Retrospective Analysis of Plankton Community Structure in the Benguela Current Large Marine Ecosystem (BCLME), to provide an Index of Long-term Changes in the Ecosystem

4TH INTERIM PROGRESS REPORT

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Introduction

Several of the world's productive upwelling regions of the eastern boundary current systems have experienced substantial, decade-scale food web changes over the past four to five decades. These changes are not only reflected in extensive fluctuations in pelagic fish yields and regime shifts of fish populations (Lluch-Belda *et al*. 1989, 1992, Schwartzlose *et al*. 1999). They are also manifested in long-term variations in the abundance, distribution and species composition of plankton (see Perry *et al*. 2004 and references therein) on which these fish, at one or another stage of their life history, are relying for their successful growth and recruitment.

In the southern part of the BCLME off South Africa, an initial retrospective analysis of plankton samples collected over five decades in the pelagic fish recruitment area of St Helena Bay on the West Coast has shown a significant increase in zooplankton, accompanied by marked changes in its community structure (Fig. 1), which coincided with changes in the recruitment and abundance of anchovy *Engraulis encrasicolus* and sardine *Sardinops sagax* (Verheye *et al*. 1998, Verheye and Richardson 1998, Verheye 2000).

While extensive plankton collections exist for the central/northern BCLME off Namibia (referred to as the SWAPELS collections – South West African Pelagic Egg and Larval Surveys), to date no equivalent retrospective analysis has been undertaken there. As a consequence, it has not been possible to quantify (suspected) large changes in this part of the ecosystem (but see Hansen *et al.* 2005). A pilot programme of retrospective analysis of zooplankton off Namibia, focussing on a limited number of SWAPELS transects and years has, however, recently been initiated through the BENEFIT Programme (e.g. Tsotsobe *et al.* 2003, 2004; Mainoane 2003).

The overall objective of this BCLME project is therefore to extend and fast-track the abovementioned BENEFIT pilot programme so that changes in the entire BCLME region over the past 50 years can be properly documented and quantified. The provision of such baseline and time-series is crucial in the assessment of natural (climate change) and anthropogenically forced changes (fishing activities) in the ecosystem. Knowledge of such past changes is a prerequisite for sustainable ecosystem management in the future, and forms the subject of several global initiatives such as GLOBEC (Global Ocean Ecosystems Dynamics) and GOOS

(Global Ocean Observing System), the protocols of which are largely followed in the BCLME.

