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Minireview

Challenges for marine botanical research in East Africa: Results of a bibliometric survey

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A bibliometric review was made of published and grey literature on marine botanical research in the Western Indian Ocean (1950–2000) to evaluate the current status of marine botanical research in the East African region. All literature references indexed in Aquatic Sciences and Fisheries Abstracts, Life Sciences Collection, and other computerised databases, as well as annual reports, bibliographies, web-sites, review articles, cross-references, papers and reports published in grey literature — obtained from various institutions and libraries operating in this region — were systematically analysed to provide a diagnosis of strengths and weaknesses in the marine botanical research in the region to date. The results of the analysis are discussed in order to identify the main challenges to be faced as a solid basis for future research efforts in marine botany in the East African region.

Introduction

Marine botanical research activities in the Western Indian Ocean region have increased significantly over the past two decades, contributing to a growing awareness and enhanced understanding of the important values and functions of the main primary producers in the coastal ecosystems of this region (UNEP 1982). Whereas a major proportion of the research has been descriptive, focusing on the distribution and general biology of mangrove, seaweed and seagrass plants and microalgae, more recent research has diversified its attention to include various other more quantitative and applied research topics (Björk *et al.* 1996). Throughout the region, increasing efforts are underway for coastal zone management, mangrove rehabilitation and marine conservation (e.g. Tanzania Coastal Management Partnership 1999), which call for a solid scientific knowledge base. Yet, new research initiated without a thorough review of past and recent research outputs may lead to a deficiency in the relevance of the knowledge being produced (Hatcher *et al.* 1989). The present review of the current status of marine botanical research (1950–2000) in the Eastern African region was made to provide a diagnosis of its strengths and weaknesses, with the aim of identifying the main research challenges to be faced to assist in the development of a solid basis for the management, conservation and wise use of the marine botanical resources in this region.

Material and Methods

A review is provided of the current status of marine botanical research through a bibliometric survey of the literature produced over the period 1950–2000. The bibliometric study involved a search for all publications produced on marine botanical research in East Africa between 1950 and 2000. Marine botanical research was interpreted broadly as any research on mangroves, seaweeds, seagrasses, salt marshes, phytoplankton, or benthic microalgae (Dawes 1998), including research on associated fauna and studies on their conservation, management and utilisation. The East African region (or Western Indian Ocean) was considered to include Somalia, Kenya, Tanzania, Mozambique, Madagascar, Seychelles, Comoros, Mauritius and Reunion.

The literature search was conducted from computerised databases on CD-ROM (such as 'Aquatic Sciences and Fisheries Abstracts' and 'Life Sciences Collection'), library catalogues and collections at University of Dar es Salaam and RECOSCIX-WIO (based at KMFRI, Mombasa), bibliographies and review papers (e.g. Rollet 1981, Erftemeijer 1994, Semesi 2000), web-sites (e.g. of VUB and SAREC), lists of publications in annual reports of research institutes and universities (incl. Ruwa 1995), proceedings from local and international symposia and workshops, and personal literature collections of the authors. Additional literature references were obtained through cross-reference checks and by

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posting out requests on the seagrass and mangrove research internet discussion lists. All literature was considered, including publications in peer-reviewed international scientific journals, national and local journals, university theses, workshop and symposium proceedings, technical reports, and other grey literature. Substantial effort was made to ensure a search for literature references that was as complete as possible, yet it is inevitable that several reports and papers, especially those with a limited distribution, have escaped our attention.

For all references collected, the year of publication, country of study, plant type studied, origin of authors, type of publication, the approach used in the study, and its research topic was recorded. The methodology used in this bibliometric survey largely followed that used by Duarte (1999). Data were processed in simple Excel spreadsheets. Records for the year 2000 are likely to be underestimated in this study (and hence omitted from some of the graphs and interpretations), because not all papers had been published or indexed at the time the search was conducted (October 2000). The complete bibliography of all references used in this study (Erftemeijer and Semesi 2000) can be accessed at the following web site:
http://science.udsm.ac.tz/home/botany/index.html.

Results

General results

A total of 478 papers were retrieved in the search. The bibliometric analysis clearly showed an exponential increase in the scientific production, with a doubling of the annual publication rate every two years since the mid-1980s (Figure 1). A strong geographical imbalance was observed, with Tanzania and Kenya accounting for 76% of all marine botanical research efforts in this region (Figure 2). A significant proportion (30%) of all papers were published in international, peer-reviewed scientific journals (Figure 3), but most research was published in other more restrictive outlets, such as technical reports (21%), workshop and conference proceedings (20%), national and local journals (13%), university theses (11%) and book chapters (4%). Whereas the overwhelming majority (93%) of all publications were in English, 4% used French and 3% other languages (Portuguese, Dutch, Italian and German) to disseminate research findings.

