos) and some coastal rhenosterbosveld (Fig. 1.10). A closer analysis of the coastline using Sensitivity Atlas data showed that *vywers* are found on all coastal types but always in close association with rocky features (Fig. 1.11). Those shown as lying on fine-grained sandy beaches had an underlying rock planation shelf that provided the building material. A comprehensive database was compiled with an entry for each set of *vywers* (Appendix 1, see p. 55).

Ortho-imagery

Seventeen sets of *vywers* were photographed for the production of ortho-imagery, of which four sets were ground-controlled for production of geo-rectified orthophotos (Figs 1.12 – 1.15). The *vywer* within the Breede river mouth is an example of the fully constructed rectangular type (Fig. 1.12). The *vywers* at Kanonstrand, the most easterly of the surveyed traps, are of the pond variety (Fig. 1.13): only one constructed wall exists, the main area of the trap being created by removing boulders to form ponds. The *vywers* at the Still Bay Harbour (Fig. 1.14) and Rietvlei (Fig. 1.15) show a combination of the use of natural features and built walls to create a complex series of arcs. These four sets of *vywers* consist of traps with an average perimeter of 220 m and average area of 2966 m^2.

Some orthophotos taken in 1938 at low-tide show the *vywers* clearly. It is evident that those that are maintained regularly have changed little between then and my survey, such as those at Noordkappershoek (Fig. 1.16), whereas those that have lain neglected, such as at Struisbaai, have deteriorated to a state where it is difficult to clearly define walls (Fig 1.17).

Figure 1.12. Orthophoto of the *vywer* within the Breede river mouth.

Figure 1.13. Orthophoto of the *vywers* at Kanonstrand, just east of the Gouritz River showing the pond-like structure of the *vywers*.

	Area (m²)	Perimeter (m)
A	931	141
B	589	103
C	2539	255
D	913	129
E	2947	274
F	1294	152
G	1976	179
H	1553	148
I	1374	220

Figure 1.14. The complex of arcing *vywers* on a boulder field at the Still Bay harbour.

Figure 1.15. The complex of arcing *vywers* built within a boulder field at Suiderstrand, just east of Cape Agulhas, using the natural boulder spit.

Figure 1.16. *Vywers* at Noordkappershoek in 1938 and in 2006. The *vywers* are well maintained and new *vywers* added since 1938 can be seen.

Figure 1.17. Struisbaai: In the 1938 orthophoto, two sets of respectively six and ten *vywers* are evident. In the 2006 photograph, only the western set can be seen and the *vywers* there are barely distinguishable.

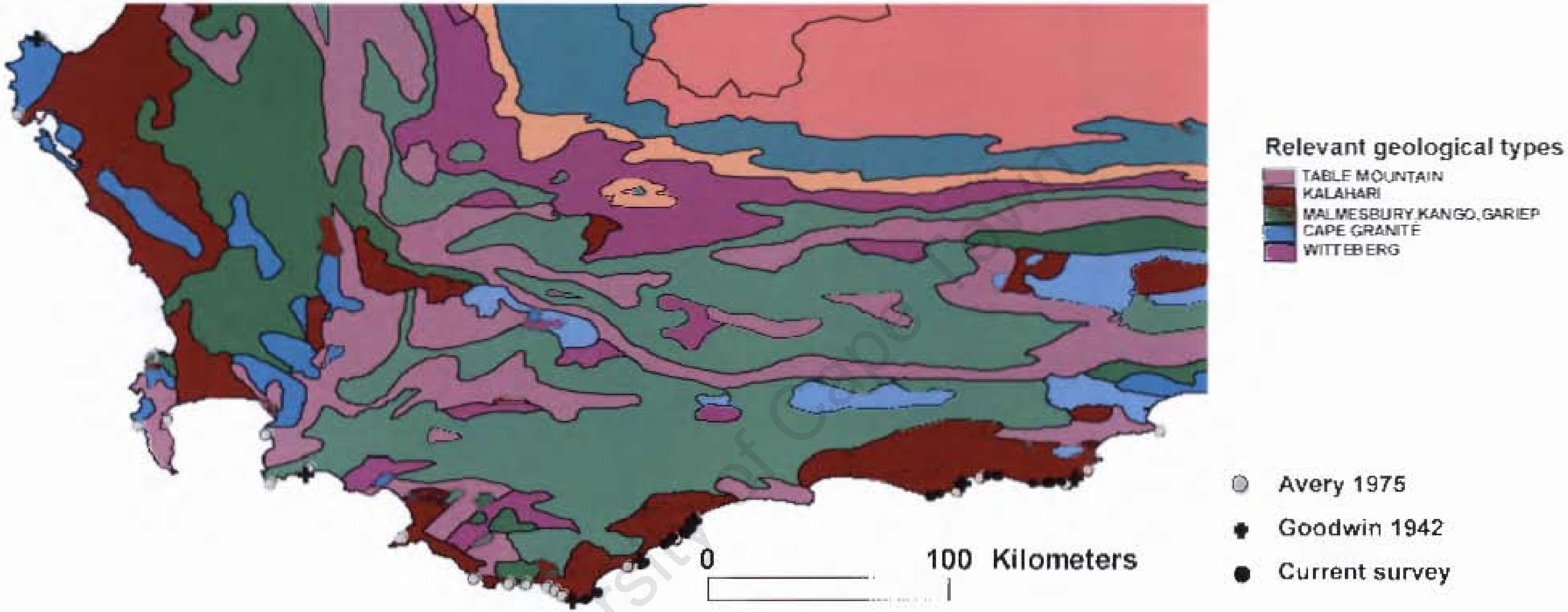


Figure 1.9. Underlying geological features associated with the location of the *vywers* along the south coast (ENPAT 1998).

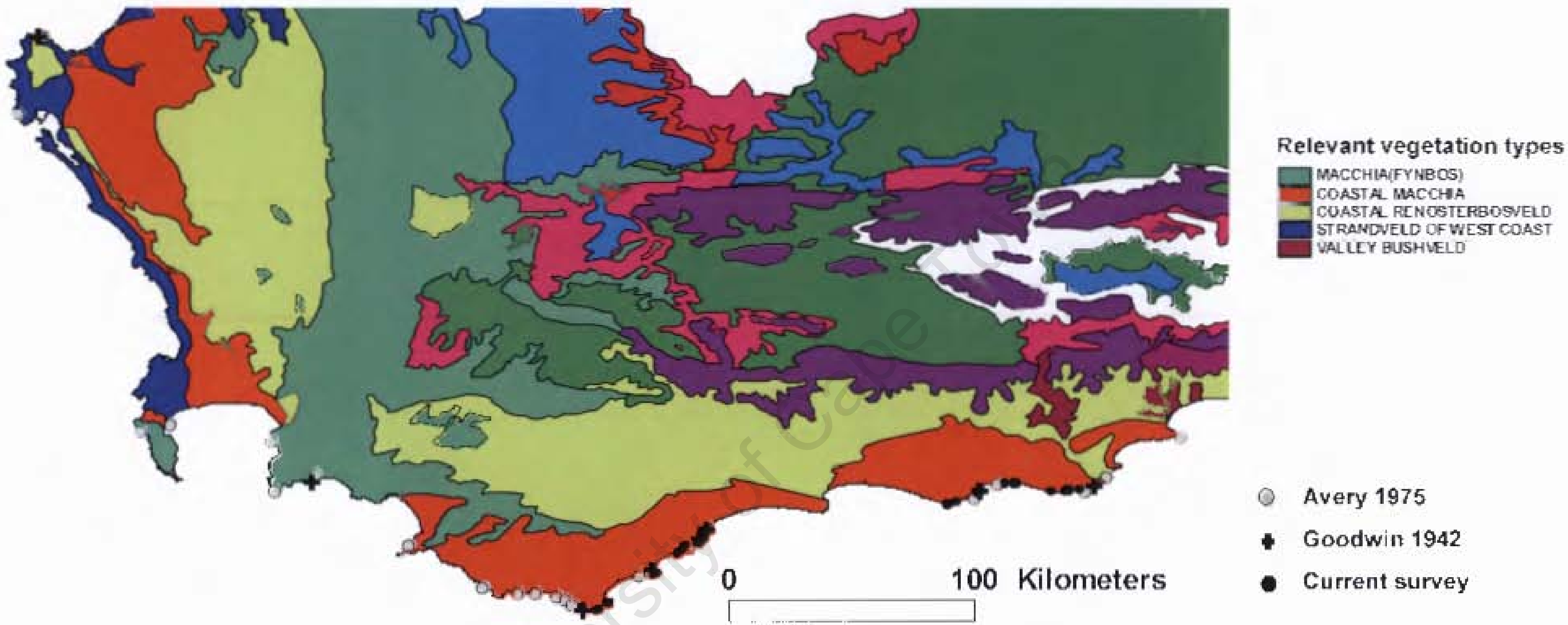


Figure 1.10. Acocks vegetation classifications and the association with the location of the *vywers* on the south coast (ENPAT 1998).

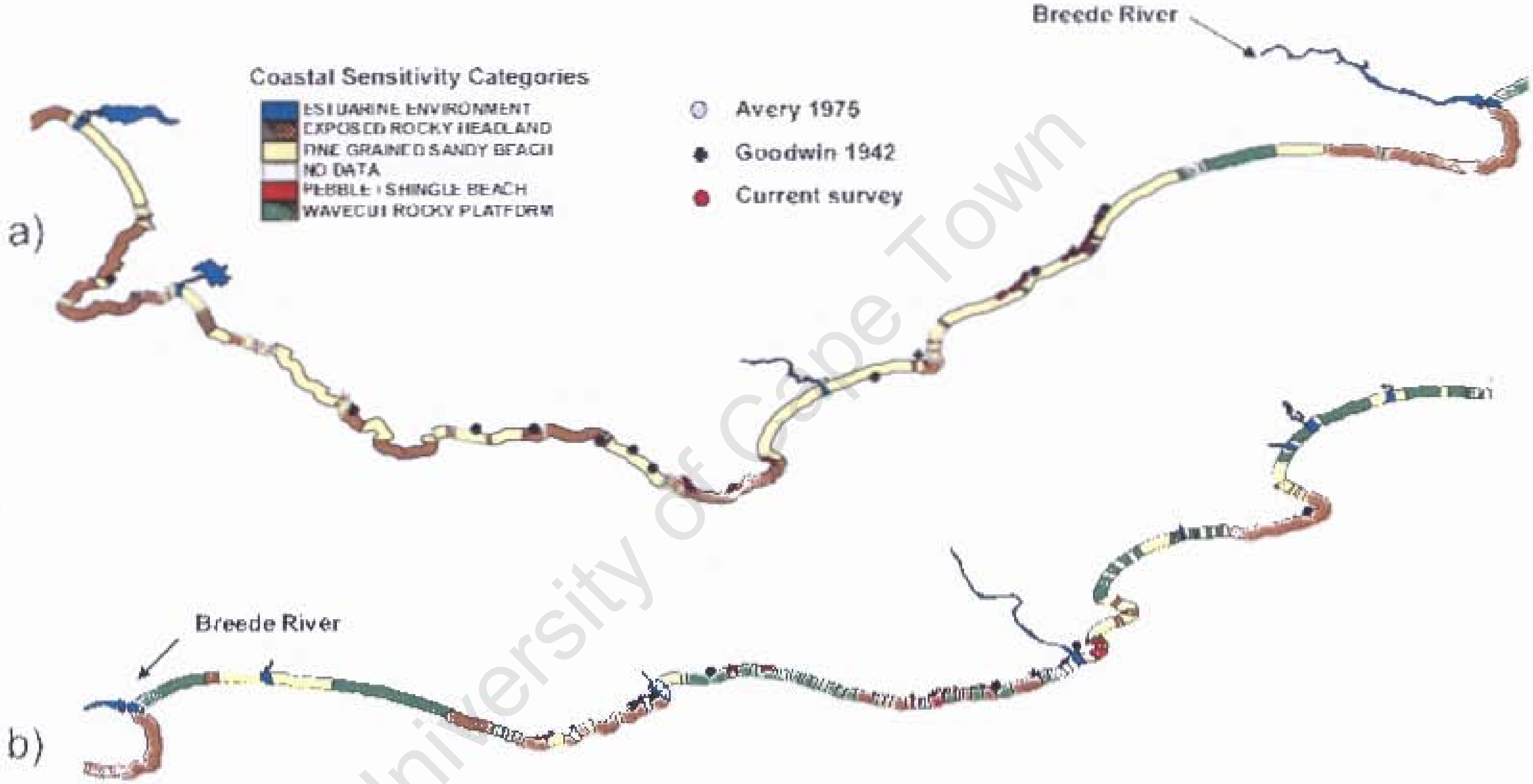


Figure 1.11. The location of *vywer* sites with relation to the Coastal sensitivity Atlas categories along the south coast (a) west of the Breede River and (b) east of the Breede River.

DISCUSSION

The aerial survey proved effective in locating 47 possible *vywer* sites along the explored section of the South Coast. Four of these, on ground truthing, proved to be natural features. Some *vywers* were also in a poor state of repair and were difficult to distinguish from surrounding boulder fields. There is a chance that some *vywers* of greater antiquity or deterioration may have been overlooked, but review of digital video and still photography minimised this risk. The *vywers* reported by Goodwin (1946) and Avery (1975) west of Suiderstrand were not detected from the air and may have deteriorated to the point where they are no longer visible within the boulder fields. The majority (60%) of the *vywers* were built with angular lines, either as a single rectangular *vywer* (15%) or as a complex of up to seven *vywers* linked by common walls (45%). The rest of the *vywers* (40%) were built along curved lines, either as single arcs (5%) or in interconnected complexes (35%). It is not evident if either of these styles is of greater antiquity, and there is no spatial grouping of similar types other than for the series of *vywers* within the OTB. The *vywers* currently being maintained and fished (at Arniston and Still Bay) include both rectangular and curved shapes, suggesting little advantage of using one type over the other. Curved walls may, however, have the advantage of better dissipating wave force.

The majority of *vywers* are built using natural features, such as boulder spits, rocky reefs and gullies. The building material used merely corresponds to the rock material available. *Vywers* within boulder fields were constructed with boulders, mostly round in shape at localities such as Still Bay, or irregular at localities such as Arniston. The *vywers* at Skipskop and Ryspunt were rectangular and built from flat slabs of shale-like quartzite laid upright. These slabs were broken and shaped with crowbars to form very structured walls that were built (or re-built) as recently as the 1980s, either as new traps or using the remnants of existing pre-colonial traps. The ENPAT analysis based on coastal sensitivity parameters found the traps to be located, as expected, where building materials exist. There is, however, an area between the most eastern Skipskop *vywers* and the westerly Cape Barracouta *vywers* that has appropriate materials for the construction of *vywers*, but aside from the Breede River mouth, there are no *vywers* in this area. There could be a number of explanations for this. For much of its extent, this area is associated with Table Mountain Sandstone that is different from the underlying geological structure associated with most *vywers*. Table Mountain Sandstone does not erode easily and so little building material would exist. In addition, the soils derived from this group are nutrient-poor. If the original users were pastoralists, they may have avoided this area as a result of poor grazing. The area also has a higher relief gradient and the construction of *vywers* would have relied on a gentle intertidal gradient (Avery 1975). Data were not available but an interesting comparison would also be the location of freshwater springs that would have provided drinking water for people and livestock, in relation to the existence of *vywer* sites.

The aerial photogrammetry methodology tested in this study has shown that it is possible to accurately and quickly survey and map large areas and create a detailed record of these cultural heritage sites. The database will be stored with the South African Heritage Resource Agency and will be available for use, addition and refinement as new data become available.

Archaeological maritime sites such as these are subject to natural forces that cause them to deteriorate but it would be false to assume that conservation implies keeping these forces at bay (Boehler et al. 2001). It is clear that over decadal time scales (see Fig. 1.17) the structure of the *vywers* will be progressively undermined. This, coupled with active destruction by fishers collecting wonderworm *Eunice aphroditois* for bait, will lead to the loss of a valuable cultural heritage unless ongoing maintenance is undertaken. Some of the *vywers* lie adjacent to terrestrial reserves and the set at Still Bay falls within a proposed marine protected area (Anon. 2005a). Protection and maintenance of these should be a priority. All *vywers* lie on public land as they fall within the intertidal zone, which may not be privately owned, but some, such as those in the OTB, are inaccessible because the public is excluded from the area. This does provide indirect protection but diminishes their educational and tourism value and does not eliminate the need for ongoing maintenance, which is currently being undertaken by the OTB.

The best-maintained sets of *vywers* are those at Arniston and Still Bay, both of which are repaired on an ongoing basis by the fishers who actively use them to harvest fish. Their activities and the uneasy tension between them and the desires of the authorities to maintain *vywers* but at the same time to circumscribe overfishing, are the subjects of the following chapter.

CHAPTER 2

UTILISATION OF SOUTH AFRICAN COASTAL STONEWALL FISH TRAPS: A SURVEY OF THE 'FISHERY', ITS MANAGEMENT AND LEGAL STATUS

INTRODUCTION

Stonewall fish traps on the south coast of South Africa, locally called '*vywers*', were built in the intertidal zone by aboriginal people about 1700 to 3500 years ago (Avery 1975). These ages were derived from the current position of the *vywers* in the intertidal zone relative to estimated sea-level fluctuations over time. It is surmised that around 2000 years ago, with the rise of pastoralism, the Khoekhoe people moved to the coast and made use of existing *vywers* (Avery 1975), but few details are available about historical fishing practises within the *vywers* (Goodwin 1946, Avery 1975, Gribble 2005). Many of the extant *vywers* now lie neglected but a few are still being actively maintained and fished. The ancient techniques involved in building and fishing the *vywers* are now in danger of becoming lost. This would result in a deterioration of the physical structures of the remaining *vywers* and diminution of their associated cultural significance.

The *vywers* are carefully and tightly packed walls built of stones or boulders gathered on site. The precise design and construction of the walls are vital for the *vywers* to catch fish. The inner walls need to be vertical to deflect fish back into the *vywer*, while the outer walls are sloped to reduce the effects of wave action. The tops of the walls need to be exactly horizontal along their entire length, without even the slightest gaps, to prevent the escape of fish. Lack of artificial cementation leaves the walls prone to erosion by rough seas, but Avery (1975) notes that the *vywers* are mostly situated in sheltered bays, often behind the protecting influence of sandbars, reefs or boulder spits. Over time, the core structure of the walls has become naturally cemented together with marine life (mostly the polychaete *Pomatoleios kraussii*). The effect of natural cementation is to protect the *vywers*, but any loose boulders that are knocked from the walls by strong seas or human disturbance generally settle around the core walls, so also helping to preserve the shape of the *vywers*. In this condition, the *vywers* are no longer efficient at catching fish but are still visible as artificial constructions.

The few *vywers* that are actively maintained and fished have become the topic of much debate. Conflict has arisen between the fishers and fisheries management officials. The fishers maintain the *vywers* and so expect to keep whatever fish they catch. However, coastal management authorities are obliged both to preserve the cultural heritage of the *vywers* and also to enforce sustainable fishing practises. The debate is complicated by the reluctance of some of the fishers to comply with current fishing regulations, which does not aid their cause.