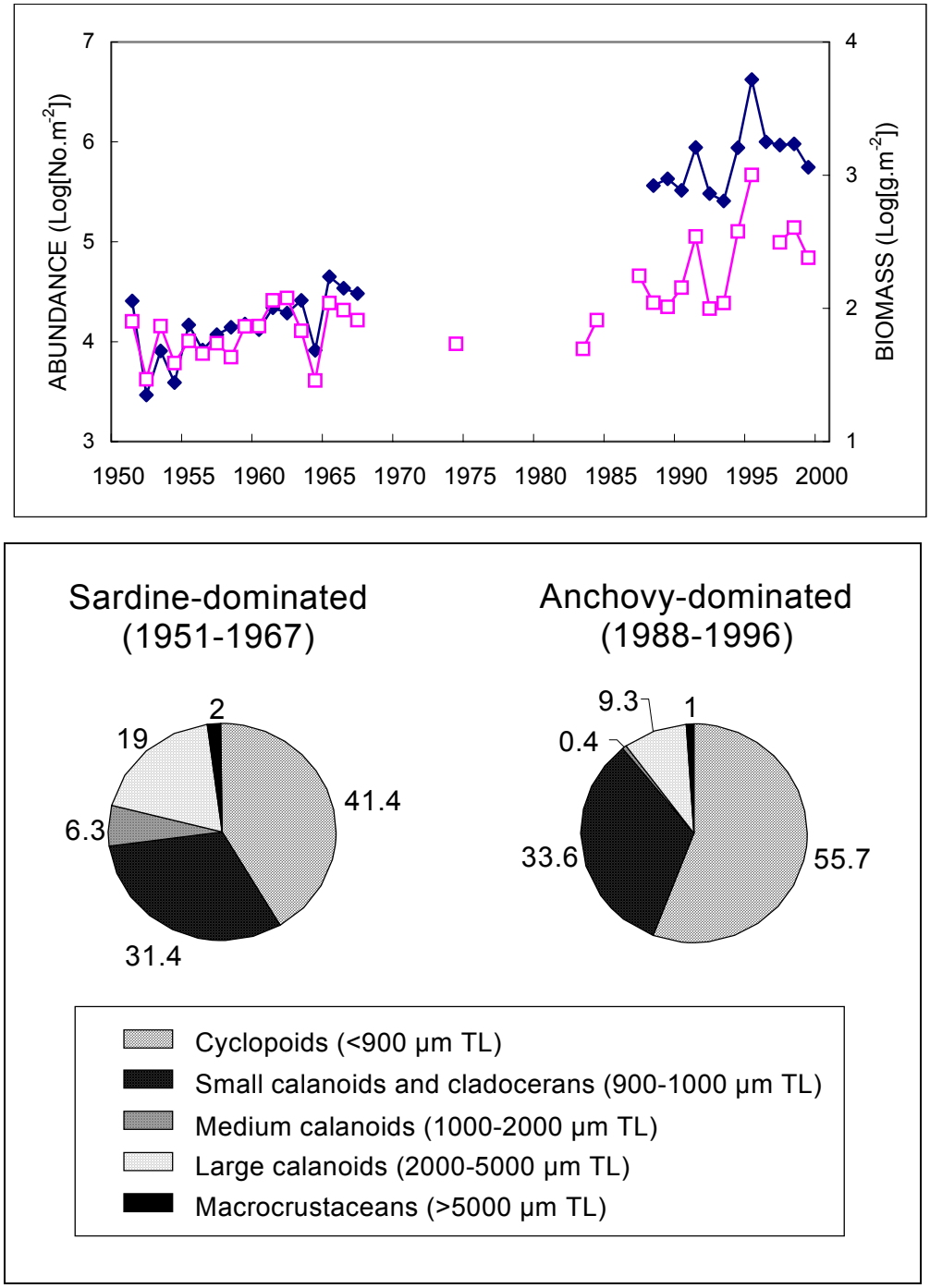

Figure 1. Southern Benguela: (Top) Time-series of copepod abundance (diamonds) and dry mass (squares) in St Helena Bay, 1951-1999; note the logarhitmic scale [$Log_{10}(x+1)$] on both y-axes. (Bottom) Community structure (%) of crustacean zooplankton during periods of sardine and anchovy dominance. Redrawn from Verheye *et al*. (1998) and Verheye and Richardson (1998).

The primary focus of this BCLME project is on the retrospective analysis of a representative amount of samples collected during the monthly SWAPELS surveys between the Cunene River (17ºS) and Lüderitz (26ºS) off the Namibian coast during the 1970s and 1980s (Fig. 2).

