supervising scientist report **161**

Wetland inventory, assessment and monitoring: Practical techniques and identification of major issues

CM Finlayson, NC Davidson & NJ Stevenson (editors)

Proceedings of Workshop 4
2nd International Conference on Wetlands and Development,
Dakar, Senegal,
8–14 November 1998

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This report should be cited as follows:

Finlayson CM, Davidson NC & Stevenson NJ (eds) 2001. *Wetland inventory, assessment and monitoring: Practical techniques and identification of major issues*. Proceedings of Workshop 4, 2nd International Conference on Wetlands and Development, Dakar, Senegal, 8–14 November 1998, Supervising Scientist Report 161, Supervising Scientist, Darwin.

The Supervising Scientist is part of Environment Australia, the environmental program of the Commonwealth Department of Environment and Heritage.

Supervising Scientist
Environment Australia
GPO Box 461, Darwin NT 0801 Australia

ISSN 1325-1554

ISBN 0 642 24367 0

e-mail: publications@eriss.erin.gov.au

Internet: http://www.ea.gov.au/ssd/index.html

Printed in Darwin by NTUniprint

Foreword

The 2nd International Conference on Wetlands and Development aimed to review progress in wetland conservation and development since the 1st Conference (Malaysia, 1995). The conference reviewed trends in wetland development and management, and identified issues and solutions which could benefit agencies and individuals concerned with the wise use of wetlands at all levels. Special focus was given to Africa, with the aim of developing new partnerships, networks and programs for the future.

Endorsements for the conference were received from the Convention on Biological Diversity, the Convention to Combat Desertification, the Convention on the Conservation of Migratory Species of Wild Animals, the Ramsar Convention on Wetlands, the UN Economic Commission for Africa, and the World Heritage Convention. More than 40 donors provided funds to the conference.

The Conference was opened by the Senegalese Minister of Environment and Nature Protection, in the presence of the Senegalese Minister of Foreign Affairs. Opening and keynote speeches were made by the President of Wetlands International (also representing IUCN-The World Conservation Union and The World Wide Fund for Nature — WWF), the Commissioner for Rural Development of the Economic and Monetary Union of West Africa, the Director of National Parks in Senegal, the Chair of Wetlands International-Asia Pacific, HRH The Litunga Ilute Yeta IV of Barotseland, and representatives of the UN Economic Commission for Africa and the UN Environment Program.

The Conference included 5 workshops covering:

1 Strategies for wise use of wetlands: Best practices in participatory management

2 Strategies for conserving migratory waterbirds

3 Integrated wetlands and water resources management

4 Wetland inventory, assessment, monitoring and valuation

5 Mechanisms for financing the wise use of wetlands.

The proceedings of workshop 4 are presented in this report.

Acknowledgments

The editors acknowledge staff at Wetlands International for supporting this workshop and making arrangements with the Senegalese hosts. The speakers and authors are thanked for their contributions. We also thanks Luis Naranjo (Universidad del Valle Colombia and Wetlands Inventory and Monitoring Specialist Group), Abdoulaye Ndiaye (Wetlands International) who assisted by chairing the sessions, and Isabell von Oertzen (Cambodian Wetland Inventory Project), Ian Eliot (University of Western Australia), Scott Frazier (Wetlands International) and Jurgen Volz (Water Storage Corporation Brabantse Biesbosch, Netherlands) who acted as official rapporteurs.

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In addition, a large number of participants have been sponsored through projects supported directly by a number of additional agencies.

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Wetland inventory, assessment and monitoring: Practical techniques and identification of major issues

Introduction and review of past recommendations

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Abstract

A review of recommendations from previous international conferences and workshops on wetland inventory, assessment and monitoring is provided. This lists the main recommendations from each meeting and summarises them as:

- Collection of long-term data on wetlands;
- Standardisation of techniques, guidelines and manuals;
- Provision of training;
- Reviewing gaps and co-ordination of data collection;
- Developing and making greater use of networks; and
- Developing means to audit existing effort.

In many cases, however, the recommendations have not been enacted and little progress made. An exception is the inventory project that was developed under the Mediterranean wetland program known as MedWet. This program received institutional and financial backing and was able to achieve its objectives through participation of technical experts from a number of countries and organisations. The lessons learnt from these experiences are given as examples in developing further programs.

Keywords: wetland inventory, wetland assessment, wetland monitoring, Ramsar Convention

Introduction

Inventory, assessment and monitoring are vital components of effective wetland management. Together they provide the essential data and information that support management decisions (Dugan 1990, Finlayson 1996a). Furthermore, they provide feedback on management actions and implementation of principles and frameworks to ensure that they deliver the information necessary for managers and other decision makers (Finlayson 1996b). With the recognition that inventory, assessment and monitoring cannot be treated separately from management processes, increasing attention has focused on the design and implementation of effective and integrated programs.

For inventory, a global review of wetland inventories (GRoWI) for the Ramsar Convention has recommend future good practice and priorities (Finlayson & Davidson 1999, Finlayson et al 1999). For assessment, the Ramsar Convention in conjunction with the Environmental Research Institute of the Supervising Scientist, Australia, has developed a framework for conducting wetland risk assessment as an integral component of management planning processes (van Dam et al 1999). For monitoring, general principles and frameworks have been developed, for example under the Ramsar Convention (Finlayson 1996b) and the Mediterranean wetland initiative (MedWet) (Finlayson 1996c, Grillas 1996, Tomàs Vives & Grillas 1996).

The aims of this workshop, held as a part of the 2nd International Conference on Wetlands and Development (Dakar, Senegal, 10–14 November 1998) were to review past and current projects, and to develop recommendations for further implementation of wetland inventory, assessment and monitoring.

The main objectives were to:

- promote the inventory, assessment and monitoring of wetlands, through discussion of practical approaches, methodologies and techniques;
- identify the working tools needed to improve delivery of wetland inventory and assessment; and
- identify priorities for wetland inventory and assessment in support of biodiversity conservation in Africa.

Previous conference recommendations

Several major wetland conferences during the last 10 years have produced recommendations for improved wetland inventory, assessment and monitoring. Those that are most relevant to the objectives of this workshop are summarised below.

Managing Waterfowl Populations (Matthews 1990) — IWRB, Astrakhan, Russia (former USSR), 2–5 October 1989

This conference was convened by the International Waterfowl and Wetland Research Bureau (IWRB) at the invitation of the USSR State Committee for Environment Protection. Six technical sessions were held to discuss the distribution, status and management, with an emphasis on hunting, of waterfowl. The conference was attended by more than 150 wetland scientists and marked a turning point in open contact between scientists from both sides of the 'Iron Curtain' that divided Europe at the time. Recommendations specific to waterbird inventory, assessment and monitoring are listed below:

- Collect long-term data on waterbird populations for an understanding of population processes and as a basis for conservation actions;
- Provide regular feedback of data and information to participants involved in surveys;
- Standardise and promote procedures used for data collection;

- Develop a manual for sampling waterbird populations and hold training workshops;
- Address gaps in regional waterbird data sets with relevant national and local personnel.

