A biologists' personal overview of the SA Marine Science community and its outputs (2001-2006)*[1]

Mark J Gibbons, Department of Biodiversity and Conservation Biology, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa. Email: mgibbons@uwc.ac.za

ABSTRACT

I have analysed 1 295 of the outputs published by the South African Marine Science Community (SAMSC) in either peer-reviewed journals or as books/book chapters for the period 2001-2006, with a view to identifying trends in the field, summarizing institutional overlaps and assessing the demographic state-of-play. Although almost 70% of our outputs were published internationally, we published the bulk of our research in strictly marine science journals which suggests, perhaps, that we need to be thinking bigger. More than 22% of all outputs were led by International colleagues, and these were published in journals with a significantly higher Impact Factor than those led by local authors. Women led less than 25%, and persons from previously disadvantaged backgrounds led less than 10%, of all outputs: this needs monitoring, discussion and pro-active response by employers. Thirty-six authors (~95% male, ~97% white) were responsible for more than 50% of all outputs, which suggests that the field is not totally dominated by an ageing cohort. Despite the fact that the bulk of the SAMSC is centred in the SW Cape, our study areas are approximately equally spread around the coastline, though there is an obvious institutional bias to the geographical location of study sites. Globally-orientated studies were generally published in "better" outlets than locally-orientated work, and were more likely to be led by international colleagues. There was a disappointing amount of work conducted in other African states, and indeed, we published more work from the Southern Oceans than from our (even) immediate neighbours, indicating that perhaps were not playing as much of a role within the region as we could. Little of our work is being conducted in habitats that have been defined as threatened and studies in coral reefs or rocky reefs and in demersal environments are perhaps particularly needed. Vertebrates continue to be better studied than

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invertebrates, and there is a definite bias in our research towards organisms that are directly exploited as resources, or which are indicators of ecosystem health. There were no studies on bacteria or viruses, in any context, and these need to be initiated if we are to understand the functioning of our ecosystems fully. At a disciplinary level, most of our outputs were of an ecological or taxonomic nature, and though the latter is encouraging, the study groups remain those that are better known. The traditional disciplines of behavior or physiology are not widely practiced, and the newer disciplines involving molecular techniques have not been widely taken-up by members of the SAMSC. Some of the biggest disciplinary gaps continue to remain in the fields of conservation, policy and socio-economics, and it is clear that new ways to engage all stake-holders are needed. Although there is a significantly consistent relationship between institutions in terms of their outputs by geographical location of study area, study habitat, study organism and discipline of study, all institutions have a clear niche and are playing an important role in advancing our understanding of the marine environment at the national level.

INTRODUCTION

Unlike the approach taken to research planning in other fields within South Africa, that devoted to the study of the marine environment can perhaps be considered to be bottom-up. It is the members of the marine science community itself, in partnership with national funding bodies and relevant national government departments that sets the research agenda. The marine science community has a very broad base and encompasses oceanographers and atmospheric scientists, chemists, biologists, mathematicians, managers, economists and policy makers (amongst others) from across the country and so the research agendas generated have (in) tended to be inclusive. The reason for this is quite simple – the marine environment is fluid and the link between physics and biology is strong: changes in wind stress along one area of the coast can have an impact on biological resources in another which in turn can have serious implications for the economic and social well-being of human communities.

Communication between the disparate members of the South African Marine Science Community (SAMSC) is mediated through SANCOR (South African Network for Coastal and Oceanic Research). And it is SANCOR that has been responsible for drawing the community together and for driving much of the research planning process. That does not mean to say that

SANCOR has been responsible for facilitating the funding of all research activities in the marine environment within South Africa. Just like any other community, the SAMSC is comprised of individuals and organizations with personal interests and responsibilities, each of which has access to different funding opportunities, but SANCOR has provided the all important medium of communication between community members and has allowed them to coordinate efforts. The main role of SANCOR, however, has been directed towards driving the research being funded from the NRF-DEA(T) joint agreement. This pool of money probably represents the greatest investment in research in the South African marine environment, and it has been disbursed through a series of "Sea and the Coast Programmes". Each programme has had a finite lifespan, whereupon it has been externally reviewed and a new agenda has been established for the next time-period. Although these programmes have been open to all members of the SAMSC, in effect they have been directed at those residing within tertiary institutions because of the strictures imposed by the funding parties. As a consequence, the reviews have been restricted to a subset of the community's outputs and so it has not really been possible to get an overall picture of progress against aims.

Here I attempt to review the published scientific outputs from the whole SAMSC for the period 2001-2006. No special significance can be attached to the dates chosen, which span two Sea and the Coast Programmes, and as a consequence I am not attempting to review outputs against any up-front criteria: I cannot say whether we have been "successful" or not in our endeavors. Rather, the review represents a (dated and perhaps belated) summary of who is doing what where, and more importantly, are there any things that we as a community are not doing? The funding landscape for science in South Africa is changing, and not for the better (in my opinion), and it will not be as easy for us to coordinate our research with the explicit guidance of SANCOR in the future. As a consequence, I believe that any attempts to identify weaknesses and gaps in our research can only be useful for planning the way forward – but those gaps need to be based on an inclusive analysis. Whilst the small contribution here is undoubtedly biased by the author's personal views, its value lies by way of example, I hope.

MATERIALS AND METHODS

I have created a database of all published outputs produced by the marine science community in South Africa for the period spanning 2001-2006, inclusively. Members of this community were identified by their conspicuous presence at local and regional scientific meetings and by their historical involvement in the field, as known to the author. All data have been captured from the annual reports of some 44 Departments in 24 institutions, including CSIR and Marine and Coastal Management (MCM - Department of Environmental Affairs (and Tourism – as was)). In some cases it was necessary to contact the institutions directly, as data were not freely available. I have included peer-reviewed articles, regardless of the journal of publication, as well as full conference publications, and books and book chapters: I have not included grey-literature (internal or contract reports), published conference abstracts or popular articles.

Journals were classified as either local/regional or international, and where possible ISI Impact Factors for each were obtained from Thomson Reuters' Journal Citation Reports (March 2009). Books and book chapters have been given an arbitrary citation value of 0.5, whilst peer-reviewed articles published in non-ISI journals were scored a value of 0.1. The senior author, last author, number of authors and identity of all permanently employed members of the local marine science community[2] were noted for each output, as well as their host institutions. We could thus track outputs per individual, and unique outputs per institution, the latter being defined regardless of the number of same-institution authors. Information on the race, gender and SA residence status of all senior authors and full-time members of the local marine science community were also collated, as was the latter's individual "h" factor, lifetime output and age. The latter three measures were derived from Thomson Reuters' Science Citation Index (March 2009); age being inferred from the year of first publication in an ISI evaluated journal plus an arbitrary 25 years. We could thus track both the demographics of outputs over the review period, and assess relationships between measures using non-parametric Spearman Rank Correlations.

Each output was scored, if appropriate, by a) geographic area of study (e.g. Namibia, South African East coast), b) habitat of study (benthos, pelagos, coral reef etc), c) organism of study (e.g. bony fish, copepod, macroalgae etc) and d) discipline of study (e.g. physical oceanography, geology, aquaculture, ecology etc). Outputs that encompassed more than one

[2] This includes full-time salaried employees as well as those full-time staff affiliated to, or on long-term contract to, an institution/department. It excludes postdoctoral fellows and postgraduate students, but includes technical and/or support staff.

distinct subject matter were apportioned accordingly. For example, Benguela-wide studies were equally divided amongst Angola, Namibia and the West coast of South Africa, whilst studies on mesoscale coupling between plankton and ocean structure were split amongst physical oceanography and ecology. Subject scores were then summed across unique outputs to provide an overview of the work conducted during the period under review. It should be stressed that subject scores were delimited on the basis of information contained within the article's title only, and reflect this biologist's bias.

Subject scores were also summed across institutionally unique outputs in order to provide information on the "expertise" of individual institutions. This dataset was then used to explore issues of diversity within, and similarity between, institutions. The diversity of outputs was calculated separately for each subject grouping (geographic area, habitat, organism and discipline), by institution, using the Shannon Weiner Information H' Statistic, which were then summed across groupings to provide an overall index of diversity: the lower the value of H' the lower the diversity. Similarity matrices between institutions were computed using the Bray Curtis Measure, for each subject grouping after standardization (by institution), and relationships visualized using dendrograms constructed using group-average sorting. These analyses allow for the identification of institutional "niches" and potential areas of institutional overlap. All analyses were conducted using Primer 6 software (Clarke & Gorley, 2006).

I have compared the resemblance matrices between institutions for each subject grouping in pairwise comparisons using the RELATE routine in PRIMER (Clarke & Gorley, 2006). This software computes Spearman Rank correlations (ρ) between the matching entries of the two resemblance matrices and effectively compares the results from those generated from 999 random permutations of the same. The null hypothesis is that there is no relationship between the two matrices ($\rho = 0$).

RESULTS AND DISCUSSION

Overview of Outputs and their Origins

A total of 1 295 outputs were produced by the SAMSC over the period 2001-2006, averaging 216 outputs per annum (Table 1), but varying between a minimum of 162 in 2004 and a maximum of 266 in 2006. The bulk of these outputs were in the form of peer-reviewed articles, and books/book chapters represented slightly less than 10% of the total (Table 1). Almost 69% (on average) of the outputs were published internationally, and this fraction varied little between years. The average ISI Impact Factor of the publishing outlet used by the SAMSC was 1.35. Again, this varied little across the time series examined here.

Although we published in 239 peer-reviewed journals, 23 of these journals accounted for almost 57% of all journal outputs (Table 2). We can crow about our outputs in *Nature* and in *Science*, but our favourite journals were clearly local/regional (Table 2). The *African Journal of Marine Science* (including its fore-runner, the *South African Journal of Marine Science*) made up for almost 17% of total journal outputs, whilst the *South African Journal of Science* and *African Zoology* accounted for just over 5% and 3% respectively (Table 2). The journals of choice were also largely marine science journals, rather than those orientated towards a wider, more general audience. The journal of output plays a big role in determining how often a paper is likely to be read, which in turn influences how often it is cited etc. Journals of a more general disciplinary nature tend to have higher ISI Impact Factor values than those that are strictly marine. While not all of our locally produced work may be suitable for publication in these broader journals, much can be with suitable massaging and contextualization: the effort involved may be considerable, but so will the rewards. I would encourage all publishing members of the SAMSC to think bigger than they perhaps currently are, and to take the occasional rejection by a big-picture journal in their stride.

The 1 295 outputs examined here were led by 580 different senior authors, and demographic information could be traced for 90% of these. Outputs from the SAMSC were penned by an average of 4.2 authors, though the modal author list was two and extended up to a maximum of 26 (Figure 1). Of the senior authors that could be identified, ~22% were international, and their outputs were published in journals/books with a significantly higher ISI Impact Factor (Mann-Whitney U Test, $U = 112121.5$, adj $Z = -5.77$, $p<0.0001$) than were those of the 78% led by local authors (mean ISI 1.71 and 1.24, respectively).

If we confine our demographic analyses to those outputs published by identifiably SA authors (citizens or permanent residents), then it is clear that less than 10% were led by persons from historically disadvantaged backgrounds: the bulk of outputs were led by white South Africans (Table 3), more specifically white male South Africans. This figure compares unfavourably with the demographic breakdown of papers (oral or poster) presented at the main regional scientific meeting for the SAMSC; the South African Marine Science Symposium (SAMSS). The SAMSS is held every three years and it provides a student-friendly opportunity for SAMSC members to present the results of their latest research. I was able to get demographic information for almost 96% of all senior authors making poster or oral presentations at the three SAMSS that cover this review period (1999, Cape Town; 2002, Swakopmund; 2005, Durban), and it is clear from these data (Table 3) that persons from historically disadvantaged backgrounds led ~30% of all outputs. Because some members of the SAMSC will not have made presentations at the three SAMSS meetings, but will have contributed to the outputs reviewed here, comparisons need to be restricted to those that contributed outputs to both. These results do not differ materially from the previous set, and again suggest that persons from historically disadvantaged backgrounds led less than 10% of all outputs over the study period. Some would argue that science is not led from the front, but from the rear. If we look at the racial breakdown of last authors on the published outputs for the period under review, it is clear that persons from historically disadvantaged backgrounds are "leading" less than 5% of all outputs (data not shown). These results indicate a number of things. Firstly, they indicate that persons from previously disadvantaged backgrounds are leading some marine science (as measured here) in South Africa. However, the discrepancy in the demographics between the outputs from SAMSS and those that make it through to the hard literature is worrying. It suggests that while we may be training scientists from disadvantage backgrounds, most do not end up leading science. Any number of explanations can be dreamt up to account for this, but rather than be provocative or defensive, I will just say that it deserves serious attention from all levels within the SAMSC and it deserves to be monitored on an ongoing basis. Deserving too of our attention is the very strong gender bias in the results (Table 3). Despite a number of national initiatives to try and rectify this, it is very clear that at least at the science leadership level, females are still playing a relatively minor role.