Although the international scientific publications are distributed over 54 international journals, they are highly concentrated in a few of them (50% in 6 journals). Hydrobiologia (16%) and AMBIO (10%) clearly stand out as the leading journals, together printing nearly one-quarter of all papers. Journal of Experimental Marine Biology & Ecology (7%), Aquatic Botany (7%), Botanica Marina (5%) and Marine Ecology Progress Series (5%) are also important outlets of research on marine botany in East Africa. Seven scientific meetings (out of a total of 32) account for 67% of all papers published in conference proceedings. The Journal of the East African Natural History Society (7 papers) and the University Science Journal (Dar University) (7 papers; continued as Tanzania Journal of Science) hold 23% of all publications in a total of 39 local journals.

Most (51%) of all papers had an East African senior author, but non-African scientists published 37% of all the papers as senior authors without any African co-authors, and 12% of all papers in collaboration with one or more African scientists as co-authors (Figure 4). The number of publications by African scientists increased steadily, most notably over the past 20 years. African scientists started

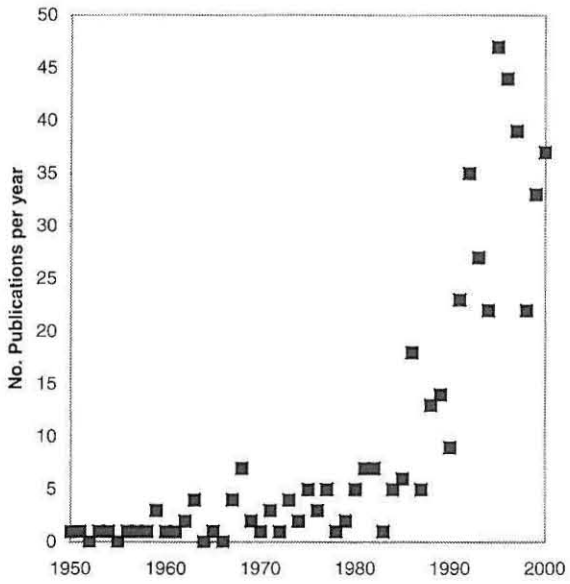

Figure 1: Annual scientific productivity (in number of new publications per year) of marine botanical research in East Africa in the period 1950–2000

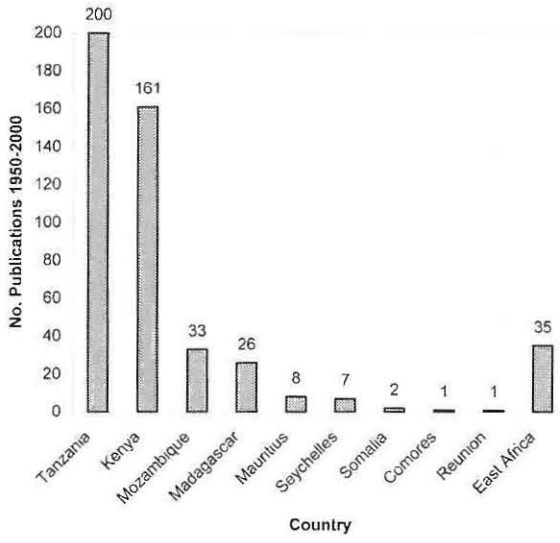

Figure 2: The number of papers published in the period 1950–2000 on marine botanical research carried out in the 9 different East African countries. (The category 'East Africa' caters for papers dealing with the region in general)

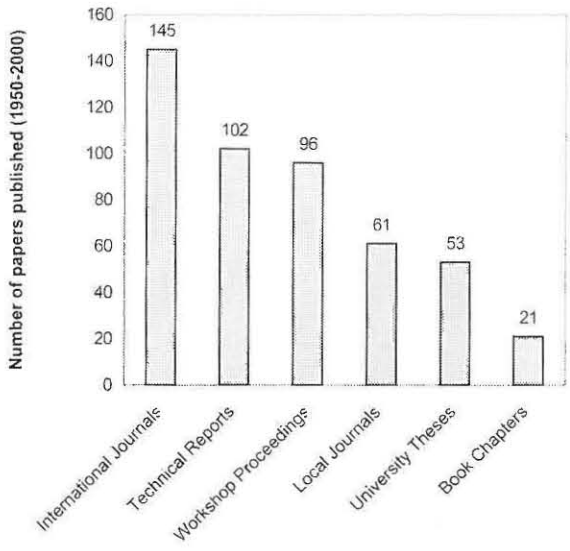

Figure 3: The number of papers on marine botany in East Africa published in the period 1950–2000 in different types of publications

