# The role of multidisciplinary research programmes in the management of water resources*

**RD Walmsley**
*Foundation for Research Development, PO Box 2600, Pretoria 0001, South Africa*

## Abstract

The South African National Scientific Ecosystem Programmes, initiated in the early 1970s, were designed to provide a means by which multidisciplinary research could be co-ordinated in order to address specific complex environmental problems. Numerous aquatic ecosystem subprogrammes were co-ordinated by the Foundation for Research Development (FRD) under the auspices of the Inland Water Ecosystems Research Programme. This included studies of reservoirs (Hartbeespoort, PK le Roux, Wuras and Midmar), rivers (Pongola, Umgeni, Vaal) and wetlands. This paper presents an overview of several of these co-operative studies, discusses their overall impact on water resource management and also outlines some of the basic ingredients which are essential for any successful interinstitutional multidisciplinary co-operative research programme.

## Introduction

The future prosperity of nations and individuals will depend on both the quality of the environment and the availability and utilisation of natural resources (World Resources Institute, 1987). Future health and well-being will depend on man's ability to direct environmental change and adapt to it when it comes (IUCN, 1989). Management of the environment requires three basic ingredients (Fig. 1):

- human capacity
- information
- technology

These ingredients can best be obtained by developing an appropriate education, research and management approach. In the mid 1970s the South African scientific community responded to this challenge by launching a series of multidisciplinary co-operative programmes (National Scientific Programmes) to address specific environmental problems (Huntley, 1987). These programmes were co-ordinated by a section within the CSIR which progressively evolved from being a small unit (Co-operative Scientific Programmes) to a larger well-structured foundation, the Foundation for Research Development (FRD). The National Scientific Ecosystem Programmes had, amongst others, sections on Inland Water Ecosystems, Terrestrial Ecosystems and Nature Conservation with the overall goal of developing a predictive understanding of the structure and functioning of South African ecosystems (Auret, 1986).

Accordingly, numerous research programmes were initiated, both on specific ecosystems (e.g. Nylsvlei, Midmar Dam, Hartbeespoort Dam, etc.), ecosystems types (e.g. wetlands, rivers, Karoo biome, etc.), or specific topics (e.g. endangered species, invasive biota, fire management, etc.). All were aimed at providing South Africa with a better scientific system on which to base environmental management decisions. In 1988, as a result of organisational restructuring within the CSIR, the FRD announced that it would be phasing out the National Scientific Programmes and would phase in a new approach to its environmental programmes. This paper presents a statement on several of the aquatic ecosystem subprogrammes which were carried out under the auspices of the Inland Water Ecosystems Programme (IWE) and discusses their relevance and impact on water resource management.

## Activities and approach of the National Scientific Ecosystem Programmes

The general approach taken by the National Scientific Ecosystem Programmes was to involve as wide a spectrum of scientists, decision-makers and resource managers as possible in both the conceptual development and operating activities of subprogrammes (Huntley, 1987). To achieve these objectives the FRD co-ordinated a network of committees which focused attention both on specific issues and problem ecosystems.

The National Ecosystem Programmes played a key role in initiating, stimulating and co-ordinating interaction between scientists at universities, museums and other research institutes as well as involving environmental user agencies and resource

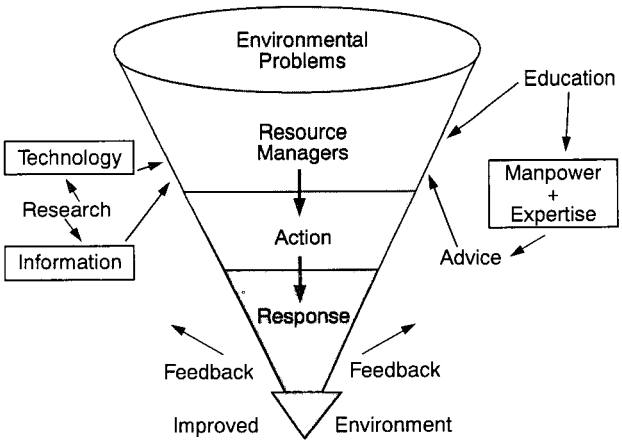


*Figure 1*
*Schematic representation to illustrate the roles of human resources, technology, education, research and information in solving environmental problems*