Managing Mediterranean wetlands and their birds for the Year 2000 and beyond (Finlayson et al 1992) — IWRB, Grado, Italy, 3–10 February 1991

This conference was convened by the International Waterfowl and Wetland Research Bureau (IWRB) at the invitation of the Regione Friuli-Venezia Giulia, Italy. Specific technical sessions and workshops were used to develop a strategy to stop and reverse wetland loss and degradation in the Mediterranean (*A strategy to stop and reverse the wetland loss and degradation in the Mediterranean basin* 1992). The conference was attended by approximately 280 wetland experts from 28 countries and principally addressed wetland management issues. Recommendations specific to wetland inventory, assessment and monitoring are listed below:

- Develop an inventory and assess all water resources of the Mediterranean;
- Strengthen monitoring procedures for Ramsar sites.

Old world and new world wetlands (Mitsch 1994) — Intecol Wetland Conference, Columbus, USA, 13–8 September 1992

This conference was organised by the School of Natural Resources, The Ohio State University, USA, on behalf of the International Society of Ecology (Intecol). A total of 905 wetland experts attended to discuss a variety of wetland topics as outlined in more than 500 papers. Several formal resolutions were adopted at the conference and those relevant to wetland inventory, assessment and monitoring are listed below:

- Develop and adopt an international classification system and guidelines for national wetland inventories;
- Establish an international committee to develop these (IWRB/IUCN/Ramsar) and promote their use.

Waterfowl and wetland conservation in the 1990s — A global perspective (Moser et al 1993) — IWRB, St Petersburg Beach, Florida, USA, 12–19 November 1992

This conference was convened by the International Waterfowl and Wetlands Research Bureau (IWRB) at the invitation of the United States Department of the Interior, Fish and Wildlife Service. Six technical workshops were held to review specific wetland and waterbird topics and provide guidance to IWRB as it developed its workplan for 1993–95. The conference was attended by approximately 240 wetland experts from 54 countries. Recommendations specific to wetland inventory, assessment and monitoring are listed below:

- Continue and extend the International Waterbird Census and collect information on waterbird habitats;
- Coordinate international data and overviews by continuing and extending the International Waterbird Census and collect information on waterbird habitats;
- Disseminate the results of monitoring waterbird populations and wetlands;
- Develop a set of criteria and a manual for measuring ecological change;

- Prepare materials for and undertake training courses on monitoring ecological change;
- Review existence of and fill gaps in national wetland inventories;
- Develop techniques and manuals for data collection and making inventories more useful;
- Develop techniques for socio-economic assessments of wetlands;
- Develop a communications network for inventory and monitoring experts.

International conference on wetlands and development (Prentice & Jaensch 1997) — Wetlands International, Kuala Lumpur, Malaysia, 9–13 October 1995

This conference was organised by the Asian Wetland Bureau (AWB), the International Waterfowl and Wetland Research Bureau (IWRB), and Wetlands for the Americas (WA), and hosted by the Ministry of Science, Technology and the Environment, the Selangor State Government and the Institute of Advanced Studies, University of Malaya. Four technical workshops were held to address global issues of wetland conservation and management in a changing world. About 290 delegates from 60 countries participated. Recommendations specific to wetland inventory, assessment and monitoring are presented below:

- Establish links for open exchange of monitoring information between agencies and NGOs;
- Develop guidelines and standards for monitoring ecological change in wetlands;
- Develop means of evaluating and auditing wetland monitoring programs;
- Develop and maintain databases of monitoring programs in different regions;
- Provide technical support and training for design of monitoring programs;
- Develop standardised techniques and manuals for monitoring specific threats to wetlands.

Common recommendations from previous conferences

Recommendations from these meetings have been broadly consistent and can be grouped under six common themes:

- Collection of long-term data on wetlands;
- Standardisation of techniques, guidelines and manuals;
- Provision of training;
- Reviewing gaps and co-ordination of data collection;
- Developing and making greater use of networks; and
- Developing means to audit existing effort.

The consistency of the recommendations may be partly attributable to a degree of consistency of attendance and participation of personnel from or associated with Wetlands International (formerly IWRB). However, as the conferences were held in different geographic locations it is likely that many other, and different, interests were also represented: the bulk of participants were not the same. Further, the nature of the meetings, as reflected in their titles, has profoundly broadened from a focus on waterbirds, to waterbirds and their habitats, and then to wetlands and their management. The outcomes thus represent a decade of developing interest in wetlands and an increasing awareness that wetland inventory, assessment and monitoring was either needed or, where it existed, was inadequate.

Implementation of previous recommendations

There is, however, little evidence that all these recommendations listed above have been widely implemented, if at all. Whilst many of the recommendations are worthy they have proved to be unrealistic and possibly over-ambitious given the past and present levels of institutional capacity and capability on the ground. Unfortunately it seems that the rhetoric and *bon homie* of the conferences (and their workshops) have been difficult to translate into on-the-ground action after the conference. Realistic recommendations with clear mechanisms for implementation are needed. This need was also apparent in the Ramsar Convention review of wetland inventory (Finlayson & Davidson 1999, Finlayson et al 1999).

A major exception to the general lack of implementation is provided by the Mediterranean wetlands program MedWet, which has contributed substantively to standardising techniques for wetland inventory (Costa et al 1996) and monitoring (Tomàs Vives 1996). MedWet has its origins in the conference *Managing Mediterranean wetlands and their birds for the year 2000 and beyond* (Finlayson et al 1992) held in Grado, Italy in 1991 (see above). Like other wetland conferences, the Grado conference presented a large number of recommendations, culminating in a far-reaching and controversial statement known as the Grado Declaration (see Finlayson et al 1992).

Unlike other conferences, the Grado symposium was regionally oriented and a program to enact at least some of the recommendations was developed further after the conference was held and the proceedings published. Its implementation was facilitated by the receipt of major project funding from the European Commission. The MedWet inventory, assessment and monitoring initiative, developed through this funding, now operates as just one part of a much broader, and expanding, Mediterrean wetlands program being implemented under the *aegis* of the Ramsar Convention on Wetlands. Above all, the Medwet program demonstrates that all the conference talking can, with the right amount of will and resourcing, be translated into action and delivery. The MedWet inventory methodology is described by Costa et al (2001).