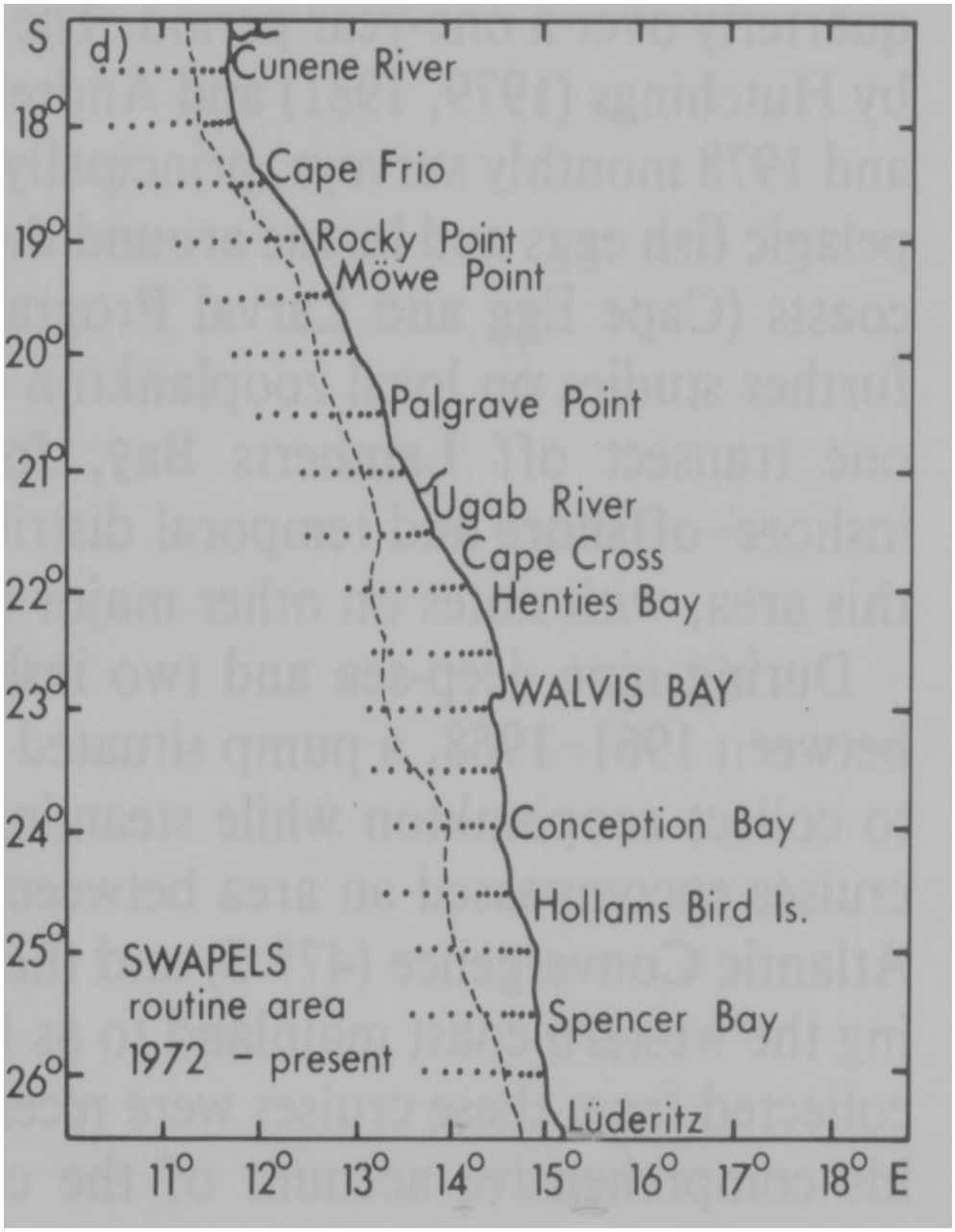

Figure 2. Northern Benguela: Map showing the cross-shelf transects and station positions sampled monthly during the SWAPELS programme, 1972-1989 (from Shannon and Pillar 1986)

The analysis of this enormous collection (in total approx. 20 000 samples were collected; however, an as yet unknown proportion is no longer available), which

is housed at MCM's sample store in Cape Town, involves students pursuing degrees at BSc(Hons), MSc and PhD level, and is backed up by technical assistance of a contracted sample analyst. Cataloguing and curation of this sample collection, for which partial funds were previously obtained from the Envifish and VIBES/IDYLE programmes in recognition of the collection's scientific value, is continued by a contracted sample curator. Ultimately, the SWAPELS long-term time-series data will form an important component of the comprehensive inventory of plankton and ancillary hydrographic and fisheries data archives in the BCLME region, which is to be established by a contracted data manager. This regional database will allow relationships between indices of upwelling and demographic parameters of zooplankton and pelagic fish to be examined, with the primary focus on decade-scale variability and ecosystem change.

Progress to date

1. Administrative update

The agreement between UNOPS and BENEFIT for the execution of this BCLME project was signed on 16 March 2004. The work plan covering the activities for the first year (2004/2005) made provision for a number of tasks, which are listed in Table 1. The status of progress made since then with regard to the recruitment and appointment of human capacity, on which the project relies heavily, is summarized in Table 1.

Table 1. Overview of project tasks and summary of progress status

TASK	STATUS
1. Sample analysis	
a. recruitment of **1 B.Sc.(Hons) student** (Mr I. Kauvee) b. analysis of ca. 180 samples from 1983 (N and S of Lüderitz) completed, forming the basis for a BSc Honours project on "Observations on the composition of the copepod community either side of the Lüderitz upwelling cell"	Studies at Univ. of the Western Cape completed during 2004; BSc(Hons) degree awarded on 8 April 2005.
c. recruitment of **1 M.Sc. student** (Mr I. Kauvee) d. detailed analysis of all developmental stages of 2 dominant	Student registered at Univ. of Cape Town, Feb. 2005; MSc