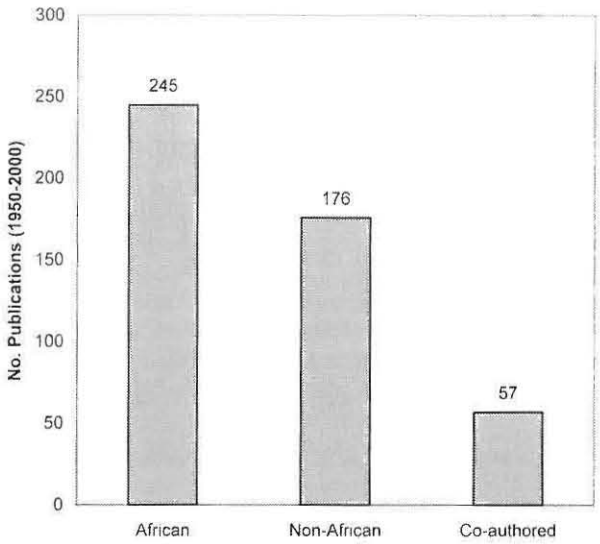

Figure 4: The number of papers on marine botany in East Africa published in the period 1950–2000 by senior authors of different origin. (Africa: senior author is of East African origin; Non-African: senior author as well as all co-authors are of non-African origin; Co-authored: senior author is of non-African origin but co-authors include at least one of East African origin)

publishing in international journals in 1986, and are increasingly using international journals to publish their research findings relatively in proportion (up to 25% at present) to their total research output (Figure 5).

By far the majority (56%) of marine botanical studies in this region focussed on mangroves. Research on seaweeds accounted for 20% of all publications, while only 9% of the papers dealt with seagrasses and 5% with phytoplankton and microbenthic algae (Figure 6). An additional 9% of the publications dealt with marine botanical studies in general, without specifying either one of the above plant categories, or dealing with several of them together in one paper. Only 2 papers dealt with salt marshes.

The vast majority (77%) of the studies were descriptive in nature. Experimental approaches (15%) and research aimed at synthesising available knowledge (modelling/predictive and comparative analyses, 5%) remained a minor fraction of the reports and studies (Figure 7). In the past 15 years, however, the high effort devoted to descriptive studies is gradually declining, with the percentage of descriptive studies dropping from around 90% in the mid 1980s to approximately 65% in the late 1990s (Figure 8). The main effort was allocated to studies on associated fauna (17%), utilisation (16%), distribution (15%) and management (10%) of mangroves, seaweeds and — to a lesser extent — seagrasses. Seasonal dynamics, natural regeneration, growth/production, flowering/phenology, and hydrological aspects of mangroves, seagrasses and macroalgal vegetations have received only marginal attention over the past 5 decades (Figure 9).

Mangrove research

A total of 265 papers were retrieved which dealt with research on mangroves in East Africa. In general, results were very similar to those of the overall bibliometric analysis, showing an exponential increase in the number of publications on mangroves since the 1980s, with research carried out primarily in Tanzania (43%) and Kenya (43%), published by African (47%) and non-African (40%) scientists, or jointly with African co-authors (13%). Most mangrove research in this region has been published in international scientific journals (31%) or as technical reports (24%), while local workshop proceedings and university theses accounted for 18% and 13% of all references respectively (Table 1). More extremely than with other plant types, the vast majority of mangrove studies (80%) in this region have been descriptive in approach. Only a fraction of the research effort was devoted to experimental (11%), methodological (4%), comparative/synthesising (3%), or modelling/predictive (2%) studies.

The main effort (27%) was allocated to study mangrove-associated fauna. Out of a total of 72 papers on associated fauna, 46% represented studies on crabs, 28% on other benthic fauna, and 15% on fishes and/or shrimps. A substantial proportion of publications were devoted to the distribution (14%) and management (14%) of mangroves, including a significant number of management plans and several papers and reports dealing with mangrove restoration, rehabilitation and conservation (Table 1). Studies on utilisation (mariculture, wood products and fisheries) accounted for 11% of all publications on mangroves, as did research on nutrient cycling (11%, notably on litter degradation, nutrient exchange with adjacent ecosystems, and microbial activities in the sediment). Studies on the impacts from mariculture development, rice farming and other land uses, deforestation, sewage pollution, and sea-level rise contributed only 5% to the total research output. Another 5% of the papers