To further complicate the matter, one actively-fished set of *vywers* lies on a section of land that is in the process of being declared a Marine Protected Area (MPA) linked on the landward side of the bay with a provincial Nature Reserve declared in 2000 (Anon. 2005a). The marine habitat up to three nautical miles out to sea will then fall under the protection of local and national conservation authorities. The conditions of 'no-take' MPAs require that no marine life may be removed from the sea, but if the *vywers* are to be maintained as a 'living' cultural heritage site then active fishing may have to be permitted within at least a portion of this MPA. Fishers are unlikely to maintain the *vywers* without some form of compensation, 'piscal' rather than fiscal, but without their skill at maintaining the *vywers* an ancient cultural heritage resource will be under threat from wave action.

This chapter reviews historical techniques and catches, and assesses current techniques and catches, to offer management proposals that could preserve the *vywers* without compromising the goals of both sustainable fisheries management embedded in the Living Marine Resources Act 18 of 1998 (Anon. 1998) and cultural preservation (Anon. 1999).

METHODS

1. The *vywer* 'fishery' in the past

I collated and reviewed information from interviews with key informants and from published literature on the historical structure and uses of *vywers*. For a comprehensive discussion of the structure and location of extant *vywers* derived from the literature and from my own surveys refer to Chapter 1 of this thesis.

2. The current *vywer* 'fishery'

A survey of current fishing was undertaken at Arniston and Still Bay (Fig. 2.1) as these were known actively fished *vywers*. Literature and initial enquiries suggested that catches in *vywers* are very sporadic and would require an extensive survey spanning several years to detect any trends. Given the limited time available, questionnaires were the most feasible way to collect data. A questionnaire was developed with the primary aim of collecting data about catch size, frequency, species

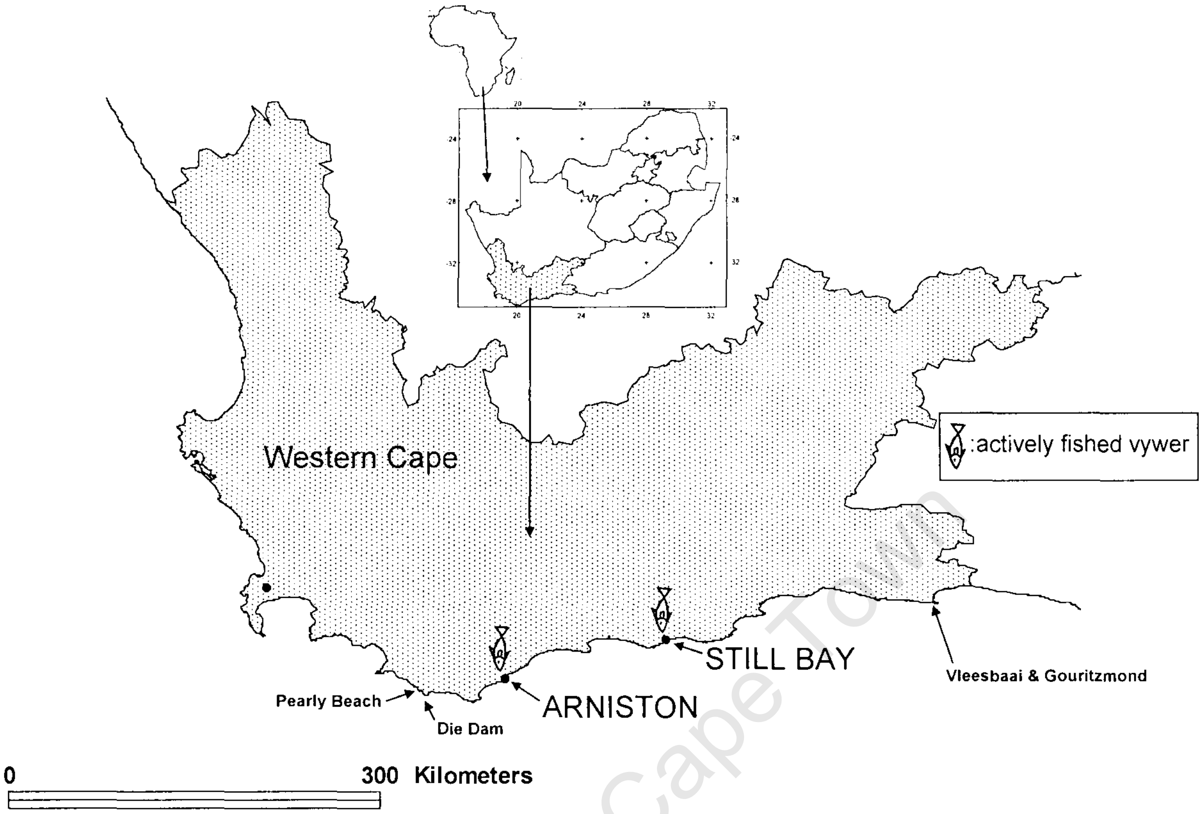


Figure 2.1. Map showing location of actively fished *vywers* and other locations mentioned in the text.

composition and seasonality (Appendix 2, see p. 56). Available stakeholders involved in or knowledgeable on the use of *vywers* were questioned informally and in their mother tongue, to ensure they were at ease and that questions were fully understood and their anonymity was respected.

Few fishers were found to be involved in using the *vywers*. For this reason my survey was limited to four fishers, a Fisheries Compliance Officer, the head of a local fishing club and a member of the local Nature Conservation office (n=7). Only two other stakeholders were located but they declined to participate in the questionnaire. Some fishers were known to have transgressed fishing regulations on a number of occasions and so may not have imparted reliable information. I verified the answers to the questionnaires wherever possible by cross-referencing different answers and by comparisons with my own surveys. An initial visit was made to each active site to introduce myself to the stakeholders and familiarise myself with the *vywers*. A second fieldtrip was undertaken to cover five days of fishing at each site, spanning the new moon springtide when the *vywers* had been reported to be most actively fished (Goodwin 1946, Avery 1975). Each day I took part in the fishing expeditions and arrived before dawn, before or with the fishers, to assess the night's catch. Catch composition was noted daily. All fish caught were measured, but when this was not possible sizes were estimated visually to assess whether they were larger than the legal size limit (if applicable).

RESULTS

1. The *vywer* 'fishery' in the past

Species composition

No information is available to estimate the relative contribution that fish from the *vywers* made to the diet of the San and Khoekhoe, despite the presence of large middens adjacent to many of the *vywers* (Gribble 2005). The earliest records of fish species are those reported by Goodwin (1946). He reported catches by fishers at the Vleesbaai-Gouritzmond *vywers* of predominantly blacktail *Diplodus sargus* and haarder or flathead mullet *Mugil cephalus* (which at that time incorporated both this species and the as yet unrecognized southern mullet *Liza richardsonii*; Smith 1949). Catches of some young musselcracker *Sparodon durbanensis* and octopus *Octopus vulgaris* were recorded but the absence of kabeljou *Argyrosomus japonicus* was specifically noted. Later Avery (1975) reported catches made by a fisher at Die Dam and Pearly Beach as predominantly haarder (70%), blacktail (24%), with a few white steenbras *Lithognathus lithognathus*, galjoen *Dichistius capensis*, musselcracker, stumpnose *Rhadosargus* spp., shad *Pomatomus saltatrix* and strepie *Sarpa sarpa*. He also noted that species composition differed among *vywer* sites. Anecdotal reports of sporadic catches of several thousand fish are of interest in relation to the sustainability of local stocks, especially in light of the currently depleted state of many linefish (Griffiths 2000) and current restorative fisheries policies (Anon. 2005b).

Seasonality and moon phase

Seasonality and moon phase appear to affect catch composition and size. Goodwin (1946) recorded flathead mullet as being most easily caught in large numbers during the winter months. However, Avery (1975) reported the summer months of October to May as being the best months for fishing the *vywers* but did not specify which species accounted for this seasonality. Catches reported for January to April were substantially greater on a new moon than at full moon (Avery 1975).

Fishing technique

The respondents to the questionnaire reported that, in the past, fish trapped in the *vywers* by an ebbing tide would have been pinned against the sides of the walls by spiny branches of coastal vegetation, predominantly of the *Rhus* species that grow abundantly in these areas, and then pulled out by hand. Burning bunches of thatch reed *Restio* spp. were used for pre-dawn illumination of the fishing.

2. The current '*vywer*' fishery

Only two sets of *vywers* are still maintained and fished regularly along the south coast of South Africa, at Arniston and Still Bay (Fig. 2.1). A few other *vywers* are used but so infrequently that they were not considered fully functional. At each of the two sets of active *vywers* there was only one chief fisher, who was usually assisted by up to three others. Both chief fishers actively maintain the *vywers* by restoring or replacing dislodged boulders. At Arniston the *vywers* also attract the attention of some local woman, who fish but do not participate in the labour-intensive operations of *vywer* maintenance.

Species composition

Of the 20 fish species caught in *vywers*, eight are of conservation concern (Table 2.1). All sources concurred that *vywers* yield large catches of mullet, dominated by southern mullet *Liza richardsonii* with a few flathead mullet *Mugil cephalis* also caught. Smaller numbers of elf *Pomatomus saltatrix* and blacktail *Diplodus capensis* are also caught but other species are caught only incidentally, sporadically or opportunistically. There are unconfirmed reports of rare but spectacular 'killings' of galjoen, the sizes of which are inflated or downplayed depending on whether the source is a concerned manager or a worried fisher. Only two invertebrate species were recorded among the catch from the *vywer* walls, namely octopus and the giant periwinkle *Turbo sarmaticus*. Five species that were recorded in Avery's (1975) survey were not recorded in the current survey: poenskop *Cymatoceps nasutus*, hottentot *Pachymetopon blochii*, sea barbel *Galeichthys* spp., vaalhaai *Galeorhinus galeus* and fransmadam *Boopsoidea inornata*. Two species were reported from the questionnaires as being caught occasionally in more recent times, namely yellowtail *Seriola lalandi* and springer *Elops machnata* (more likely a mullet species). At both sites I observed no selection process for the fish harvested. All fish trapped in the *vywers* were removed, regardless of size or species.

Seasonality and moon phase. All respondents to the questionnaires claimed that capture by the *vywers* relies on the tide falling below the tops of the walls during darkness. Catches were reported to be best at new moon spring tide during the winter months. Still Bay respondents do not fish the *vywers* at full moon spring tide unless it is rainy, misty or there is heavy cloud cover. In addition, the Still Bay fishers do not maintain the *vywers* during summer as they do not regard it worthwhile to fish them

Table 2.1. Fish catch composition from earlier reports by Goodwin (1946) and Avery (1975) and my 2005 data from the questionnaire survey and personal observations. Invertebrates harvest from the *vywer* walls are also included and species of conservation concern are indicated.

	Goodwin (1946)	Avery (1975)	Arniston (2005)	Still Bay (2005)	Conserv. concern
Haarder (*Liza richardsonii*)			✓PV	✓PV	
Flathead haarder (*Mugil cephalus*)	✓	✓	✓PV	✓PV	
Elf/ Shad (*Pomatomus saltatrix*)	✓	✓	✓PV	✓	Y*
Strepie (*Sarpa sarpa*)		✓	✓P	✓	
White musselcracker (*Sparodon durbanensis*)		✓	✓	✓	Y*
White steenbras (*Lithognathus lithognathus*)		✓	✓		Y†
Zebra/wildeperd (*Diplodus hottentotus*)		✓	✓	✓	
Fransmadam (*Boopsoidea inornata*)		✓		✓	
Galjoen (*Dichistius capensis*)		✓	✓	✓	Y*
Dassie/blacktail (*Diplodus capensis*)	✓	✓	✓	✓P	Y*
Kabeljou/ Kob (*Argyrosomus japonicus*)		✓	✓	✓	Y†
Stumpnose (*Rhadosargus* spp.)	✓	✓	✓	✓	
Vaalhaao (*Galeorhinus galeus*)		✓			Y†
Sea barbel (*Galeichthys* spp.)		✓			
Hottentot (*Pachymetopon grande*)		✓			
Poenskop (*Cymatoceps nasutus*)		✓			Y†
Baardman/ Belman (*Umbrina robinsoni*)				✓	Y*
Leopard catshark (*Poroderma pantherum*)				P	
Yellowtail (*Seriola lalandi*)			✓		
Springer (*Elops machnata*)- probably *M cephalus*			✓		
Alikreuk (*Turbo sarmaticus*)			✓	✓	
Octopus (*Octopus vulgaris*)	✓	✓	✓	✓PV	
Total number of species	**5**	**16**	**15**	**15**	**8**

V observed violations of current fishing regulations
P personal observations
* no-sale species † suggested no–sale species

then. These respondents commented that catches are enhanced if a south-easterly wind is blowing, whereas a southerly or south-westerly wind is purported to herald smaller catches, if any at all. Arniston fishers reported greater catches of mullet in summer months and better galjoen and blacktail in winter months.

Of the five days spent observing fishing at each site, only three days were successful at each site in terms of fish being captured within the *vywers*. The southern mullet *Liza richardsoni* dominated the catch on all occasions (Fig. 2.2). The caranteen *Sarpa sarpa* was the only other species caught in any substantial numbers, and then only on a single day only at Still Bay. At Still Bay, from my observations, the largest catch (85% of the total) occurred around new moon (Fig. 2.3). On day one of the Arniston sampling series, the night sky was overcast with a strong south-easterly wind. Mullet *Liza* spp. caught at Arniston at this time were all greater than 20 cm total length (Fig. 2.4). At Still Bay the majority of *Liza* spp. caught were estimated visually to be of a similar size class (20-25cm), but a few smaller fish were kept as bait. All other species caught were larger than the minimum sizes stipulated by the 2005 fishing regulations released by Marine and Coastal Management (MCM; Anon. 2005b).

Fishing technique

Fishers arrive before or at dawn when the low tide has fallen below the level of the walls. The fish trapped within the *vywers* are chased through smaller stone gateways into waiting scoop- or gill-nets. All fish were removed and used for personal consumption or sold. Octopus was harvested using a gaff.

Still Bay fishers held recreational permits for angling and bait. They were however clearing the *vywers* using scoop-nets not authorised by these permits.

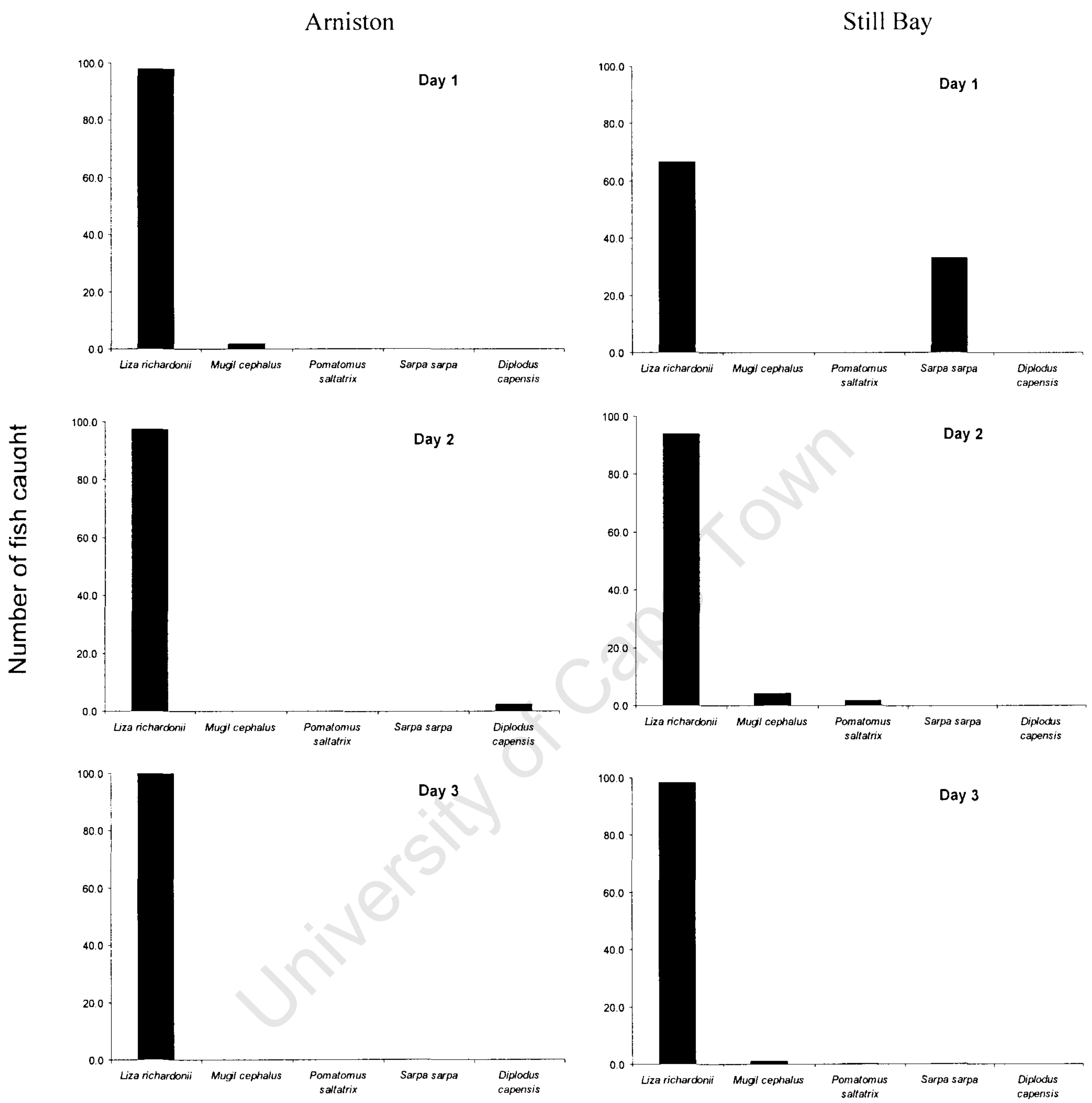


Figure 2.2. Species composition of catch for both active *vywer*s (Still Bay on the left and Arniston on the right) on three successive successful harvest days.