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TABLE 1
SUMMARY OF IWE SUBPROGRAMMES, NUMBER OF PROJECTS, POSTGRADUATE THESES AND PUBLICATIONS

| Subprogramme | Number of projects | | Postgraduate theses | | Number of publications | |
|---|---|---|---|---|---|---|
| | FRD funded | Other | Ph.D. | M.Sc. | Programme reports | Refereed articles |
| Midmar | 19 | 5 | 3 | 3 | 1 | 5 |
| Wuras | 13 | 5 | 1 | 6 | 1 | 23 |
| PK le Roux | 9 | 3 | 1 | 2 | 1 | 28 |
| Hartbeespoort | 8 | 3 | 4 | - | 2 | 63 |
| Pongola | 10 | - | 3 | 6 | 3 | 7 |
| Vaal | - | - | - | - | 2 | - |
| Mgeni Catchment | 5 | 2 | - | 1 | 2 | - |
| Wetlands | 8 | 10 | - | 3 | 3 | 8 |
| Rivers | 10 | 6 | 1 | 3 | 4 | 15 |

managers. The numerous subprogrammes succeeded in attracting a large number of environmental researchers and decision-makers in South Africa by promoting activities such as:

- workshops
- symposia
- courses
- field excursions
- international liaison
- evaluation of projects and programmes
- publications
- project funding and management

The system developed a so-called "invisible college" of environmental expertise in South Africa without any costly infrastructure; contributed to a forum in which environmental problems and research priorities could be debated; and also raised the general standard of ecological research (Huntley, 1987).

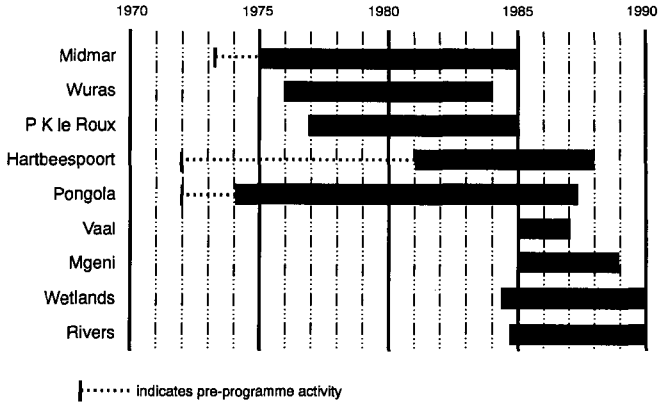


*Figure 2*
*IWE subprogrammes and their duration*

## Inland water ecosystem (IWE) programmes

The IWE Section of the National Programmes was established in 1974 and arose out of a need to co-ordinate co-operative multidisciplinary research on aquatic ecosystems which was already in place or needed to be developed. The main aims of the constituted IWE were:

- the development of the understanding necessary to predict the effects of natural events, planned development and management actions on inland water ecosystems;
- improving the scientific basis for utilising these systems; and
- the search for solutions to particular environmental and management problems related to inland water ecosystems.

The research needs of South African inland waters were defined (Noble and Hemens, 1978) and, under the guidance of a steering committee comprised of research leaders and water resource managers, numerous co-operative research subprogrammes were initiated and co-ordinated (Fig. 2, Table 1). Much of the emphasis between the years 1975 to 1985 was placed on the understanding of reservoir systems, particularly the potential detrimental impacts of eutrophication and suspensoids. These reservoir studies began phasing out in the early 1980s and were superceded by more catchment-orientated programmes involving the Vaal and Mgeni, in addition to general ecosystem programmes on wetlands and rivers.