Yet as many of the papers in this proceedings (and the recent global assessment of the state of wetland inventory; Finlayson & Spiers 1999) describe, there remains a very long way to go to achieve adequate and consistent delivery of wetland inventory, assessment and monitoring.

Practical implementation of inventory recommendations

The success of the MedWet program is illustrative, but it should not shield the reality that this success has not been replicated elsewhere. Other regional conferences and workshops have not succeeded in this manner and further wetland inventory, assessment and monitoring is still urgently needed. This was shown by the regional reviews of the Ramsar Convention's inventory project (see reports in Finlayson & Spiers 1999). Thus, if we are to see further improvement in wetland inventory, assessment and monitoring we need to also identify processes that can translate recommendations into action.

In order to promote the discussion of practical techniques for wetland inventory, assessment and monitoring the Dakar workshop was purposefully linked with two other workshops. The first was a component of the Ramsar project to review the global extent of wetland inventory (*Global review of wetland resources and priorities for wetland inventory (GRoWI);* Finlayson & Davidson 1999, Finlayson et al 1999) which had the dual purpose of reviewing the extent of wetland resources and identifying gaps in wetland inventory and inventory techniques. The second was a Biodiversity Conservation Information System (BCIS) workshop that began development of a suite of wetland inventory and assessment implementation activities.

These workshops provided a backdrop for our discussion on practical techniques for wetland inventory, assessment and monitoring. However, this background was not overly positive — it had not been possible to present many examples of standardised techniques, nor to provide a reliable estimate of the extent of the global wetland resource (a preliminary minimum estimate was 12.8 million km^2). Thus, the workshop on practical techniques commenced with the backdrop of a totally inadequate estimate of the extent, let alone the condition of the global wetland resource.

Thus, as well as hearing about a number of current and recent initiatives on wetland inventory and assessment, the workshop provided an opportunity to test the ideas emerging from the earlier two workshops with a very wide-ranging audience for evaluation, and particularly to learn more about the issues and needs in an African context. As one of the papers in the proceedings (Stevenson & Frazier 2001) outlines, wetland inventory in Africa is scant and patchy, although not necessarily any more or less so than in most other parts of the world (Finlayson & Spiers 1999).

We are pleased to report that a number of the recommendations from the workshop (Finlayson et al 1999) are already being taken forward, notably through implementation by the Ramsar Convention and its partner organisations such as Wetlands International of Resolution VII.20 of the Convention's meeting of the Conference of Parties in Costa Rica in May 1999. This Resolution (see appendix 1) was developed from the recommendations of the GRoWI analyses, the preparation of which were in turn assisted by the discussions in this 1998 Senegal workshop. Substantive steps are now being taken to both develop standardised guidance and protocols for wetland inventory, the database tools to compile and make new inventory information available, and national inventory in several parts of the world.

Although it is a globally daunting task to then undertake the inventory work itself in the many parts of the world where such vital baseline information is lacking, we hope that by the time a future meeting on the topic takes place there will be much progress to report. That would provide both a practical demonstration of capacity-building for the sustainable use of wetlands — and that not all conferences are just hot air.

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Appendix 1 People and wetlands: The vital link

7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971), San José, Costa Rica, 10–18 May 1999

Resolution VII.20 — Priorities for wetland inventory

1. RECALLING Recommendation 1.5 which called upon Contracting Parties to prepare inventories of their wetlands *as an aid to the formulation and implementation of national wetland policies* to assist in promoting the wise use of wetlands in their territory;
2. RECALLING ALSO Recommendation 4.6, Resolutions 5.3 and VI.12, and Action 6.1.2 of the Strategic Plan 1997–2002 which recognised the value of national scientific inventories for identifying sites suitable for inclusion in the List of Wetlands of International Importance (Ramsar List) under the Convention;
3. AWARE of Action 6.1.3 of the Strategic Plan 1997–2002 which calls upon the Ramsar Bureau and the International Organisation Partners to *utilise information from regional wetland directories, national scientific inventories of wetlands and other sources, to begin development of a quantification of global wetland resources, as baseline information for considering trends in wetland conservation or loss*;
4. NOTING the report entitled *Global review of wetland resources and priorities for wetland inventory* and its recommendations as prepared and presented by Wetlands International to Technical Session IV of this Conference, in response to Action 6.1.3 of the Strategic Plan 1997–2002;
5. APPRECIATIVE of the financial support provided for the preparation of the above report by the Governments of the Netherlands, Norway, and the United Kingdom;
6. NOTING WITH CONCERN the findings of the Wetlands International report that, based on the information gathered within the constraints of this project, few countries, if any, have comprehensive national inventories of their wetland resources, and that it is therefore not possible to provide a baseline of the world's wetland resources with any confidence;
7. RECOGNIZING the priorities for future wetland inventory, both in terms of types and regions, as identified in the report and endorsed by the Second International Conference on Wetlands and Development (Dakar, Senegal, November 1998);
8. CONSIDERING that this Conference has also adopted *Guidelines for developing and implementing National Wetlands Policies* (Resolution VII.6), the *Wetland Risk Assessment Framework* (Resolution VII.10), the *Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance* (Resolution VII.11), and Resolution VII.17 on *Restoration as an element of national planning for wetland conservation and wise use*, all of which, as noted by the previous Resolutions and Recommendations referred to in paragraphs 1 and 2 above, would be greatly assisted by the availability of national scientific inventories;
9. TAKING ACCOUNT of the findings given in the report prepared by the World Conservation Monitoring Centre and presented to COP7 Technical Session IV entitled *Shared wetlands and river basins of the world*; and
10. NOTING the scope of the proposed Millenium Assessment of the World's Ecosystems, currently under development, to deliver valuable related information of relevance to the application of the Convention.

The Conference of the Contracting Parties

11. URGES all Contracting Parties yet to complete comprehensive national inventories of their wetland resources, including, where possible, wetland losses and wetlands with potential for restoration (Resolution VII.17), to give highest priority in the next triennium to the compilation of comprehensive national inventories, in order for related actions such as policy development and Ramsar site designations to be carried out with the best information possible;

12. FURTHER URGES that in undertaking inventory activities Contracting Parties give consideration to affording highest priority to those wetland types identified as at greatest risk or with poorest information in the *Global review of wetland resources and priorities for wetland inventory* report;

13. REQUESTS Contracting Parties to give consideration in their inventory activities to adopting a suitable standardised protocol for data gathering and handling, such as that provided by the Mediterranean Wetlands Initiative (MedWet), and the use of standardised low-cost and user-friendly Geographic Information System methods;

14. ENCOURAGES Contracting Parties with shared wetlands or river basins to work cooperatively in the gathering of inventory and related management information, as urged through the *Guidelines for international cooperation under the Ramsar Convention* (Resolution VII.19);