copepods (*R. nasutus* and *C. carinatus*) from SWAPELS samples off Walvis Bay, forming the basis for a MSc project on "Population dynamics of the calanoid copepod *Rhincalanus nasutus* (Copepoda: Calanoida) in the northern Benguela".	project proposal submitted; MSc thesis Chapter 1 drafted (**Appendix A** – obtainable from PI); studies and sample analysis ongoing.
e. recruitment of **1 Ph.D. student** (Ms F. Cazassus) f. SWAPELS samples currently being analysed: samples from 2 months of contrasting hydrographic conditions (upwelling vs. quiescence) every year at 3 stations (inshore, mid-shelf, offshore) on 9 transects (at latitudes 17, 19, 20, 21, 22, 23, 24, 25 and 26˚S), forming the basis for a PhD project entitled "Long-term variations of the zooplankton community of the northern Benguela ecosystem"	Student arrived in Cape Town on 22 Sept. 2005 (i.e. >1 year later than originally planned), and registered at Univ. of Cape Town, Zoology Dept; 3-yr PhD research proposal completed (**Appendix B** – obtainable from PI), literature review ongoing, sample analysis started and ongoing;
g. recruitment of **1 sample analyst** (Mr F. Kotze) h. analysis of samples from 1978-1983 on Walvis Bay line 70 (23˚S) completed; data used in the reconstruction of long-term trends (1959-2005); sample analysis of line 48 off Palgrave Point is near completion.	Analyst appointed on 1 Aug. 2004; contract renewed on 1 Aug. 2005; sample analysis and data entry ongoing.
2. Training	
i. identification of training opportunities: ongoing; Regional zooplankton taxonomy workshop (originally planned for end 2005) postponed until 2006; Automated Sample Analysis Workshop in San Sebastian, Spain Attended during November 2005 (report: **Appendix C**)	Various students being trained at different academic levels and institutions; MSc student enrolled to take additional courses in Biostatistics and Population Dynamics Models;
3. Curation of sample collections	
j. recruitment of **1 sample curator** (Mr P.H. de Vos)	Curator appointed 1 August 2004; contract extended on 1 Aug. 2005 for 1 extra year; almost 10 000 zooplanktopn samples thus far curated and catalogued.
4. Preparation of data archives for transfer to SADCO	

k. recruitment of **1 data manager**	IOI-SA contracted on 14 March 2005; contract period extended until end September 2006, however without any financial implications; see **Appendix D** for progress made since last interim report

Since his registration in February 2005 for a M.Sc. degree (by dissertation) at the University of Cape Town (UCT) (supervisors: Dr C.L. Moloney, UCT & Dr H.M. Verheye, MCM), Mr Ignatius Kauvee has nearly completed a detailed microscope analysis of selected SWAPELS samples collected off Walvis Bay at 23˚S, focussing on the abundance, distribution and demographic structure of two dominant copepod populations, *Rhincalanus nasutus* and *Calanoides carinatus*. These species appear to have similar feeding ecologies and spatial and temporal distribution patterns. In his study, Mr Kauvee is exploring and testing a number of hypotheses concerning rates of reproduction, growth, development and mortality of these seemingly ecologically similar copepod species. Information on their life history thus obtained will be used to infer population maintenance strategies. An IBM (individual-based model) will be constructed using known parameters to arrive at population maintenance strategies that are not attainable from empirical data.

A copy of the first chapter of Mr Kauvee's thesis, entitled "Population dynamics of the calanoid copepod *Rhincalanus nasutus* (Copepoda: Calanoida) in the northern Benguela", is appended to this interim report (**Appendix A** – obtainable from PI). It outlines the various assumed similarities of the two species, and details the hypotheses and tests to be performed. Although this degree is pursued by dissertation, Mr Kauvee is nevertheless also attending some classes on Biostatistics and on Population Dynamics Models, which form part of the taught M.Sc. course at UCT.

Ms Fabienne Cazassus, the PhD candidate from France, arrived in Cape Town on 22 September 2005, after a lengthy recruitment process wrought by time-consuming bureaucracy. Since her arrival, she has embarked on a comprehensive literature study of the Benguela Current ecosystem, and has completed drafting a comprehensive research proposal (**Appendix B** – obtainable from PI) for submission

to the University of Cape Town. She has familiarized herself with the region's zooplankton community, as well as with the different types of gear used historically in the region to collect zooplankton samples, and with the standard approaches and methods used in the region's plankton laboratories for the analysis of zooplankton samples.