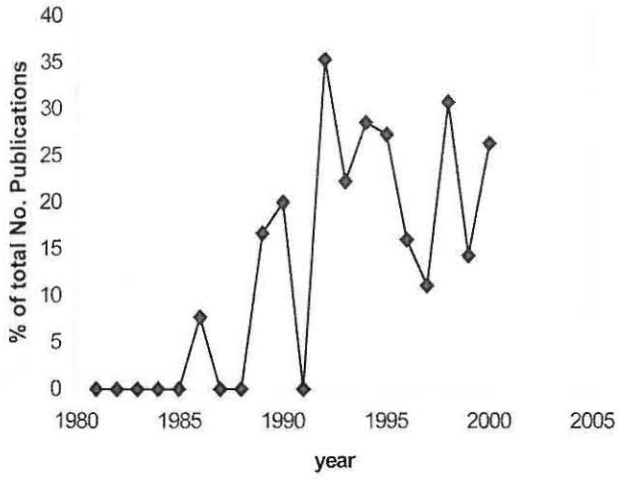

Figure 5: Publications on marine botanical research in international scientific journals by East African scientists as percentage of their total number of new publications produced in the period 1980–2000

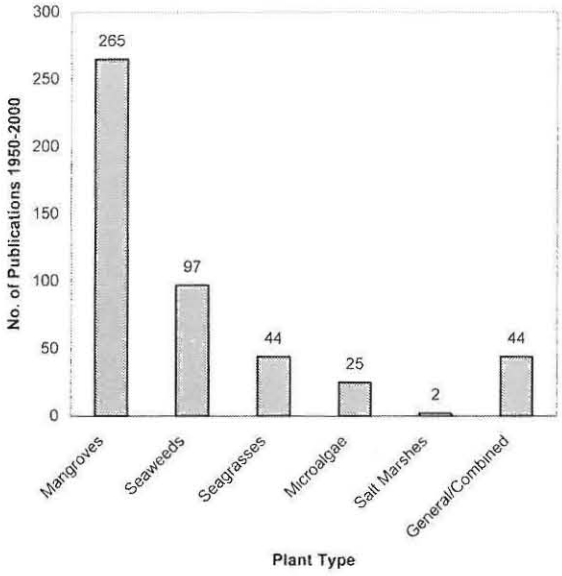

Figure 6: The total number of publications in East Africa produced in the period 1950–2000 on different types of marine plants. (The category 'general/combined' caters for those papers dealing with marine botany in general, or with more than one plant type simultaneously)

deal with mangrove dynamics (notably large-scale vegetation dynamics, natural regeneration, secondary succession, and monitoring of artificial rehabilitation efforts) and another 4% on taxonomy and floristic descriptions. The growth and production (2%), physiology (1%) and hydrology (1%) of East African mangroves received only marginal attention in the literature published over the past 50 years (Table 1).

Seaweed research

A total of 97 literature references were retrieved that dealt with research on seaweeds (macroalgae) in East Africa. Consistent with the general results of all marine botanical literature, there has been an exponential increase in the number of publications on seaweeds, but this increase already started in the early 1970s, a decade earlier than mangrove research. By far, most scientific work on seaweeds has been carried out in Tanzania (48%), while Kenya (16%) and Madagascar (15%) also contributed significantly to the research effort (Table 1). Seaweed research only received marginal attention in the other six countries of the region, together being responsible for only 10 publications (10%) on macroalgae to date.

More than with other marine botanical research, the majority of seaweed research (63%) was carried out and published by African scientists, while only 24% was published by non-African scientists and 13% jointly with African co-authors. Most seaweed research in this region has been published in international scientific journals (28%), local workshop proceedings (27%) and local journals (21%), while only 9% was published in the form of technical reports or university theses, and 6% as book chapters. Whilst the majority of seaweed studies (70%) in this region have been descriptive in approach, a good 27% of the research effort was devoted to experimental work. A mere 3% of the papers dealt with methodological aspects of seaweed research, while (to our knowledge) no single study aimed at synthesising available knowledge (modelling and comparative analyses).