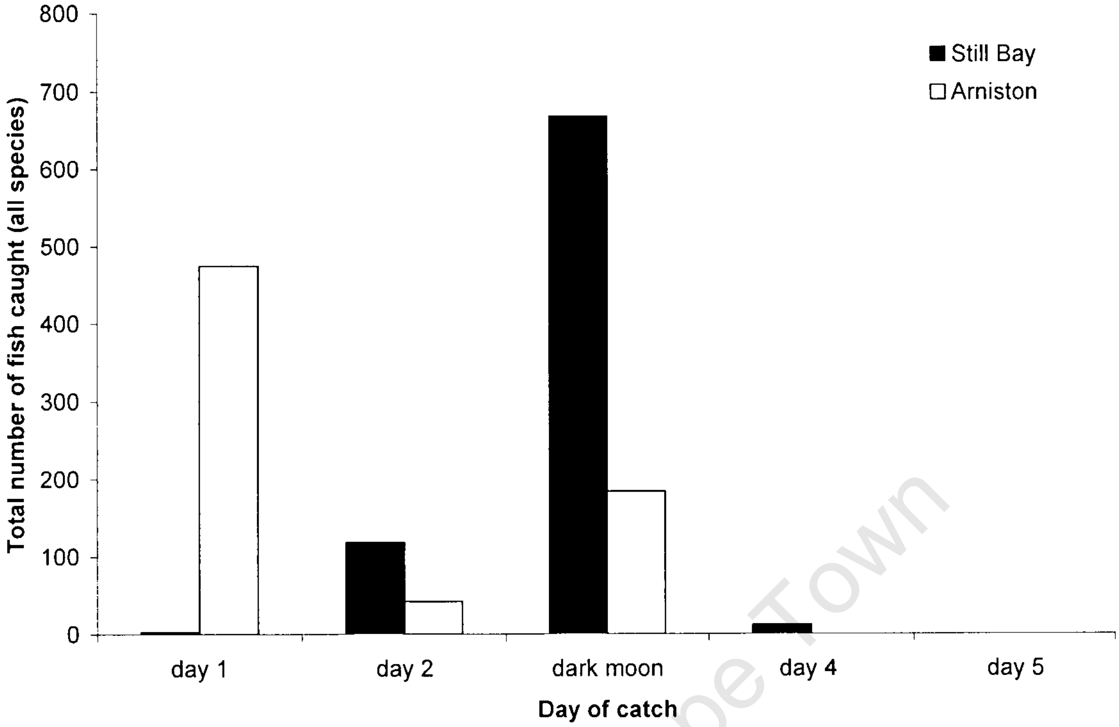


Figure 2.3. Pattern of catch size over the new moon spring tide phase at both Arniston and Still Bay.

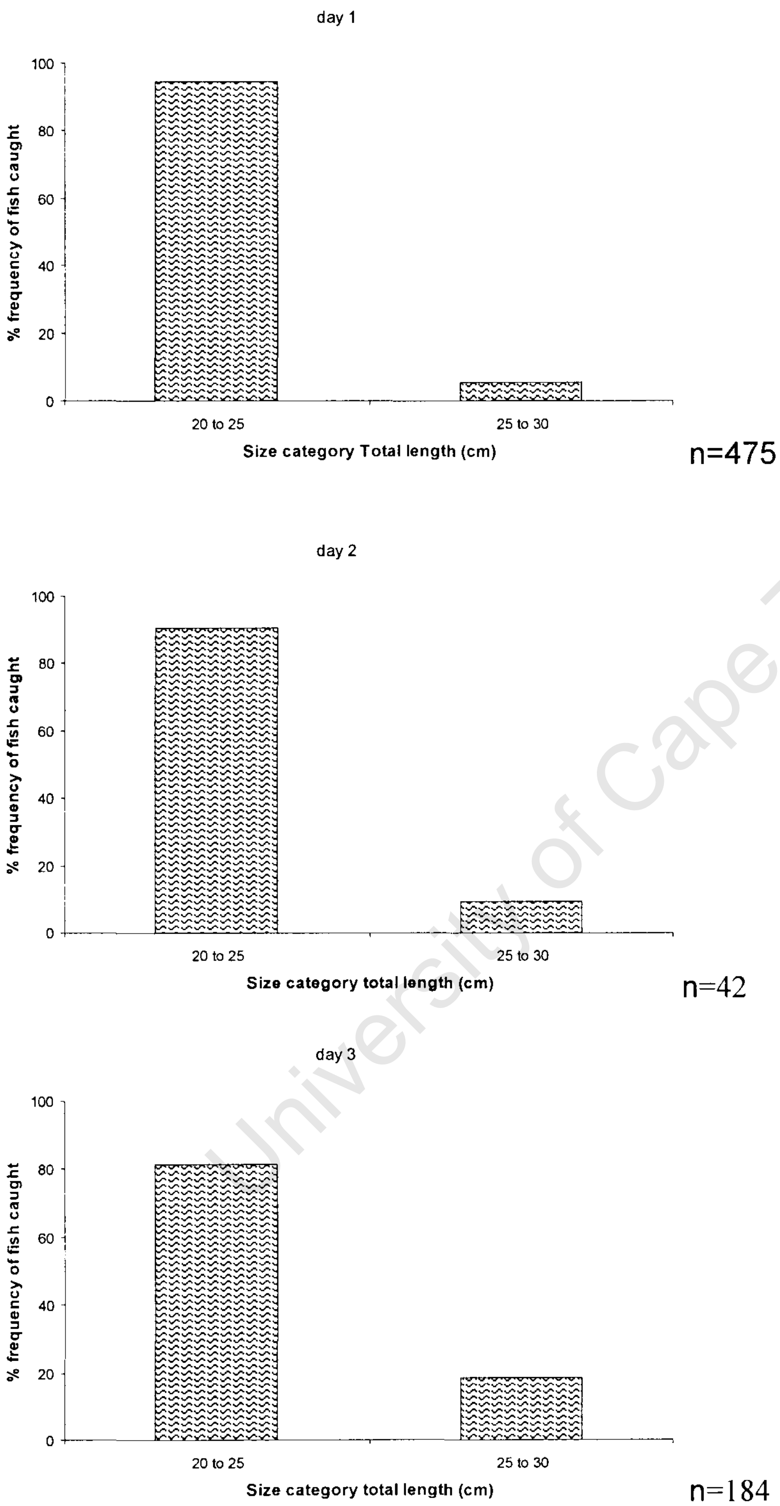


Figure 2.4. Percentage frequency of size classes caught for three consecutive days of fishing at Arniston.

Likewise the Arniston fisher held a recreational permit, endorsed for cast-netting, but fished with sections of gill-net. Both fishers were acting outside the terms of their permits, and their actions were therefore illegal.

Respondents from both sites were aware of the fishing regulations regarding size limits, bag limits and closed seasons. However, fishers at both sites were of the opinion that fishing regulations did not apply to the *vywers*. They reasoned that they were doing society a favour by maintaining the *vywers* and that any fish they kept was just reward for their services. Both groups of fishers had been inspected by a Fisheries Compliance Officer within the three weeks prior to completion of the questionnaire but no action was taken.

DISCUSSION

Changes in technique and current regulations

The way the *vywers* are fished has changed with time. Previously torches made of bunched, burning R*estio* spp. were used when the *vywers* were visited at night, whereas modern head-torches are used today. Originally fish were harvested from the *vywers* using the spiny branches of *Rhus* spp. to trap fish against the walls and allow them to be pulled out by hand. This would presumably have been a less efficient technique than the gill- and scoop-nets currently used to capture and remove fish.

The use of gillnets is illegal as no gillnetting is allowed on the coast of South Africa, other than west of Yzerfontein on the west coast. Gillnets are banned because they are non-selective, killing all sizes of fish as well as non-target species such as penguins. However, as used in the *vywers*, gillnets are not set overnight but are used only to catch the fish driven into the nets after the tide has already dropped below the level of the *vywer* walls. As such, gillnets used in the *vywers* do not pose the same environmental threats as those deployed and left unattended in coastal and estuarine waters. Their capacity to catch is reduced by the size of the *vywers* and there is no by-catch of birds. Fishers take any fish from the *vywers*, regardless of size or species, and the *vywers* are merely being fished faster and not necessarily any harder using modern methods. Because the Arniston *vywers* attract the attention of some local woman, the chief fisher rises long pre-dawn to catch what he considers his proprietary share of the trapped fish, by making use of the efficiency of the gillnet, before leaving the remainder for the women.

Scoop-nets are also not a legal means of capturing fish in *vywers*. They may be used with a recreational permit, but only for catching fish already on a line. Commercial beach-seine net-fishing is not permitted to the east of Cape Hangklip. A legal option currently available to the fishers would be the use of cast-nets under a recreational permit endorsed for cast-netting. There are limitations, however, that would hamper their use in *vywer* fishing (e.g. bag and size limits and the fact that cast-nets are not permitted for fishing in the dark). One of the respondents has applied for a cast-net permit, suggesting faith in their efficiency.

Environmental factors affecting capture success

Capture of fish in a *vywer* requires the tide to ebb below the top of the walls during darkness. This is most likely to occur during new-moon spring tides associated with the longer nights of winter, though thick cloud or mist with the right wind conditions may also be favourable. Supporting this view, Avery (1975) reported that 87% of the catches he recorded occurred over dark-moon spring tides and only 13% over full-moon spring tides. His results were consistent over the four month for which there were complete data (Jan – April) and across all species recorded. In winter months the spring tide falls below the level of the walls before sunrise, whereas in the longer days of summer the tide is still above the level of the walls at dawn (Fig. 2.5). This crucial timing of darkness is necessary to prevent fish escaping from the *vywers* before the water falls below the level of the walls. The need for darkness for *vywers* to trap fish is supported by reports that several of the Still Bay *vywers* are no longer functional due to light pollution from new housing developments.

Also of interest is the effect of wind on catch success. Wind increases turbidity, which decreases the chance of fish realising they are trapped and escaping before the water drops below the level. It also forces offshore upwelling; the cold upwelled water pushes fish inshore, and this increases the chances of fish being caught in the *vywers*.

Lack of legal definition

It appears that the lack of compliance with fishing regulation is due to a perception that the *vywers* fall within a unique category and hence are exempt from current regulations. The fishery associated with the *vywers* does not fall within the laws for recreational fishing, since (a) no fish caught with a recreational license may be legally sold, and (b) sporadically large catches are taken and sometimes include numbers of sought-after linefish in excess of recreational bag limits. The *vywer* fishery could potentially be considered as either subsistence or a small-scale commercial operation (Branch et al. 2002, Harris et al. 2002). In most respects (see Table 2.2) the fishery falls within the subsistence category, as even the occasional large catches of galjoen and stumpnose cannot be considered as being of commercial proportions. Averaged over a year, such infrequent catches do not result in a high income. The two main

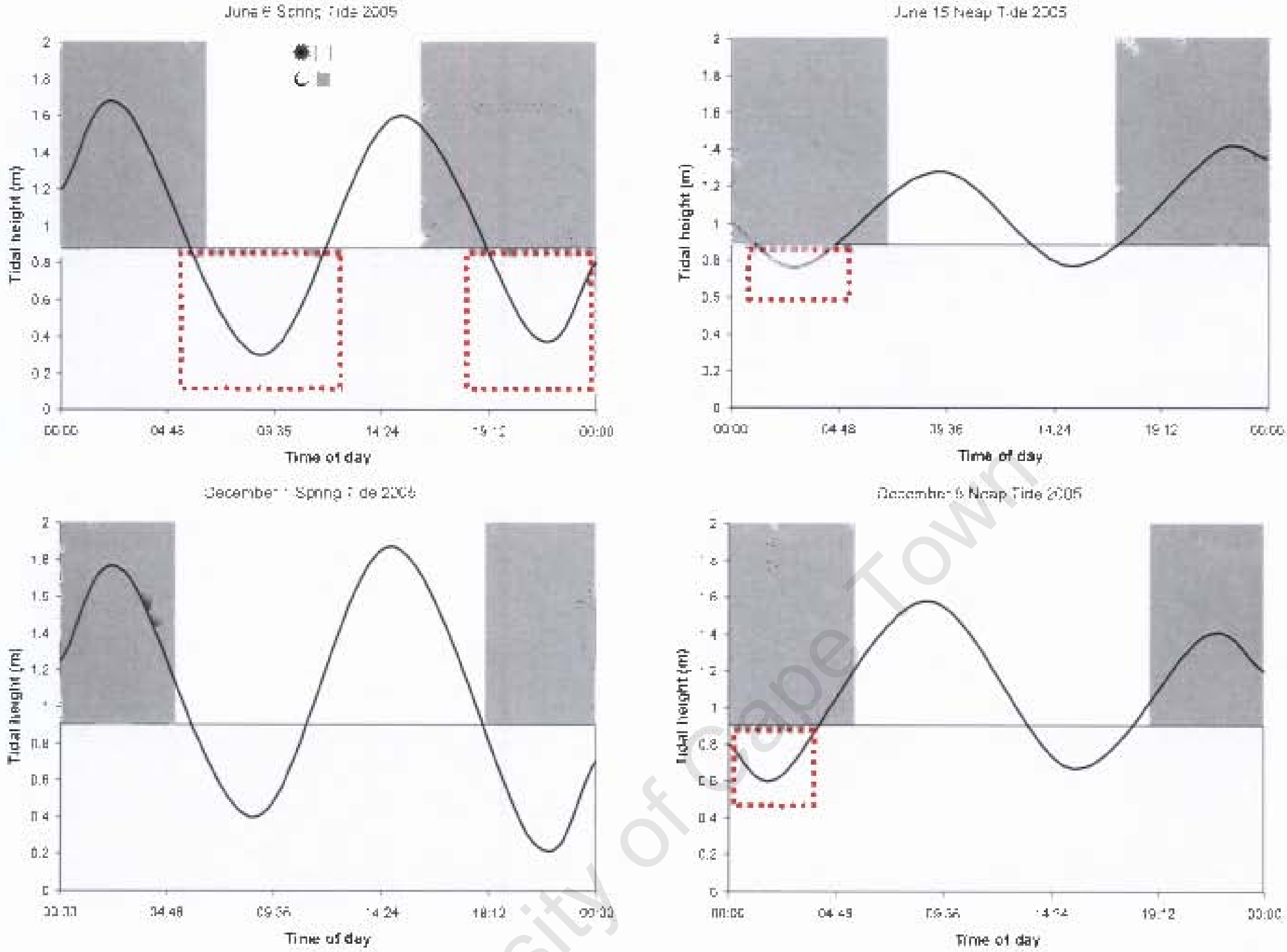


Figure 2.5. Tide (Naval Hydrographer 2005) superimposed on a 24 hour cycle (Naval Hydrographer 2005) to indicate sea-level relative to the height of *vywer* walls during day and night. Spring and neap tides for June and December were chosen to emphasise seasonal differences. Red box illustrates fishing window of opportunity.

Table 2.2. Criteria for subsistence and small-scale commercial fisheries relative to activities in Arniston and Still Bay *vywers*.

Criteria for definition	Arniston	Still Bay
Subsistence fishery		
Need the resource to meet basic needs	✓	×
Operate near or on the shore	✓	✓
Live within 20km of the resource	✓	✓
Consume or sell the resource locally	✓	✓
Low technology gear	✓	✓
Resource has low cash value	✓	✓
Long history of fishing (>30 years or generational)	✓	✓
No other employment	✓	×
Not exceeding sustainable levels of harvest	?	?
Sale of resource is personal and within local area	✓	✓
Small-scale commercial fishery		
Owner must be involved in day-to-day operations	✓	✓
Live close to the operation	✓	✓
Long history of fishing	✓	✓
Must generate >75% of their income	✓	×
Operate near or on the shore	✓	✓
Small enterprise	✓	✓
Low capital and income	✓	✓
Resource has commercial value	×	×

fishers involved differed in their personal socio-economic circumstances, with the Arniston fisher being dependent on the fishery for his income and survival whereas the Still Bay fisher was not as he had other sources of income.

Status of the fishery

Due to the sporadic nature of the catch and the limited data currently available, it is obvious that long-term catch records are needed to evaluate the fishery. Occasional large catches of species that are of conservation concern because their stocks are severely over-fished (Griffiths 2000, Mann 2000) may threaten the viability of local populations. From the data available, there appear to be have been no major changes to the species composition taken in the *vywers* over the past 60 years (Table 2.1). The *vywers* consistently capture mullet in large numbers. The mullet species recorded for these areas are found in the following proportions: *Liza richardsonii* 70%, *L. dumerillii* 20%, *L. tricuspidens* 5%, *Mugil cephalus* 5%, *M. capensis* <1% and *L. macrolepis* < 1% (S. Lamberth unpublished data). There is a daily bag limit of 50 for all mullet combined but no size limit for any mullet species, which are not regarded as threatened species.

In a crude extrapolation from the data available, based on south-coast estimates of five haarder to the kilogram (K. Hutchings pers. comm.), with one new-moon spring tide a month, the yearly catch per *vywers* site will average 1 700 kg of haarders. The current overall annual haul of haarders along the entire south coast of Western Cape is an estimated 400 tons: 200 tons consistently within False Bay (Lamberth 1994) and a further 200 tons for the rest of the south coast (K. Hutchings pers. comm.). This can be considered an overestimate, as effort has been greatly reduced along the south coast over the past five years, and is considered sustainable.

At these rates, the two actively fished *vywers* catch a mere 0.4 % of the total estimated catch for the south coast. Even if there is a 10-fold error, the *vywer* catch only amounts to 4% of the total catch.

There are other species, however, that are being caught in *vywers* and are considered threatened stocks. Of the 20 species recorded for the *vywers*, eight are flagged as being of conservation concern (Griffiths 2000, Mann 2000). Species such as the white musselcracker and poenskop have vulnerable life history strategies (long lived, slow maturing, late reproducing) and are prone to overexploitation. Catches of a number of species are considered strictly recreational and no sale of species such as white musselcracker, elf, dassie and belman is permitted. MPAs are of little use for migratory species, such as elf, but have proven beneficial for species such as white musselcracker, galjoen, dassie, poenskop and belman. Incidental large catches of any of these species may have implications for local resident populations, and may even affect migratory species such as elf, although the effects may not be noticed for a while even if catches are regular. It does appear though that large catches are irregular and infrequent, and that unless further sets of *vywers* become operational, fishing in the two existing *vywers* is unlikely to have any serious conservation implications. Currently, however, there is pressure on Marine and Coastal Management for permission to fish at least four additional sets of *vywers*.

By analogy, the *vywer* fishery resembles the in-shore net fishery that targets mullet but has a by-catch of species of conservation concern (Hutchings & Lamberth 2002). However, by-catch in the *vywers* can be ameliorated if capture takes place without gillnets, because fish can be released without damage.

Recommendations

At present there are obvious discrepancies between fishing regulations and the activities of fishers using *vywers* to catch fish. Many of their activities are illegal. They are operating with recreational permits but are catching more than the daily recreational bag limits and are selling fish. On the other hand they do maintain the *vywers*, thus contributing to the preservation of a cultural heritage resource. This places managers on the horns of a dilemma: how to maintain the *vywers* and associated cultural activities while regulating associated fishing activities within sustainable and legal limits. An additional difficulty is that insufficient long-term data exist to allow a proper assessment of the effects of fishing in *vywers*. To obtain this information it will be necessary to legalise and control these activities and to implement monitoring. Given this, the following recommendations are advanced:

1. Permits should be issued for an interim period of two years to the two main fishers at the two currently fished *vywers* on formal application. If management is concerned that overexploited species will still be harvested, despite stringent rules associated with the permit, a research programme can be instigated instead. This would provide the same information but would be under the supervision of a project manager rather than fisheries inspectors or community monitors.