An examination of individual outputs of members of the SAMSC indicates that the bulk of research is being driven by a small number of individuals (Figure 2). Indeed, thirty six persons were responsible for more than 50% of the published outputs over the period under review, with one individual producing 59 outputs! The demographic breakdown of the "player" list (data not shown but available on request) reveals that 97.2% of these were white, and that 94.4% of them were male. Spearman Rank Correlations between individuals' measures are shown in Table 4, from which it can be seen, unsurprisingly, that there were positive relationships between most. The weighted (by number of outputs) mean age of an author over the period under review was

46.9 years, whilst the average age of an output's author was 43.5 years. More than 50% of the outputs were produced by SAMSC members aged 50 years or older (Figure 3), a finding in common with some of the analyses conducted by the NRF on scientific output across the national science community. Put another way, however, 50% of the outputs were produced by SAMSC members aged less than 50, which suggests perhaps that the field is not as dominated by an ageing cohort as in other areas of research! There were no correlations within the data when portioned by either gender or race group.

A breakdown of institutional (unique) outputs and attributes is shown in Table 5, and a matrix of Spearman Rank Correlations between measures is shown in Table 6. The institutions listed in Table 5 exclude those eight that failed to generate an average of more than one output per year. It should be noted that the number of staff per institution was calculated as the number of full-time permanent staff, as well as those full-time staff affiliated to, or on long-term contract to, an institution/department. It should be stressed too that these numbers refer to numbers of staff involved in generating the outputs analysed here. There is a very strong positive relationship between productivity and number of staff, as expected, though when the data are expressed per head, the relationship becomes negative (Table 6). These results are strongly biased by a single institution, MCM, which although it is the largest single employer of marine scientists in the Republic clearly has a large number of staff that are not output-orientated. In fact this relationship would likely be even more strongly negative, if it were to be based on the full scientific complement. Part of the reason for this undoubtedly reflects the fact that MCM's prime mandate is the provision of advice to national government regarding the management of marine living resources, and although much of this advice is based on solid scientific research, there is no obligation on staff to publish the results of that research in the main-stream literature. Many MCM staff will argue that they no longer have the time to convert their research into hard outputs and that the technical report used by government represents the full extent of their responsibilities. That said, of course personal promotion within MCM is decided (or should be decided), in part, on staff finding the time to convert technical reports into peer-reviewed outputs, and it is noteworthy in this regard that 20% of the "players" were based at MCM. Similar arguments can be advanced to explain why per-capita staff output is low in all of those institutions that serve the state or province in some sort of advice capacity (CSIR and Ezemvulu KZN Wildlife), but it could then be argued that the data collected at the expense of the tax-payer should become more freely available for others within the SAMSC to take further (perhaps in collaboration). The organization that sits unhappily in this list is ORI, which as an NGO effectively has to fund its own research activities and this will obviously limit it outputs.

There was an understandably strong relationship between the overall diversity of outputs and the number of staff, as well as between the percent internal (within South Africa) collaboration and the number and diversity of outputs. In other words, we are more productive when we collaborate than when we don't. The Impact Factor of the publishing outlets varied quite markedly between institutions, but this reflects the disciplines practiced at each. For example, institutions that were largely involved in taxonomic work such as SAIAB, IZIKO and the Natal Museum were obviously publishing in low Impact Factor outlets because the discipline is not one that is covered by ISI. On the other hand, those institutions conducting research in areas of molecular biology (US ZOO), climate (UCT OCEAN, UZULU ENV) or novel chemistry (RU CHEM) are publishing in high Impact fields.

Geographic Area of Study

Table 7 summarises the outputs by geographic area of study, partitioned by major habitat types and some disciplines. As expected, the bulk of the research has been conducted around South Africa. Despite the fact that the SAMSC is dominated by members based in the SW Cape (Table 5), approximately equal numbers of outputs have been generated from studies in each of the three coastal sectors. This is perhaps surprising, given the financial impetus to Benguela research provided through BENEFIT, BCLME and IDYLE. However, as research in the former two programmes has largely been driven by personnel outside the tertiary sector (see above), any reduction in effort along the west coast could reflect the effective demise of the previously successful (largely university based) BEP, as well as a nationalization of Western Cape interests. At the same time, however, there was a significant investment by DST in the flagship ACEP, which has lead to considerable research along the east coast and in the SW Indian Ocean. The SAMSC continues to produce relatively high numbers of outputs from Antarctic and sub-Antarctic environments. Indeed, it produces more outputs from this part of the world than from its neighbouring states (combined). This undoubtedly reflects the personnel involved, but begs questions about our role within the region. Disappointingly few outputs were generated from global studies, indicating that our science is generally of the "small-picture" variety. While this strongly suggests that our research may be focused on regionally relevant issues - that are nonetheless of wider interest to the scientific community given that we are able to publish the results of those studies in the international literature - it is perhaps important for us to engage more in “big-picture” science. The average Impact Factor of the journals in which we published our global studies was markedly higher than that for the more local ones (Table 7). If one looks at these globally focused outputs a bit more, we can see that a little over 12% of the outputs led by international colleagues were of a global nature, as opposed to fewer than 6% of those led by local community members (data not shown). This indicates perhaps that our international colleagues are better able to see the global value of our data than ourselves!

A breakdown of the institutionally unique outputs by study area and institutional location (Table 7) suggests, understandably, that workers tend to focus their research on those environments on their door-step. SAMSC members in the SW Cape conduct more research in the Benguela system whilst those along the east coast are more active in the systems influenced by the Agulhas Current. Inland colleagues show no pronounced geographic focus of research: the high proportion of Antarctic outputs reflects the work of zoologists at the University of Pretoria.

In his review of littoral research during the 1980s, McQuaid (1989) noted a disparity in the studies being conducted in the different geographic areas around South Africa. In particular he noted a tendency for research in the SW Cape to be primarily ecological, whilst that along the east coast was more taxonomic in nature. McQuaid (1989) attributed this to differing expertise in the two areas. Examination of Table 7 however, suggests that this same trend is no longer true – at least for ecological work, though there is an ongoing bias in taxonomic outputs that undoubtedly reflects the increased diversity of the east coast systems, as well as the concentration of local expertise at SAIAB, ORI and the Natal Museum: there is little taxonomic expertise left in the SW Cape. Interestingly, taxonomy is probably the most internationalized of all the disciplines considered here (Table 7), as it rightly should be considering the nature of the systematic project. There has been comparatively less oceanographic work conducted along the east coast, despite the best efforts of the ACEP, and this discipline continues to be undertaken largely in the Benguela system (including Namibia/Angola) and along the south coast. Operational oceanography is expensive science and it is therefore only possible with the sorts of funding and support generated through BENEFIT and the BCLME, or through collaboration in the routine activities of MCM. Hopefully, in the light of significant new international funding being directed at the West Indian Ocean (ASCLME and SWIOFP) this situation will change in the not-too distant future.

Although outputs on benthic and pelagic habitats appear to be evenly spread around South Africa (Table 7) there is a pronounced reduction in research on the former outside our borders. This can partly be explained by the multinational and trans-boundary nature of recent pelagic research and perhaps also by the costs and risks of undertaking benthic research in unfamiliar locations. Most of the estuarine research conducted in South Africa is focused along the east coast (Table 7), and to a lesser extent the south coast: little research has been conducted along the west coast. This clearly reflects the distribution of estuaries around the coastline.

Habitat of Study

Table 8 provides an overall summary of the outputs conducted in different habitats over the review period, whilst Table 9 breaks this up by selected disciplines. It can quickly be seen from Table 8 that the bulk of our outputs were from marine systems, and more particularly, from the pelagos. One should remember, however, that this category includes outputs based on the habitats of organisms that reside there, even if the work was actually conducted in the laboratory. So, research into abalone (*Haliotis midae*) aquaculture has been included amongst studies of the benthos, whilst work on surface currents or albatrosses will have been considered pelagic.

Given the above, the results are perhaps not surprising. Interestingly, our most valuable fishery resources are demersal, and yet outputs conducted in this habitat are comparatively few, perhaps because of the costs and specialized logistics required by their study. However, that demersal research which has been conducted appears to be appropriate: quantitative fisheries, fisheries management and ecology. Alternatively, the very variability of pelagic systems is such that they demand greater attention in order to develop a comparable understanding, and the majority of outputs here have been of an ecological or oceanographic nature. Regardless of the reasons for the differences, little work has been undertaken in demersal environments which, given the fact that this habitat has been highlighted by Lombard and Strauss (2004) as data poor and particularly threatened, suggests that more emphasis should be paid here in the future.

Although rocky and coral reefs are important habitats, with special management requirements, they received scant attention during the period under review. In the case of rocky reefs, which provide important habitats for temperate species of commercially valuable line-fishes, the effort has gone into appropriate discipline fields: there was an emphasis on management and understanding rather than “discovery”. These outputs contrast with those from coral reefs, which were dominated by taxonomic studies and by research into organismal biology. The high diversity of these systems and the relative paucity of detailed local knowledge have encouraged such exploratory work, and this reflects the interests of the parties involved, all of which are located along the east or south coasts. That said, the “coral reefs” encountered in South Africa are at the southern limit of their distribution in the SW Indian Ocean and they could provide an important global barometer for climate change, so should perhaps be deserving of greater attention.

South Africa has a very rich and extensive history of research in intertidal habitats, and a number of locally based scientists have had international impacts with their work. Indeed, some influential academic texts on the ecology of sandy (Brown 1990) and rocky (Newell, 1979) shores have been constructed around work conducted in the region, and a suite of more popular books on life in these habitats have been produced (Day, 1969; Branch and Branch, 1981; Branch et al., 1994). Benthic habitats (excluding coral and rocky reefs) continue to be the habitat of choice for many members of the SAMSC (Table 8), and we have conducted a diversity of research in them (Table 9). In the interests of brevity, I note only a few obvious features here: while our interests in sandy and rocky shores are comparable, it would appear that there is more of an emphasis on subtidal than intertidal habitats. Both of these observations may appear counter-intuitive, given that there were no large research programmes on either sandy shores or subtidal systems during the period under review. Rather they reflect (in part) the way the data were collected, as noted above. Since the departure of Anton McLachlan to the Middle East in the1990s, there has been no dedicated local hub for the study of sandy shore ecology, yet the results indicate that ecological work in these systems is as prevalent today as it is in rocky shores. Work in this field is being conducted piecemeal across the country by a number of workers, often with an estuarine emphasis (Table 10) – there is still a need to rekindle truly sandy shore ecology as these systems comprise the bulk of our beaches. In the case of subtidal systems, there was a greater emphasis on hard than soft substrata, which possibly reflects both their greater (comparative) diversity and fact that they are home to some commercially (actual and potential) important species. Regardless for the reasons between the disparity in emphasis on subtidal than intertidal subtidal systems, it is encouraging as it suggests we are placing emphasis where emphasis is needed (Lombard and Strauss, 2004).