15. REQUESTS the Scientific and Technical Review Panel, in collaboration with Wetlands International, the Ramsar Bureau, and other interested organisations, to review and further develop existing models for wetland inventory and data management, including the use of remote sensing and low-cost and user-friendly geographic information systems, and to report their findings to the 8th Meeting of the Contracting Parties with a view to promoting international common standards;

16. CALLS UPON Contracting Parties to review the arrangements they have in place for housing and maintaining their wetland inventory data where it exists, and, as necessary, to seek to establish a central repository or to ensure that access to this information resource is possible for all decision-makers, stakeholders and other interested parties, where possible through the World Wide Web and CD-ROM formats;

17. ALSO ENCOURAGES Contracting Parties and other interested organisations and funding bodies to provide the resources to allow Wetlands International to complete and document suitable standardised protocols for data gathering and handling as well as a comprehensive assessment of wetland inventory information, and to develop procedures for regularly updating this information and making it readily available through the World Wide Web and CD-ROM formats;

18. FURTHER CALLS UPON the bilateral and multilateral donors to give priority to supporting the wetland inventory projects submitted by developing countries and those in economic transition, noting, as urged above, the desirability of such projects being undertaken; and

19. DIRECTS the Standing Committee to give special attention to appropriate wetland inventory projects in its consideration of projects submitted to the Ramsar Small Grants Fund.

Considerations for undertaking a wetland inventory

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Abstract

Wetland inventory at many scales has been undertaken for many parts of the world with great resolve, often on limited budgets. However, whilst a large amount of information has been collected many information gaps remain and most inventory programs have not been developed on a recurrent basis. Further, the information has not been widey disseminated, partly as the outputs have not been available in electronic formats.

The advent of more sophisticated data collection, storage and analysis provides an opportunity to build on past effort and produce more useful inventories. The technology revolves around advances in remote sensing and in data information systems. With these advances and supported with ground-truthing we have the potential to improve. But first we need to address a few basics and a number of questions. Why do we want an inventory? How will it be used? How will it be updated? What scale will we use? The latter is particularly critical. It not only dictates the choice of technique, but also provides a basis for assessing the likely usefulness of the inventory. These issues and questions are addressed as a basis for outlining a protocol for designing an inventory program.

The protocol can be summarised as five basic questions: What do we currently know? What do we want to know? How will we do it? How will we report it? How will we review it? If these questions are answered, ie all attendant issues and technicalities are adequately addressed, then we may be better placed to avoid the many inadequacies reported for wetland inventory as conducted in many locations over the past few decades.

Key words: wetland inventory, data management, Ramsar Convention

Introduction

Throughout the 1980s and into the 1990s there was a concerted international effort to develop wetland inventory and hence provide an improved information base for the wise use of wetlands. These efforts were spearheaded by a number of international organisations, notably WWF (World Wide Fund for Nature), IUCN (The World Conservation Union), ICBP (now Birdlife International), and IWRB (now Wetlands International). The extent of this inventory effort was impressive and broadscale coverage included Asia (Scott 1989), South America and the Carribean (Scott & Carbonell 1986), Africa (Hughes & Hughes 1992), the South Pacific and New Zealand (Cromarty & Scott 1995) and the Middle East (Scott 1995). These efforts were augmented by national efforts in large countries such as the USA (Cowardin et al 1979, Cowardin & Golet 1995, Wilen & Bates 1995), Canada (Zoltai & Vitt 1995) and

Australia (Usback & James 1993, ANCA 1996). Thus, at a global level the extent of wetland inventory seemed to have improved immensely (Finlayson & van der Valk 1995a).

However, there was still great uncertainty and many gaps in the information (Finlayson & van der Valk 1995b), as was pointed out in various international and regional symposia held by IWRB and partner organisations (eg Matthews 1990a, Finlayson et al 1992, Moser et al 1993, Prentice & Jaensch 1997). Whilst a large amount of information had been compiled it was still difficult to assess the state of the global wetland resource or to establish priorities for wetland management (Finlayson & van der Valk 1995b, Sahagian & Melack 1998, Darras et al 1999).

Wetland inventory has been plagued by a number of common problems.There has been little agreement on what constitutes a wetland (see papers in Finlayson & van der Valk 1995a). Information has been required at a number of geographical scales, ranging from local (site) to national and global scales, that result in non-comparable results. Furthermore, the scattered nature of the information has prevented accurate assessment of the size and extent of wetlands. And finally, it has not always been possible to corroborate the accuracy or currency of some information. Recognition of this inadequate situation led to the global review of wetland resources conducted on behalf of the Ramsar Convention Bureau by Wetlands International through its Wetland Inventory and Monitoring Specialist Group and in cooperation with the Environmental Research Institute of the Supervising Scientist (Australia) (Finlayson & Spiers 1999, Finlayson et al 1999).

At the same time Phinn et al (1999) conducted a review of the usefulness of remote sensing for wetland inventory and monitoring in Australia, noting that most past reviews had been focussed on the continental USA. Using the information presented by Phinn et al (1999) and drawing on the inadequacies in wetland inventory identified by other authors I consider here some basic issues that could enable us to take advantage of current technologies and improve our wetland information base through coordinated and/or standardised inventory approaches.

Definitions and concepts of wetland inventory

Whilst an extensive wetland 'inventory' effort has occurred in the past two decades in particular, there has been little agreement on what constitutes an inventory, and how (or if) this is distinct from a wetland directory. The continental inventories such as those for Asia (Scott 1989) and the Neotropics (Scott & Carbonell 1986) were extensive collations of existing information, but did not involve delineating and mapping of wetlands. The national wetland inventory in the USA involved extensive delineation and mapping of wetlands (Wilen & Bates 1995). The Australian wetland directory involved collation of existing information and strategic collection of further information (ANCA 1996). The Croatian wetland inventory produced by Muzinic (1994) was a listing of wetland sites.

Finlayson (1996a) differentiated between a wetland inventory and a wetland directory as follows: 'A directory and an inventory are used to compile the same type of information, but the former is limited to current information and may not be comprehensive. An inventory generally includes investigative steps to obtain more information and thereby presents a comprehensive coverage of sites. Thus, a directory may often be the precursor of an inventory'. However, Finlayson (1996a) further notes 'In reality, however, the terms are often used interchangeably, and hence the point has become pedantic and need not be a hindrance to further discussion about the extent of wetland inventory'.

The global review of wetland inventory conducted on behalf of the Ramsar Convention Bureau (Finlayson & Spiers 1999) addressed this issue in the broadest possible manner and used a multitude of source materials under the broad description of ‘international, regional and national wetland inventories (including regional and national directories of important wetlands) as well as other general information on global wetland resources from publications, Ramsar Convention literature, and information collected by other institutions doing work on the same or related subject(s)’ (Finlayson & Davidson 1999). Thus, it was taken that an inventory was a collation of information on wetlands and specifically their location and size and possibly also on their biophysical features and management. Given that wetland inventory seems to cover many purposes and involves many different forms of information a similarly broad approach is taken in this paper.