2. Only mullet species may be captured in unlimited quantities for sale. Species indicated in Table 2.1 as being of conservation concern shall not be captured for sale and may only be caught in quantities stipulated by regulations for recreational fishing. Other species listed in Table 2.1 may be caught for sale but in quantities specified by the permit.

3. To avoid damage to fish that must be released, capture of fish in *vywers* will be permitted with scoop-nets or a fine-mesh seine-net no longer than 10 m, but not with gillnets.

4. Monitoring shall be implemented for (a) catches and (b) species recorded in *vywers* that may not be harvested.

5. Fishers permitted to harvest fish from *vywers* shall be responsible for maintaining the *vywers*. This should be jointly managed by MCM and South African Heritage Resource Agency.

6. Permitted fishers will be allowed to fish in the *vywers* at Still Bay even although they fall within a proposed MPA.

7. Any transgression of permit conditions will result in withdrawal of the permit and prosecution.

8. Evaluation will take place after two years to see if the fisheries are viable and sustainable. If so, the decision on whether they should be classed as (a) subsistence or (b) small-scale commercial operations, and whether permits can be issued for other *vywers*, will be considered.

These recommendations are made for the following reasons:

1. Both *vywers* and fishing in *vywers* can be regarded as part of our cultural heritage that needs to be maintained, at least at representative sites.

2. Current levels of fishing in these *vywers* do not constitute a threat to fish stocks, provided they focus on mullet and do not breach regulations for species of conservation concern.

3. Adequate data on the *vywer* fisheries need to be obtained to evaluate the viability and sustainability of both existing *vywers* and potential expansion into other *vywers*.

4. It is government policy to promote small-scale fisheries to alleviate poverty, providing they are sustainable.

These recommendations are advanced in the spirit of achieving a practical solution to the conflicts between managers concerned with overexploitation of many linefish and the needs of fishers. Both existing fisheries lie within 5-km of the nearest Fisheries Compliance Office and community monitors could be appointed to assist with data gathering. Both fisheries could be co-managed, giving joint responsibility to fishers and managers, opening the way for education workshops to dispel existing misinformation and establish workable laws and ground rules.

CHAPTER 3

EFFECT OF ANCIENT STONE WALL FISH TRAPS ON INTERTIDAL BIODIVERSITY ALONG THE SOUTH COAST OF SOUTH AFRICA

INTRODUCTION

Concern has been expressed about the increasing trend of development (breakwaters, seawalls, jetties, groynes and pier-pilings) within the intertidal zone (Walker 1988, Chapman & Bulleri 2003, Bulleri 2005a, b, Chapman et al. 2005). Little is known about the impacts that these developments may have on intertidal communities, although interest is increasing. A number of studies have shown that invertebrate and algal communities on artificial structures in the intertidal zone can differ from surrounding natural rocky reefs, suggesting a loss and fragmentation of natural habitat (Ambrose & Anderson 1990, Chapman & Bulleri 2003, Qiu et al. 2003, Bulleri & Chapman 2004).

Even if artificial and natural habitats are composed of the same materials, as is the case for South African stonewall fish-traps, or *vis-vywers*, research at Australian boulder fields (McGuinness & Underwood 1986) and harbours (Chapman & Bulleri 2003), and at Italian marinas (Bulleri & Chapman 2004) has shown that they do not necessarily support similar intertidal assemblages. Once the substrate has been raised into walls, other physical factors come into play in defining the abundance and species composition of communities, including the orientation and height of walls, altered exposure to wave action (Dayton 1971, McQuaid & Branch 1984, Bustamante

& Branch 1996), and the creation or elimination of micro-habitats in crevices and cracks (McGuinness & Underwood 1986 among others). These processes affect species assemblages, biomass and diversity on large spatial and temporal scales (Sousa 1979a, b, Branch 2001, Thompson et al. 2002, Menge & Branch 2001) and, along with smaller-scale biotic interactions, determine the community zonation so characteristic of rocky intertidal shores (Bustamante et al. 1997, Stephenson & Stephenson 1972).

The age of artificial structures is also important (Glasby 1998) as it offers a temporal perspective on changes in intertidal communities. If the currently available dating of the *vywers* at 3500 - 1700 years BP is accepted (Avery 1975), then the walls of the *vywers* are the earliest constructed coastal walls in southern Africa (J. Sealy pers. comm.). The *vywers* thus offer a unique opportunity to assess the long-term effects of construction in the intertidal zone.

The majority of South African *vywers* are found within or adjacent to boulder fields. Boulder fields are non-equilibrium systems where diversity is maintained by continually varying levels of disturbance (Sousa 1979a). To build the *vywers*, loose rocks and boulders were moved and stacked to form walls (see Chapter 1 for details of the design and construction). This process alters the original dynamics, whereby a previously periodically destabilised system, spatially homogenous at the scale of the shore as a whole, is transformed into a more stable but also more heterogeneous one (Chapman 2002). Over time, many of the walls become consolidated by marine life, mainly the polychaete *Pomatoleios krausii*, which creates intertwined calcareous tubes that naturally cement the walls together. On ebb tides, the inner walls create, in effect, a sheltered slow-draining tidal-pool while the outer walls are subject to wave action. In addition, building walls raises the height of the boulders, thus exposing them to different environmental forces from those lower down and on flatter shores. Since it has been established that species diversity increases as more habitats are made available in the intertidal zone (McGuinness & Underwood 1986, Archambault & Bourget 1996, Thompson et al. 2002), I predicted that the construction of *vywers* will increase diversity, both in terms of the *vywers* themselves (α diversity) and on the shores as a whole (β diversity).

Geographically, most *vywers* are closely associated with shell middens, but it has not been possible to correlate the remains on these middens with the *vywers* because *vywers* lack any remnants that allow them to be dated absolutely (Avery 1975). The middens have been dated stratigraphically, and the sudden discontinuation of use of megamiddens (huge open shell deposits of up to 30 000m^3 in area) about 2100 years B.P. corresponds with the appearance of pastoralism (Buchanan 1988, Sealy & Yates 1994, Jeradino & Yates 1996). It is of interest to establish if the invertebrate species in these middens correlate with species found more abundantly in association with *vywers* than on adjacent rocky shores. Could construction of *vywers* have favoured growth and accumulation of edible invertebrate species as well as capturing fish?

This study was designed to determine if *vywers* promote a new suite of species compared to 'control' shores (those unaffected by but associated with *vywers*) and whether this alters diversity. I predicted that the communities associated with the *vywers* would be different from those in adjacent control areas, that the presence of *vywers* would increase overall diversity, and that the more homogenous nature of *vywers* would lead to biotic assemblages that would be more uniform within *vywers* than on control shores.

METHODS

Study Sites

Four sites at which *vywers* were present along the south coast of South Africa were chosen for this analysis (Fig. 3.1). Each of these sites displays different characteristics in design, positioning, material used and degree of 'cementation' by marine life (see Chapter 1 for details and Table 3.1 for a summary). Briefly, Ryspunt and Skipskop *vywers* have lain neglected for nearly two decades, while Arniston and Still Bay *vywers* are still actively fished and maintained. Arniston and Still Bay *vywers* are built with boulders, while the Ryspunt and Skipskop *vywers* are built of shale packed upright. The walls of the Arniston and Still Bay *vywers* are highly cemented by marine life, those at Ryspunt and Skipskop less so.

Table 3.1. Comparisons between the condition, structure and use of study *vywers*.

	Arniston	Ryspunt	Skipskop	Still Bay
Rock material	Irregular boulders	Shale	Shale	Round boulders
Fishing	Current	Not used	Not used	Current
Wave action	Strong-mod	Moderate	Moderate	Sheltered
Biotic cementation	Substantial	Moderate	Moderate	Substantial
Maintenance for fishing	Ongoing	None	None	Ongoing

Sampling

Sampling was conducted at each of the four study sites in March 2004. Various localities within each *vywer* and, as 'controls', analogous locations adjacent to the *vywers* but unaffected by them, were selected for sampling. At each location, up to ten 0.5 x 0.5 m^2 replicate quadrats were positioned randomly on the walls of the *vywers*, or on comparable positions at equivalent heights for controls, and sampled. The numbers of locations and replicates at each site differed due to site conformation,

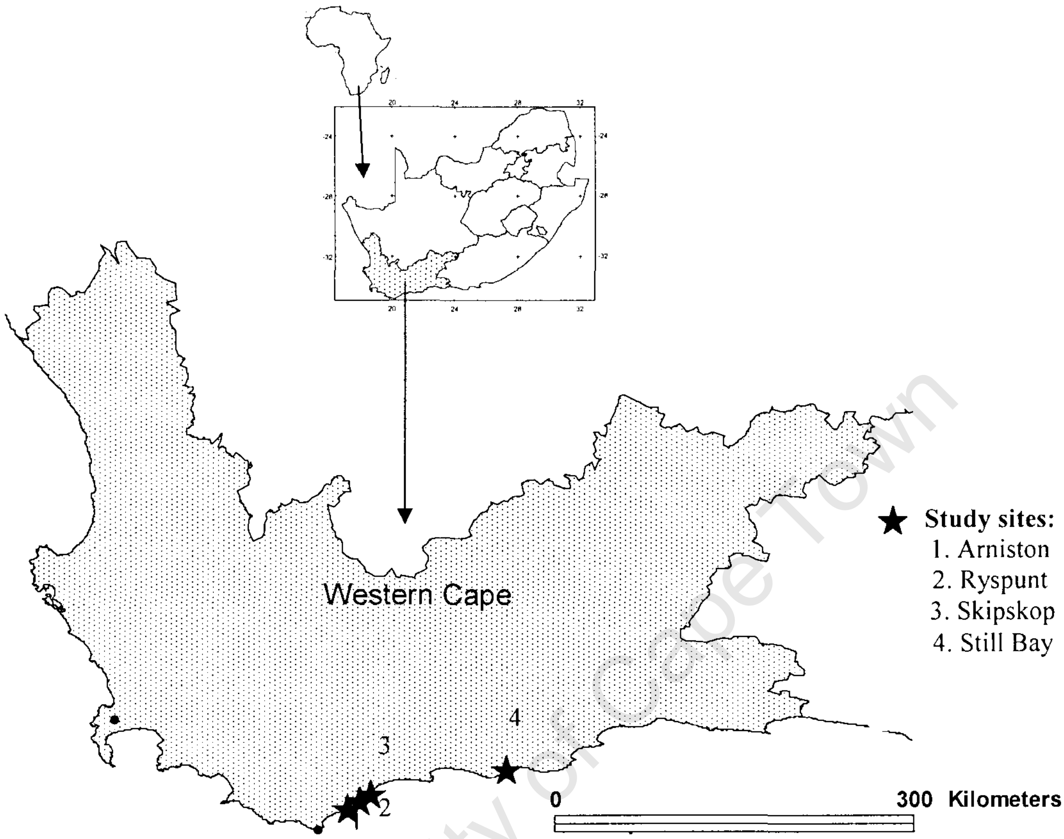


Figure 3.1. Location of the study sites on the south coast of the Western Cape Province, South Africa.

weather and tidal encroachment (Table 3.2). In each quadrat, counts were made of mobile species and percentage cover estimated for sessile species. These numerical data were converted to wet biomass ($g.m^{-2}$) for analysis, using conversion factors in Appendix 3 (see p. 57).

Table 3.2. Study sites and sampling intensity

Study site	Number of locations sampled	Number of replicates at each location
Arniston	6 (+4*)	10 (5*)
Still Bay	5	5
Ryspunt	5	5
Skipskop	4	10

* For stability and heterogeneity indices

At Arniston, the walls of the *vywers* were sufficiently tall to justify sampling the top and bottom of the walls separately, together with control samples at equivalent heights, to explore the interactive effects of shore height and *vywers*. For both Ryspunt and the low shore at Arniston, it was possible to distinguish wave-exposed and sheltered *vywer* walls, which were sampled separately in conjunction with controls experiencing equivalent wave action, to examine the joint effects of wave exposure and *vywers*. To determine the level of disturbance within the boulder fields from wave action and boulder tumbling a Stability Index was devised and calculated using the following equation:

$$\text{Stability} = (\%\text{ cover of stable rocks} \times 1) + (\%\text{ cover of semi-stable rocks} \times 0.5) + (\%\text{ cover of unstable rocks} \times 0)$$

Stable rocks were taken to be those that could not be moved by the researcher, semi-stable rocks could be moved using two hands and unstable rocks with one hand. A Heterogeneity Index was devised to determine the level of heterogeneity within the samples.This was measured using a 2-m long chain with 2-cm links that was draped over the rocks to follow their contours, and then calculated as:

Heterogeneity = 1 - (chain length draped over substratum / taut chain length)

These indices were calculated for established stable *vywer* walls, equivalent control shores adjacent to the *vywers*, disintegrating destabilised vywer walls, solid unbroken flat natural rock (all at Arniston) and artificial surfaces (the walls of tidal swimming pools at nearby Struisbaai). All measures of stability and heterogeneity were restricted to high-shore sheltered situation.

Midden sampling

A surface survey of the middens at Arniston (34°41'19.3"S, 20°14'01.4"E) was undertaken to establish what species made up the majority of remains in middens associated with the *vywers* there. Arniston was chosen for this study as the middens were undisturbed by development and not covered with dune vegetation, unlike many of the other sites. Twenty quadrats of 0.25 cm^2 were randomly thrown within the midden area. Shell remains within each quadrat were identified to species level, counted and measured along the longest axis. Shell fragments were excluded. *Turbo sarmaticus* opercula were also counted and measured, as they provided a more accurate record for this species than shell remains. Opercular diameters were converted to shell size using the conversion formula of McLachlan & Lombard (1981):

Operculum (mm) = 0.504 shell breadth (mm) + 1.791.

This approach provides only a preliminary assessment. A systematic archaeological excavation would have been preferable, but was precluded by legislation governing protection of middens. Surface samples will include only remains currently exposed by moving sand, and smaller species or shell fragments may not have been detected as they might have been removed or remained concealed within the strata of the middens. In addition, the contribution of *T. sarmaticus* may be over-estimated as opercula are erosion-hardy.

Statistical analysis

Multivariate analyses

Multivariate analyses (Primer 5.2.2, Plymouth Marine Laboratory, Clark & Warwick, 1994) were used to examine patterns in invertebrate community structure and composition. Analyses were conducted on fourth-root transformed, non-standardized wet biomass data. Analysis of Similarities (ANOSIM, test statistic R), using Bray-Curtis similarities, was used to test for significant differences among the samples. Non-metric Multi-dimensional Scaling (MDS) plots were used to graphically demonstrate differences, and a Similarity Percentage Breakdown Analysis (SIMPER) demonstrated which species characterised and distinguished treatments (Clark & Warwick, 1994).

Univariate analyses

Species numbers and biomass per quadrat were compared using either t-tests or Mann-Whitney U tests. Species diversity was assessed by three indices: Margalef's Richness Index (d), Pielou's Evenness Index (J') and the Shannon-Weiner Diversity Index (H'). All univariate analyses were conducted using STATISTICA (Version 6 for Windows, StatSoft Inc. 2004). The minimum significance level was set at $p = 0.05$.

RESULTS

For all four sites combined, a grand total of 49 species was found; 45 on the *vywers* and 40 on the adjacent natural rocky shore (see Appendix 3 p. 57 for complete species lists and biomass conversions).

Effect of *vywers* on community structure

When tested across all sites, community structure differed significantly between communities within and outside the *vywers* (1-way ANOSIM; r = 0.299, p = 0.01), although overlap was evident (Fig. 3.2). However, the four sites differed physically in terms of construction (style and materials) and position (bay or beach). When they were compared (combining locations within and outside *vywers*) the sites were significantly different (1–way ANOSIM R = 0.295; p = 0.01). I therefore continued the analysis by considering each site separately. The MDS plots for the individual sites showed that the communities differed discretely and significantly between locations within versus outside *vywers* at each site (Fig. 3.3). The amount of variability among samples was consistently less for *vywers* than control sites as reflected in the relative spreads of data (Fig. 3.3).

A SIMPER analysis showed that a suite of barnacles (*Tetraclita serrata*, *Chthamalus dentatus* and sometimes *Octomeris angulosa*) dominated on *vywer* walls but were between two-fold and twenty-fold less abundant at control sites outside the *vywers*, collectively contributing 20 – 80% to the dissimilarities (Table 3.3). The polychaete *Pomatoleios kraussii* contributed 39% to the dissimilarities at Still Bay and 30% at Arniston. Algae (*Gelidium, Laurencia, Ralfsia* and upright corallines)

EFFECT OF *VYWERS*

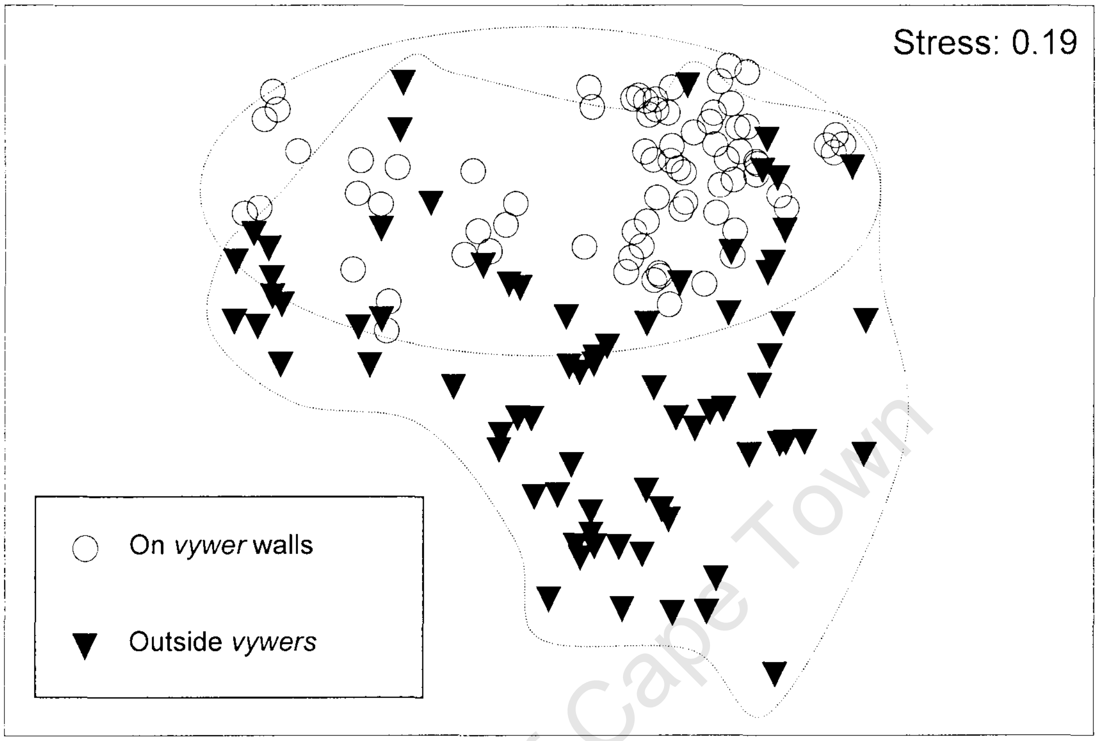


Figure 3.2. MDS ordination plot based on Bray-Curtis indices of similarity derived from root transformed species biomass data for all sites combined.