Following a comprehensive evaluation of the SWAPELS sample collection that is currently being curated under this BCLME-funded project (see below), Ms Cazassus discovered *inter alia* that many of the samples collected during 1980 and 1981 were not well preserved, with many specimens beyond recognition. This makes measurements of zooplankton abundance and biomass at best inaccurate. Moreover, substantial parts of the 1986 and 1987 sample collections appear to have vanished from the sample store, creating considerable gaps in the dataset. In addition, there is currently no record found of the sampling details during SWAPELS cruises from 1985 onwards. As a result, unless such information regarding e.g. sampling depth, tow duration, and flow rate is retrieved, which is crucial for the calculation of the volume of water filtered by the nets, no accurate estimates of species abundance and biomass will be able to be made for those years.

Ms Cazassus has also initiated an extensive microscope analysis programme focussing on a representative number of SWAPELS zooplankton samples from both to the north and south of the Walvis Bay region throughout the sampling programme. Samples from nine transects along latitudes 17°, 19°, 20°, 21°, 22°, 23°, 24°, 25°, 26°S have been targeted (Fig. 3). For each year of the SWAPELS programme, a minimum of three stations (one nearshore, one mid-shelf, and one offshore) sampled per transect during at least two months characterised by contrasting hydrographic conditions (upwelling versus quiescence) will be analysed. Thus far, about one third of the intended microscope work has already been completed and the species abundances are being captured in a database together with data obtained from previous analyses of various portions of the SWAPELS collection under this BCLME project (e.g. Kauvee et al. 2005a, b) and the BENEFIT programme (e.g. Tsotsobe 2005, Tsotsobe et al. 2003, 2004, 2005, Verheye et al. 2005, Mainoane 2006).

During the period under review, good progress has been made in respect of the curation (by Mr Philip de Vos) of both the Namibian SWAPELS zooplankton sample archive as well as various historical collections made in South African waters. To date, a total of almost 10 000 zooplankton samples have now been curated under

this BCLME project: i.e. for each individual sample, the state or condition has been checked and recorded, the sample jar topped up with formalin and relabelled when

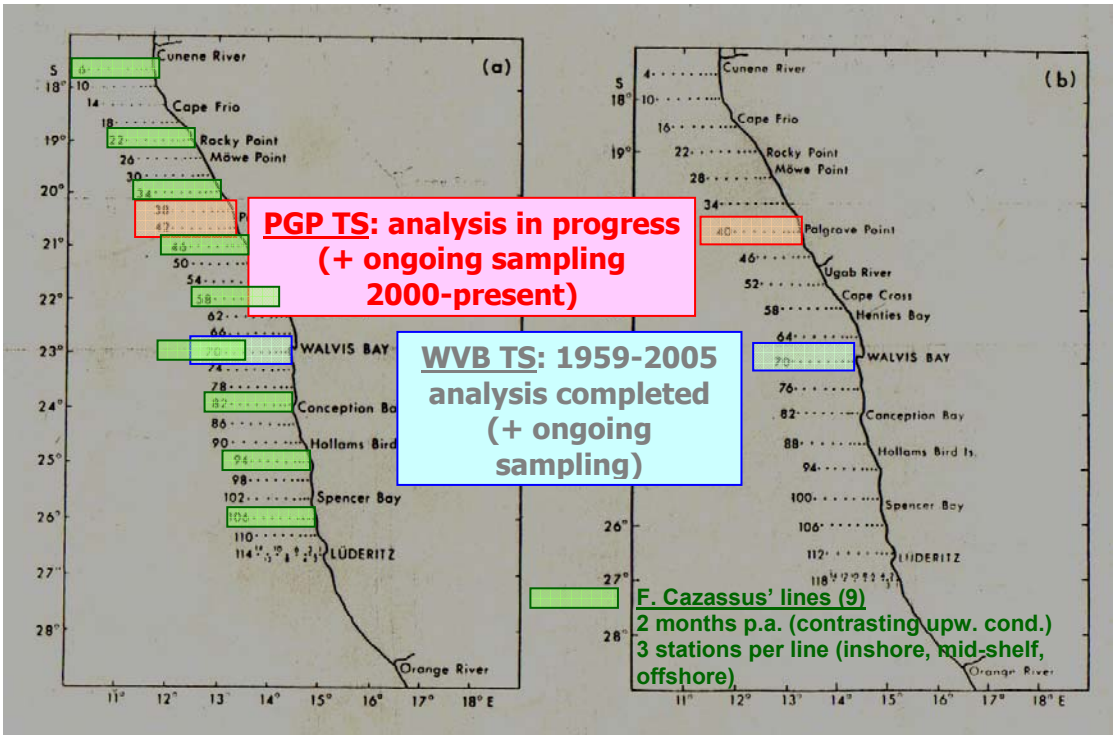

Figure 3. Change in the SWAPELS sampling grid, showing a reduction in sampling effort from September 1981 onwards as a result of increased spacing between latitudinal transects from (a) 20 n.mi to (b) 30 n.mi. The positions of the Walvis Bay (blue) and Palgrave Point lines (red) are indicated, as well as the 9 lines currently being analysed by F. Cazassus (green).

necessary; all samples have been re-boxed, keeping them dust-free, and the boxes have been labelled and their contents recorded. A detailed catalogue is being prepared, which later on will be transcribed electronically.