Past and current wetland inventory effort

Much wetland inventory has been based on ground-survey, often with the support of aerial photography and topographic maps and, more recently, satellite imagery (Johnston & Barson 1993, Taylor et al 1995, Phinn et al 1999). Aerial photography, mainly infra-red and false colour infra-red, has been used extensively to produce maps of the vegetation composition within small/medium sized wetlands. Photographs have typically been joined together to produce a mosaic that is subject to visual interpretation to produce an overlay of vegetation classes. Nowadays these can be digitised and used within a Geographic Information System (GIS). Satellite imagery within the constraints of spatial scales has also increasingly been used for wetland inventory (Phinn et al 1996, Yamagata 1999, Darras et al 1999).

Aerial photography has been favoured for many inventory efforts, such as the national wetland inventory in the USA (Wilen & Bates 1995). In such instances this has often resulted in the collection of detailed information on the location, size and biophysical features of wetlands. However, in many countries its usefulness has been limited by the availability and cost of the photography, particularly when large areas are involved, inaccessible terrain for effective ground-truthing, and problems of cloud cover. However, there is no doubting that aerial photography has been an extremely valuable tool for wetland inventory. Advances in satellite imagery may soon resolve some of the problems currently experienced with aerial photography (Phinn et al 1999), although ground-truthing and costs will still need consideration.

Much inventory effort has also relied on literature searches to unearth already existing information from, for example, fisheries or forestry inventory, for collation and presentation. This approach has undoubted value and can ensure that existing information is utilised before further information is collected. However, it suffers from difficulties in identifying and locating existing information, particularly in the grey-literature and where published materials are out of print, and from a lack of rigour in assessing the quality and currency of the information. Finlayson and Davidson (1999) point out that the value of many literature reviews is limited due to a failure to corroborate fully much of the information that has been collated. This has particularly been the case where different wetland definitions and classifications have been used, or the origins of the data have not been clearly given.

The problem of relying on existing information can be compounded when the information dates and loses its currency, or limited copies of valuable reports become scarce or even impossible to locate. The latter is a problem that has plagued many of the inventory projects of the past two decades. In making these comments it is noted that these problems could be reduced by adopting strict information management procedures. However, a great deal of wetland inventory has been conducted within tight budgets and timelines, and in competition with more ‘action’ related tasks, without resources being available for sound or ongoing information management.

Future wetland inventory

In discussing appropriate methods for future wetland inventory the relative merits of different forms of satellite imagery are an important issue. Rapid advances in acquiring and applying such data are being made and readers are referred to recent reviews for further information (eg Sahagian & Melack 1998, Phinn et al 1999, Darras 1999). Rather than repeat this debate, in this paper I focus on the issues of data collection and management and the purpose(s) of wetland inventory — issues which are fundamental to appropriately conducted inventory, whatever methods are then employed for data acquisition.

Purpose of wetland inventory

When undertaking wetland inventory it is important initially to articulate the purpose and hence define the objective of the inventory. Once this is done the methodology and data reporting steps should be clear, much as recommended by Finlayson (1996b) for designing a wetland monitoring program. The issue of scale also emerges: what is an appropriate scale to achieve the objective of the inventory program?

Wetland inventory has been done for a number of purposes, such as: providing a list of a particular type or even all wetlands in an area; identifying wetlands of national or international importance based on agreed criteria; describing the occurrence and distribution of various taxa, such as birds or vegetation; identifying or describing natural resources such as peat, fish or water; and providing a base for assessing wetland loss or degradation. For the Mediterranean basin Costa et al (1996) listed the following four objectives for wetland inventory: to identify where wetlands are, and which are priority sites for conservation; to identify the functions and values of each wetland; to establish a baseline for measuring change in a wetland; and to provide a tool for planning and management.

The purpose or objective for wetland inventory is inseparable from the spatial scale of the inventory. Phinn et al (1999) notes that wetland inventory has been carried out at a number of spatial scales, with specific objectives at each scale:

- Global **—** presence/absence in specific continents and islands (eg Matthews 1990b)
- Continental **—** distribution of regions within continents or islands dominated by wetlands (eg Wilen & Bates 1995)
- Regional **—** scale of predominance of specific wetland types (eg Jensen et al 1986)
- Local **—** individual wetlands (eg Phinn & Snow 1996a,b)
- Site **—** variability within wetlands (eg Finlayson et al 1989)

Thus, when choosing a scale it is necessary to first determine the objective and assess how this can be achieved, noting that budget issues will affect the final decision, and hence the choice of scale. Finlayson (1999) chose three scales for wetland inventory within a hierarchical approach for an Australia-wide inventory as follows: i) wetland regions within a continent with maps at a scale of 1:5 000 000; ii) wetland aggregations within each region with maps at a scale of 1:250 000; and iii) wetland sites within each aggregation with maps at a scale of 1:50 000 or 1:25 000.

Minimum data requirements

Given past difficulties with obtaining inventory data in many locations it is proposed that a minimum data set sufficient to describe the wetland(s) is established. This should include the location and size of the wetland and those features that provide value and benefits to humans. This has been done for a proposed national wetland inventory in Australia where a core data set was chosen to provide an information base for delineating wetland habitats and describing the basic ecological character of the delineated habitats (Finlayson 1999). The preferred situation is for this to be done using a time series of data, but as this has seldom been possible in the past it is recommended that sufficient information (a core or minimum data set) should be derived to enable the major wetland habitats to be delineated and characterised for at least one point in time. On this basis a standard set of core data has been recommended (table 1).

This core data can be supplemented with further information from bibliographical or managerial sources. However, these data are more associated with wetland assessment than with inventory. The decision on whether to undertake an inventory based only on the core data or to include additional information (see table 1 for recommended additional information), for assessment purposes will most likely be based on individual priorities, needs and resources. However, the global review of wetland inventory found very few examples where such additional data had been successfully incorporated into an inventory. Where this had been attempted it had proved difficult to collate the information for all sites or to verify the accuracy and currency of the information. The recommendation that an inventory focuses initially on the essential core data is based on the recognition that few programs are sufficiently resourced to enable a thorough and comprehensive program to be successfully completed.