EFFECT OF INDIVIDUAL *VYWERS*

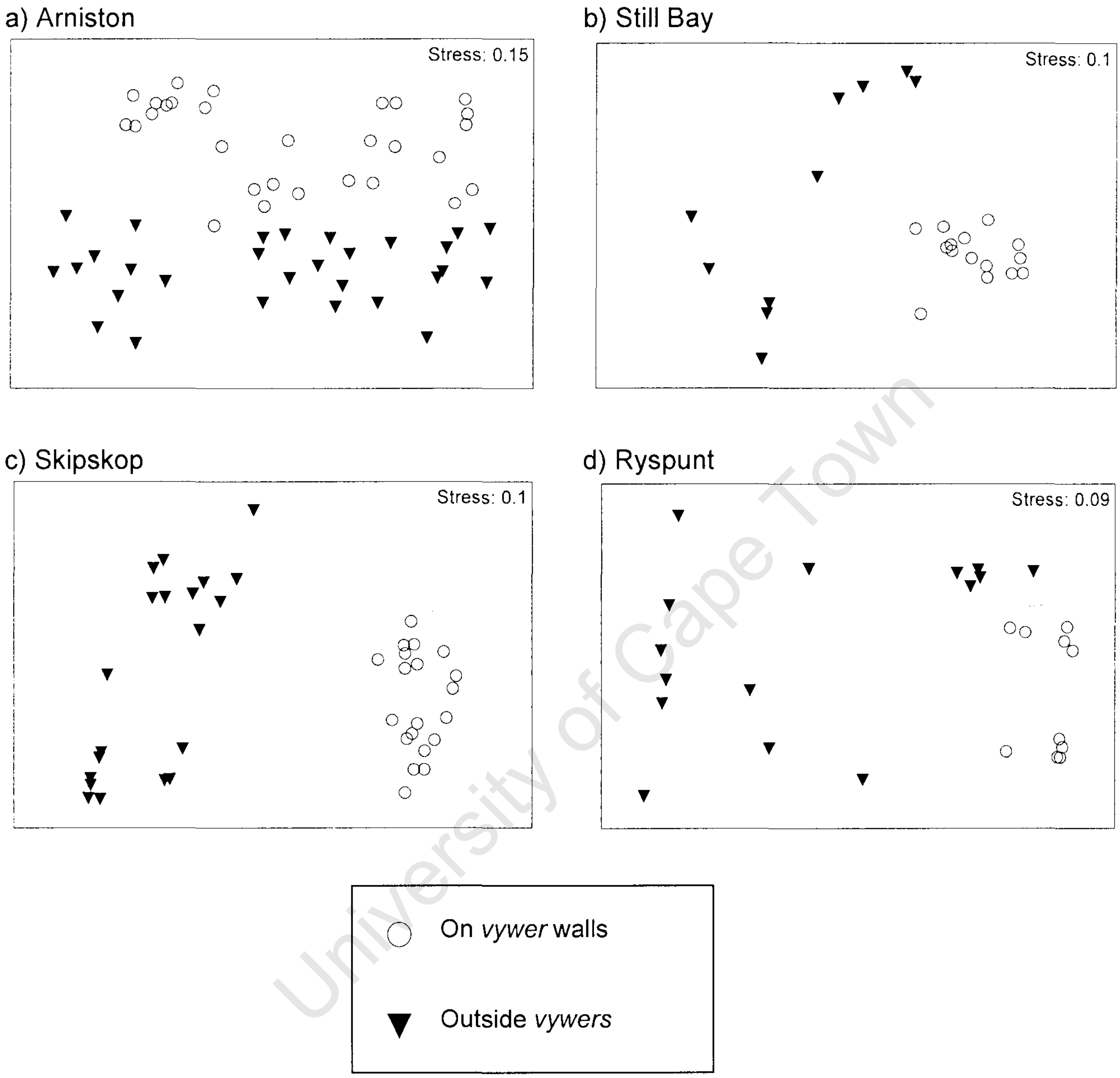


Figure 3.3. Comparisons of communities at individual *vywers* and control sites: MDS ordination plot based on Bray-Curtis indices of similarity derived from root transformed species biomass data for each site.

Table 3.3. Species responsible for differences between *vywers* and control localities at each of the four sites, identified using SIMPER analysis with 80% cut-off for cumulative percentage contribution. S = within-site similarity; Av. Abund = average abundance of species in wet mass g.m^{-2}; Av. Diss = average dissimilarity between sites; Diss/SD = ratio of mean/standard deviation of dissimilarity as a measure of consistency of dissimilarity; Contrib. % = percentage contribution of species to the dissimilarity between sites. Cum. % = cumulative contribution to the dissimilarity between sites.

Skipskop: average dissimilarity = 90.78

	vywer **(S = 61.75)**	**control (S = 44.79)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Tetraclita serrata	16108.2	376.2	51.43	2.69	56.65	56.65
Chthamalus dentatus	6728	0	25.53	1.18	28.13	84.78

Still Bay: average dissimilarity = 84.51

	vywer **(S = 64.18)**	**control (S = 33.09)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pomatoleios kraussii	5162.67	396	32.66	2.65	38.64	38.64
Tetraclita serrata	4240.8	273.6	28.57	3.11	33.80	72.44
Chthamalus dentatus	1948.8	46.4	13.18	1.68	15.6	88.04

Ryspunt: average dissimilarity = 90.78

	vywer **(S = 55.71)**	**control (S = 27.48)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Tetraclita serrata	13748.4	456	45.59	1.59	54.06	54.06
Chthamalus dentatus	5846.4	3712	21.09	1.25	25.01	79.06
Perna perna	2271.2	178.13	8.24	0.86	9.77	88.84

Arniston: average dissimilarity = 82.70

	vywer **(S = 31.61)**	**control (S = 24.99)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pomatoleios kraussii	10428	440	24.79	1.21	29.98	29.98
Tetraclita serrata	3420	1276.8	9.17	0.9	11.08	41.06
Chthamalus dentatus	2954.13	587.73	7.12	0.93	8.6	49.67
Gelidium pristoides	1504.8	1276.8	7	0.7	8.46	58.13
Laurencia glomerata	640	1408	5.91	0.7	7.14	65.27
Ralfsia verrucosa	1383.84	1051.2	5.46	0.95	6.61	71.87
Octomeris angulosa	1238.67	0.8	4.75	0.54	5.74	77.61
Upright corallines	597.33	512	3.07	0.79	3.71	81.32

collectively contributed 26% to differences at Arniston, and the brown mussel *Perna perna* contributed 10% at Ryspunt.

At all or most sites *Chthamalus dentatus*, *Tetraclita serrata*, *Perna perna* and *Pomatoleios kraussii* were major contributors to biomass and were exclusively present or substantially more abundant on walls of *vywers* than at control sites (Fig. 3.4). Other species that were also more abundant in *vywers* but only present at particular sites included the sea urchin *Parechinus angulosus*, the tunicate *Pyura stolonifera*, and the limpets *Scutellastra cochlear* and *S. longicosta* (at Arniston), and *Cymbula oculus* and *S. longicosta* (at Still Bay). Foliose algae were often either not significantly different between treatments or more abundant at control sites than in *vywers*.

In terms of overall biomass, *vywers* consistently supported biomasses that were two to ten times higher than at control sites (Fig 3.5a). The number of species that were more abundant on *vywer* walls than at control sites was also consistently greater than the number of species that were equally abundant in both treatments, or more abundant in controls than *vywers* (Fig. 3.5b).

When the four sites were pooled, species richness and diversity were significantly greater for *vywers* than controls, but there was no significant difference in evenness (Fig. 3.6). These patterns remained evident when the sites were considered individually, with the exceptions that the differences were non-significant in some cases and the outcomes for evenness and diversity were reversed at Arniston and Skipskop (Fig. 3.7).

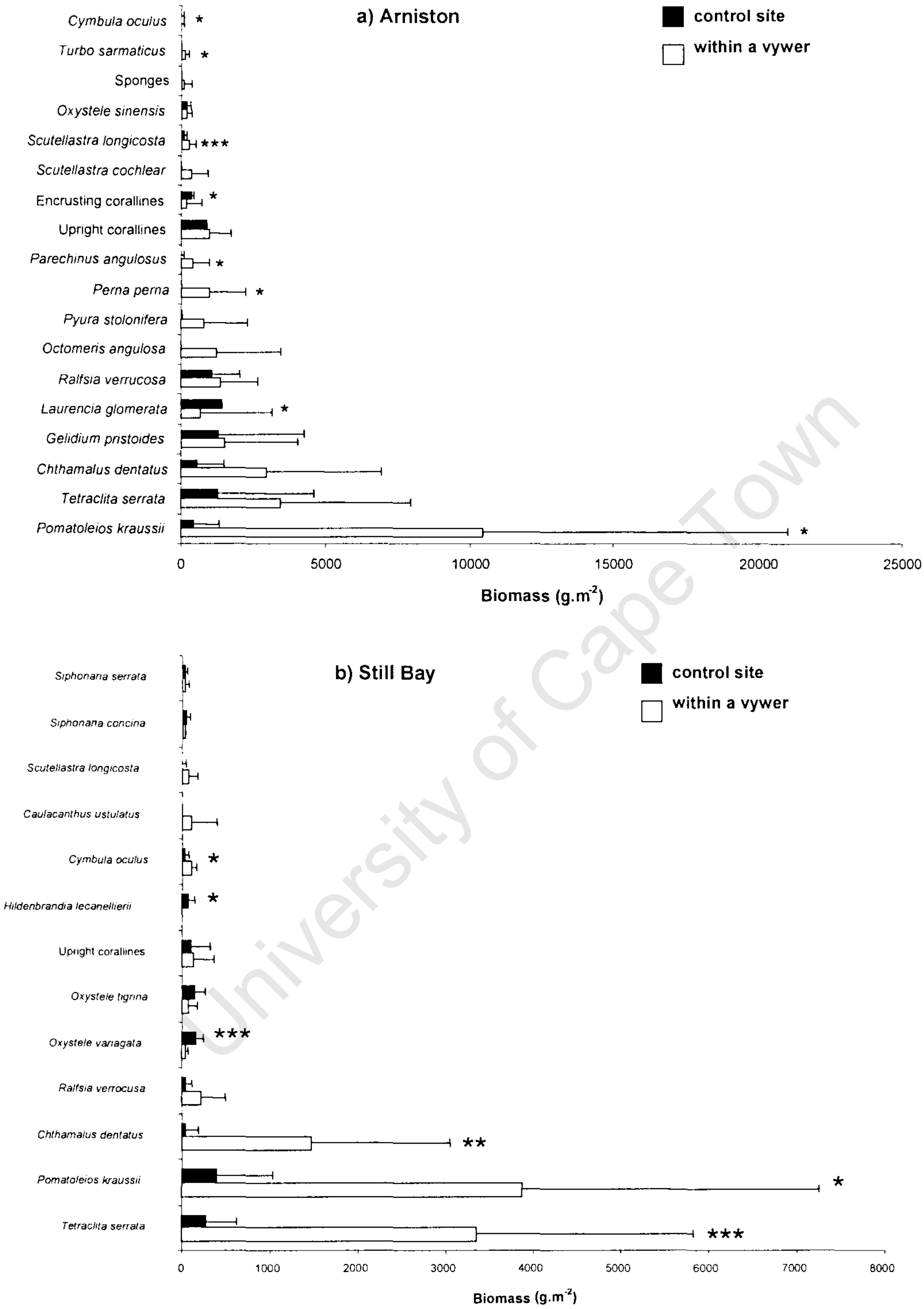
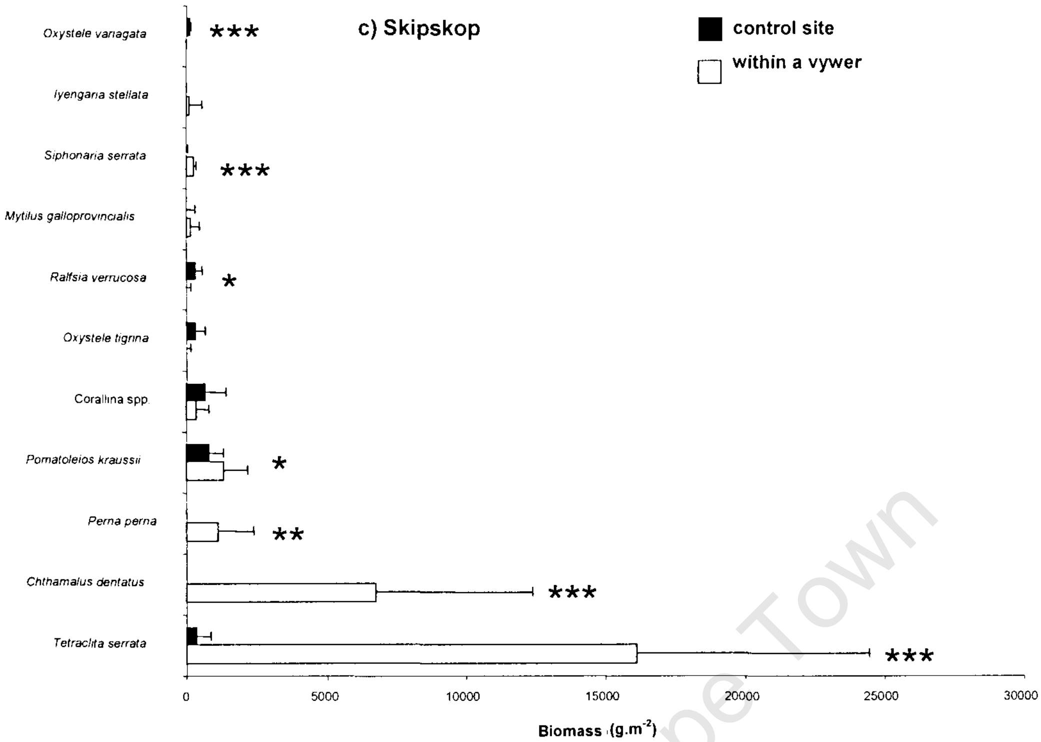


Figure 3.4. Differences in species abundance (means and 1SD) at *vywers* and control locations at each of the four sites. Average biomass (g.m^{-2}) contribution is shown (see Table 3.3.). Note different scales. (Figure continues overleaf.)



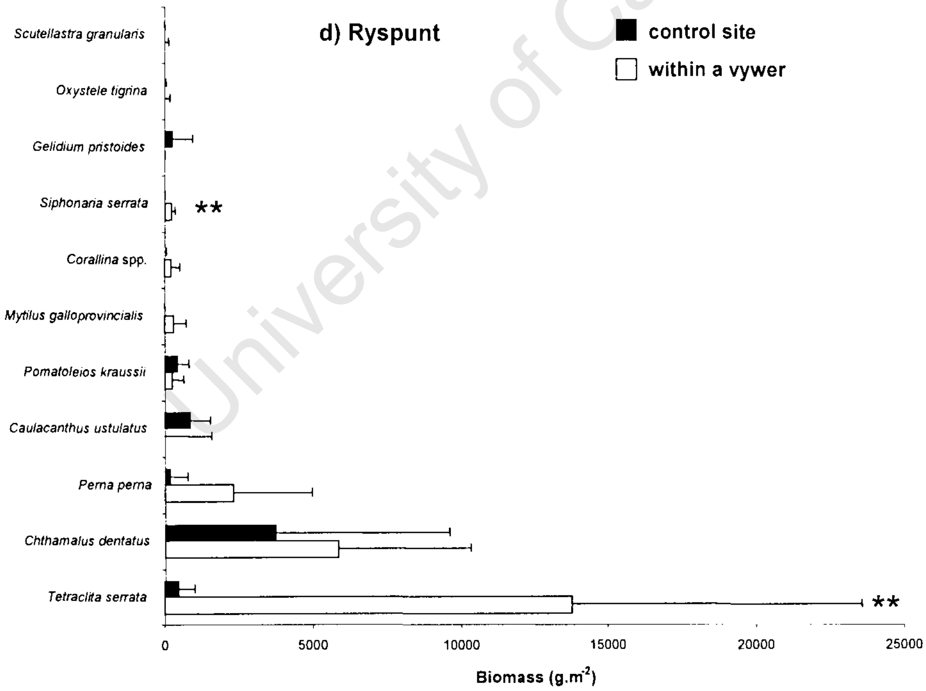
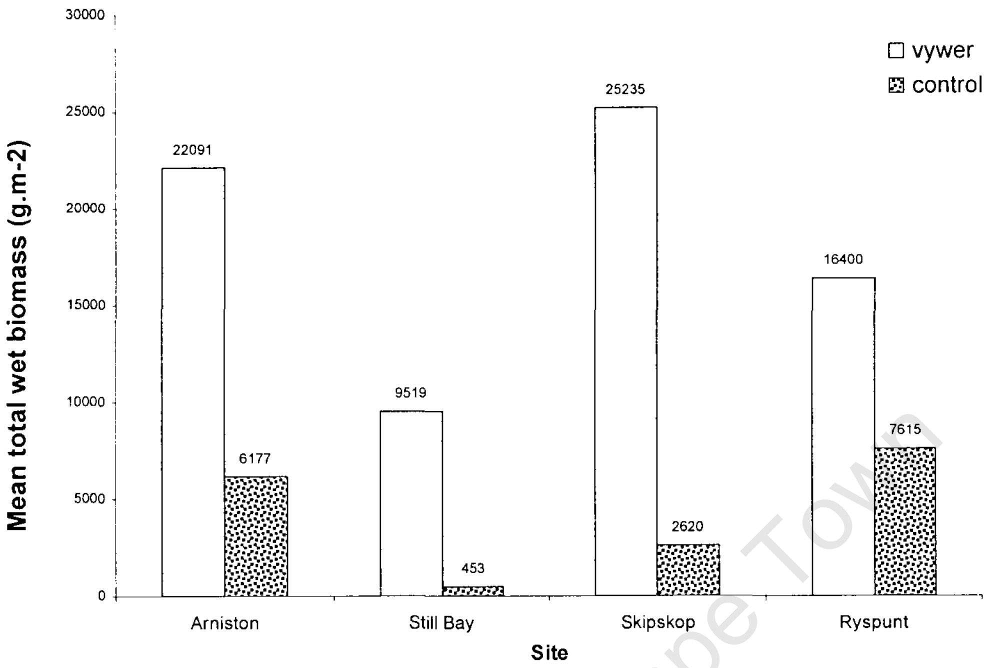


Figure 3.4. Continued

a)



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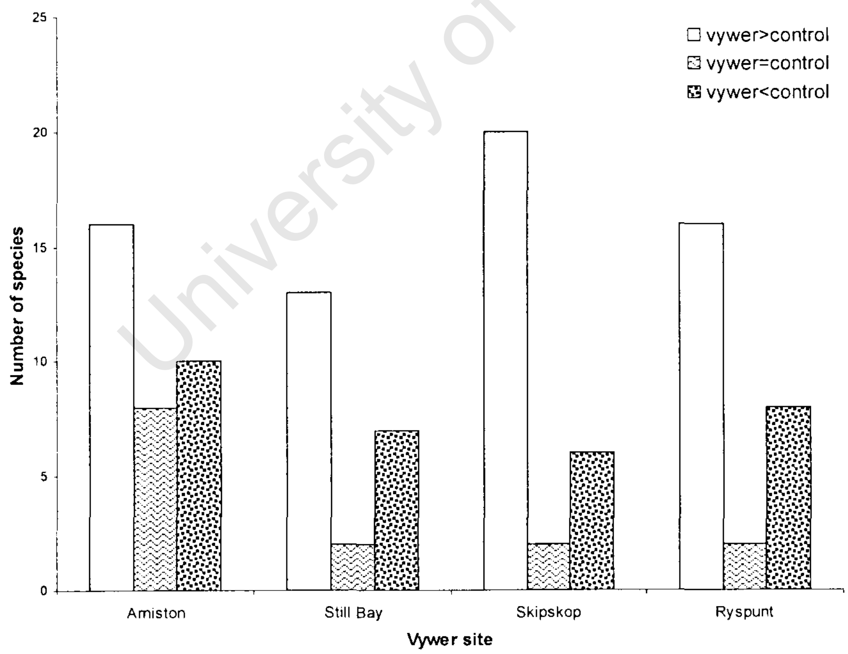

Figure 3.5. (a) Species wet biomass and (b) species number compared for each of the four sites.