It is not possible to provide a detailed analysis of the total funding which went into the overall IWE programme. This is because there were a large number of participating organisations for which there is no available record of financial inputs. The allocation of funding to specific subprogrammes through the FRD succeeded in attracting inputs into projects from numerous other agencies (Table 1). A relative picture of the funding situation can be obtained from a record of the funding allocated to IWE subprogrammes via the FRD (Figs. 3 and 4). Based on these figures it can be seen that the IWE programme reached a peak between 1980 and 1983 when reservoir ecosystems (Midmar, Wuras, PK le Roux and Hartbeespoort) were being investigated. Thereafter there was a small decline between 1984 and 1985 followed by an increase (1986 to 1987) as a result of the initiation of programmes on rivers and wetlands. The decision to phase out the subprogrammes was made in 1988 and no funding of IWE projects was made beyond 1990. Financial contributions to the IWE programme via the FRD were made by the Department of Environment Affairs (42%), the Water Research Commission (8%) and the CSIR (49%).

Attempts to provide quantifiable general assessments of the outputs from ecological research programmes have proved to be difficult (Huntley, 1987). This is because of the variety of products which emanate from such programmes and the different perspectives of the various users of these products. Thus a programme which focuses on an ecological methodology or technique might not be at all useful to a resource manager, but extremely valuable to researchers themselves. Conversely, a programme which monitors a particular situation (e.g. phosphate levels in a lake) might produce ideal results for a resource manager, but be of lesser value to researchers themselves. In this overview an attempt has therefore been made to address certain basic questions for each of the subprogrammes, viz:

- did the subprogramme achieve its objectives?
- did it develop expertise?
- did it provide adequate documentation for scientists and resource managers to utilise for reference?
- were the results helpful or potentially helpful in the management of South Africa's inland water resources?

**Midmar**

The Mgeni River has particular significance in view of its contribution as a water supply to the Pietermaritzburg-Durban complex. In the early 1970s concern was expressed about the potential impact of urban and rural development on water quality in this river and its impounded water supplies. The IWE subprogramme on Midmar Dam, the uppermost impoundment of the Mgeni system, was initiated with the following objectives:

- developing a conceptual model reflecting nutrient loading, mixing, sediment water interactions, light availability and main energy pathways;
- developing an efficient sampling strategy for the estimation of nutrient loading;
- validation of current eutrophication models with Midmar data; and
- provision of guidelines for the assessment of the impact of development and management options.

The subprogramme was able to meet all of the stated objectives with a published record of the research findings and management implications being contained in a synthesis report by Breen (1983), six postgraduate theses and five refereed articles (Table 1). The findings have proved valuable in assessing water quality conditions in the reservoir as well as the potential implication of raising the height of the dam wall to increase the impoundment's capacity.

**Wuras Dam**

The inland waters of South Africa are generally highly turbid (Noble and Hemens, 1978) and high priority was allocated by the IWE programme to establishing whether the presence of suspended material (suspensoids) could have modifying effects on the response of water bodies to changes in water quality. Accordingly, a multidisciplinary research programme on Wuras, a small turbid reservoir in the Orange Free State, was initiated with the main objectives of identifying and quantifying the interactions between suspensoid concentrations and various physical, chemical and biological characteristics of the reservoir. Some 18 projects, involving 17 researchers, were carried out with

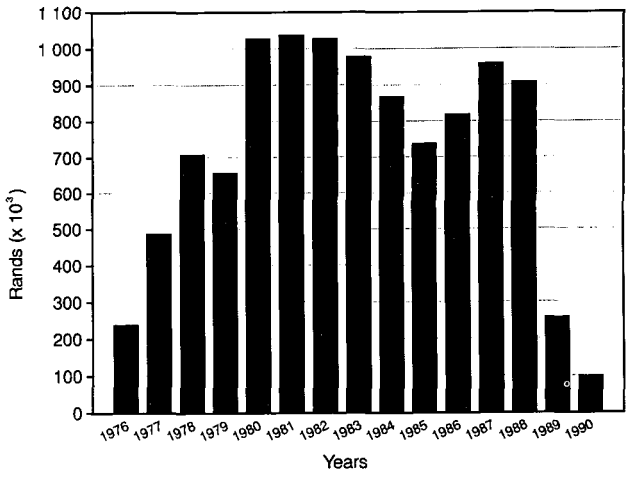


*Figure 3*
*Total annual funding administered by FRD to IWE between the years 1974 and 1990 (figures corrected to 1990 rand values)*