Organism of Study

Table 11 summarises our outputs by organism of study, broken down by selected disciplines and geographical location of study site. Vertebrates represent more than 50% of the study organisms, with boney fishes alone accounting for just over a quarter of the total. The organisms studied by the SAMSC reflect members' interests and experience, as well opportunities. Fish are of great economic and societal importance to the region, and much of the driving force behind the implementation of BENEFIT, ACEP and the two LME programmes (BCLME and ASCLME) has been fish and fisheries, especially those of a trans-boundary nature. South Africa has a rich history in ichthyology that is being continued to this day at MCM, ORI and the DIFS at RU, SAIAB and the Iziko Museum of Cape Town, while fisheries policy and management are central issues of research at UWC's PLAAS and UCT's Department of Geographic and Environmental Science. Clearly we are a nation of fish-lovers! Feathers and fur are also popular, reflecting largely the efforts of scientists at UCT and UP, respectively, with important involvement by staff at MCM. By contrast to our research on fishes, however, work on birds and mammals has largely been conducted in Antarctic and sub-Antarctic environments (data not shown), and along the South African west coast. Molluscs continue to be well studied (McQuaid, 1989), in part because of a flurry of work on the ecology and culture of the imperiled abalone (Table 11), but also because of ongoing research into bivalve and limpet ecology on rocky shores. As also noted by McQuaid (1989), crustaceans remain comparatively poorly studied overall, with most such work still focused on commercially valuable lobsters (Decapoda).

One of the more interesting comparisons shown in Table 11 is the distribution of organisms across disciplines. Proportionally more outputs were generated in the field of taxonomy than ecology for taxa of limited commercial value, although as ever there were some exceptions, chief amongst them being cnidarians. Benthic cnidarians are functionally and structurally important members of coral reef communities whilst pelagic cnidarians are important components of disturbed pelagic ecosystems.

Strict comparisons with McQuaid's (1989) results require that our data be analysed by benthic habitat. When this is done (Table 11), these results indicate that there have been some shifts in interest over time. While there were slightly less (proportionally) outputs on vertebrates and molluscs over the recent review period, and significantly less outputs on macroalgae and echinoderms, these were compensated for by large increases in outputs on crustaceans and cnidarians. A number of taxa have appeared amongst our study organisms since McQuaid's (1989) review (Porifera, Bryozoa, Polychaeta and Tunicata), and only two have dropped off. One of these reflects the retirement of a single expert (Echiura) and is fairly trivial, but the other is far more significant – Bacteria. There have been no studies of marine bacteria by members of the SAMSC over the period under review, and there have never been studies on regional marine viruses, to the best of our knowledge. Bacteria were a key component of the holistic studies being conducted in the early days of the BEP, both within kelp-bed systems and in the pelagos, yet there has been no continuation of this work. Viruses are now recognized as playing a vital role in regulating phytoplankton populations elsewhere in the world, and even though a South African (D Schroeder, Plymouth Marine Laboratory) is playing a leading role in some of this work overseas, we as a local community are neglecting this important component of the system. Both of these groups of organisms play vital roles in our marine systems and are deserving of our attention.

Discipline of Study

While many comments can made regarding the disciplinary emphases of our outputs over the period under review (Table 12), in many cases the patterns observed reflect the pool of available expertise and interest (Table 5), the relevance of the work and the ease with which funds can be found to support it, as well as the ease with which work can be conducted and converted into a measured output. I am not going to explore the data in any detail, but will confine observations to some of what I consider to be the most important results.

The bulk of our work is of either an ecological or taxonomic nature (Table 12). While the latter appears to be encouraging, given the poor state of taxonomic science nationally (Gibbons, 2000), we should not be complacent and remember that the majority of this effort is still directed towards fishes (Table 11), where there is considerable existing expertise. Most of the concerns raised by Gibbons (2000) are still valid, and despite the fact that the NRF has ring-fenced monies to support taxonomy (SABI) there has been no new national investment in non-fish marine taxonomists.

Ecology is a very large discipline and all institutions within The Republic have ecologists on their staff (Table 5), so it is perhaps no wonder that the number of outputs is so high. Traditionally the discipline of ecology is separated into the study of individuals and populations, communities, and ecosystems, though there is naturally a significant overlap between each. Approximately 68% of the SAMSC's outputs in ecology have been directed towards the studies of individuals and populations (excluding quantitative fisheries), ~21% towards communities and only 11% towards ecosystems. There are many reasons for this distribution of outputs (ease of work, ecological or economic relevance of study species, poorly resolved taxonomy etc) but the crux of the matter probably reflects the increasing knowledge demand required when moving from individuals through populations to communities and eventually ecosystems. South Africa has been a leader in studies at the ecosystem level since the advent of the Kelp Bed Project and the BEP, and we are still leading when it comes to the ecosystem approach to fisheries. Work at the ecosystem level requires significant computer modeling and simulation, and expertise in these fields is relatively restricted, so our outputs here are encouraging.

Traditional biological disciplines like physiology (especially animal physiology) and behavior were poorly represented amongst the outputs (Table 12), which suggests little has changed since McQuaid undertook his review in 1989 (McQuaid, 1989). There is still much scope for work in these fields, as neither should be considered esoteric. Behaviour can play an important role in influencing population processes and dynamics, especially those of fish and other vertebrates. Knowledge of the physiological responses of organisms to their environment has been used elsewhere to predict likely changes in population size and distribution in the face of global climate change. McQuaid (1989) also noted a scarcity of outputs in the field of contemporary biogeography and evolution. Both these discipline fields have been lumped together here under the category “Diversity”, which incorporates studies into population genetics and phylogeography. While molecular methods are being used extensively elsewhere in the world to explore all sorts of ecological and evolutionary questions, the SAMSC has been slow to take these up. Work in the field of contemporary biogeography is being conducted by taxonomists and ecologists at institutions with a traditional interest in marine science, while studies on population genetics and phylogeography have been taken up by departments and institutions that are relatively “new” to the community. The field is new, and my impression is that the staff engaged in this work are few, they are stretched (in the sense that they are conducting work in marine, freshwater and terrestrial environments) and relatively young: they are geneticists first and marine scientists second. Molecular methods provide us with the tools to engage in research at the cutting edge, as well as to conduct very important and relevant work. There is space within the SAMSC for more such people!

Perhaps the three biggest explicit disciplinary gaps relate to some of the most pressing, challenging, strategic and relevant fields: conservation, policy, and socio-economics. The paucity of studies in the first of these is somewhat mystifying, given that our international commitments, but it probably reflects the paucity of in-community expertise. It says quite a lot that (probably) the most influential work in SA marine conservation has been led by conservation biologists from the terrestrial community (Lombard and Strauss, 2004). It says quite a lot too that this document is technically a “Report”!

Since its inception, the activities of SANCOR have largely been driven by natural scientists. But the umbrella organization includes social and economic scientists, lawyers, architects and engineers amongst its constituents. SANCOR, the DST, the NRF and MCM, indeed all members of the SAMSC, have long recognized the need to draw social and economic scientists (especially) into our research (where appropriate) because we understand that while conducting research into the biology of exploited resources and systems is important for drawing up management plans, unless there is a thorough understanding of the human dimension, our best plans can readily come to naught.

The Sea and the Coast Programme funded much of the research conducted by the SAMSC over the review period. This programme was supported by monies from the national departments of Environmental Affairs (and Tourism), and Science and Technology (NRF) and was effectively drawn up by the SAMSC (facilitated by SANCOR) as a way to direct members' research activities into relevant and appropriate areas. In the last ten years or so, the Sea and the Coast Programme has explicitly made space for, and prioritized, research into social and economic science issues, yet there has been almost no take-up of the opportunities provided. This has been reflected in the various independent reviews of the Sea and the Coast Programmes, and it is clear that as a community, we have failed to engage properly with these stake-holders. There are many possible explanations for this, chief of which is probably the inability of natural and social scientists to "understand" each other and the unwillingness of the former to engage with the latter and to move beyond their comfort zones. Regardless of the reasons, it is clear that if we want to involve social and economic scientists in SA marine science, then other mechanisms need to be sought. To simply let natural scientists drive the process will not lead to the desired outcome and in recognition of this the NRF's most recent call for project proposals in the Sea and the Coast Programme has been restricted to projects of a socio-economic or policy nature.

As noted previously (Table 5), the Impact Factor of the publishing outlet varied with discipline. Interestingly too so did the mean number of authors per output. The most author-rich outputs were produced either in the most multidisciplinary areas (conservation, biogeochemistry and oceanography) or in those areas with high impact outlets (Table 12). Lowest numbers of authors per output were observed generally in the fields of taxonomy, biology or policy and this reflects either the small number of subject specialists (policy) or the degree of subject specialization (taxonomy, biology).

Multi-Disciplinarity

Table 12 provides an indication of the percentage of outputs that are considered to be multidisciplinary, as well as those disciplines were used together most frequently. Table 5 provides some comparable data by institution. Caution should be exercised in the over-interpretation of these data as they were subjectively identified on the basis of information contained within the title of each output as well as from knowledge of the specialist expertise of the authors concerned. Some of the combinations, in retrospect, are perhaps redundant (e.g. parasitology and taxonomy; geology and palaeontology), but regardless, because the data were all compiled by a single person, they can be used in a relative manner. None of the observations in Tables 12 are particularly surprising: Taxonomy and physiology were largely practiced as standalone disciplines, whilst chemical oceanography and biogeochemistry were more multidisciplinary. Interestingly, there was a trend for more multidisciplinary outputs to be published in outlets with a higher ISI Impact Factor (Table 13), though this result is not significant. Overall, ~60% of all outputs were based on single-disciplinary studies, ~28% were based on two disciplines and ~12% were based on three or more disciplines.

Institutional Overlaps

One of the key objectives of this study was to try and get a handle on institutional niches – in order to try and determine if all institutions within the SAMSC are doing the same thing or whether in fact we are different. The dendrograms showing the similarity in institutional outputs are shown in Figure 4, as are the categories responsible for determining (up to 90% of) the similarities between institutions within each identified cluster. Although there is a significant relationship between the similarity matrices generated for each category of analysis (geographical location of study site, habitat of study etc), as shown by the Rho statistics in Table 14, the actual values are relatively small. This effectively means that overlaps between institutions, based on their outputs, are limited even if there are strong similarities in general disciplinary emphases (Table 5). Overall similarities were higher for habitat of study (50.8%) and geographical location of study site (45.9%), than for discipline (25.9%) or organism (15.1%) of study. I am not going to discuss these results in any detail, but they do serve to show that institutions similar in one category are distinguished in another. The results are intriguingly similar to those that would be expected in ecological studies of niche complimentarity, whereby potential competition between organisms along one niche axis is offset by niche use along axis! It is clear that there is space within the SAMSC for all and that each institution has a unique role to play.

SOME GENERAL CONCLUSIONS

A large number of conclusions can be reached based on the above, and many others will become apparent to readers when they peruse the tables. The following are perhaps some of the more obvious:

- We should think about publishing more of our outputs in non-marine journals.
- While we may be training substantial numbers of persons from historically disadvantaged backgrounds in marine science, few of these are then going on to lead outputs. While this statistic may be dated, I believe that we need to monitor this investment on an ongoing basis and attempt to address it in the workplace.
- While MCM may be the largest employer of marine scientists, few of these are actively publishing on an ongoing basis. This needs to be addressed in the workplace.
- We need to be conducting (and publishing) more work with colleagues in neighbouring states. South Africa has a leading role to play in African marine science and we need to be building on our expertise, in a collaborative and supportive way.
- We need to start thinking bigger than local in our marine science. While most of our work is of a national nature and relevance, there are surely global debates that we can contribute to.
- We need to be putting more research into demersal and reef environments, as well as those of soft benthic substrata, which are recognized as data-poor.
- We need to rekindle research into bacteria and meiofauna and we need to start building (fungi and) viruses into our research programmes.
- We should not forget some of the traditional disciplines such as behavior and physiology, which can contribute important insights to resource management.
- New molecular approaches to biology should be actively embraced by the SAMSC. At the moment this field of research is being undertaken by a small number of (relatively)

young people in isolated departments and institutions, yet the questions that can be asked and answered using biochemical approaches are important ones.

- We should be putting more effort into research in fields that are of material relevance to the nation: conservation, socio-economics and policy.
- We need to continue to think in a multi- and inter-disciplinary fashion.
- Although many institutions are conducting similar research, the pool of expertise is still sufficiently small that overlaps and duplication are minimal at the national level. This is encouraging.

RECOMMENDATIONS FOR FUTURE STUDIES OF THIS SORT

I believe that the exercise conducted here has been useful, and I believe that it should be repeated either on an ongoing basis or that it should be conducted regularly. It provides us with an opportunity to assess ourselves as a community and it gives us a solid foundation that can be used in planning for the future. That said, there are a number of issues that should be addressed in mapping the way forward based on this approach. The list of suggested improvements that follows is by no means exclusive, and merely represents what I consider to be some of the more obvious points.