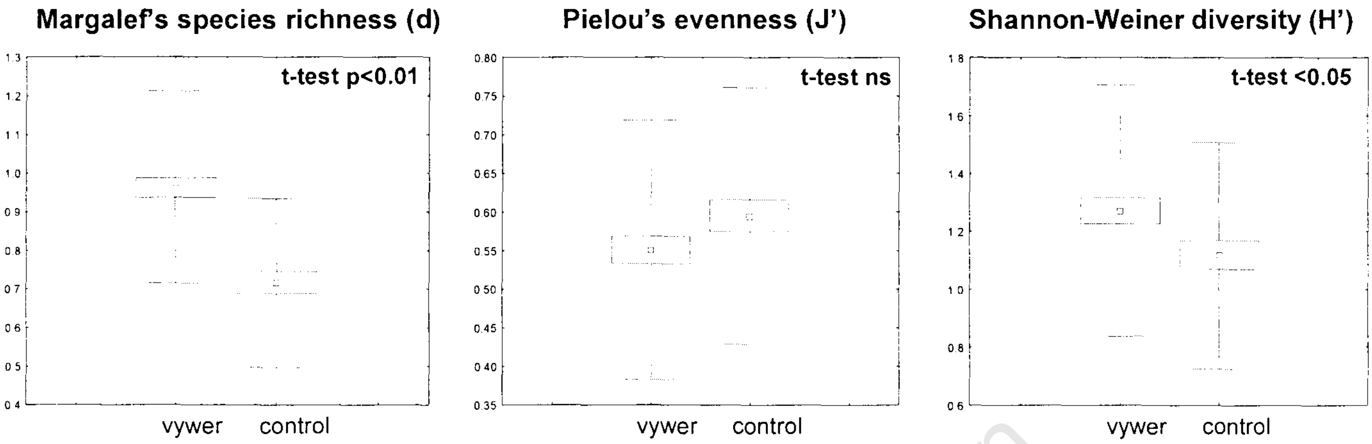

Figure 3.6. Effect of the construction of *vywers* on species diversity for all four sites combined. Boxes show standard errors around the means, whiskers the standard deviations. t-test = Students t-test, ns = not significant.

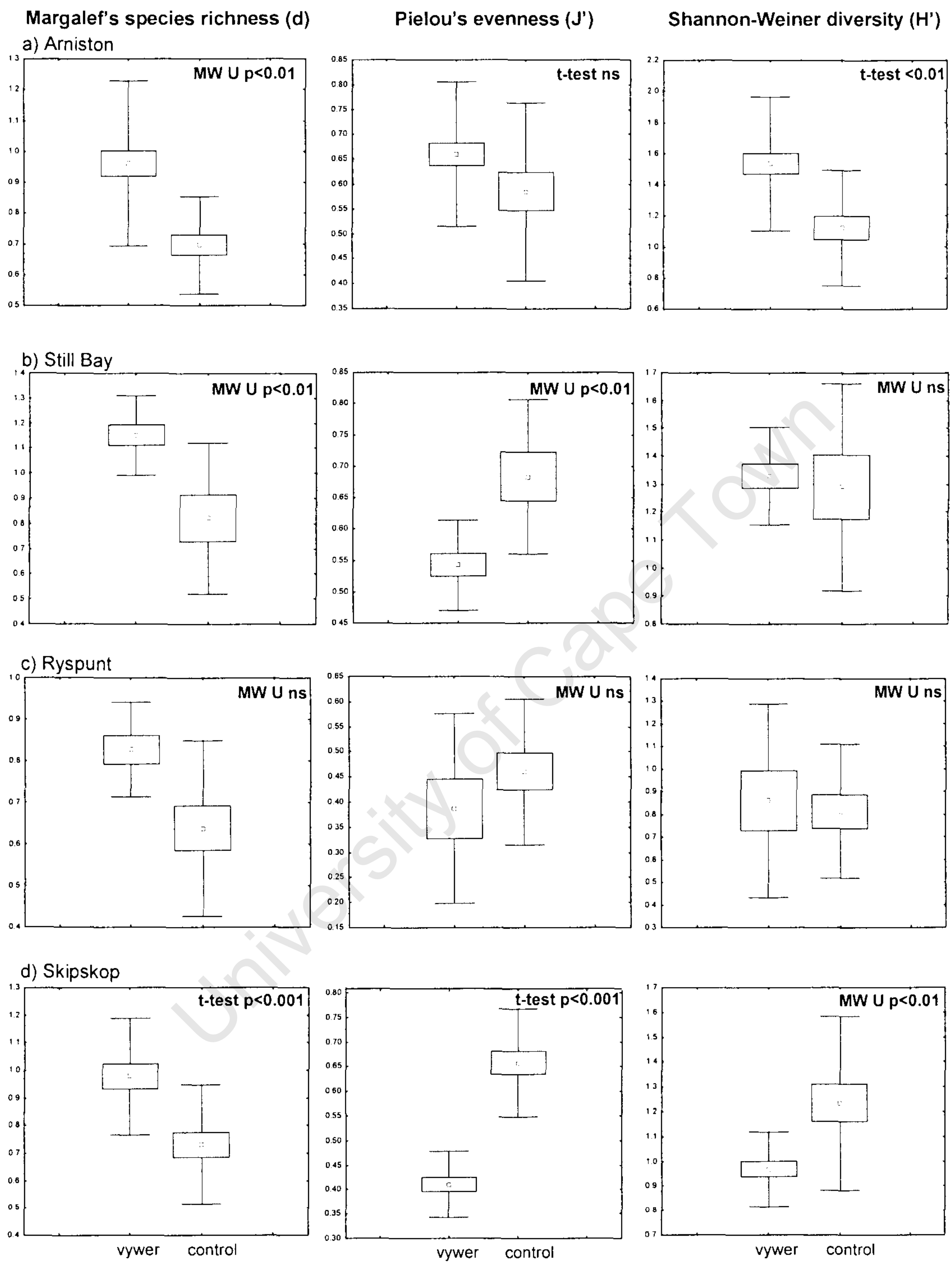

Figure 3.7. Effects of *vywers* on species diversity for each of the four sites. Boxes show standard errors around the means, whiskers the standard deviations. MW-U = Mann-Whitney U-test, t-test = Students t-test, ns = not significant.

Interactive effect of *vywers* and shore height on community structure

Shore height significantly affected community composition at Arniston, but differences between *vywers* and control areas remained significant in both zones (ANOSIM R = 0.646; p = 0.01, Fig. 3.8).

SIMPER analyses of the differences showed that on the low shore the barnacles *Tetraclita serrata* and *Chthamalus dentata*, along with the polychaete *Pomatoleios kraussii* were the predominant species discriminating between *vywers* and control areas, all being 1 – 2 orders of magnitude more abundant on the *vywers*. On the high shore, a larger suite of species was responsible for the differences. All of the invertebrates involved were more abundant inside the *vywers* than at control sites, but two foliose algae, *Gelidium pristoides* and *Laurencia glomerata*, were less abundant there (Table 3.4, Fig. 3.9). All the diversity indices were greater for the low-shore samples than high-shore samples, though not significantly so for richness (Fig. 3.10).

Interactive effect of *vywers* and wave exposure on community structure

Clear differences in communities existed in response to wave action, but communities inside and outside *vywers* were distinct when comparisons were made at equivalent intensities of wave action (Fig. 3.11). For most species at Arniston, biomass in exposed areas was higher than in sheltered areas (Table 3.5, Fig. 3.12). However, *P. kraussii*, *Tetraclita serrata* and *Gelidium pristoides* showed the reverse pattern.

At Ryspunt, barnacles contributed most to the dissimilarity, with *Chthamalus dentatus* most abundant in exposed areas and *T. serrata* most abundant in sheltered areas. With one non-significant exception, all three diversity indices were greater for exposed than sheltered shores (Fig. 3.13).

EFFECT OF SHORE HEIGHT

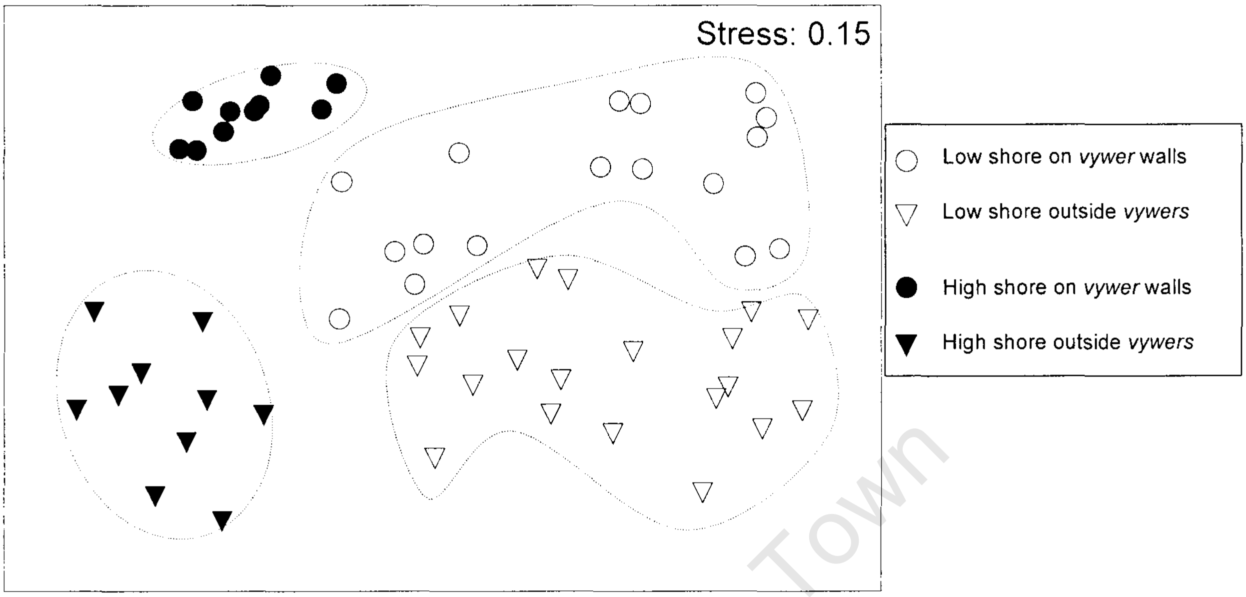

Figure 3.8. Effect of shore height and *vywers* on communities: MDS ordination plot based on Bray-Curtis indices of similarity derived from root-transformed species biomass data for Arniston for both the high and the low shore, within and outside the *vywers*.

Table 3.4. The most important species responsible for the significant differences between sites within the high-shore and low-shore localities at (a) Arniston *vywers* and (b) Arniston controls. See caption for Table 3.3 for further details and interpretation of abbreviations.

a) Arniston *vywers*: average dissimilarity = 87.55

	Low-shore (S = 31.45)	High-shore (S =78.86)				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pomatoleios kraussii	2434.67	23980	36.49	3.21	41.67	41.67
Tetraclita serrata	273.6	9439.2	15.51	2.13	17.71	59.38
Chthamalus dentatus	262.93	8676.8	14.15	2.91	16.17	75.55
Gelidium pristoides	1185.6	1641.6	3.5	0.78	4	79.54
Laurencia glomerata	2048	0	3.44	0.78	3.93	83.47

b) Arniston controls: average dissimilarity = 82.81

	Low-shore (S = 51.35)	High-shore (S =46.15)				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Gelidium pristoides	3146.4	0	22.41	1.15	27.06	27.06
Tetraclita serrata	684	3146.4	18.06	0.99	21.8	48.87
Ralfsia verracosa	1814.4	168.48	14.58	1.96	17.61	66.47
Chthamalus dentatus	0	1160	10.54	1.1	12.73	79.2
Pomatoleios kraussii	1056	264	9.73	0.87	11.75	90.95

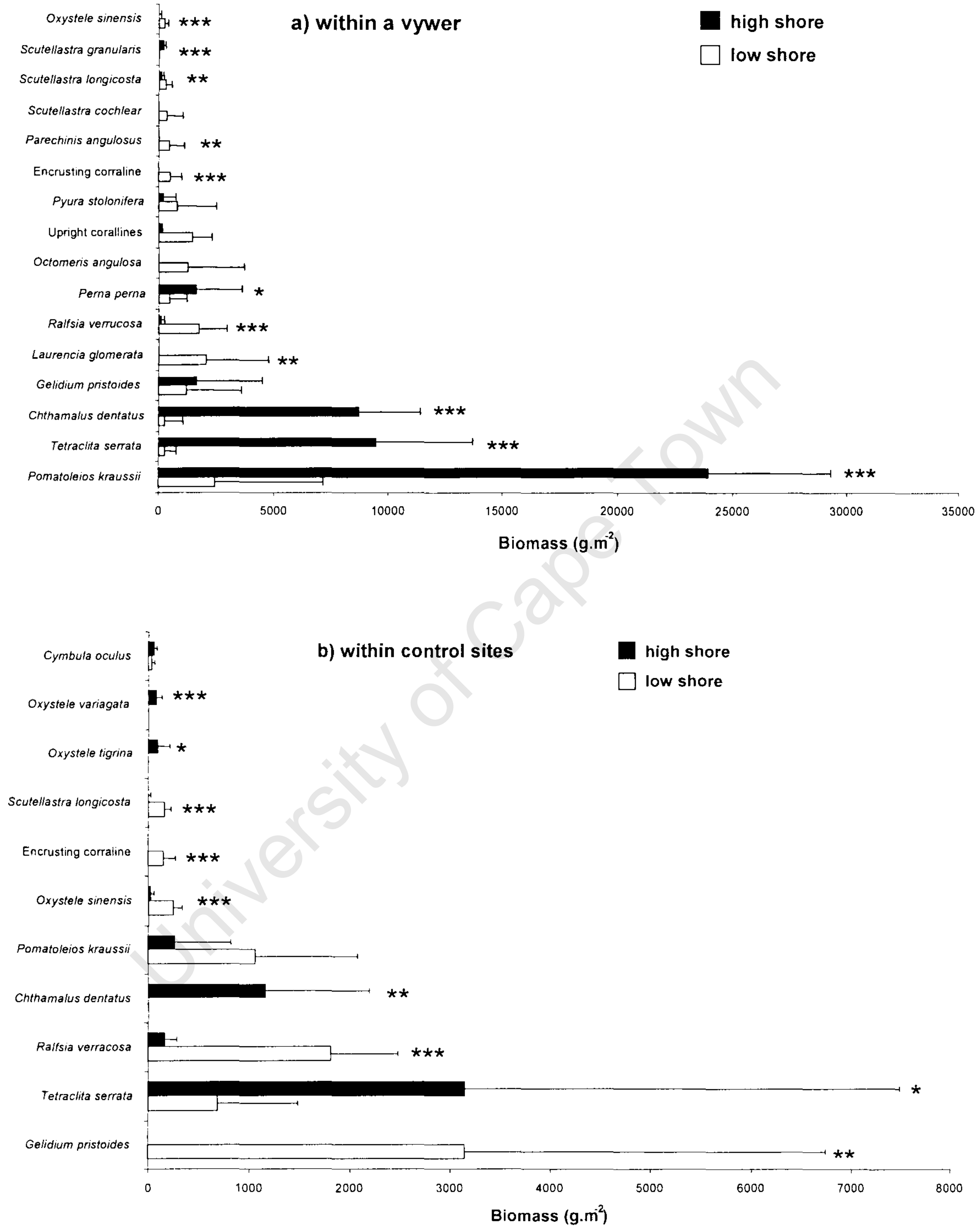

Figure 3.9. Differences in average biomass of species (mean and 1SD) between the high-shore and the low-shore at Arniston in a) *vywer* and b) control samples (see Table 3.4). Note different scales. Significance levels: * p< 0.05; ** p< 0.01;*** p< 0.001.

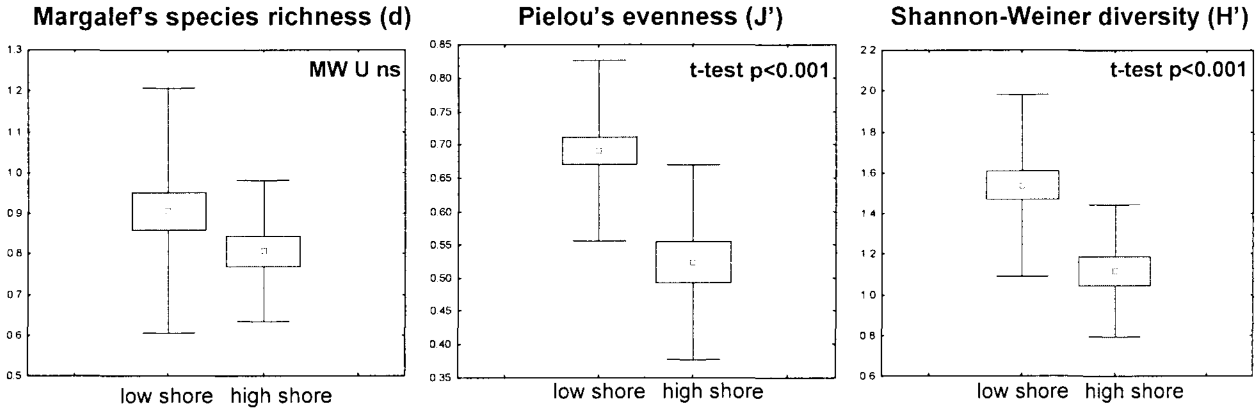

Figure 3.10. Effects of shore height on species diversity at Arniston for the low- and high-shore. Boxes show standard errors around the means, whiskers the standard deviations. MW-U = Mann-Whitney U-test, t-test = Students t-test, ns = not significant.