Upon completion of the analysis of samples from transect 70 off Walvis Bay at 23°S, microscope analysis of samples collected on transects 38, 40 and 42, all three off Palgrave Point at ca. 20°S, was initiated by Mr Ferdinand Kotze, and is ongoing. The selection of this area for retrospective analysis of SWAPELS zooplankton samples is based on the fact that, similar to the Walvis Bay area, regular monitoring of the environment, including plankton, is currently being conducted by NatMIRC, MFMR, Namibia, thus providing the opportunity to examine decade-scale changes. It is noteworthy that, in an effort to reduce sampling owing to ship's time constraints, the SWAPELS sampling grid was modified in September 1981 by increasing the spacing between transects (see Fig. 3), and transects 38, 40 or 42

were selected to represent the Palgrave Point area prior to (line 38 or 42) and after (line 40) that date of change. Thus far, some 130 samples from the Palgrave Point area have already been analysed and data on species composition and abundance, together with station information and limited hydrographic data, are continually being added to the database. It should be noted that special attention was devoted to the identification of the smaller copepods in the analysis of samples, which slows down the identification and enumeration process considerably.

2. Training and capacity building progress

The regional zooplankton taxonomy training workshop, which was scheduled to take place at the end of 2005, was postponed owing to time constraints in respect of compiling an adequate budget. The workshop will be rescheduled for later during 2006, and assistance will be sought from BENEFIT's newly appointed Training Officer for the preparation of this important regional event.

A junior MCM staff member, Mr Sakhile Tsotsobe, whose M.Sc. thesis work has contributed to the objectives of this BCLME project (see Tsotsobe 2005, Tsotsobe et al. 2003, 2004, 2005), was funded by BCLME to attend the GLOBEC/SPACC ZooImage Workshop, which was hosted by AZTI-Tecnalia in San Sebastian, Spain (1-3 November 2005). This workshop focussed on new image analysis and recognition methods for identification and enumeration of zooplankton. Such automation offers substantial advantages over the very labour-intensive and time-consuming (yet more accurate) classical 'manual' analysis methods using microscopy. A detailed report on the workshop is appended to this interim report (see **Appendix C**).

ZooImage is a new, free (GPL license), software to analyse digital images of (zoo)plankton or other similar biological material. The download area is located at: http://sourceforge.net/projects/zooimage. There are now three websites available to help improving image analysis of zooplankton: (i) the *ZooImage Website*, located at http://www.sciviews.org/zooimage**,** is the main portal where news can be found about image analysis software, hardware, events, and other contributed information; (ii) the *Zooplankton Image Analysis* Forum, located at http://zooimage.overchord.net, is set up for users to ask for help or give comments on a range of topics from application specifics to other topics of relevance to other users; and (iii) the *ZooImage Wiki*,

located at http://zooimage.sciviews.org/wiki, is the documentation site for the ZooImage software; a user's manual and a developer's manual are being created while tutorials will also appear on the site; the wiki is a collaborative effort amongst developers writing the documentation. In addition, there are two mailing lists for ZooImage: https://lists.sourceforge.net/lists/listinfo/zooimage-announce is for general announcements and http://lists.sourceforge.net/lists/listinfo/zooimage-devel is for developers.

3. Data management progress

A report, compiled by Dr Kim Prochazka, Director of IOI-SA, on activities and progress made by IOI-SA during the period under review is attached to this interim report (**Appendix D**). The report identifies potential problems around the future transfer of regional plankton data to SADCO. As an interim measure, until SADCO can develop the necessary functionality, it is recommended that an existing tool, viz. MATT (metadata Authoring Tool) be used to add plankton metadata and that the SADC Marine Fisheries/Environmental Metadata Directory (located at http://196.21.45.131:8080/metadata/index.html) be used as the interim host for these metadata.