1. The data set analysed here reflects the outputs I was able to readily capture without recourse to detailed institutional or individual follow-ups. I know I have missed some data, though exactly how much data are missing is unknown. To avoid this in future it is suggested that all outputs from the SAMSC be centrally archived (perhaps by SANCOR), in much the same way the CREST captures the outputs from tertiary institutions for the DoE. This will not only allow for an institution's full contribution to each output to be recognized, but it will also give us an opportunity to assess the extent and nature of international collaboration. Importantly too, it would also allow for rigorous data auditing.
2. All organizations/institutions and individuals that are members of the SAMSC should be canvassed to supply their outputs to the central archive. The ones covered here are only those that are known by me to be active, but there will be others. Foremost amongst

these are probably the geological councils and private industries, but others on the SANCOR mailing list may also be generating research outputs that should be included.

3. The subject categories used here reflect those identified by the authors and are based solely on the titles of the outputs. Inevitably, different individuals will categorize the same data in different ways, and it is very likely that the full scope of an output is not accurately captured in its title. To avoid these it would be necessary for members of the SAMSC to agree on suitable pigeon-holes for their work and then to submit some sort of check-list based on these when they submit data to any central archive.

4. Technical reports have not been captured here, despite the fact that they are sometimes important documents that have been peer-reviewed. These types of outputs can represent a significant proportion of the total numbers of outputs generated by some members of the SAMSC, particularly in the fields of policy, quantitative fisheries and fisheries management. Any centralized database needs to capture such documents, if they have been subject to peer-review. This is important because this study has been based on published outputs in peer-reviewed outlets. It represents the visible side of South African marine science, and some may argue it can be misleading: just because we are not publishing in a particular discipline or habitat does not mean we do not have the relevant expertise or are not doing the relevant research. In identifying gaps therefore we should be pulling in the technical reports, as well (perhaps) as student theses. Although published and peer-reviewed papers may not result from a student's completed thesis, the human capitol output may go on to lead science and this information could also be compiled.

5. I would not like to see institutions or individuals penalized by the outputs that can be generated from a study such as this. The intention of the study was to identify issues that can move the whole community forward and possibly guide future funding initiatives. We are a small, relatively harmonious, "ego-free" and closely networked community and each of us has valuable a role to play. Comparative performance analyses, while useful for in-house management purposes, can lead to negative feelings of worth unless used judiciously because there are a number of unmeasured factors at work.

GLOSSARY of ACRONYMS

ACEP – African Coelacanth Ecosystem Programme

ASCLME – Agulhas Somali Current Large Marine Ecosystem

BCLME – Benguela Current Large Marine Ecosystem

BENEFIT – Benguela Environment Fisheries Interactions and Training

BEP – Benguela Ecology Programme

CREST – Centre for Research on Science and Technology

CSIR – Council for Scientific and Industrial Research

DEA(T) – Department of Environmental Affairs (and Tourism)

DoE – Department of Education

DST – Department of Science and Technology

MCM – Marine and Coastal Management

NRF – National Research Foundation

ORI – Oceanographic Research Institution

SABI – South African Biosystematics Initiative

SAIAB – South African Institute for Aquatic Biodiversity

SAMSC – South African Marine Science Community

SAMSS – South African Marine Science Symposium

SANAP – South African National Antarctic Programme

SANCOR – South African Network for Coastal and Oceanic Research

SWIOFP – South West Indian Ocean Fisheries Programme

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LEGENDS TO TABLE AND FIGURES

Table 1: Overview of outputs by the South African Marine Science Community over the period 2001-2006.

Table 2: Favourite journals in which members of the South African Marine Science Community published their research outputs over the period 2001-2006, showing numbers (percentages) of outputs published in each.

Table 3: The demographics of senior authors on the peer-reviewed outputs and books/book chapters produced by the South African Marine Science Community over the period 2001-2006 (centre). Comparative information for the South African led outputs from the (left) three South African Marine Science Symposia (SAMSS) spanning this period (1999,2002,2005), (right) both SAMSS and published outputs.

Table 4: Spearman Rank correlations between output measures of individual authors in the South African Marine Science Community. Data highlighted in bold significant at the 5% level.

Table 5: Institutional summary of unique outputs (N), output diversity and associated bibliometrics. The number of permanent, or full-time affiliated, staff also shown, as are the major disciplines of published outputs. Percent collaboration indicates the percent of SA institutions with which each has collaborated. Data exclude those institutions that produced less than six outputs over the period under review.

Table 6: Spearman Rank correlations between output measures of institutions in the South African Marine Science Community (Table 5). Data highlighted in bold significant at the 5% level.

Table 7: The distribution (%) of output study site locations, by institutional location and selected habitat and disciplines. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details). Also shown is the mean ISI Impact Factor for outputs based on work in the different geographic areas. Data exclude outputs without a geographic area.

Table 8: Distribution of outputs (%) produced by the South African Marine Science Community over the period 2001-2006, by A) Environment, B) Habitat, C) Benthic Habitat.

Table 9: Distribution (%) of outputs by habitat across selected disciplines. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

Table 10: Distribution (%) of outputs in benthic habitats, by environment. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

Table 11: The distribution (%) of subject organisms, by selected disciplines, study site locations and habitats. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

Table 12: The distribution of peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details), across disciplines. Also shown, by discipline, are the mean numbers of authors and the mean ISI Impact Factor of publishing outlet as well as the percentage of outputs that are considered multidisciplinary and which disciplines were practiced together.

Table 13: Number of peer-reviewed outputs and books/book chapters produced by the South African Marine Science Community over the period 2001-2006 considered here by extent of multi-disciplinarity. Also shown are the mean ISI Impact Factors (and Standard Error, SE) of the publishing outlet.

Table 14: Spearman rank correlations between the similarity matrices generated between institutions in respect of the geographic location of output study site, the habitat of output study, the organism of output study and the discipline of output study (cluster analyses shown in Figure 4a-d). All values are significant at the 5% level.

Figure 1: Bar graph showing the frequency distribution of South African Marine Science Community outputs by number of authors per output, and a line plot displaying cumulative percentage of same. Data for the period 2001-2006

Figure 2: Distribution of authors (blue), cumulative percentage distribution of authors (green) and cumulative percentage distribution of total outputs (red) by number of outputs per author. 50% of the outputs were generated by less than 20% of the marine science community.

Figure 3: a) Age Structure of the publishing component of the SAMSC over the period 2001-2006 (grey), weighted by number of outputs (black). b) Cumulative data of same (stippled, solid respectively), indicating that more than 50% of outputs generated by community members older than 46 years of age.

Figure 4: Cluster diagram showing percent similarity (Bray Curtis Measure) between institutions based on a) the geographic location of output study sites, b) the habitat of output study, c) the organism of output study, d) the discipline of output and e) the geography, habitat, organism and discipline of outputs. Only those institutions producing more than one output per year over the period 2001-2006 included. Diagram constructed using group-average sorting. Also shown, below each figure, are those categories responsible for 90% (60% in 4e) of the similarity between institutions within separated clusters, as identified by the SIMPER routine in PRIMER v6, with an indication of the average (standardized) percent of each amongst outputs.

	2001	2002	2003	2004	2005	2006	ALL - Sums	ALL - Averages
Number of Outputs	192	222	227	162	226	266	1295	215.83
Mean ISI	1.23	1.45	1.07	1.59	1.37	1.39	--	1.35
Mean No Authors	3.73	4.35	4.02	4.70	3.99	4.44	--	4.20
Number Books/Chapters	10	20	40	12	14	26	122	20.33
No Journal Articles	182	202	187	150	212	240	1173	195.50
Local/Regional	64	62	87	38	82	72	405	67.50
International	128	160	140	124	144	194	890	148.33

Table 1: Overview of outputs by the South African Marine Science Community over the period 2001-2006.

Journal Title	N	%
African Journal of Marine Science	195	16.6
South African Journal of Science	58	4.9
Marine Ecology Progress Series	42	3.6
African Zoology	36	3.1
Estuarine and Coastal Shelf Science	34	2.9
Geophysical Research Letters	26	2.2
Marine & Freshwater Research	26	2.2
Polar Biology	22	1.9
African Journal of Aquatic Science	19	1.6
Deep Sea Research II	19	1.6
Marine Biology	19	1.6
ICES Journal of Marine Science	18	1.5
Aquaculture	16	1.4
Journal of Experimental Marine Biology & Ecology	16	1.4
WaterSA	16	1.4
ZooTaxa	15	1.3
Fisheries Research	14	1.2
Ostrich	14	1.2
South African Journal of Wildlife Research	14	1.2
Deep Sea Research A	12	1.0
Journal of the Marine Biological Association of the UK	12	1.0
Journal of Marine Systems	10	0.9
Journal of Plankton Research	10	0.9

Table 2: Favourite journals in which members of the South African Marine Science Community published their research outputs over the period 2001-2006, showing numbers (percentages) of outputs published in each.

	SAMSS Outputs	Published Outputs	BOTH
Gender			
Male	59.0	75.8	63.8
Female	41.0	24.2	36.2
Race			
Black	13.7	2.4	2.3
Coloured	10.5	3.5	3.9
Indian	5.9	2.9	2.3
White	69.9	91.2	90.8
Gender Ratios (M:F) by Race			
Black	1.2	1.3	1.0
Coloured	1.2	2.6	3.5
Indian	0.7	1.7	0.6
White	1.6	3.3	1.9

Table 3: The demographics of senior authors on the peer-reviewed outputs and books/book chapters produced by the South African Marine Science Community over the period 2001-2006 (centre). Comparative information for the South African led outputs from the (left) three South African Marine Science Symposia (SAMSS) spanning this period (1999,2002,2005), (right) both SAMSS and published outputs.

	Age	Number of Outputs	Mean No Authors per paper	Average ISI JNL Impact	No ISI Results	ISI 'h'	Average Diversity
Age	--						
Number of Outputs	**0.294**	--					
Mean No Authors per paper	0.060	0.054	--				
Average ISI JNL Impact	0.109	0.116	**0.248**	--			
No ISI Results	**0.682**	**0.599**	0.007	**0.191**	--		
ISI 'h'	**0.685**	**0.561**	0.155	**0.230**	**0.899**	--	
Average Diversity	**0.246**	**0.495**	0.078	0.137	**0.401**	**0.417**	--

Table 4: Spearman Rank correlations between output measures of individual authors in the South African Marine Science Community. Data highlighted in bold significant at the 5% level.