Table 1 Essential core data elements and recommended additional information categories identified for wetland inventory and assessment (Finlayson 1999, Finlayson et al 1999)

Essential core data
Area and boundary (size and variation, range and average values)*
Location (coordinates, map centroid, elevation)*
Geomorphic setting (where it occurs within the landscape, linkage with other aquatic habitat, biogeographical region)*
General description (shape, cross-section and plan view)
Soil (structure and colour)
Water regime (periodicity, extent of flooding and depth)
Water chemistry (salinity, pH, colour, transparency)
Biota (vegetation zones and structure, animal populations and distribution, special features including rare/endangered species)
Recommended additional information
Landuse — local and in the catchment
Impacts and threats to the wetland — within the wetland and in the catchment
Land tenure and administrative authority — for the wetland parts of the catchment
Conservation and management status of the wetland — including legal instruments and social or cultural factors
Climate — zone and major features
Groundwater features — noting that catchment boundaries may not correspond with those of groundwater basins
Management and monitoring programs — in place and planned

* These features can usually be derived from topographic maps or remotely sensed images, especially aerial photographs

Data management

Eliot et al (1999) contend that the lack of appropriate data and information results in poor decision-making and contributes to inappropriate management. Thus, an investment in data collection is essential, but this could be undermined by poor data management. Ensuring the latter does not occur is essential to reduce uncertainty, improve decision-making, and enhance management capability and ensure that unnecessary funds are not spent on ill conceived projects. This is equally relevant for wetland inventory and raises specific issues, including the quality and value of existing and future data and the custodianship of all data and information. It is recommended that these issues are addressed at the beginning of all inventory programs and any potential problems resolved before the data collation or collection commences.

Technological advances in data acquisition potentially present many challenges for those who need to use and manage the data. It is stressed than when inventory information is recorded it should be accompanied by clear records that describe when and how the information was collected and its accuracy and reliability. Such information was absent from many of the inventories reviewed and reported in Finlayson and Spiers (1999). Thus, in addition to reaching agreement on a minimum or core data set it is also necessary to determine how the data will be obtained, corroborated and stored for future use or distribution. With increasing usage of geographic information systems a large amount of data can be stored and displayed, but these capabilities could be undermined if the data is not well managed and stored in formats that are readily accessible and usable. Data management or storage procedures should not limit or obstruct the usage of the data.

In addition to following strict protocols for managing the data collected during an inventory program it is also recommended that a meta-database should be used to record basic information about individual inventory datasets. This would include a description of the type of data collected and details of custodianship and access by parties who did not collect or fund the collection of the data. The need for a standard and versatile meta-database has been recognised at both global and national levels as more and more data has been collected and stored. At this stage there is no agreeement on the data fields for a wetland inventory meta-database, but a format has been proposed by Finlayson and Davidson (1999) and is repeated in figure 1. It is also recommended that this format is supplemented by further fields for 'data ownership' and 'name of the organisation or individual who actually undertook the inventory'. These fields are not clearly covered in figure 1 and could be added at either a primary or secondary level in the hierarchy as shown. Regardless of the fields that are finally adopted it is essential that the database is constructed in line with an established data protocol and is easily accessible. Such a database could be established and made accessible via the increasingly sophisticated designs possible through the internet.

The latter is an important consideration and would support the recommendation of Finlayson and Davidson (1999) that a central repository for wetland inventory information is established through the aegis of the Ramsar Convention on Wetlands. It is unlikely to be feasible, or even necessary, for all inventory information to be held in a single location, but a meta-database listing of such material could be held and made accessible to interested parties via the internet. Thus, interested parties would be presented with a description of the information and directed to the custodians.

How will the inventory be used?

Intricately linked to the above points is the consideration of how an inventory will be used once the data is collected/collated and reported. To a large extent this question is inseparable from considerations of methodology and data management that are derived from establishing the purpose and objective of the inventory program. However, we also need to consider direct access to the data and/or report in order to maximise its usefulness. Unfortunately, limited availability of hard-copy inventory reports has restricted the usefulness of some past wetland inventory.

It is recommended that where-ever possible both hard-copy and electronic copies of the report are produced to enable usage by both a specific and wide audience. Hard-copy reports are still favoured by many users/readers, whereas electronic copies on disc, CD-ROM or the internet are cheap to produce and easy to reproduce and make available to larger numbers of people, assuming they have access to current technology and that data formats are compatible.

The actual presentation of the data and information should also be considered with decisions based on the extent and type of access required. Thus, readability and layout are important features. Further, if it is anticipated that the data/information will be updated, this should be planned from the outset.

Protocol for planning a wetland inventory

The following protocol is presented as a guide for planning a wetland inventory. The protocol is not prescriptive, rather it outlines a number of steps that can be followed to ensure that the best decisions are made in relation to the objectives and available resources. It is also pointed out that an understanding of the limits of various techniques suited to wetland inventory should be investigated and where necessary expert technical advice sought.

Protocol

Identify the extent of existing knowledge and information	Review the published and unpublished literature and determine the extent of knowledge and information available for wetlands in the region being considered. That is, establish the baseline and identify gaps in available knowledge.
Establish the purpose and objective for the inventory	Based on the step above and determined by management priorities outline the exact purpose of the inventory and establish the objective. That is, articulate the reasons for undertaking the inventory and why the information is required, and hence establish the scale and the minimum core data set.
Choose the methods and variables	Review available methods and seek expert technical advice to ensure that methods that can supply the required information are adopted. That is, ensure that the minimum core data can be obtained and the scale is practical. Ensure that all data management processes are established, in particular those for data collation and/or collection, analysis and interpretation, and storage.

Assess the feasibility and cost effectiveness	Assess whether or not the program, including reporting of the results can be done within the context of the management processes and financial resources available. Assess factors that influence data collation and/or collection: availability of trained staff; access to sampling sites; availability and reliability of specialist equipment; means of analysing and interpreting the data; usefulness of the data and information; means of reporting in a timely manner. Determine if the costs of data acquisition and analysis are within the budget and that the budget is available and/or renewal as appropriate.
Conduct a pilot study	Test and fine-tune the method and specialist equipment being used, assess the training needs for staff involved, and confirm the means of collating, collecting, analysing and interpreting the data. In particular, ensure that any remote sensing can be supported by ground-truthing. This does not imply that all likely conditions and variations that may be experienced over an extended period are assessed, but it does imply that the operators have confidence in the procedures and their ability to respond to adverse conditions.
Collect the samples	Staff should be trained in all data collation and/or collection methods before the project begins, including the necessary documentation required: such as, date and location, names of staff, sampling methods, equipment used, means of storage or transport of samples, all changes to the methods, and general observations. Data and samples should be processed within a timely period and all data documented: date and location; names of staff; processing methods; equipment used; and all changes to the protocols.
Analyse the samples and data	Sample and data analysis should be done by rigorous and tested methods and all information documented: date and location; names of analytical staff; methods used; equipment used; data storage methods.
Report the results	Interpret and report all results in a timely and cost effective manner. The report should be succinct and concise and indicate whether or not the objective has been achieved, and contain recommendations for management action, including whether further information or data is required. Record the meta-data using a standard format and make this available to interested parties and other agencies through electronic and hardcopy formats. Make the report publicly available in suitable formats, including hard-copy, CD-ROM and/or on the internet to ensure usage of the information can be maximised.