An overwhelming majority (43%) of papers dealt with various aspects of seaweed utilisation, notably on extractable chemical compounds (such as carrageenans, phycocolloids, polysaccharides and alginates), anti-microbial characteristics of seaweeds, their farming and economic potential. Most experimental work on seaweeds focussed on their physiology (16%), in particular on their tolerance and responses to light-stress, oxidative stress, variations in pH, and competition. Substantial attention (19%) was also devoted to the distribution of seaweeds in this region, often with reference to their economic potential for exploitation and cultivation. Taxonomic studies and floristic descriptions accounted for 8% of all seaweed publications. Only marginal research effort was allocated to nutrient uptake, growth and production of macro-algae, and none to their modes of (a)sexual reproduction, management or conservation (Table 1). Since seaweeds do not generally form typical ecosystems of their own (like seagrass meadows or mangrove forests), few of the publications could be classified under the more ecosystem-oriented categories of research such as nutrient cycling, dynamics, hydrology, impacts or associated fauna.

Seagrass research

The bibliometric survey yielded 44 papers that dealt with seagrass research, half of which have been published by non-African scientists. The majority of these studies (73%) were published during the last decade (Table 1), predominantly in international journals (50%). Most (41%) seagrass studies were carried out in Kenya, while the remainder of the research on seagrasses was done primarily in Mozambique (25%) and Tanzania (16%). Only two papers were published

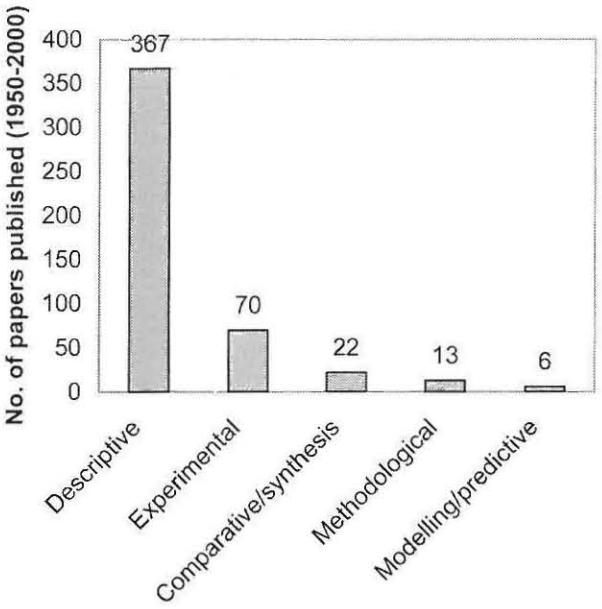

Figure 7: The number of publications on marine botany published in the period 1950–2000 using different approaches

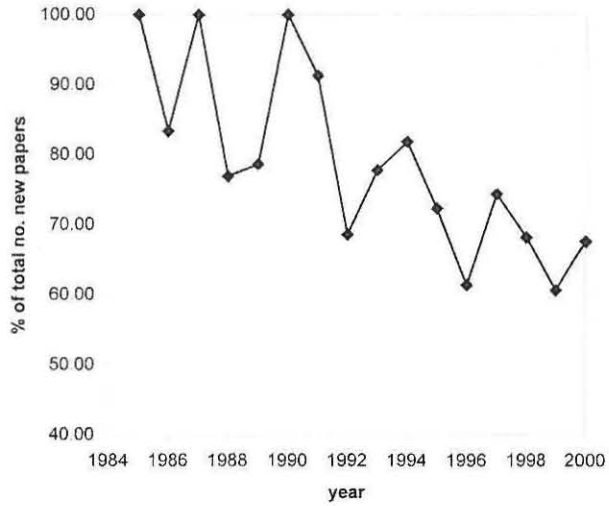

Figure 8: The number of descriptive papers published on marine botanical research in East Africa as a percentage of the total number of publications produced in the period 1950–2000

on seagrass studies in Madagascar. Virtually nothing is known about seagrasses in Mauritius, Seychelles, Somalia, Comoros and Reunion. Consistent with the results for mangroves and seaweeds, most seagrass studies have been descriptive (68%) in approach (Table 1). An additional 23% of the research effort was allocated to experimental studies, while only marginal attention was devoted to methodological aspects of seagrass research or to the synthesis of available knowledge (predictive modelling and comparative analyses). The 44 seagrass papers addressed a range of research topics, notably the distribution (23%), nutrient cycling (16%), physiology (11%), and associated fauna (11%) of seagrasses and their meadows. It is noted here, that — with only 44 papers published to date — research on seagrasses in East Africa is still in its infancy in comparison to seaweeds and mangroves. Hence, information on nearly any aspect of seagrass biology (including distribution and taxonomy) in this region is scarce and insufficient.