An inventory of national and foreign oceanographic/plankton cruises in Angolan waters was obtained during a visit by Dr Prochazka to the Angolan government fisheries agency, INIP, in Luanda in September 2005. In its present state, the inventory is rather rudimentary and requires the assistance from Angolan scientists to be further developed.

The report further summarizes findings regarding plankton datasets collected in the BCLME region by Russian scientists. Between 1963 and 1989, a total 85 444 plankton records were made by the Ukrainian Institute of the Southern Seas in the BCLME, spanning 324 samples at 259 stations. Furthermore, results of a literature search performed by a M.Sc. student show that there are in total 178 publications in 42 journals, which deal with plankton in the BCLME region.

Owing to various reasons, the data management component of the project has fallen somewhat behind schedule, but an extension (without financial

implications) was granted to IOI-SA until September 2006 to enable a product to be delivered that is useful to the region.

4. Scientific progress

Figure 4 shows updated time-series of total zooplankton biomass (biovolume) and the abundances of total copepods and of four dominant copepod species of different body size (given in the Figure caption in parentheses for adult females only, in terms of total length [TL] and dry body mass [DM]), for transect 70 off Walvis Bay.

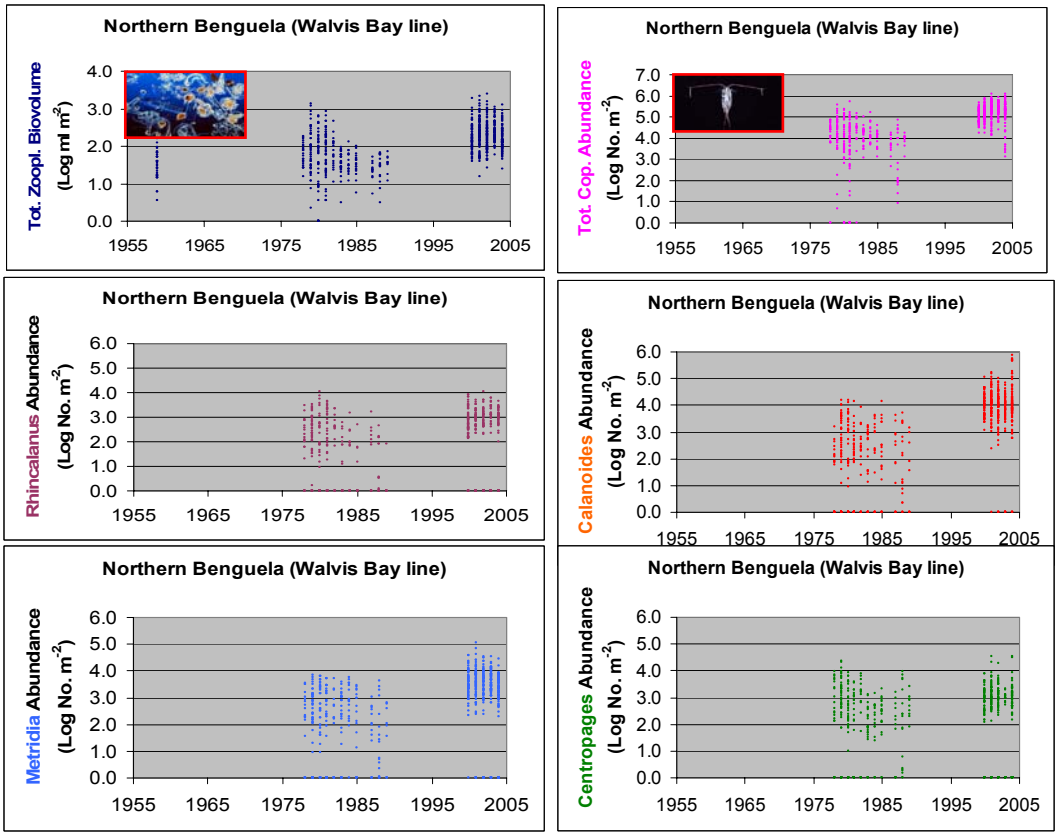

Figure 4. (Top 2 panels) Updated time-series of (left) total zooplankton biovolume within 30 n.mi. from the coast, and (right) total copepod abundance within 70 n.mi. from the coast off Walvis Bay (23˚S) during 1959-2004. (Bottom 4 panels) Updated time-series of abundance (adult males + females) of *R. nasutus* (4 319µm TL, 461µg DM), *C. carinatus* (2 445µm TL, 80µg DM), *M. lucens* (2 294µm TL, 39µg DM), and *C. brachiatus* (1 677µm TL, 21µg DM) during 1978-2004. Each data point represents one sample, irrespective of distance or month. Data sources: (i) published literature (Kollmer 1963, Unterüberbacher 1964, Hansen *et al*. 2005), (ii) ongoing post-graduate thesis work under the BENEFIT and BCLME (Kauvee *et al*. 2005a, Tsotsobe *et al*. 2003, 2004, 2005, T. Mainoane 2006), (iii) NatMIRC's current environmental monitoring programme (courtesy Mr R. Cloete and Dr A. Kreiner), and (iv) results from this BCLME project, generated by the sample analyst, Mr Kotze.