INSTITUTION	No Staff	N	Annual Mean	Mean ISI	Mean No Authors	Diversity - H'					% Collaboration	Disciplinary Focus
						Overall	Geography	Habitat	Organism	Discipline		
BAYWORLD	2	37	3.1	0.811	5.568	5.7	2.0	1.1	0.7	1.2	25.0	Ecology
CSIR	9	30	0.6	0.977	5.293	6.7	1.6	1.9	0.7	1.8	22.7	Phys Ocean/Chem Ocean/Ecology
E-KZNW	2	10	0.8	0.820	7.100	5.0	0.9	1.8	0.5	1.3	22.7	Fish Mngmnt/Ecology
IZIKO	2	33	2.8	0.771	3.000	4.1	2.0	1.0	0.3	0.6	13.6	Taxonomy
MCM	55	299	0.9	1.217	5.105	7.6	1.9	1.6	0.9	1.9	56.8	Ecology/Phys Ocean/Fish Mngmnt
NATAL MUS	1	8	1.3	0.205	2.111	5.0	1.7	1.7	0.6	0.8	2.3	Taxonomy
NMMU BOT	3	18	1.0	1.148	4.250	6.0	1.3	1.6	0.7	1.9	15.9	Phys Ocean/Ecology
NMMU ZOO	3	50	2.8	1.175	4.585	7.5	1.9	1.9	0.9	1.6	29.5	Ecology/Phys Ocean
NSB	3	21	1.2	2.561	4.880	4.1	1.3	0.8	0.4	1.4	11.4	Ecology/Medical
ORI	9	58	1.1	1.065	3.333	6.4	1.0	2.0	0.7	1.8	20.5	Ecology/Fish Mngmnt/Quant Fish
RU CHEM	1	22	3.7	2.340	5.652	6.0	1.7	1.5	0.7	1.2	11.4	Chemistry & Natural Products
RU DIFS	3.5	71	3.4	1.058	3.386	7.3	1.4	2.0	0.8	2.0	27.3	Aquaculture/Ecology/Quant Fish
RU ZOO	3.5	89	4.2	1.464	3.690	6.8	1.4	1.9	0.9	1.1	22.7	Ecology
SAIAB	8	108	2.3	0.822	2.434	5.7	2.0	2.0	0.3	1.1	25.0	Taxonomy/Ecology
UCT APP MATHS	2	33	2.8	0.728	2.763	6.3	1.9	1.5	0.8	1.0	6.8	Quant Fish/Fish Mngmnt
UCT BOT	1	38	6.3	1.080	3.711	5.7	1.7	1.6	0.4	1.5	15.9	Taxonomy/Ecology
UCT ENV	1	20	3.3	0.908	4.300	4.9	1.5	1.1	0.6	1.6	15.9	Fish Mngmnt/Policy
UCT GEOLOGY	2	23	1.9	1.928	3.217	4.3	1.5	1.6	--	1.2	6.8	Geology/Chem Ocean
UCT MCB	1	6	1.0	1.130	3.000	4.7	1.3	1.4	0.9	0.6	6.8	Taxonomy/Diversity
UCT OCEAN	6	146	4.1	2.002	4.532	6.4	2.4	0.9	0.8	1.4	22.7	Phys Ocean/Climate
UCT STATS	2	72	6.0	0.811	4.397	5.0	1.9	1.6	0.2	1.1	11.4	Ecology
UCT ZOO	9	179	3.3	1.295	4.392	7.9	1.9	1.9	0.9	1.8	54.5	Ecology/Fish Mngmnt
UFS ZOO	2	16	1.3	1.058	3.040	4.0	0.9	0.7	0.8	0.9	6.8	Parasitology & Disease/Taxonomy
UJ ZOO	1.5	21	2.3	1.186	2.857	4.5	1.2	0.9	0.7	1.1	6.8	Parasitology & Disease/Taxonomy
UKZN BOT	1	6	1.0	1.301	2.167	1.3	--	1.3	--	--	0	Physiology
UKZN ZOO	3	40	2.2	1.401	3.349	7.8	1.7	1.9	0.9	1.7	18.2	Ecology/Phys Ocean
UL ZOO	1	10	1.7	0.723	2.769	2.5	0.7	0.5	0.5	0.7	4.5	Taxonomy/Parasitology & Disease
UP ZOO	2	74	6.2	1.314	4.675	3.6	1.6	0.7	0.1	0.9	20.5	Ecology
US ZOO	0.5	10	3.3	2.774	4.700	5.3	1.7	1.7	0.8	0.6	11.4	Diversity
UWC BOT	1	9	1.5	0.768	3.909	5.3	1.3	1.3	0.6	1.8	6.8	Aquaculture/Ecology/Taxonomy
UWC PLAAS	1	8	1.3	0.476	5.222	2.1	1.1	--	--	1.0	11.4	Fish Mngmnt/Socio-Econ
UWC ZOO	1	42	7.0	1.579	4.200	6.3	1.7	1.6	0.7	1.3	25.0	Ecology/Taxonomy
UZULU ENV	1	12	2.0	1.627	2.417	2.3	1.1	0.5	--	0.7	2.3	Climate/Phys Ocean
UZULU ZOO	2	14	1.2	0.841	2.071	3.3	--	1.3	0.7	0.7	11.4	Ecology

Table 5: Institutional summary of unique outputs (N), output diversity and associated bibliometrics. The number of permanent, or full-time affiliated, staff also shown, as are the major disciplines of published outputs. Percent collaboration indicates the percent of SA institutions with which each has collaborated. Data exclude those institutions that produced less than six outputs over the period under review.

	No Staff	N	Annual Mean	Mean ISI	Mean No Authors	Overall	% Collaboration
No Staff	--						
N	**0.727**	--					
Annual Mean	-0.147	**0.505**	--				
Mean ISI	0.098	0.252	0.244	--			
Mean No Authors	0.180	0.240	0.127	0.210	--		
Overall	**0.607**	**0.665**	0.219	0.180	0.316	--	
% Collaboration	**0.671**	**0.763**	0.259	0.143	**0.538**	**0.720**	--

Table 6: Spearman Rank correlations between output measures of institutions in the South African Marine Science Community (Table 5). Data highlighted in bold significant at the 5% level.

STUDY AREA	ALL	INSTITUTIONAL LOCATION				Habitat			Discipline			ISI IF
		Inland	East	South	West	Benthos	Pelagos	Estuarine	Oceanography	Ecology	Taxonomy	
SA West coast	20	14.3	5.0	12.5	30.2	26	17	8	21	22	10	1.18
SA South coast	19	23.0	8.6	27.5	19.2	23	16	27	18	19	17	1.21
SA E coast	18	19.1	57.2	23.4	10.4	27	15	52	11	19	17	1.08
Namibia	6	6.2	0	2.7	7.7	3	8	0	12	8	2	1.52
Angola	2	1.7	0	0	3.2	0	4	0	8	2	1	1.43
Mocambique	1	0.3	3.8	0.9	0.7	2	1	1	1	1	3	0.88
Other African	0	0	0.6	1.0	0.2	0	0	1	0	0	1	0.78
Southern Ocean	10	25.0	1.1	11.6	8.7	1	18	1	6	16	6	1.34
Indian Ocean	5	0.6	10.6	3.8	4.4	4	4	0	3	2	12	1.29
Atlantic Ocean	4	2.6	2.8	4.3	2.6	2	5	3	6	2	8	1.92
Pacific Ocean	3	0.6	0	4.8	2.0	1	3	1	0	1	13	1.05
Global	8	5.8	5.9	3.5	8.8	7	8	2	8	7	11	2.45

Table 7: The distribution (%) of output study site locations, by institutional location and selected habitat and disciplines. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details). Also shown is the mean ISI Impact Factor for outputs based on work in the different geographic areas. Data exclude outputs without a geographic area.

Habitat		% Outputs	
A	Marine		86.9
	Estuarine		12.8
	Coastal		0.2
B	Pelagic		51.7
	Demersal		7.7
	Rocky Reef		4.0
	Coral Reef		3.7
	Benthos		32.8
C	Intertidal		38.7
	Hard	50.7	
	Soft	49.3	
	Subtidal		61.3
	Hard	59.8	
	Soft	40.2	

Table 8: Distribution of outputs (%) produced by the South African Marine Science Community over the period 2001-2006, by A) Environment, B) Habitat, C) Benthic Habitat.

Discipline	Pelagic	Demersal	Reefs		Intertidal Benthos		Subtidal Benthos	
			Rocky	Coral	Hard	Soft	Hard	Soft
Taxonomy	7.6	38.7	22.4	40.8	26.6	8.0	20.9	7.0
Ecology	45.8	28.8	32.4	26.5	46.2	50.3	27.7	44.8
Behaviour	1.3	--	2.8	1.0	1.6	1.3	0.7	0.6
Diversity	3.4	1.7	0.9	4.1	8.5	7.1	8.4	6.2
Biology	1.9	2.5	5.6	11.2	5.5	2.6	2.7	2.3
Physiology	1.2	--	--	--	0.4	5.1	2.0	5.3
Disease	0.1	--	--	--	--	--	--	--
Parasitology	0.1	0.8	0.9	--	--	--	--	--
Quant Fish	3.5	8.6	18.4	--	2.0	3.2	4.7	4.4
Aquaculture	0.4	0.8	--	3.1	0.4	2.2	12.8	2.8
Policy	0.4	--	--	--	0.4	1.0	0.5	1.2
Conservation	0.4	--	1.6	--	--	--	--	--
Socio-Econ	0.1	--	--	--	0.4	0.6	0.8	0.3
Fish Mngmnt	4.0	12.2	12.2	2.0	--	4.2	3.2	4.1
Phys Ocean	16.5	1.6	--	--	0.8	5.1	1.0	5.3
Chem Ocean	3.8	2.0	--	--	--	3.8	--	4.8
Biogeochemistry	4.0	0.6	--	--	--	0.4	--	0.4
Geology	0.1	0.4	--	4.1	--	0.9	0.7	5.9
Climate	3.2	0.4	0.9	--	--	0.4	--	0.4
Medical	0.3	0.8	--	--	0.4	--	0.7	--
Natural Products	--	--	--	--	1.2	--	1.7	0.6
Pollution	1.5	--	1.9	3.1	2.0	2.6	2.7	2.5
Chemistry	0.4	--	--	4.1	3.9	1.3	8.6	1.2

Table 9: Distribution (%) of outputs by habitat across selected disciplines. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

Habitat 1		Intertidal		Subtidal	
Habitat 2		Hard	Soft	Hard	Soft
Marine	West	35.3	8.2	39.0	15.6
	South	38.2	7.5	34.8	1.4
	East	26.5	6.1	26.2	1.4
Estuarine	West	--	9.5	--	9.9
	South	--	28.6	--	29.8
	East	--	40.1	--	41.8

Table 10: Distribution (%) of outputs in benthic habitats, by environment. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

TAXON	ALL	ECOLOGY	TAXONOMY	AQUACULTURE	BEHAVIOUR	PHYSIOLOGY	WEST	SOUTH	EAST	BENTHOS
Bivalvia	3.5	5.4	0.8	1.9	4.0	4.5	4.7	6.1	6.5	9.9
Gastropoda	7.1	3.7	2.8	56.8	18.0	9.1	13.4	13.5	4.6	19.7
Cephalopoda	2.8	3.3	0.5	--	8.0	--	2.3	4.5	2.1	2.1
Decapoda	5.0	4.7	1.5	7.4	4.0	18.2	7.1	5.6	4.9	13.8
Euphausiacea	0.5	1.1	--	--	--	--	--	--	--	--
Copepoda	2.2	2.6	3.5	--	--	9.1	1.3	1.8	2.4	--
Mysidacea	0.7	0.7	1.5	--	--	4.5	--	0.5	1.0	1.2
Other Arthropods	1.1	0.2	2.5	2.5	--	--	0.6	1.8	0.9	0.8
Tunicata	0.2	0.2	0.5	--	--	--	0.3	0.3	0.3	0.4
Cnidaria	4.3	5.4	3.5	--	--	--	2.1	0.8	6.5	7.5
Porifera	2.1	0.1	4.5	--	--	--	1.7	1.4	2.9	5.8
Echinodermata	0.3	0.7	--	--	6.0	--	0.3	0.3	0.3	0.9
Bryozoa	0.1	0.1	0.5	--	--	--	--	0.1	0.1	0.4
Polychaeta	0.6	0.6	0.5	3.1	--	--	1.6	1.6	--	1.8
Nematoda	0.2	--	0.5	--	--	--	--	0.5	--	0.3
Platyhelminthes	0.3	--	1.5	--	--	--	--	--	1.0	--
Other Invertebrates	0.3	--	1.0	--	--	--	0.5	0.5	0.3	--
Chondrichthyes	8.6	5.6	15.1	4.9	--	9.1	7.0	7.3	14.1	2.6
Osteichthyes	25.3	24.8	30.2	9.9	36.0	4.5	23.2	25.6	28.6	7.7
Aves	12.1	18.9	4.5	--	12.0	9.1	12.5	8.7	6.2	7.5
Mammalia	9.4	12.2	5.5	--	12.0	--	5.7	4.2	3.8	--
Macroalgae	4.2	2.8	8.5	9.9	--	--	6.0	5.1	6.0	11.4
Microalgae	5.8	5.7	4.5	3.7	--	4.5	8.1	6.7	4.1	2.1
Other Protista	1.8	0.3	6.0	--	--	--	0.8	3.0	0.5	0.6
Angiosperms	1.3	0.9	--	--	--	27.3	0.9	--	2.7	3.7

Table 11: The distribution (%) of subject organisms, by selected disciplines, study site locations and habitats. Data based on peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details)