Microalgae/phytoplankton research

The present bibliometric search and analysis yielded only 25 papers (less than 5% of the total) that deal with microalgae (benthic or planktonic), of which 24% was in international journals (data not shown). Two-thirds of all papers on microalgae were published during the past five years, making this perhaps the youngest sub-discipline in marine botanical science in the region. The research on micro-algae is mainly (76%) carried out by young African scientists, primarily in Tanzania (44%) and Madagascar (24%). The main research effort has been devoted to the study of primary productivity and photosynthesis of phytoplankton (28%), and their community structure and seasonal dynamics (20%). Other aspects that have received some attention include phytoplankton culture (three papers), nitrogen transformations by cyanobacteria (two papers), biodiversity of littoral diatoms (two papers), and ciguatera poisoning by dinoflagellates (two papers in medical research journals). There are several more general papers and expedition reports dealing with phytoplankton productivity of the Indian Ocean, but these were not retrieved in the bibliometric search due to their wide geographic scope.

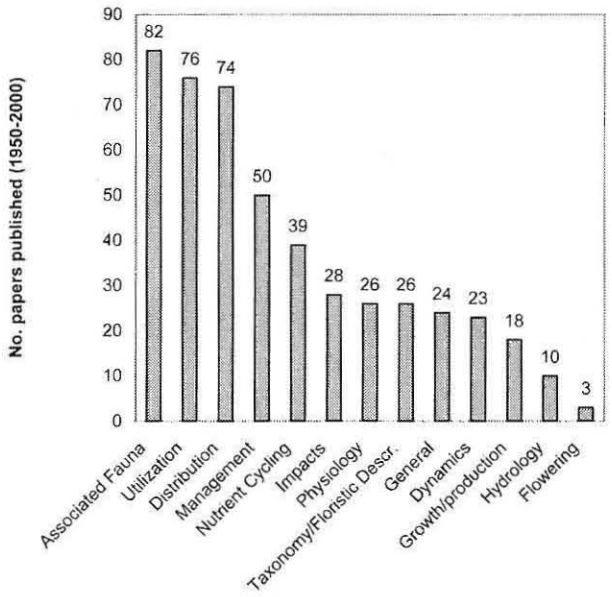

Figure 9: The number of papers on different topics of marine botanical research carried out in East Africa in the period 1950–2000

Table 1: Results of bibliometric survey for the three main plant types: Mangrove (n = 265), Seaweed (n = 97) and Seagrass (n = 44). Data represent number of publications for each category and percentage of total (between parenthesis)

Data type	Category	Mangrove	Seaweed	Seagrass
Years	1950–1960	10 (4)	1 (1)	0 (0)
	1961–1970	9 (3)	4 (4)	4 (9)
	1971–1980	16 (6)	11 (11)	2 (4)
	1981–1990	41 (15)	19 (19)	6 (14)
	1991–2000	189 (71)	62 (64)	32 (73)
Country	Tanzania	114 (43)	47 (48)	7 (16)
	Kenya	114 (43)	16 (16)	18 (41)
	Mozambique	13 (5)	5 (5)	11 (25)
	Madagascar	1 (0.4)	15 (5)	2 (4)
	Mauritius	0 (0)	4 (4)	0 (0)
	Seychelles	4 (1)	1 (1)	1 (2)
	Somalia	2 (1)	0 (0)	0 (0)
	Comores	1 (0.4)	0 (0)	0 (0)
	Reunion	0 (0)	0 (0)	0 (0)
	East Africa (WIO-region)	13 (5)	9 (9)	5 (11)
Authors	African	125 (47)	61 (63)	22 (50)
	non-African	106 (40)	23 (24)	18 (41)
	co-authored	33 (13)	13 (13)	4 (9)
Publication	international journal	83 (31)	27 (28)	22 (50)
	technical report	63 (24)	9 (9)	6 (14)
	workshop proceedings	49 (18)	26 (27)	5 (11)
	local journal	26 (10)	20 (21)	5 (11)
	university theses	36 (13)	9 (9)	3 (7)
	book chapters	8 (3)	6 (6)	3 (7)
Approach	descriptive	211 (80)	68 (70)	30 (68)
	experimental	29 (11)	26 (27)	10 (23)
	comparative/synthesis	10 (4)	3 (3)	2 (4)
	methodological	9 (3)	0 (0)	2 (4)
	modelling/predictive	6 (2)	0 (0)	0 (0)
Topic	associated fauna	72 (27)	2 (2)	5 (11)
	utilisation	28 (11)	42 (43)	0 (0)
	distribution	36 (14)	19 (19)	10 (23)
	management	37 (14)	0 (0)	1 (2)
	nutrient cycling	28 (11)	1 (1)	7 (16)
	impacts	14 (5)	6 (6)	1 (2)
	physiology	3 (1)	16 (16)	5 (11)
	taxonomy/floristic description	11 (4)	8 (8)	4 (9)
	general	12 (4)	1 (1)	1 (1)
	dynamics	14 (5)	1 (1)	2 (4)
	growth/production	6 (2)	1 (1)	4 (9)
	hydrology	3 (1)	0 (0)	1 (2)
	flowering	0 (0)	0 (0)	3 (7)