As mentioned earlier in this report, a lack of information on the volume of water filtered by the net for SWAPELS samples from the period 1986-1989 precludes any accurate calculations of the above zooplankton parameters, hence the species abundances shown for these years (obtained by extrapolation from previous years' volume filtered data), which tend to be substantially lower than previous years (see Fig. 5), remain questionable.

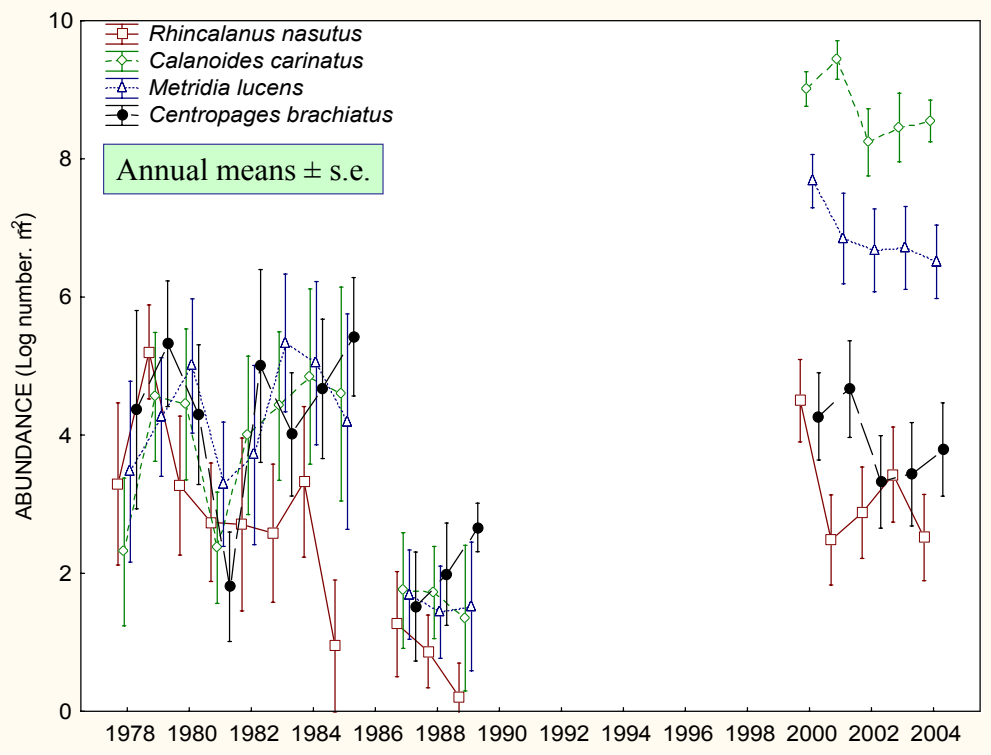

Figure 5. Updated time-series of annual mean abundance (± 1 s.e.) of the four dominant calanoid copepod species (adults only) shown in Figure 4. Note the lack of data in 1986 and the possibly underestimated abundances during 1987-1989 (see text).

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APPENDICES

Appendix A. (obtainable from the PI)

Kauvee, I.K.V. – Population dynamics of the calanoid copepod Rhincalanus nasutus (Coeppoda: Calanoida) in the northern Benguela. Chapter 1. General introduction and literature review. 37 pp.

Appendix B. (obtainable from the PI)

Cazassus, F. – Long-term variations of the zooplankton community of the northern Benguela ecosystem: PhD Research proposal, University of Cape Town, 21 pp.

Appendix C.

Tsotsobe, S.V. – GLOBEC/SPACC ZooImage Workshop: Report, 4 pp.

Appendix D.

Prochazka, K. – Progress report of the Data Manager on development of the inventory and database for plankton data in the Benguela Current, submitted by the International Ocean Institute, Southern Africa (28 February 2006), 14 pp.