Discipline	No Authors	Mean ISI	No Papers	% Papers	Multidisciplinarity				
					1	2	>3	Discipline 1	Discipline 2
Taxonomy	**2.58**	0.65	183.7	14.2	77.0	20.5	2.5	Parasitology (57.7)	Ecology (13.5)
Palaeontology	**3.29**	1.94	8.3	0.6	0	76.5	23.5	Geology (52.4)	Climate (14.3)
Ecology	**3.66**	1.47	474.2	36.6	76.6	17.9	5.5	Phys Ocean (16.4)	Fish Mngmnt/Quant Fish (29.2)
Behaviour	**3.77**	1.87	15.6	1.2	30.8	61.5	7.7	Ecology (88.9)	
Diversity	**4.16**	1.83	48.4	3.7	76.8	16.1	7.1	Taxonomy/Ecology (71.4)	
Biology	**2.96**	1.34	37.5	2.9	63.8	29.8	6.4	Ecology (29.4)	Taxonomy (23.5)
Physiology	**3.18**	1.41	18.8	1.5	77.3	18.2	4.5	Biology/Aquaculture/Ecology/Behaviour (57)	
Parasitology & Disease	**3.23**	1.94	37.2	2.9	10.0	82.5	7.5	Taxonomy (85.7)	Biology (8.6)
Quantitative Fisheries	**3.27**	1.24	55.0	4.2	56.0	36.0	8.0	Ecology (69.4)	Fish Mngmnt (13.9)
Aquaculture	**3.20**	1.41	33.0	2.5	68.3	22.0	9.8	Ecology (53.8)	
Policy	**2.50**	0.36	9.9	0.8	22.2	66.7	11.1	Fish Mngmnt (75)	Socio-Econ (12.5)
Conservation	**5.64**	1.83	7.4	0.6	45.5	45.5	9.1	Ecology (83.3)	Fish Mngmnt
Socio-Economics	**2.94**	1.18	10.1	0.8	31.3	50.0	18.8	Fish Mngmnt (45.5)	Policy/Quant Fish (36.4)
Fisheries Management	**3.38**	1.43	64.7	5.0	43.8	49.0	7.3	Ecology (43.9)	Policy (21.1)
Physical Oceanography	**4.17**	1.98	120.6	9.3	36.3	31.9	31.9	Climate (28)	Chem Ocean (25.3)
Chemical Oceanography	**4.75**	2.35	36.8	2.8	13.9	17.7	68.4	Phys Ocean (55.9)	Ecology (27.9)
Biogeochemistry	**5.36**	1.09	26.8	2.1	7.5	5.7	86.8	Phys Ocean (61.2)	Ecology (28.6)
Geology	**3.50**	1.68	15.6	1.2	37.5	45.8	16.7	Palaeo (73.3)	Phys Ocean (13.3)
Climate	**3.28**	1.85	39.5	3.1	26.2	63.1	10.8	Phys Ocean (87.5)	
Medical	**4.50**	3.00	4.2	0.3	50.0	33.3	16.7	Natural Products (75)	
Chemistry & Natural Products	**4.50**	2.02	25.9	2.0	73.3	20.0	6.7	Medical (50)	Ecology (25)
Pollution	**3.31**	1.66	20.9	1.6	51.7	44.8	3.4	Ecology (50)	

Table 12: The distribution of peer-reviewed outputs and books/book chapters by the South African Marine Science Community over the period 2001-2006 (see text for more details), across disciplines. Also shown, by discipline, are the mean numbers of authors and the mean ISI Impact Factor of publishing outlet as well as the percentage of outputs that are considered multidisciplinary and which disciplines were practiced together.

Number of Disciplines	N	Mean IF	SE
1	971	1.3	0.06
2	246	1.4	0.12
3	56	1.7	0.28
4	21	2.3	1.22

Table 13: Number of peer-reviewed outputs and books/book chapters produced by the South African Marine Science Community over the period 2001-2006 considered here by extent of multi-disciplinarity. Also shown are the mean ISI Impact Factors (and Standard Error, SE) of the publishing outlet.

	Geography	Habitat	Discipline	Organism
Geography	--			
Habitat	0.368	--		
Discipline	0.196	0.307	--	
Organism	0.270	0.450	0.315	--

Table 14: Spearman rank correlations between the similarity matrices generated between institutions in respect of the geographic location of output study site, the habitat of output study, the organism of output study and the discipline of output study (cluster analyses shown in Figure 4a-d). All values are significant at the 5% level.

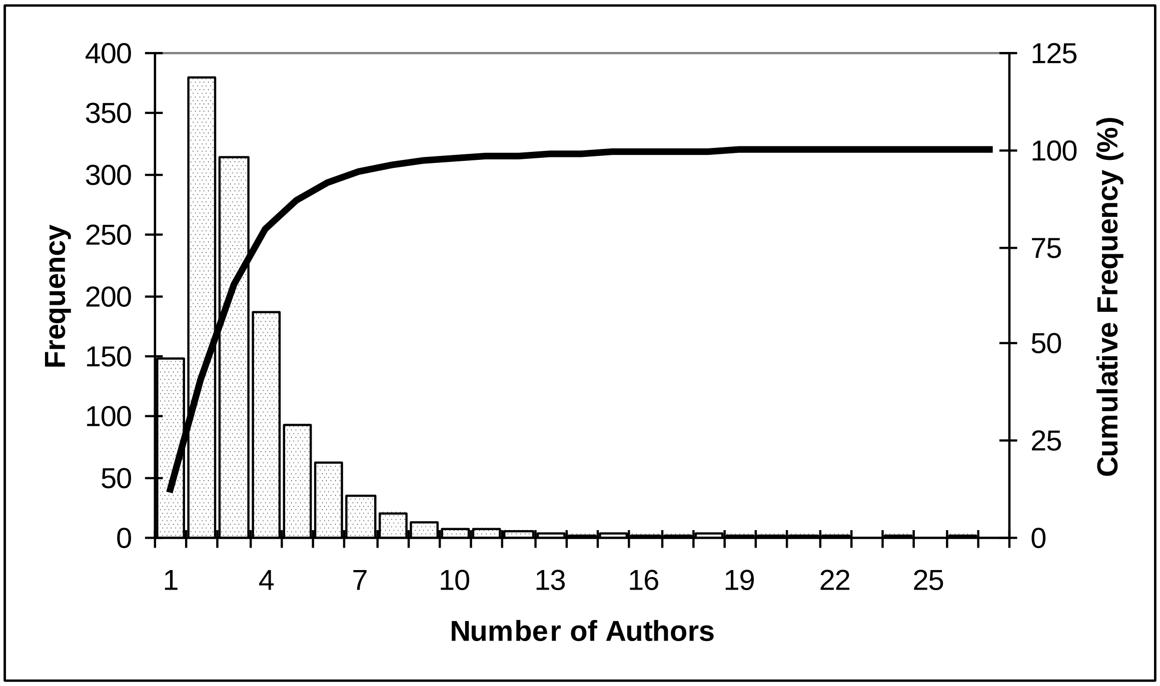


Figure 1: Bar graph showing the frequency distribution of South African Marine Science Community outputs by number of authors per output, and a line plot displaying cumulative percentage of same. Data for the period 2001-2006

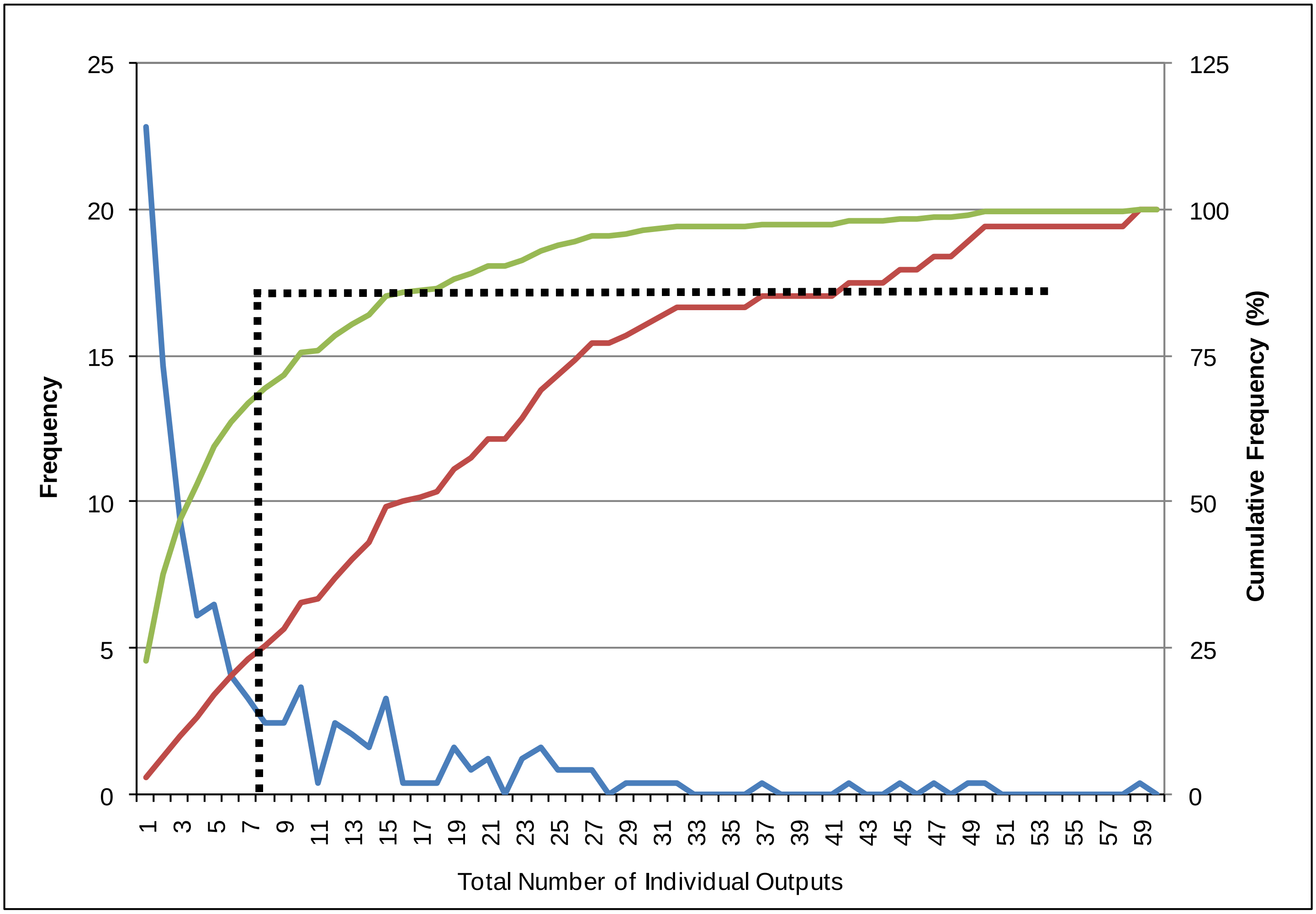


Figure 2: Distribution of authors (blue), cumulative percentage distribution of authors (green) and cumulative percentage distribution of total outputs (red) by number of outputs per author. 50% of the outputs were generated by less than 20% of the marine science community.