Discussion

Diagnosis of 50 years of marine botanical research in East Africa

The bibliometric study provides a clear picture of the current status and trends of marine botanical research in the East African region, revealing its strengths and weaknesses and allowing for the identification of the main challenges to be faced. The marine botanical research programme in East Africa can be characterised as a rapidly growing science, but one that is still predominantly descriptive in nature. The marine botanical research effort is growing exponentially in this region, particularly since the mid 1980s. It appears correct to suggest here that several programmes of international cooperation, notably the Sida/SAREC Programme in Marine Sciences (1990–2000) and the Kenya-Belgium Cooperation in Marine Sciences (KBP, 1985–1995), have contributed tremendously in encouraging this increase. Also, the funding support from the EC for various individual research projects and activities in East Africa under the Land-Ocean Interactions in the Coastal Zone Programme (IGBP-LOICZ) have made important contributions (LOICZ 1995). Furthermore, the Sida/SAREC and KBP (FAME) programmes both included a major emphasis on post-graduate training, leading to the successful completion of approximately 30 MSc and 17 PhD degrees (some still on-going) in marine sciences by East African scientists, including sever-

al on marine botanical subjects (Seys 1995, Anonymous 2000). The establishment of a regional association of marine scientists (WIOMSA) in 1991 and the organisation of several regional workshops and symposia during the 80s and 90s contributed further to the enhanced output of publications.

The accessibility of publications on marine botanical research in this region is poor, with 70% of the results published in grey literature with limited distribution. Furthermore, the libraries of universities and research institutes in this region are often poorly developed, making it hard to retrieve most of the relevant literature. For example, out of the 478 references retrieved in the current bibliometric search, less than 25% was available in Tanzania. The establishment of the project on Regional Cooperation in Scientific Information Exchange in the Western Indian Ocean (RECOSCIX-WIO) at the Kenya Marine and Fisheries Research Institute in Mombasa (Kenya) in 1987 has certainly improved the accessibility of literature and information, but the challenge remains for East African scientists to publish more of their work in international scientific journals, which would improve the quality, accessibility and wider scientific application of the published results on their work.

The results of the bibliometric study demonstrate a considerable geographic imbalance with two countries (Tanzania and Kenya) producing three-quarters of all publications, leaving the other seven countries far behind in all types of marine botanical research. Several factors, such as language, limited national investment in science education, and infrastructural constraints may have contributed to this widening gap. The fact that up to half the publications (and hence the research effort) are by non-African scientists, might indicate — at least partly — a kind of scientific imperialism, with international scientists exploiting the developing countries in this region as good sites for their own research, rather than lending their support to the capacity building of local scientists. A similar trend can be observed in all scientific publications on Africa across disciplines (Farid Dahdouh-Guebas, personal communication, November 2000).

Being focussed on a specific geographic region, the search for this bibliometric study did not capture any publications by East African scientists that were not specifically relating to the geographical region of East Africa, including papers on research methods. The overall impression of the authors, however, is that — based on our personal knowledge and experience in this field — very little work has been done by East African scientists on more fundamental research questions or methodologies in marine botany. As in most developing countries, (marine) scientific activities are often largely directed to the research of immediate, resource-related problems. As a consequence, the contribution of research efforts in East Africa to general ecological and biological theory is poor.

The research on seagrass and microalgae in the region has only recently picked up and is lagging behind enormously compared to that on mangroves and seaweeds. There is an overall need for less descriptive (currently at 77%) and more experimental studies (15%), and especially more research attention should be devoted to comparative studies, synthesis of existing information, modelling and prediction. Also, the redundant repetition of successful exemplary research models over and over again at new sites or with different species should be avoided.

In Mozambique and Madagascar, which together hold 61% of the region's mangroves (Spalding *et al.* 1997) but account for only 5% of the total mangrove research output, there is much need for basic studies to map and describe the status and distribution of the mangrove resources. In Tanzania and Kenya, where mangrove research has developed substantially, the time is ripe for a shift in attention from descriptive towards more experimental, comparative and predictive approaches. Mangrove research should increasingly focus more on impacts, dynamics, regeneration/recovery, hydrology and natural products. Research on more fundamental issues such as growth and production, flowering and phenology, and physiology of mangroves remain largely unaddressed to date.