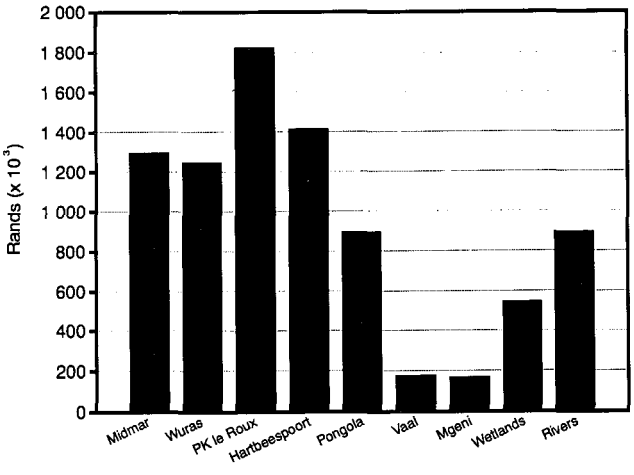


*Figure 4*
*Funding allocated by FRD to individual IWE subprogrammes (figures corrected to 1990 rand values)*

the main products being a synthesis report (Pieterse and Keulder, 1982), seven postgraduate theses and 23 refereed articles (Table 1). Although not solving any specific management problem on the impoundment itself, the programme contributed to a much-needed pool of information on the role of suspensoids, in addition to developing new laboratory and field techniques and the training of expertise.

**PK le Roux**

Many large reservoirs and lakes in Africa have proven to be extremely valuable resources in terms of their commercial fisheries (e.g. Lake Kariba, Lake Tanganyika). Following the

construction of the PK le Roux Dam in 1976 a research programme was initiated with the objectives of:

- determining the structure and biology of the fish community and its response to physical, chemical and biological events in the impoundment; and
- assessing the fishery potential of the impoundment from both angling and commercial viewpoints.

A comprehensive report was produced by Allanson and Jackson (1983) which documented not only the fishery and angling potential, but also the impoundment's general limnological characteristics. Numerous management recommendations were presented to the Cape Provincial Administration, the agency responsible for managing the fishery resources. The subprogramme also shed new insights on, and methodologies for, understanding the role of turbidity in influencing energy transfer through the food chain in large reservoirs.

**Hartbeespoort**

Hartbeespoort is a system which has for many years displayed symptoms of excessive eutrophication. The proclamation of the 1 $mg \cdot \ell^{-1}$ phosphorus standard within its catchment in 1980, and its intended implementation by 1985, prompted the necessity to investigate the impact of decreasing nutrient load on the reservoir as an ecosystem. Consequently a two-phased co-operative multidisciplinary research programme was carried out between 1980 and 1988. The main objective was to obtain a quantitative understanding of how biotic components of the ecosystem functioned, particularly with reference to phosphorus cycling.

The subprogramme was the largest reservoir ecosystem project ever to have been carried out in Southern Africa with numerous products and achievements (Zohary et al., 1988). A major finding was the fact that symptoms of eutrophication are due as much to physical conditions (wind, temperature and water currents) as those of chemical status (National Institute for Water Research, 1985). The programme was exceptional in terms of its contribution to scientific expertise, new techniques and a basic understanding of the manifestations of eutrophication. At the time of the subprogramme's phasing out in 1988 it was not possible to establish whether the reservoir had indeed responded to reduced nutrient loading possibly because of the incomplete implementation of the phosphorus standard in the reservoir's catchment area (Thornton and Walmsley, 1987).