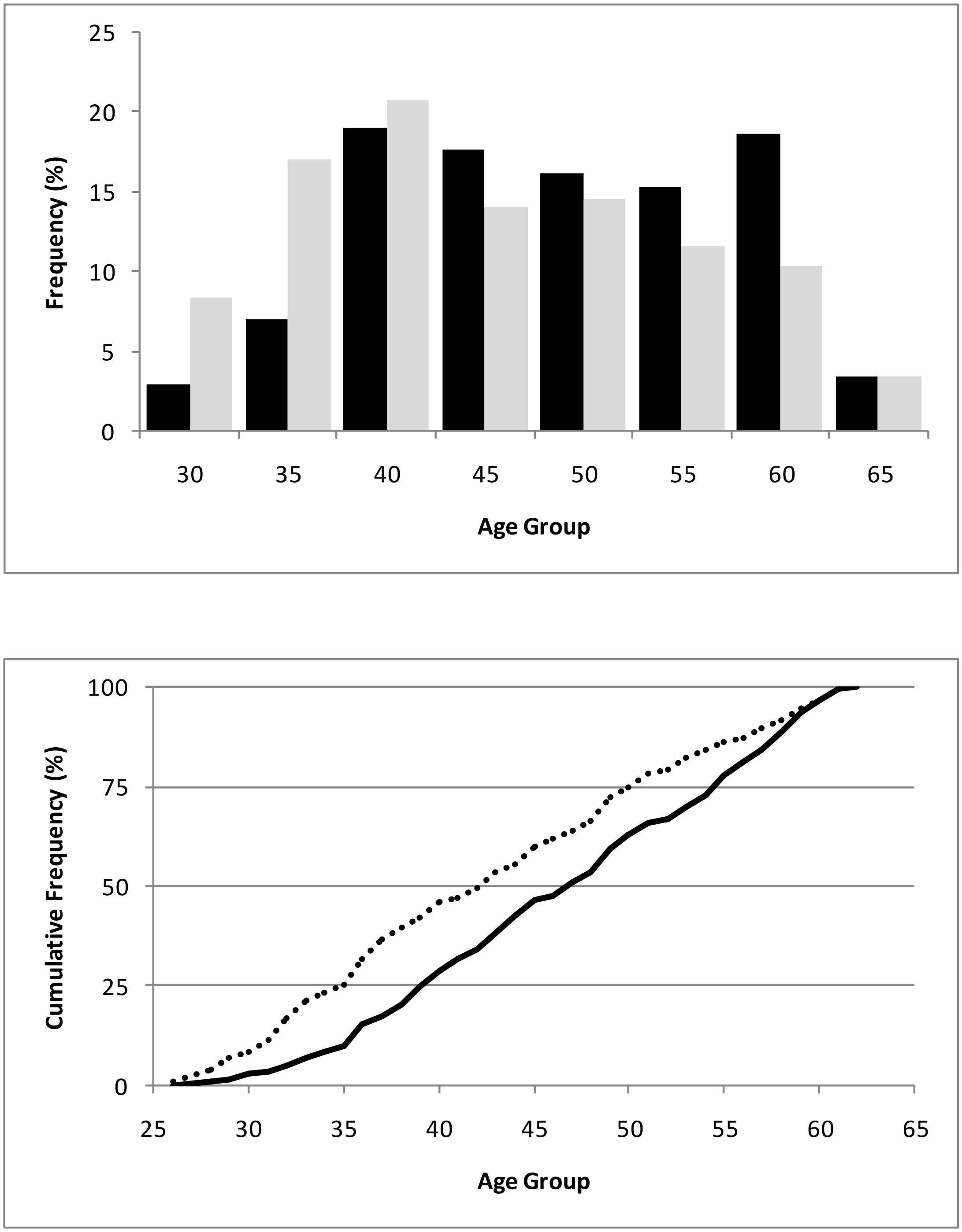
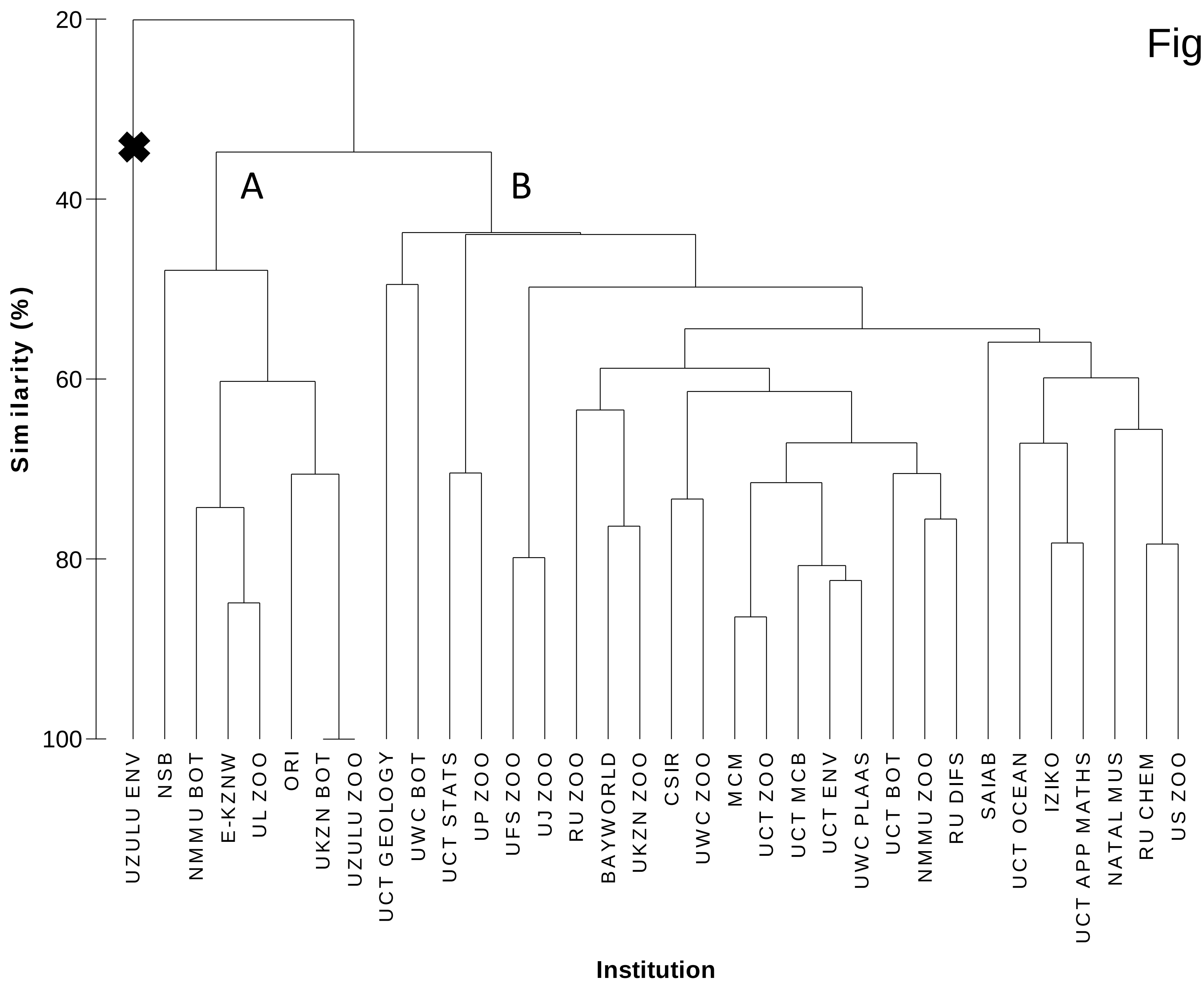


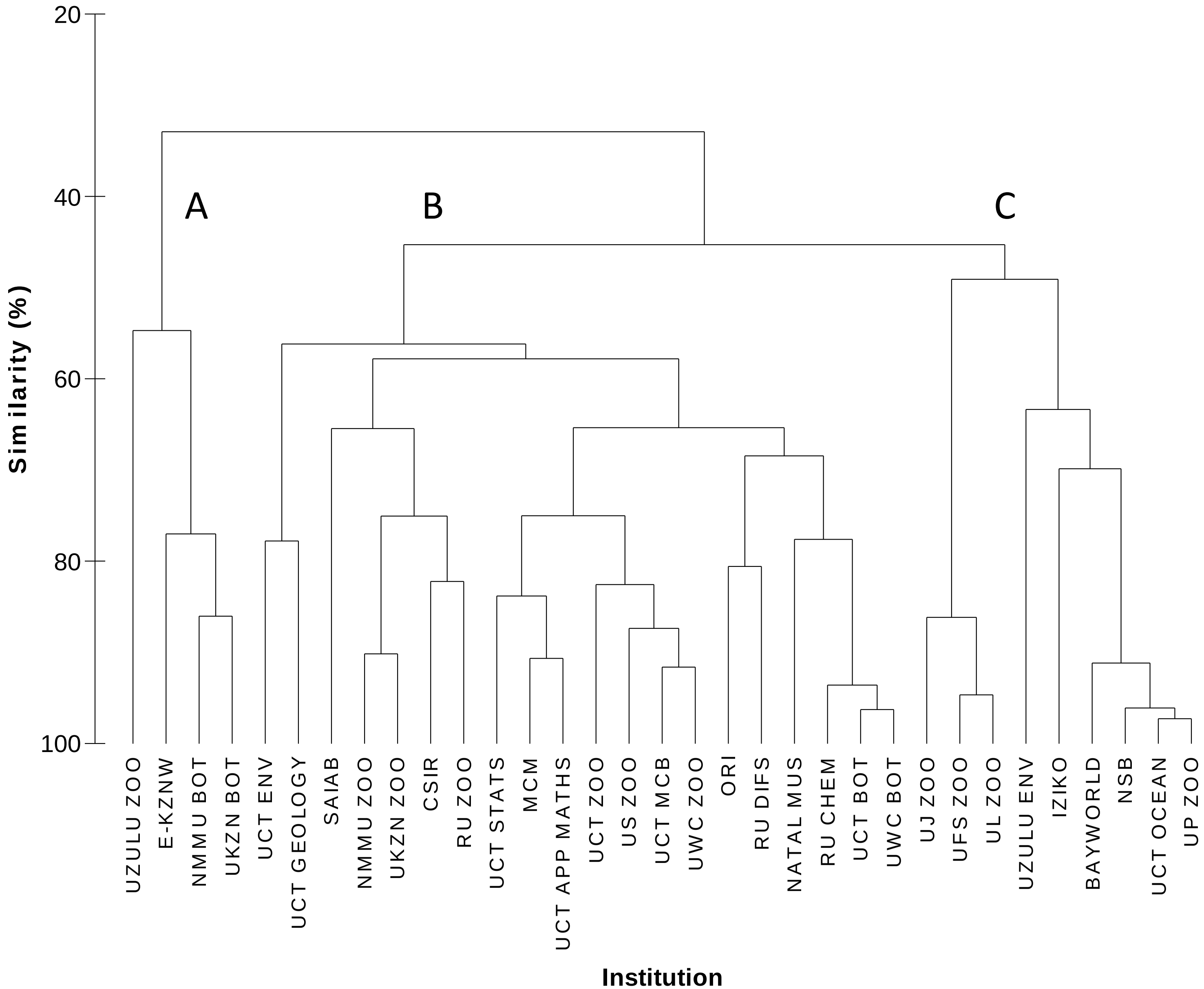
Figure 3: a) Age Structure of the publishing component of the SAMSC over the period 2001-2006 (grey), weighted by number of outputs (black). b) Cumulative data of same (stippled, solid respectively), indicating that more than 50% of outputs generated by community members older than 46 years of age.