Seaweed resources have hardly been studied in six out of the nine countries of the WIO region. Research on seaweeds should increasingly focus on comparative and predictive approaches, and studies on the nutrient uptake, growth and production, and reproduction of seaweeds should be initiated. There is a serious lack of trained taxonomists in the field of seaweed identification, and there remains a lot of work to be done on the screening of many seaweed species for their potential to utilise extractable natural products. There is an urgent need to synthesise available information on seaweed research in this region to yield general trends and reveal cost-effect relationships. From the results of such syntheses, general laws might be derived that could hold predictive power in support of coastal resource management.

Seagrass research in the East African region is still in its infancy, and even baseline information on areas of cover and distribution is largely lacking in most countries (Bandeira 2000). Almost nothing is known about seagrasses in Somalia, Mauritius, Seychelles, Comoros, Reunion and Madagascar. The recent increase in the number of seagrass publications from the region is encouraging, but there is an urgent need for more East African seagrass researchers in all countries. There remains a lot of work to be done on the seagrasses of East Africa, and once baseline surveys have been completed, increasing effort should be devoted to the monitoring and experimental and predictive studies of impacts and recovery.

Research on phytoplankton and benthic microalgae has received the least attention in this region, apart from the oceanographic work in relation to the Indian Ocean Expeditions, most of which was not captured by the search in this bibliometric survey. Being the most recent of the four categories of marine botany to develop in this region, primarily in Tanzania and Madagascar (plus Kenya and Somalia, which were covered by the Indian Ocean Expedition), there is great potential for detailed studies to emerge in relation to blooming events, river discharge impacts, and global climate change. There has been very little research on benthic microalgae and littoral diatoms.

Challenges in marine botanical research for the new century

Marine botanical research in this region holds great potential in contributing much wanted information to on-going efforts of integrated coastal management (GESAMP 1996), as it has in some other regions (e.g. Sloan 1993). Scientific research techniques and procedures that are particularly useful to ICM include resource surveys, hazard and risk assessments, modelling, economic valuations and analyses of legal and institutional arrangements (GESAMP 1996). While recent initiatives such as SEACAM and WIOMSA are encouraging, there is a need for stronger regional collaboration, networking and coordination. This will enable sharing and comparison of experiences, data and information that are currently scattered and poorly accessible. Moreover, inter- and multidisciplinary research efforts should be stepped up and the formation of thematic working groups encouraged.

Based on the developmental needs and constraints of the region, the emphasis of future studies should lie on applied research with a focus on coastal resource-related issues in support of sustainable coastal resource utilisation and management. Among such issues, we suggest that the following five broad research themes be given priority:

[1] **pollution** — sources, levels and effects of pollutants, physiological tolerance and stress response to domestic sewage, industrial effluents, agricultural run-off and oil-spills, role of marine plant systems in purification of water;
[2] **river discharges** — nutrient input, flooding, drought, damming and water diversion, salinity fluctuations, sedimentation, upstream land-use and watershed management;
[3] **habitat degradation and recovery** — natural regeneration, restoration strategies and techniques, recovery from mass mortality, sustainable exploitation.
[4] **climate change** and related aspects — sea level rise, coastal erosion, increased water temperature and UV-B radiation, greenhouse gases, amelioration of global warming through carbon fixation, carbon fluxes/sinks, sediment retention/trapping;
[5] **mariculture and natural products** — sustainable utilisation, marine plant cultivation, small-scale aquaculture, medicinal plants, etc.

Fundamental scientific aspects could be incorporated within these broader applied study themes.

It is recommended that for each of the above research themes, a five-fold approach be taken: [1] baseline surveys (inventory/mapping of the status and distribution of resources and scale of degradation); [2] monitoring (time series at selected sites); [3] experimental studies (cause-effect relationships, physiological tolerance and stress responses, perturbation studies, mesocosm experiments); [4] comparative studies (interlinkages between systems, interactions between species and systems, habitat-dependency of species, nursery functions); [5] modelling and prediction (forecasting, risk-assessment, mass-balances, budgeting, ecosystem approach, disturbed versus pristine areas). It is hoped that the agreed priority themes for the 2001–2003 Research Grants under the new Sida/SAREC-funded Marine Science for Management Programme of WIOMSA (MASMA) will allow for the accommodation of these recommendations, to contribute to a meaningful, pragmatic and maturing marine botanical research programme in the region.

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