**Pongolo floodplain**

This floodplain, one of the largest in South Africa, has been rated as one of the country's key wetland areas on the basis of its biological diversity, current subsistence utilisation by its resident population and its agricultural potential (Heeg and Breen, 1982). In the late 1960s a reservoir was constructed upstream of the floodplain and concern was immediately expressed about its ecological impact, not only on the floodplain itself, but also on the Pongola River. A multidisciplinary research programme was therefore initiated with the objectives of understanding how the river and its floodplain function in order to provide recommendations concerning the nature of upstream water releases from the Pongolopoort Dam.

The longest running of the IWE subprogrammes, this programme was able to follow a conventional ecosystem approach in which inventories and surveys were followed by studies of processes and life cycles of key biota. In its later stages ecological modelling of the floodplain system and its components was attempted. The programme was also one of the few which endeavoured to integrate scientific and sociological studies to define resource and floodplain water quantity requirements. The ecological and sociological information which was generated has proved invaluable to the Department of Water Affairs and Forestry in assessing the impact and pattern of water releases from the impoundment. The programme also provided a useful vehicle for the training of expertise on wetlands and river ecosystems (nine postgraduate students). Apart from numerous journal articles, general details and management recommendations have appeared in publications by Heeg and Breen (1982), Breen and Heeg (1986) and Walmsley and Roberts (1989).

**The Vaal River catchment**

The Vaal River, one of South Africa's most heavily utilised water resources, houses a multiplicity of users and experiences numerous water quality and quantity problems. It was recognised that two of the biggest stumbling blocks to optimal water usage from the river were firstly the absence of any ecological investigations and secondly the lack of an integrated catchment approach to understanding the Vaal. An attempt was made to initiate a research programme by convening a symposium and a workshop to solicit interest. The products of this effort were two publications which defined the water resource management problems (Foundation for Research Development, 1986) and a research approach for any future programme (Braune and Rogers, 1987). Unfortunately there was little response from either scientists or water resource management agencies to these documents with the ultimate result that further efforts to develop a research programme were abandoned.

**Mgeni catchment**

Acting on recommendations from the Midmar reservoir subprogramme, steps were taken to initiate a catchment research programme. Management problems were identified (Breen et al., 1985), a research approach developed (Walmsley and Furness, 1987) and several projects initiated. Unfortunately the subprogramme did not formally continue beyond 1989 and therefore it is not possible to provide any objective assessment on its impact.

**Wetlands**

The value of wetlands in the South African landscape has been emphasised by Begg (1986) who, following an intensive survey, also reported on their status. He stated that "... wetlands formerly occupied between 10% and 15% of every catchment in Natal. Within the last 50 years wetlands in these same areas have been reduced to a few scattered remnants, and in certain catchments virtually eliminated." The IWE programme committee, aware of the survey being conducted by Begg, initiated a wetland subprogramme in 1984 with the specific goals of:

- developing an understanding of the structure and function of wetlands sufficient to predict their response to major natural and man-derived influences; and
- identifying wetlands of special scientific or aesthetic value and developing guidelines for their management.

A subprogramme description was subsequently generated (Walmsley, 1988) which defined an approach and prioritised research areas according to user agency needs. Numerous activities were carried out and these included:

- the convening of a general conference on wetlands (Walmsley and Botten, 1987);
- the convening of a workshop to develop a national approach to inventorise and classify wetland areas (Walmsley and Boomker, 1988);
- the production of a wetlands awareness brochure which was circulated nationally to farmers; and
- numerous research projects which addressed specific wetland areas and ecological processes occurring in wetlands.

Within the time frame and the budget allocated it was not possible to attain the objectives of the subprogramme nor to develop the sufficient expertise required to manage wetland areas. The subprogramme did, however, serve a purpose in highlighting that wetland research and management remains a neglected area of South African water resource management.