Evaluate the project	Formally and openly review the effectiveness of all procedures, including reporting and dissemination of the information, and where necessary adjust or even terminate the program. The latter should not be seen as a failure if it is shown to be done for valid reasons.

The protocol can be summarised with five basic questions:

- What do we currently know?
- What do we want to know?
- How will we do it?
- How will we report it?
- How will we review it?

If these questions are answered, ie all attendant issues and technicalities are adequately addressed, then we may be better placed to avoid the many inadequacies reported for wetland inventory as conducted in many locations over the past few decades. In this respect we should be making the best use of new technologies for both obtaining, analysing and interpreting inventory information, and ensuring that this is made available in the most efficient format to the prime users.

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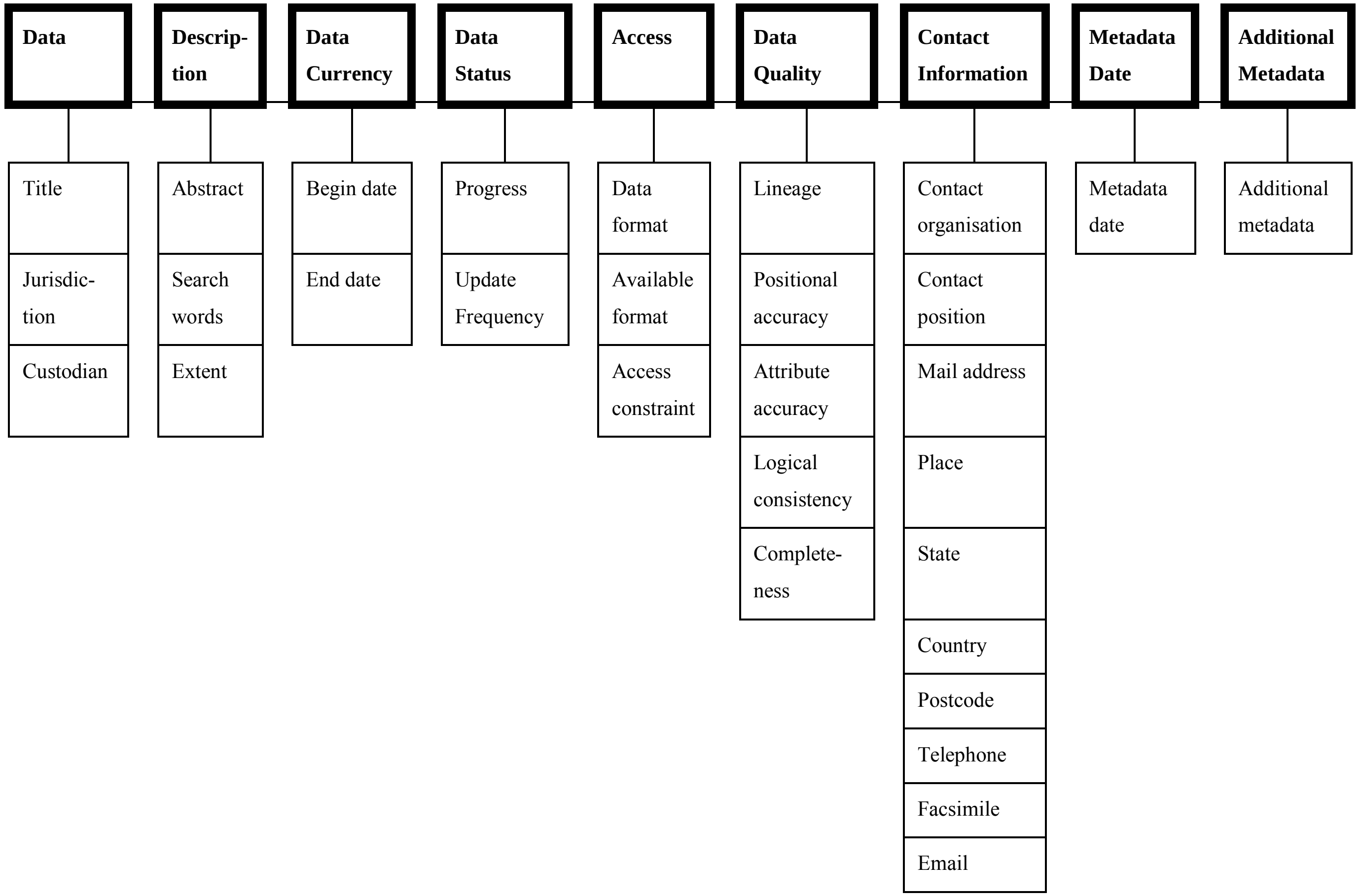

Figure 1 Meta-database format proposed by Finlayson and Davidson (1999) for recording details of individual wetland inventory projects as components of the National Wetland Inventory

Wetland inventory: Overview at a global scale

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Abstract

As part of a Global Review of Wetland Resources and Priorities for Wetland Inventory (GRoWI), global and continental scale wetland inventories were collated and assessed in order to determine the status of wetland inventory worldwide, and to identify priority areas for future inventory effort. From global-scale remote sensing analyses the natural terrestrial wetland resource has been estimate at 530–570 M ha, with rice paddies forming another 130 M ha. Major gaps in global-scale information exist, notably for artificial wetlands other than rice paddy and for coastal and marine wetlands, for which global estimates are available only for mangroves and coral reefs. Inventory at the regional and national scales is also very incomplete. Review of a wide variety of inventories and other sources of wetland information has revealed that there are also major inconsistencies in approaches to wetland inventory, which hamper its effectiveness as a management tool. GRoWI recommended techniques and strategies to improve further wetland inventory. Key recommendations include: the development and dissemination of models for improved globally-applicable wetland inventory; a national wetland inventory be conducted in every country that currently lacks one; the urgent need for quantitative studies of wetland loss and degradation in many parts of the world; and recommendations on approach and design of a wetland inventory, including the need for a clear statement of its purpose, the initial acquisition of a basic data set of key information for each wetland, and publication of inventory information in both hardcopy and electronic formats.

Keywords: global wetland inventory, status of wetlands, distribution and loss of wetlands, Ramsar Convention

1 Introduction

A Global Review of Wetland Resources and Priorities for Wetland Inventory (GRoWI) was undertaken in 1998 by Wetlands International and the Environmental Research Institute of the Supervising Scientist on behalf of the Bureau of the Ramsar Convention on Wetlands (Finlayson & Spiers 1999).