Figure 4a



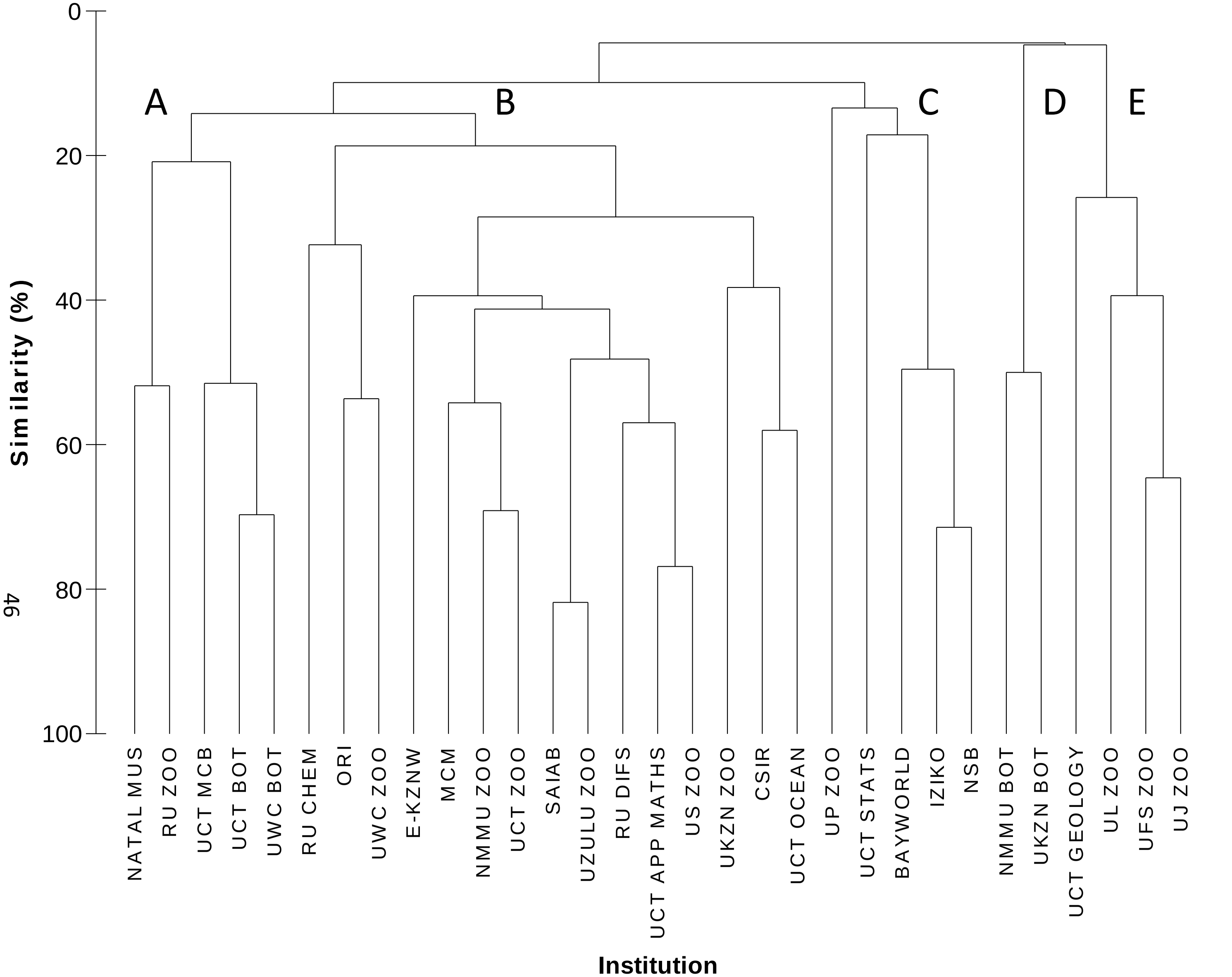
Cluster (Similarity - %)	**A** (62.11)	**B** (53.77)
Geographic Area, % Total	SA East Coast, 70	SA South Coast, 24; SA West Coast, 22; SA East Coast, 18; Global, 9; Southern Ocean, 8

Figure 4b



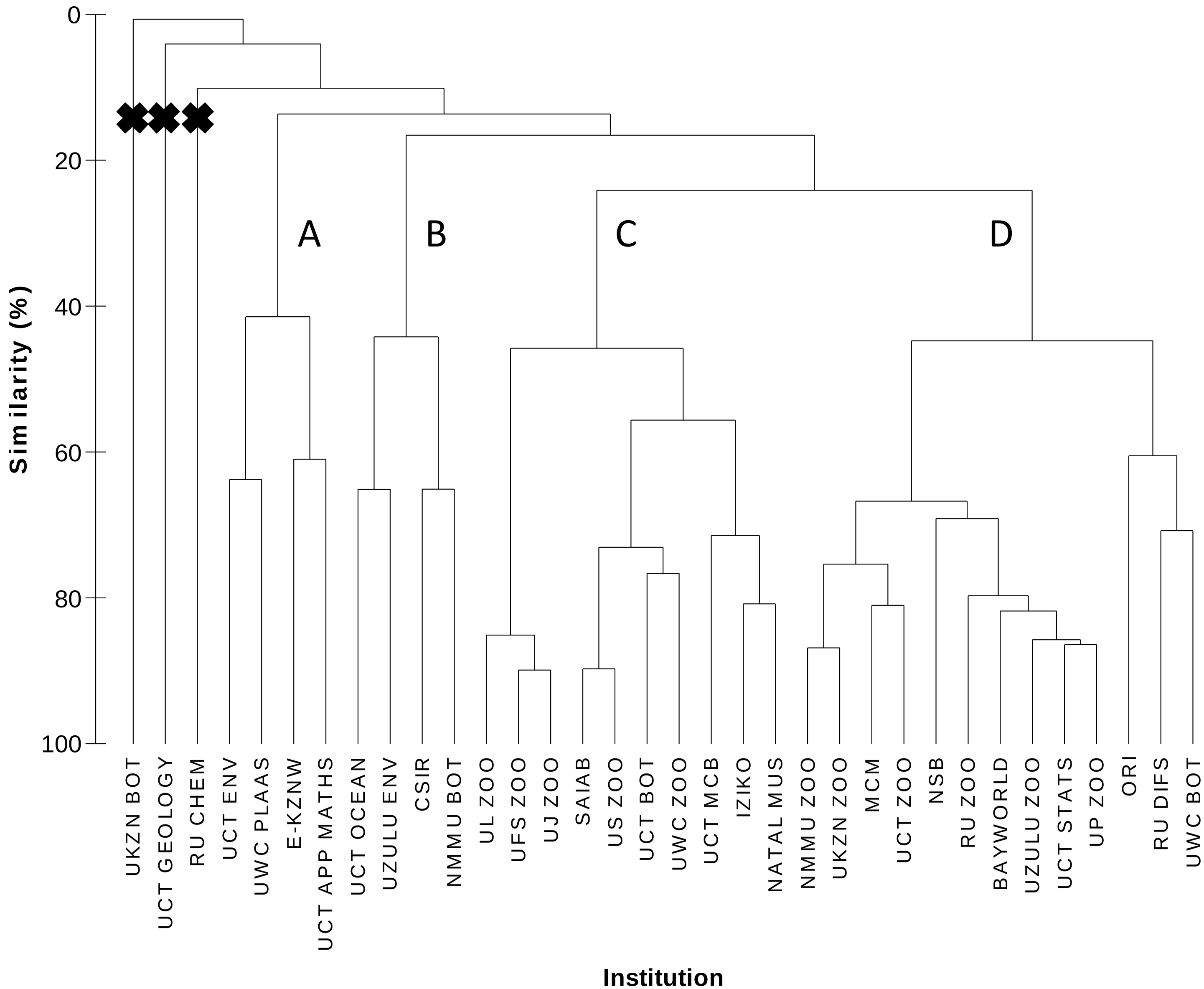
Cluster (Similarity - %)	**A** (67.35)	**B** (63.97)	**C** (64.16)
Habitat, % Total	Estuarine, 34; Soft Substrata, 22; Sub-tidal, 12; Inter-tidal, 13	Marine, 34; Sub-tidal, 14; Pelagos, 14; Hard Substrata, 13; Inter-tidal, 7	Marine, 57; Pelagos, 32

Figure 4c



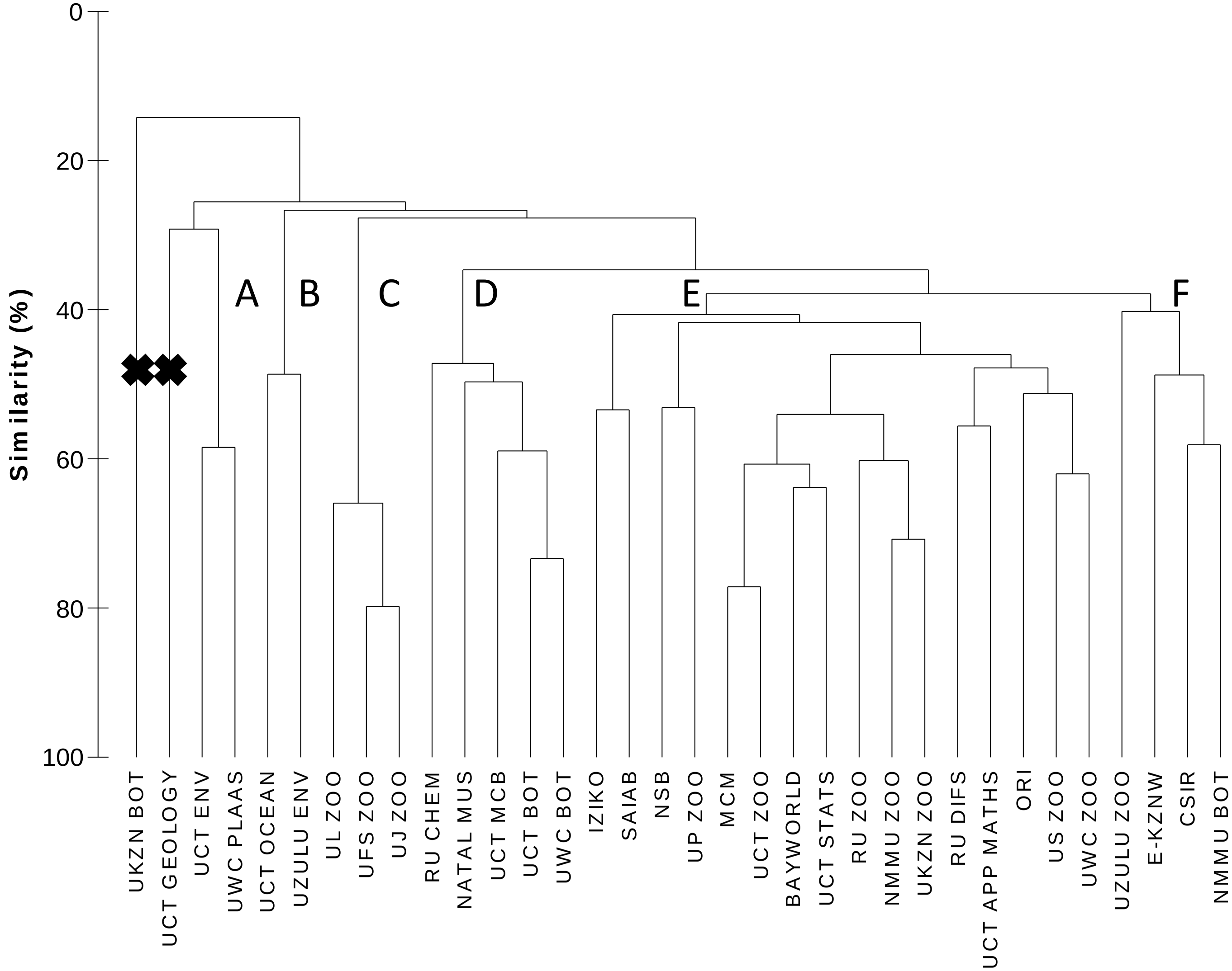
Cluster (Similarity - %)	**A** (23.26)	**B** (17.32)	**C** (35.10)	**D** (57.14)	**E** (25.2)
Organism, % Total	Gastropoda, 5; Macroalgae, 8; Microalgae, 2	Osteichthyes, 18; Decapoda, 4; Chondrichthyes, 3; Cnidaria, 3; Gastropoda, 3; Aves,6; Mammalia, 6 Other Invertebrates, 1	Chondrichthyes, 14; Mammalia, 4; Aves, 19	Angiosperms, 57	Other Invertebrates, 5; Other Protista, 4; Copepoda, 3

Figure 4d



Cluster (Similarity - %)	**A** (38.66)	**B** (29.86)	**C** (34.30)	**D** (41.62)
Discipline, % Total	Fisheries Management, 7; Socio-economics, 1; Ecology, 2	Phys Ocean, 28; Ecology, 6; Climate, 10; Chem Ocean, 5	Taxonomy, 17; Parasitology, 5; Ecology, 6	Ecology, 43; Taxonomy, 5; Pollution, 2; Quant Fisheries, 5; Biology, 3; Fisheries Management, 5

Figure 4e



Cluster (Similarity - %)	**A** (23.26)	**B** (48.63)	**C** (70.54)	**D** (55.49)	**E** (44.06)	**F** (51.86)
Overall, % Total	Fisheries Management, 43; SA W Coast, 35; SA S Coast, 30	Pelagos, 63; Phys Ocean, 49; Marine, 36	Marine, 79; Parasitology, 49; Taxonomy, 45; SA S Coast, 53	Marine, 36; Hard Substrata, 28; Macroalgae, 46; SA W Coast, 30; SA S Coast, 23; Subtidal, 21	Ecology, 46; Marine, 36; Pelagos, 23; SA E Coast, 26; SA S Coast, 17; Osteichthyes, 23	SA E Coast, 49; SA W Coast, 23; Ecology, 24; Estuarine, 25; Soft Substrata, 20; Phys Ocean, 25

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