EFFECT OF EXPOSURE

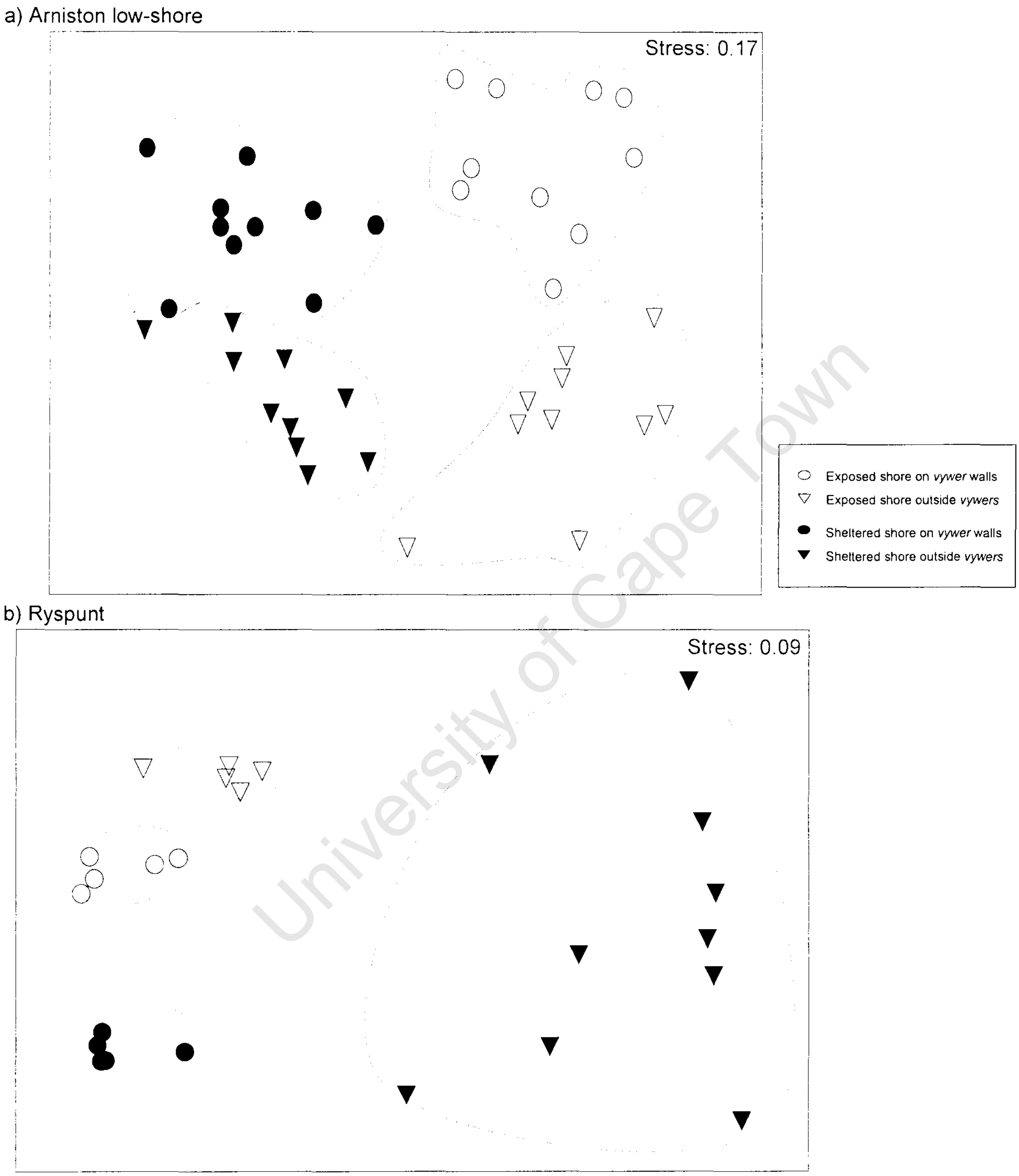

Figure 3.11. Effect of wave exposure and *vywers* on community composition: MDS ordination plot based on Bray-Curtis indices of similarity derived from root transformed species biomass data for a) Arniston high shore and b) Ryspunt within and outside *vywer*s.

Table 3.5. The most important species responsible for significant differences between exposed and sheltered sites at (a) Arniston and (b) Ryspunt. See caption for Table 3.3 for further details and interpretation of abbreviations.

a) Arniston low-shore: average dissimilarity = 79.03

	Exposed (S = 43.52)	**Sheltered (S = 39.22)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Pomatoleios kraussii	308	3872	13.6	0.96	17.21	17.21
Laurencia glomerata	2816	256	12.62	1.04	15.97	33.18
Gelidium pristoides	957.6	2394	10.14	0.86	12.83	46.01
Octomeris angulosa	1856.2	0.3	6.36	0.71	8.05	54.06
Upright corallines	1523.20	64	6.36	1.18	8.05	62.11
Ralfsia verrucosa	1419.12	2093.04	5.98	1.26	7.57	69.69
Pyura stolonifera	1215	0	3.95	0.71	4.99	74.68
Tetraclita serrata	34.2	718.2	3.3	0.89	4.17	78.85
Encrusting corallines	679.68	110.08	2.9	0.8	3.67	82.52

b) Ryspunt: average dissimilarity = 84.20

	Exposed (S = 29.66)	**Sheltered (S = 38.43)**				
Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Tetraclita serrata	2280	11012.4	34.79	1.33	41.31	41.31
Chthamalus dentatus	7021.87	881.6	28.08	1.17	33.35	74.67
Caulacanthus ustulatus	590.4	410.4	7.72	0.56	9.17	83.84

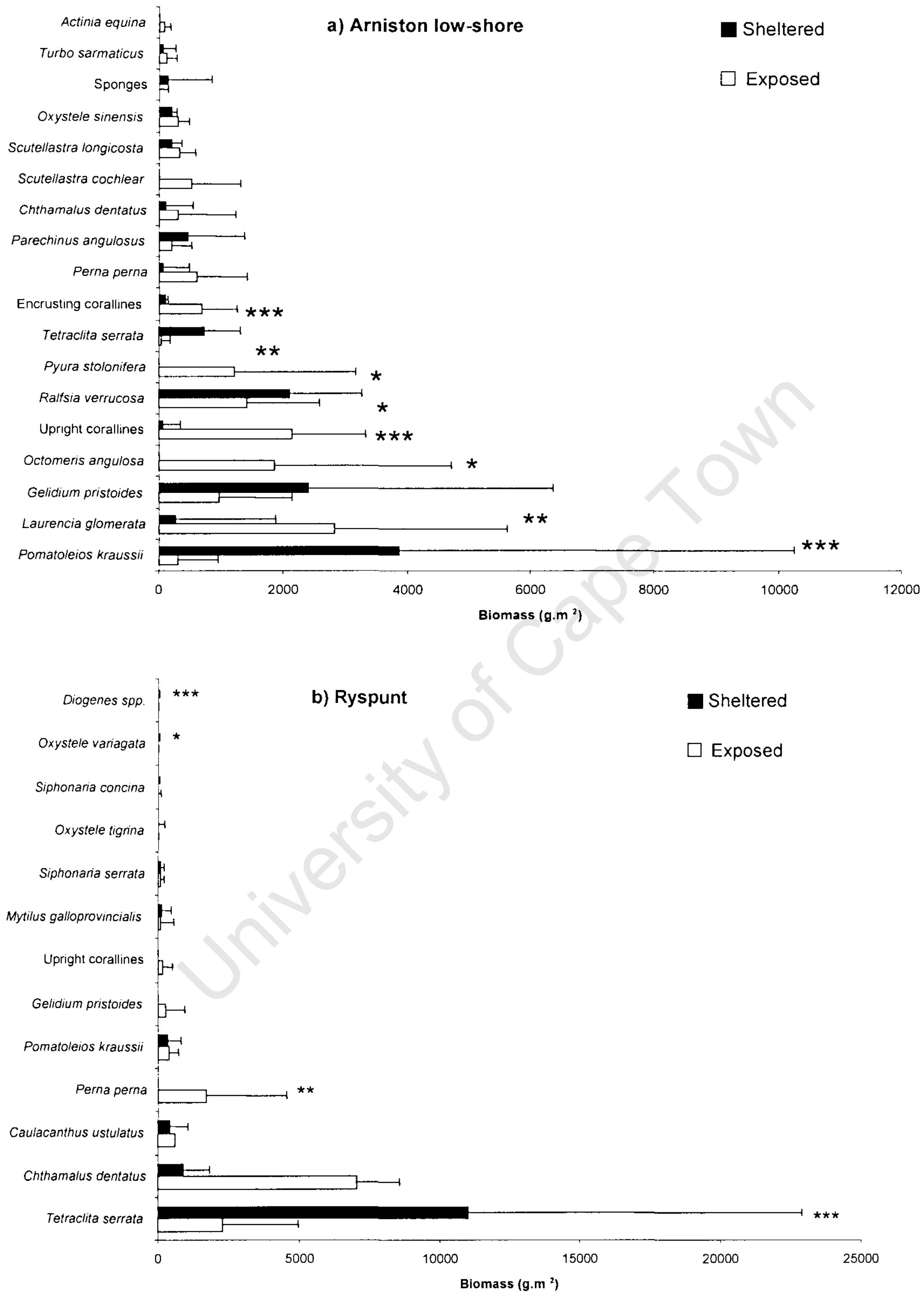

Figure 3.12. Differences of species biomass (mean + 1SD) comparing exposed and sheltered localities for (a) Arniston low-shore and (b) Ryspunt (see Table 3.5). Note different scales. Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

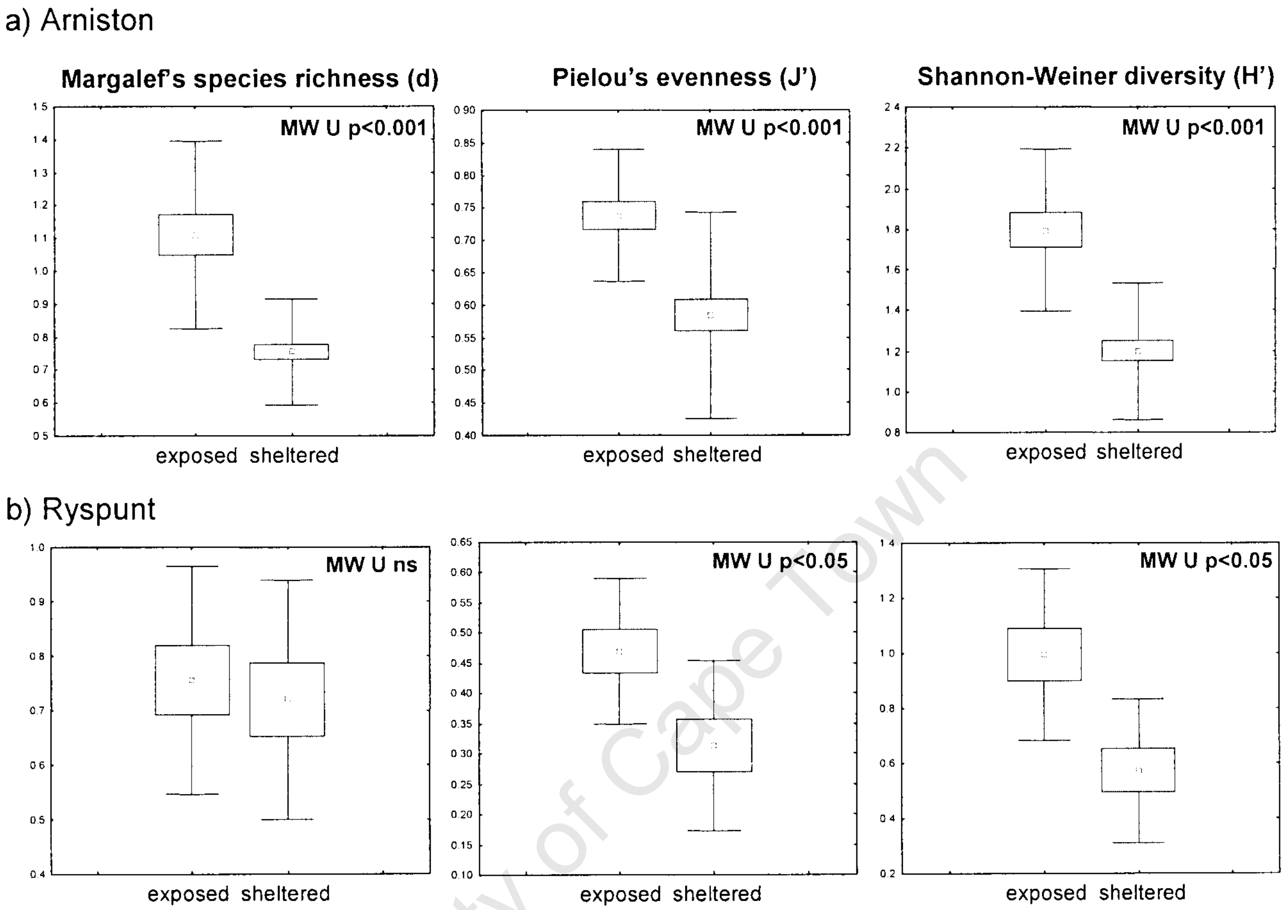

Figure 3.13. Effects of exposure on species diversity for (a) Arniston and (b) Rypsunt. Boxes show standard errors around the means, whiskers the standard deviations. MW-U = Mann-Whitney U-test, ns = not significant.

Invertebrate remains in associated middens.

The giant periwinkle *Turbo sarmaticus* was found in the greatest proportions in the middens (Table 3.6). Large limpets *Scutellastra longicosta* and *Cymbula oculus* made up the majority of the rest of the species assemblage, but the abalone *Haliotis midae* and the brown mussel *Perna perna* were also present.

Table 3.6: Species composition, size, number and percentage contribution to midden remains at Arniston. (n = 20 quadrats)

	Mean shell size (cm)	Size range (cm)	Mean no. whole shell remains/m^2	% frequency in sampled middens
Turbo sarmaticus	5.4	2.6 - 7.6	21	100
Scutellastra longicosta	5.5	3.0 – 7.0	3.6	50
Cymbula oculus	5.4	4.0 – 6.5	7	50
Haliotis midae	7.0	-	1.4	5
Perna perna	3.0	-	0.6	5

When species located in the middens or known to be harvested by fishers were considered in isolation, it was evident that the biomass of nearly all these species was substantially greater on the walls of *vywers* than on control shores, with the solitary exception of the abalone *Haliotis midae* (Fig. 3.14). *H. midae* is however heavily exploited and large shells are taken from middens as ornaments, resulting in both *vywer* and midden estimates being underestimates of true abundance.

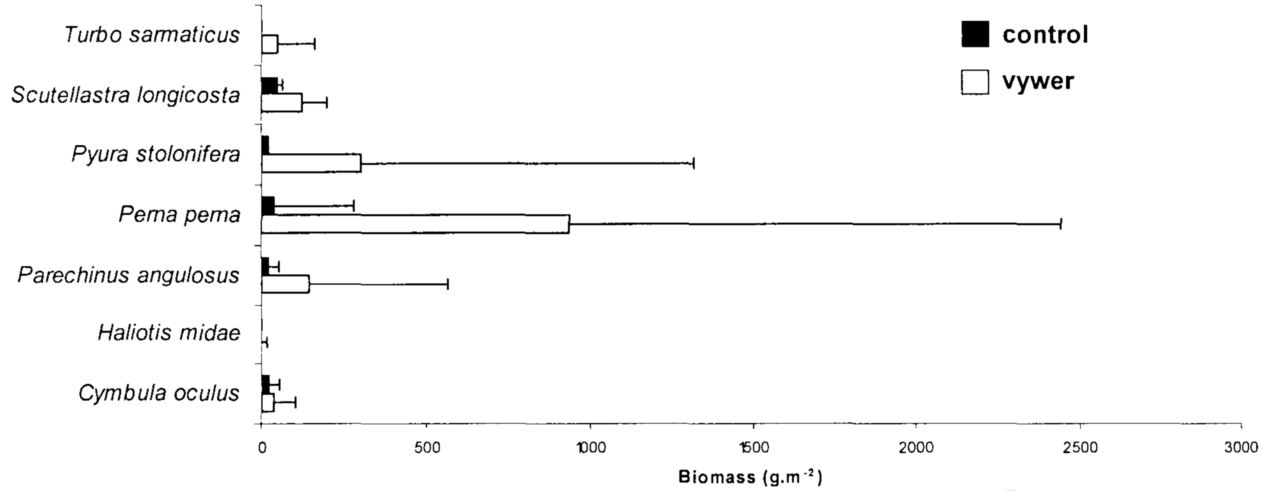

Figure 3.14. Biomass of edible species on *vywer* walls compared to control locations adjacent to the *vywers* for all sites combines.

DISCUSSION

The *vywers* consistently emerged with significantly different species assemblages from the surrounding control shores (Fig. 3.2). Discrete clustering was especially evident at Still Bay and Skipskop *vywer* communities (Fig. 3.3), but even at Arniston and Ryspunt samples taken inside and outside *vywers* clustered separately with virtually no overlap. Discrete clustering of samples inside and outside *vywers* remained evident even when comparing the effects of defining physical factors such as shore height (Fig. 3.8) and wave exposure (Fig. 3.11). Collectively, these results support the prediction that the *vywers* host significantly different communities from those on surrounding rocky shore.

The major difference between *vywers* and adjacent control sites was the increase in barnacle biomass. The filter-feeding barnacle *Tetraclita serrata* contributed most to this difference, dominating the biomass on *vywers*. McGuiness and Underwood (1986) also found this to be true for their work on intertidal boulders, and Sousa (1979b) standardised the heights of boulders for experimental work to take differences in barnacle abundance into account. The construction of the walls of the *vywers* would effectively have raised the walls into another environment, the balanoid zone. However, change of height cannot alone explain the differences between *vywers* and control sites, as the two were compared at equivalent heights.

In general, *vywers* increased richness, decreased evenness due to the greater dominance of barnacles, and had mixed effects on diversity (Fig. 3.7). Thus, unlike work done by McGuiness and Underwood (1986), the addition of new habitats led to an increase in species numbers. The construction of *vywers* not only increased richness, thereby influencing α diversity on the *vywers* themselves, but would also have enhanced β diversity for the shore as a whole, as discretely different assemblages developed on *vywers* and control shores. Both outcomes accord with my hypothesis that *vywers* would enrich diversity on the shore. At the scale of the whole shore, the addition of *vywers* roughly doubled the species richness. This is analogous to the situation described by McQuaid and Dower (1990) for sand-inundated rocky shores, where sections of the shore are inundated and support a sand-associated biota whereas other portions are not and carry different species, leading to greater β diversity.