### Rivers

There are 22 primary drainage regions in South Africa, each containing river systems of varying length and mean annual runoff. Most of these systems have been subjected to various forms of anthropogenic activity such as impoundment, abstraction of water, discharges of effluents and the introduction of alien biotic species. It was recognised by the ecological community in the early 1980s that problems in reservoirs were merely symptoms of wider landscape activities and that research on rivers should be escalated. A formal programme was therefore launched in 1985 with the objectives of:

- developing an understanding of the structure and functioning of river ecosystems sufficient to predict their response to major, natural and man-derived influences; and
- identifying rivers, or parts of rivers, of special scientific or aesthetic value and to develop guidelines for their management.

Initial activities included a review of river research (O'Keeffe, 1986a) and an assessment of general river conservation status (O'Keeffe, 1986b). By the time the IWE programme was being phased out in 1988 the rivers subprogramme and its activities had mobilised an interactive and enthusiastic community and developed a sound national research approach (Ferrar et al., 1988). Many of the activities initiated by the IWE are still on-going. Bearing in mind the current problems being experienced in assessing water quantity and quality allocations in numerous catchments this subprogramme has proved invaluable in developing expertise capable of addressing the overall issue of river management.

## General discussion

With the phasing out of the IWE programme, the South African freshwater ecological community has passed out of an era in which an attempt was made to formally structure, organise and co-ordinate research. Whereas there were many highlights and personal achievements, not all of the participants were happy with the situation. It is perhaps pertinent to outline some of the negative perceptions given by various categories of participants in the IWE programme. The main ones are as follows:

### User and resource management agencies

- IWE programmes did not contribute to solving specific problems of individual agencies;
- programmes were intrusive and critical of agencies' management policies and actions;
- programmes did not address priority problem areas;
- projects were too academic;
- too much emphasis was placed on theoretical issues; and
- programmes did not transfer information in the appropriate way.

### Research scientists

- Programmes were too goal-orientated and prescriptive;
- programmes did not allow for the answering of fundamental questions;
- programmes provided funds to inferior scientists;
- there was a lack of feedback on proposals; and
- programmes provided biased and disproportionate funds to select groups of scientists.

### Programme co-ordinators

- The difficulty in remaining an impartial facilitator;
- the difficulty in maintaining sustained commitment and leadership from scientists and resource agencies;
- difficulty in establishing who the customer was;
- the perception that FRD was an employer rather than a co-ordinator;
- a shortage of manpower (critical mass) to initiate and develop programmes;
- a difficulty in allocating sufficient funds to address real priority areas;
- too much focus placed on FRD-funded projects;
- little follow-up from user agencies; and
- the perception that FRD was the sole funding agency for ecological research.

These perceptions provide evidence of a system in which the overall expectations of the participants were not met. In the face of these one is left with answering the overall question of what precisely did the many subprogrammes contribute to water resource management? This question is possibly best answered by outlining the many services which IWE programme activities provided. Such services were available not only to active participants, but also to the wider aquatic resource community, both locally and abroad. These included:

- The provision of a continued focus on environmental issues - initiated during a period when there was a peak in water resource development schemes, particularly impoundment construction, and the IWE programme identified and focused attention on the many potential ecological problems which were likely to be encountered.
- Scientific understanding of South African aquatic ecosystems - sound management of aquatic ecosystems requires an understanding of their ecological functioning. Very few of the IWE subprogrammes failed to meet their scientific research objectives and have provided a wealth of documentation

(conceptual, factual and predictive) on reservoirs, wetlands, rivers, lakes and estuaries.

- Generation of research priorities - the IWE committee structure and the wider network of participants provided an on-going means of continually discussing and reviewing research priorities.
- Interaction between scientists and resource managers - the system of programme activities which included a newsletter, working groups, committees, workshops and symposia provided an on-going means by which researchers and resource managers could interact and hold debates on common issues.
- Co-ordination and co-operation - the IWE network provided a means by which research activities could be co-ordinated and co-operation enhanced.
- Evaluation of projects and programmes - central to the operation of IWE research activities was the principle that projects and programmes should be evaluated. Such evaluations were carried out by both scientists and resource managers in a constructive and participatory way.
- Generation and upliftment of human resources - the IWE programme contributed directly and indirectly to the training of numerous postgraduate students, many of whom now hold responsible positions in various research, educational and resource management agencies. In addition, the activities contributed to the on-going education of individuals who attended workshops, symposia or received documentation on project activities.
- International liaison - international participation both to and from South Africa was strongly promoted by the IWE programme. Operating under difficult political circumstances the programme was able to secure involvement in numerous international forums. Of particular note was the attendance by 30 South Africans of the SIL - UNEP Workshop on African Limnology in Nairobi in 1979 (Symoens et al. 1981) and the international Southern Hemisphere Limnology Symposium in Wilderness (Hart and Allanson, 1984; Davies and Walmsley, 1985). Over the years numerous international scientists visited South Africa and gave indications of a high standard of limnology in the country. The recent internationally-acclaimed book by Allanson et al. (1990) on inland waters of Southern Africa has made considerable use of scientific findings from the various IWE subprogrammes.
- Information transfer - programme activities such as workshops, symposia, newsletters, publications, etc. all provided both short- and long-term means of transferring information to scientists and resource managers.

There can be few individuals or agencies involved in South African water resource management who did not receive benefit from some, if not all of the above services. The negative perceptions of the IWE programme as outlined above are therefore possibly a reflection of a normal societal response based on vested interests - rather like the commuter who complains because the train has to stop at every station before reaching his own and therefore habitually states that he would prefer to travel privately. Such perceptions do, however, indicate a poor appreciation that water resource management requires a multidisciplinary co-operative approach and that the goals and objectives of such programmes can only be attained through a co-ordinated team/group approach.

In view of the future demands to be placed on the aquatic environment there can be no doubt that there is still a major need for co-operative multidisciplinary programmes. Their success and potential usefulness can perhaps be improved by applying certain business and management principles so as to ensure correct inputs and outputs. The following requirements are based on those previously outlined by Huntley (1987), namely that a successful co-operative multidisciplinary programme requires:

- an urgent environmental problem which needs co-operative multidisciplinary input;
- idea generators and scientific leadership;
- a critical mass of researchers;
- realistic and defined objectives with a time schedule;
- appropriate participatory input by stakeholders;
- security of funding for the duration of the programme;
- good management, co-ordination and communication;
- appropriate programme infrastructure e.g. facilities and administration; and
- a well-planned and executed information transfer programme.

Finally, the harnessing of the expertise derived from disciplines such as hydrology, chemistry, zoology, botany, physics, microbiology, geography, engineering and many others, is a fundamental requirement for any successful water resource management system. The future management of South Africa's water resources will require that a multidisciplinary approach be followed and therefore the re-establishment of an appropriate research and co-ordination system for South African aquatic ecological research is perhaps a prerequisite to ensuring such involvement.

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## References

ALLANSON, BR and JACKSON, PBN (1983) Fisheries potential of Lake Le Roux. SANSP Report No 77. 182pp.

ALLANSON, BR, HART, RC, O'KEEFFE, J H and ROBARTS, RD (1990) *Inland Waters of Southern Africa: An Ecological Perspective.* Kluwer Academic Publishers. 458pp.

AURET, EW (1986) Activities of the National Programmes for Ecosystem and Aquaculture Research, 1983. SANSP Report No 127. 65pp.

BEGG, G (1986) The wetlands of Natal. Part I. An overview of their extent, role and present status. Natal Town and Regional Planning Report No 68, Pietermaritzburg. 115pp.

BRAUNE, E and ROGERS, KH (1987) The Vaal River catchment: Problems and research needs. SANSP Report No 143. 36pp.