The *vywers* did exhibit some patchiness, reflecting the numerous micro-habitats formed by the construction of the walls, and the fact that maintenance of the walls would lead to surfaces of variable successional ages. Despite this, the assemblages associated with *vywers* were consistently more homogeneous than those of unconsolidated boulder fields in control areas (Fig. 3.3) supporting my second hypothesis that *vywers* would host more uniform assemblages than the unstable boulder fields in control areas.

The scale of sampling allowed control sites to be sampled at comparable shore heights and wave conditions within a few meters of the *vywers*. This probably ruled out the possibility that availability of larvae was responsible for the differences between communities, as proposed by Bulleri (2005b). It is more likely that post-settlement mortality accounted for the difference, which was Bulleri's (2005b) alternative explanation, with the greater stability of *vywers* enhancing survival.

Low-shore communities at Arniston were more diverse and displayed greater evenness than the high shore communities, as expected from the fact that the low shore is inundated by water for a longer period of time at each tide and so is subjected to less physical stress. Similar patterns have been demonstrated on many other shores (Newell 1970, McQuaid et al. 1985, Bustamante et al. 1997).

Wave exposure is crucial in defining community structures and interactions on rocky shores (Menge 1976, Menge & Sutherland 1987, Bustamante et al. 1997, McQuaid & Lindsay 2000, Schiel 2004). Results of the exposure analysis indicated a similar total biomass at exposed and sheltered sites, unlike the greater biomass found in exposed habitats by McQuaid et al. (1985) and Bustamante & Branch (1996). Species richness, evenness and diversity, were, however, greater at exposed localities than sheltered localities across all sites (Fig. 3.13), although the exposure did not alter the patchiness of species distribution (Fig. 3.11). This apparent anomaly may result from *vywers* creating three-dimensional refuges within the walls that generate sheltered microhabitats, but with a reduced biomass as shown by Menge & Lubchenco (1981).

In situations where a built structure in the intertidal zone alters the community structure, the finer-scale α diversity and community structure will be altered. At the larger scale of whole rocky shores, β diversity can be increased by the addition of different communities within the new or altered habitats. The clear difference between communities on the *vywers* and those at control sites represents the end point of successional processes since construction of the walls. Dye (1998) showed that a period of at least three years was necessary for experimentally cleared communities to resemble those of the controls. Although the age of the *vywers* cannot be determined accurately, they have probably been in position for two to three millennia (Avery 1975). Periodic storm damage and restoration would have taken place, but two of the *vywers* that I studied are not in current use and have not been maintained for fishing for nearly two decade. Despite this, they have maintained communities significantly distinctive from, and more uniform than, those in control areas.

My study focused specifically on the walls of *vywers*, but their presence and construction are likely to have effects that extend beyond the walls. Boulders used in the construction of walls are taken from adjacent areas, creating large ponds that are mostly boulder-free and cleared down to bed-rock or sand level, thus developing a habitat previously absent from the original boulder fields. Wave action will also have been reduced there by the erection of walls. All these alterations can be expected to change the biotic assemblages present. Perhaps the original builders of the *vywers* were aware of these changes, using them as rearing areas for edible species, all of which appear in greater biomass associated with the *vywer* walls?

My analysis of *vywer* walls upheld my two primary hypotheses – that *vywers* would increase richness affecting both α and β diversity, and would generate more homogenous assemblages, based on the greater substrate stability and uniformity. These principles do not, however, extrapolate to modern artificial structures, which are even more stable and generally create monotonously uniform structures with few crevices. Most studies have shown that such structures diminish α diversity because of their uniformity and stability, with a relatively small number of species dominating the assemblages. In addition, they cover large areas and so reduce β diversity. By analogy to the intermediate disturbance hypothesis (Connell 1978), I would argue that *vywers* are on the ascending portion of the diversity curve because they are sufficiently heterogeneous in their topography, coverage of shore height and wave action, and because they are still periodically disturbed by storms and require restorations. Modern walls, harbours and the like, by contrast, are engineered to withstand all but exceptional circumstances and are deliberately uniform in structure.

They are likely to lie on the descending arm of the diversity curve. To test this hypothesis as a postscript to my thesis I compared results for *vywer* walls with those of unbroken flat natural rocky subtrata, partly disintegrated destabilised *vywers* and the artificials walls of a tidal swimming pool. My data supported the premise that as stability increases diversity first rises and then falls (Fig. 3.15a), and modern artificial surfaces do indeed lie on the descending portion of the curve. However, as stability falls, physical heterogeneity rises (Fig. 3.16), and this is likely to have a compounding effect on diversity. Similar to stability, heterogeneity yielded a domed diversity curve (Fig. 3.15b). As I hypothesised, *vywers* are less heterogeneous and more stable than equivalent control sites. By contrast, modern man-made structures are even more stable and even less heterogeneous, diminishing diversity.

Built structures in coastal areas are set to increase as populations grow and develop (Thompson et al. 2002, Branch et al. in press). However, better understanding of associated processes will allow coastal zone managers to ameliorate the effects on biodiversity of development in the dynamic intertidal zone.

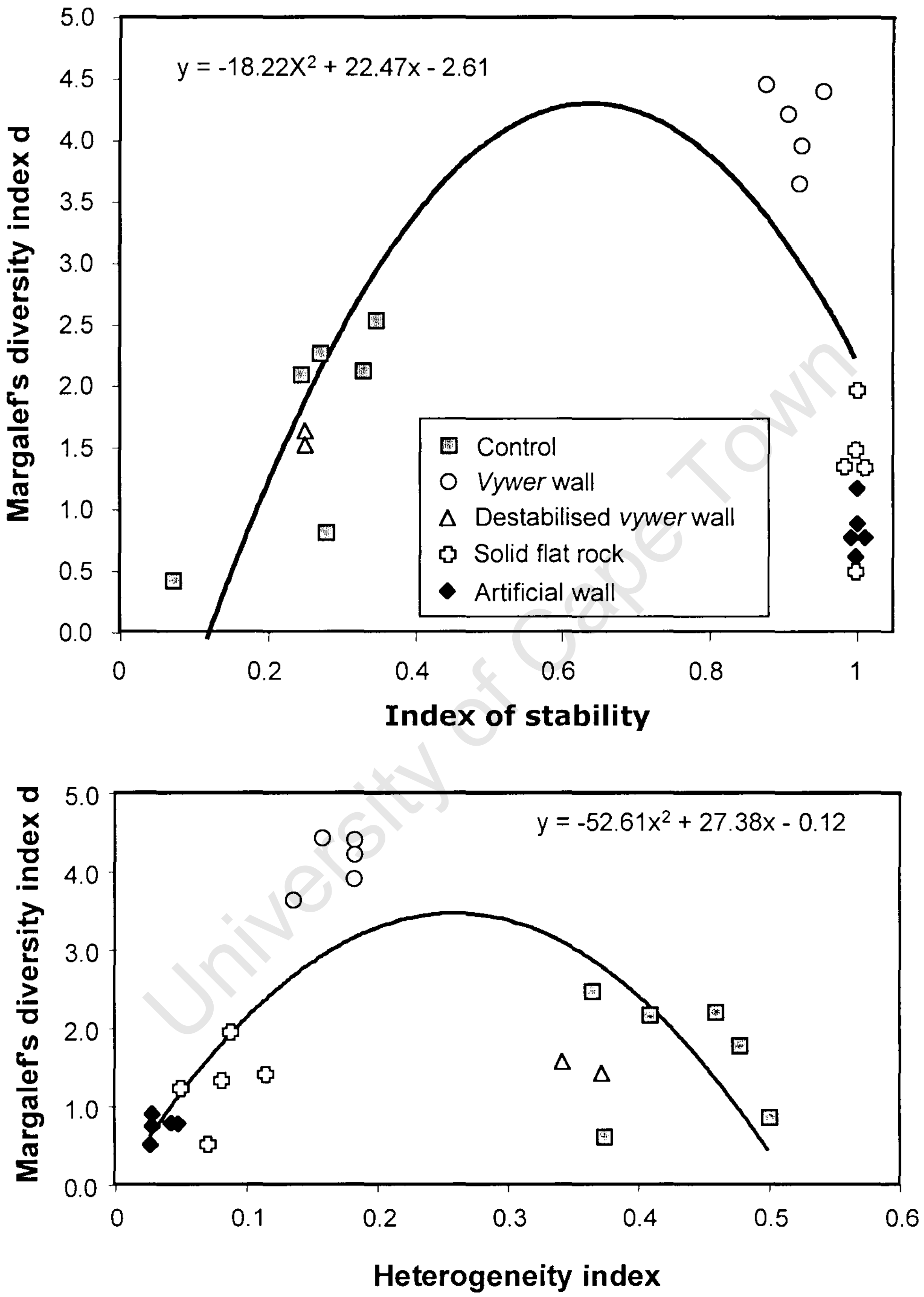

Figure 3.15. (a) Stability index and (b) heterogeneity index plotted against diversity (Margalef's diversity index *d*), with bell-shaped polynomial curves reminiscent of the Intermediate Disturbance Hypothesis (Connell 1978).

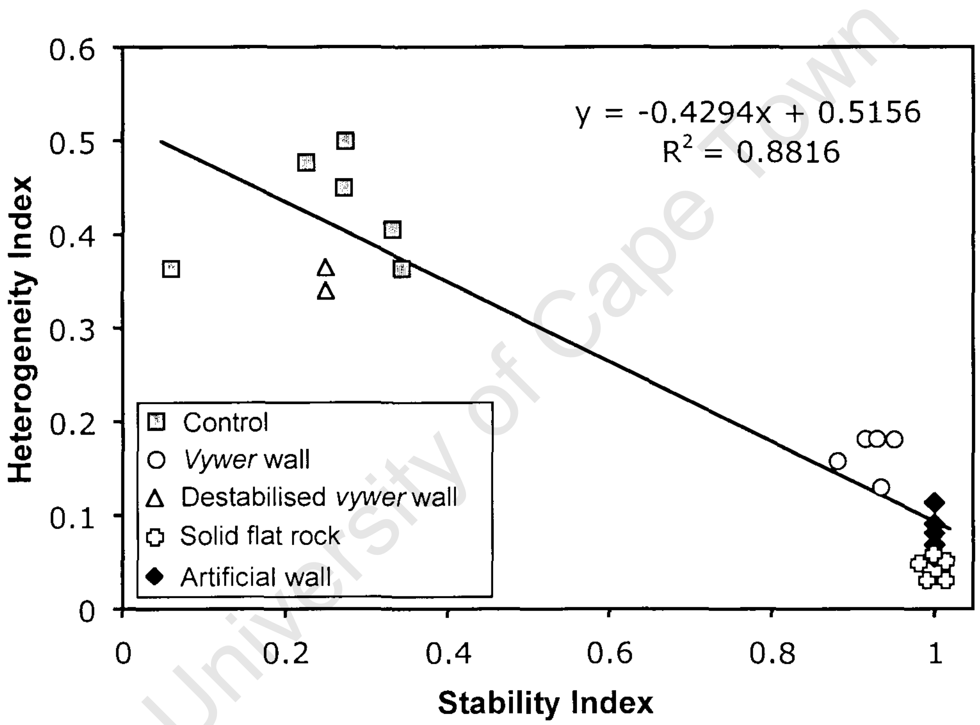

Figure 3.16. Stability indices plotted against heterogeneity indices.

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Appendix 1: Digital database of all located *vywers*.

Appendix 2: Questionnaires compiled for analysis of the current *vywer* fishery.

Fish-trap questionnaire

The information gathered in this survey is purely for research purposes and aims to investigate how the fish traps operated, both currently and in the past. Your answers are completely confidential and will only be used for the completion of this University of Cape Town project.

Place: Date: Time:

Age: Population group: Occupation:

What is your interest in the fish-traps? ____________________

How many years have you been involved in the use of the fish-traps? ________

Which fish traps do you fish at? ____________________

How often are you fishing (average tides per month)? ____________

Does this vary seasonally? YES NO How? ____________

How often are you catching (average tides per month)? ____________

What time of day are you fishing? DAY NIGHT Why? ____________

What are you catching? (average monthly fish numbers/ kg)

□ A. haarders ______ □ E. musselcracker ______ □ I. hottentot ______

□ B. elf ______ □ F. galjoen ______ □ J. streepie______

□ C. steenbras ______ □ G. octopus/chokka ______ Other ______

□ D. stumpnose ______ □ H. kabeljou, kob ______

How do you get the fish out of the traps? NET type? _____ Others? ______

What fish do you prefer catching? A B C D E F G H I J Other? ______

Do you have a fishing permit? YES NO What kind? ____________

Have your catches decreased in the last 5 years? YES NO 10years? YES NO

Why do you think that is? ____________________

What was your biggest catch ever? ____________ When? ______

When was your last big catch? ______What was in the catch? ________

What do you do with your fish? A. keep for personal use ________

B. sell on the local market ______ C. use in lieu of labor payment ______

D. Other ____________________

Are you taking anything else from within the fish-traps eg. alikreuk?

YES NO What? ________ ________

____

Do you know if there are any regulations for fishing in the traps? YES NO

Species			
Minimum size			
Bag limit			
Closed season			

Do you think these are valid regulations? YES NO Why? ____________

Do you help maintain the traps? YES NO How are they maintained? ________

____

How many other people are involved? ____________

Has your catch been inspected by a fisheries officer? YES NO When? ______

Have you ever caught any fish with tags? YES NO Did you report it? YES NO

Do you think the traps should be developed as a cultural heritage site? YES NO

Why? ____________________

I would like to speak to as many people involved as possible. Who do you think would be worth talking to? ____________________

Do you know of any other fish-traps? YES NO Where? ____________

Comments:

Vis-vywer vrae lys

Die inligting wat vir hierdie ondersoek benodig is uitsluitlik vir navorsingdoeleindes, en stel ten doel die werk-wyse van die visvywers, tans sowel as in die verlede. U antwoorde sal streng vertroulik behandel word, en sal slegs benut word vir die studie – Universiteit van Kaapstad.

Plek: Datum: Tyd: B W C O

Naam: Ouderdom: Beroep:

Wat is u belangstelling in die vis-vywers? ____________________

Hoe veel jare is u al betrokke met die vywers? ____________________

Watter van die vywers benut u?

____

Hoe gereeld besoek u die vywer om vas te stel wat gevang is (gemiddelde getye per maand?) ____________________

Verander die aantal besoek seisoenaal? __________ Weer? __________

Hoe gereeld vang u vis in die vywers? ____________________

Wat vang u? (gemiddilde nommer vis/ kg)

□ A harders ______ □ E. mosselkraker ______ □ I. hottentot ______

□ B. elf ______ □ F. galjoen ______ □ J. strepie ______

□ C. steenbras ______ □ G. seekat/tjokka ______ ANDER ______

□ D. stompneus ______ □ H. Kabeljou ______

Hoe kry u die vis uit die vywers uit? Tipe Net? ______ Ander? ______

Watter vis wat gevang word sal u verkies om vir uself te neem? ______

Het u 'n visvang permit? YA Watter sort? ______ NEE Waarom? ______

Vind u dat die vywers omgeveer dieselfde getalle as 5 jaar gelede vang? YA NEE

Wat dink u is die redes daarvoor? ____________________

____

Wat was u grootste vangs ooit? __________ Wanneer? __________

Wanner was u laaste redelike groot vangs? ____________________

Watter vis was tee nwoordig?____________________

Wat doen u tans met die vis wat vang word? A. eie gebruik? ______

B. Verkoop aan vriende of bure? ______ C. Verkoop op die mark? ______

D. Gebruik vir werkers vergoeding? ______ E. Ander? ______

Was daar ander seediere iut die vywers geneem? Soos Alikreukel? YA NEE Wat?

____

____

Weet u of daar enige regulasies is om in the vywers te vis? YA NEE? Wat? ______

Vis soort			
Minimum grootte			
Maksimum oes/ dag			
Geslote seisoen			

Dink u die regulasies van waarde is? YA NEE Hoekom? ______

Help u om die vywers te onderhou? ____________________

Is daar ander mense betrokke by die pogings?____________________

Kan u kortliks verduidelik wat die onderhoud pogings behels?____________________

____

Vas u vangs all ooit deur a vissery beampte geinspekteer? YA NEE Wanneer? ______

Het u al ooit 'n vis met 'n 'tag' gevang? YA NEE Het u dit 'report'? YA NEE ______

Dink u die vywers kan as 'n touriste- of kultuur erfenis behoe en/of ontwikkel word? YA NEE

Hoe sal so 'n stelsel ten beste uitgevoer word? ____________________

Wat wil u graag he moet met die vywers gebeur? ____________________

Ander vywers om die kus? ____________________

____

Ander mense wat my dalk al help? ____________________

Notas:

Appendix 3 Wet weight conversions for count and percentage cover into estimated biomass ($g.m^{-2}$).

			1% cover $g.m^{-2}$	$g.individual^{-1}$
		Kingdom Animalia		
Phylum Porifera		Sponge spp.	20	
Phylum Cnidaria	Class Anthozoa	*Pseudactinia flagellifera*	0.3	7.5
		Anthothoe stimpsoni		0.18
		Actinia equina		6.2
Phylum Annelida	Class Polychaeta	*Pomatoleios kraussii*	110	
Phylum Arthropoda	Class Cirripedia	*Tetraclita serrata*	171	
		Octomeris angulosa	175	1.5
		Chthamalus dentatus	116	
	Class Malacostraca	*Diogenes* spp.		13.66
		Cyclograpsus punctatus		4.5
Phylum Mollusca	Class Polyplacophora	*Acanthochiton garnoti*		2.36
	Class Bivalvia	*Mytilus galloprovincialis*	183	
		Perna perna	334	
	Class Gastropoda	*Haliotis midae*		45
		Scutellastra granularis		5
		Scutellastra cochlear		12.4
		Scutellastra longicosta		8.25
		Helcion pectunculus		1.3
		Helcion prunosis		1
		Siphonaria capensis		1.75
		Siphonaria concinna		0.68
		Siphonaria serrata		1.95
		Oxystele sinensis		3.73
		Oxystele tigrina		14
		Oxystele variegata & impervia		1.55
		Turbo sarmaticus		37.15
		Thais capensis		1.73
		Nucella dubia		7.4
		Burnupena cincta		5.09
		Burnupena laginaria		8.5
		Cymbula oculus		9
Phylum Echinodermata	Class Asteroidea	*Patiria granifera*		16.5
		Patiriella exigua		2
	Class Echinoidea	*Parechinus angulosus*		30
	Class Holothuroidea	*Pentacta* spp.		12
	Class Ascidiacea	*Pyura stolonifera*		225
		Kingdom Plantae		
Division Chlorophyta		*Codium* spp.	28	
Division Phaeophyta		*Iyengaria stellata*	168	
		Splachnidium rugosum	25	
		Ralfsia verrucosa	10.8	
Division Rhodophyta		*Gelidium pristoides*	342	
		Caulacanthus ustulatus	14	
		Laurencia glomerata	320	
		Corallina spp.	16	
		Hildenbrandia lecanellierii	3.5	
		Encrusting corallines	1.6	
		Upright corallines	207	