BREEN, CM (1983) The limnology of Lake Midmar. SANSP Report No 78. 134pp.

BREEN, CM, AKHURST, EGJ and WALMSLEY, RD (1985) Water quality management in the Umgeni catchment. Natal Town and Regional Planning Supplementary Report Vol 12. 27 pp.

BREEN, CM and HEEG, J (eds.) (1986) The Pongolo River floodplain: Research needs for rural development and resource management. FRD Occasional Report No 8. 23pp.

DAVIES, BR and WALMSLEY, RD (eds.) (1985) Perspectives in Southern Hemisphere limnology. *Developments in Hydrobiology* **28**. Dr W Junk Publishers. 263pp.

FERRAR, AA, O'KEEFFE, JH and DAVIES, BR (1988) The River Research Programme. FRD SANSP Report No 146. 28pp.

FOUNDATION FOR RESEARCH DEVELOPMENT (1986) The Vaal River ecosystem: Status and problems. FRD Occasional Report No 5. 234pp.

HART, RC and ALLANSON, BR (1984) Limnological criteria for management of water quality in the Southern Hemisphere. SANSP Report No 93. 181pp.

HEEG, J, and BREEN, CM (1982) Man and the Pongolo floodplain. SANSP Report No 56. 117pp.

HUNTLEY, BJ (1987) Ten years of co-operative ecological research in South Africa. *S. Afr. J. Sci.* **83** 72-79.

IUCN (1989) *From Strategy to Action.* IUCN, Gland, Switzerland. 96pp.

NATIONAL INSTITUTE FOR WATER RESEARCH (1985) The limnology of Hartbeespoort Dam. SANSP Report No 110. 269pp.

NOBLE, RG and HEMENS, J (1978) Inland water ecosystems in South Africa - A review of research needs. SANSP Report No 34. 149pp.

O'KEEFFE, JH (1986a) Ecological research on South African rivers - A preliminary synthesis. SANSP Report No 121. 121pp.

O'KEEFFE, JH (1986b). The conservation of South African rivers. SANSP Report No 131. 117pp.

PIETERSE, AJH and KEULDER, P (1982) The limnology of a shallow, turbid impoundment, Wuras Dam: A study of the role of suspensoids. Special Report by Working Group for Limnology, University of the Orange Free State. 87pp.

SYMOENS, JJ, BURGIS, M and GAUDET, JJ (eds.) (1981) The ecology and utilization of African inland waters. UNEP Reports and Proceedings Series 1. 185pp.

THORNTON, JA and WALMSLEY, RD (comp.) (1987) Hartbeespoort Dam 'Quo Vadis'. FRD Occasional Report No 25. 172pp.

WALMSLEY, RD and BOTTEN, ML (comp.) (1987) *Proceedings of a Symposium on Ecology and Conservation of Wetlands in South Africa.* FRD Occasional Report No 28. 313pp.

WALMSLEY, RD and BOOMKER, EA (eds) (1988) Inventory and classification of wetlands in South Africa. FRD Occasional Report No 34. 92pp.

WALMSLEY, RD (1988) A description of the Wetlands Research Programme. FRD SANSP Report No 145. 26pp.

WALMSLEY, RD and ROBERTS, CPR (eds.) (1989) Changing patterns of resource use on the Pongolo River Floodplain. FRD Occasional Report No 36. 181 pp.

WALMSLEY, RD and FURNESS, HD (1987) A programme description for water resource research in the Mgeni Catchment. Natal Town and Regional Planning Supplementary Report Vol 21. 27pp.

WORLD RESOURCES INSTITUTE (1987) *World Resources 1987.* Basic Books Inc, New York. 369pp.

ZOHARY, T, JARVIS, AC, CHUTTER, FM, ASHTON, PJ and ROBARTS, RD (1988) The Hartbeespoort Dam Ecosystem Programme 1980 - 1988. Division of Water Technology Report, CSIR, Pretoria. 8pp.