The aims of the review were to:

- provide an overview of international, regional and national wetland inventories as well as other general information on global wetland resources;
- outline steps to quantify the extent of global wetland resources and to provide a baseline for measuring trends in wetland conservation or loss; and
- identify priorities for establishing, updating or extending wetland inventories.

One component of the project reviewed international and continental-scale wetland inventories and other global wetland sources (Spiers 1999). This paper summarises the findings of this part of the GRoWI analyses.

2 Materials and methods

A broad range of inventories and other global wetland information sources were reviewed by Spiers (1999), including global atlases for particular wetland types, regional inventories, journal and conference papers, books and websites. Other sources, such as continental or global scale general maps or remotely sensed imagery, were outside the scope of this analysis, although Sahagian and Melack (1996) have identified these as a source of inventory information that requires assessment.

The broad definition of wetlands adopted by the Ramsar Convention on Wetlands was used in the review. Wetland information sources assessed by Spiers (1999) covered specific wetland types (eg seagrasses, mangroves, coral reefs, and peatlands), and wetlands in general, including Ramsar sites, protected areas, important bird areas and artificial wetlands.

The detailed methodology adopted in the GroWI analysis is summarised by Finlayson and Davidson (1999a).

3 Results

3.1 Wetland extent and distribution

Sources reviewed by Spiers (1999) provide data on extent and distribution of wetlands at various scales, from global estimates to the areal extent of particular wetland types at specific sites. There is considerable inconsistency in the information obtained for review, with data unavailable for some sites or countries due to a lack of adequate inventory or maps. Estimates of global wetland areas from global sources are listed in table 1 and those for regional wetland areas in table 2.

As part of methane-emission studies the global extent of natural freshwater wetlands was calculated by Matthews and Fung (1987) as 530 M ha, and by Aselmann and Crutzen (1989) as 570M ha (table 1). These figures are approximately double those from earlier global wetland area estimates (Lieth 1975, Whittaker & Likens 1975, Ajtay et al 1979). This seems largely because the two more recent studies used a broader definition of methane-producing wetlands, including seasonal and permanent freshwater ecosystems whether peat-forming or not (Aselmann & Crutzen 1989), and small ponded wetlands (Matthews & Fung 1987). Saltwater wetlands were excluded from these estimates since their methane production is usually insignificant (Aselmann & Crutzen 1989).

Global estimates identified during the study for particular freshwater wetland types, eg swamps, lakes, floodplains and peatlands, are listed in table 1.

No overall figure for the global extent of coastal and/or marine wetlands was located (Spiers 1999), but estimates have been made for coral reefs and mangroves (table 1). Likewise, no estimate for the global extent of saltmarshes was found, and there are large information gaps for this wetland habitat throughout the world. However, some regional salt marsh data are available (table 2), and is discussed in further detail by Spiers (1999). There are also limited data on the extent and distribution of coastal lagoon wetlands and seagrasses.

Table 1 Global area estimates obtained from wetland inventory sources

Source	Region	Wetland type	Global area (ha)
Matthews & Fung (1987)	Asia, Oceania, Africa, Europe, Neotropics, North America	Forested bog	207 800 000
		Nonforested bog	89 700 000
		Forested swamp	108 700 000
		Nonforested swamp	100 700 000
		Alluvial formations	19 400 000
		Total natural wetlands (excl. irrigated rice fields)	530 000 000
Aselmann & Crutzen (1989)	Asia, Oceania, Africa, Europe, Neotropics, North America	Rice paddies	130 000 000
		Bogs	190 000 000
		Fens	150 000 000
		Swamps	110 000 000
		Floodplains	80 000 000
		Marshes	27 000 000
		Lakes	12 000 000
		Total natural freshwater wetlands	570 000 000
Dugan (1993)	Asia, Oceania, Africa, Europe, Neotropics, North America	Wetlands (assumedly freshwater only)	560 000 000
Frazier (1996)	Asia, Oceania, Africa, Europe, Neotropics, North America	Wetland sites on the Ramsar List of Wetlands of International Importance	52 334 339 *
Spalding et al (1997)	Asia, Africa, Oceania, Neotropics, North America	Mangroves only	18 100 000
WCMC (1998)	Asia, Oceania, Africa, Neotropics, North America	Coral reefs only	30 000 000 – 60 000 000
Dugan (1993)	Asia, Oceania, Africa, Europe, Neotropics, North America	Peatlands only	400 000 000
Aselmann & Crutzen (1989)	Asia, Oceania, Africa, Europe, Neotropics, North America	Artificial wetlands — rice paddies only**	130 000 000
Finlayson & Davidson (1999b)	Asia, Oceania, Africa, Europe, Neotropics, North America	All wetlands	1 275 847 000– 1 279 211 000 ha

* Update (07/09/00): Ramsar now lists 1034 wetland Sites of International Importance, covering over 78 M ha;

** No other global areas located for artificial wetland types.

Table 2 Regional wetland area estimates by wetland type. (Note: Approximate only, refer to Finlayson and Spiers (1999) and original sources for further detail)

Region	Wetland type	Continental area (ha)	Source
Africa	Freshwater wetlands	34 500 000	Dugan (1993)
	Freshwater wetlands	35 600 000	Aselmann & Crutzen (1989)
	Tropical swamps	>34 000 000	Thompson & Hamilton (1983)
	Headwater swamps	8 500 000	Thompson & Hamilton (1983)
	Floodplains[1]	10 980 000	Denny (1993)
	Swamps[1]	12 640 000	Denny (1993)
	Shallow waterbodies[1]	2 830 000	Denny (1993)
Asia	All wetlands	>120 000 000	Scott & Poole (1989)
	Mangroves	>7 517 300	Spalding et al (1997)
Oceania	No regional estimate available		
Europe	Freshwater wetlands	670 000	Aselmann & Crutzen (1989)
	Coastal salt marshes	230 000	Dijkema (1987)
Canada	All wetlands	127 200 000	Glooschenko et al (1993)
United States of America	Marine wetlands	31 741	Wilen & Tiner (1993)
	Estuarine wetlands	2 123 199	Wilen & Tiner (1993)
	Palustrine wetlands	37 949 958	Wilen & Tiner (1993)
North America total[2]	All wetlands	167 304 898	(author's calculations)
Caribbean	All wetlands	23 500 000	Dugan (1993)
South America	Freshwater wetlands	152 000 000	Aselmann & Crutzen (1989)
Central America	Freshwater wetlands	1 750 000	Aselmann & Crutzen (1989)
Neotropics total[3]	All wetlands	>177 250 000	(author's calculations)

1 Author's calculations from figures provided in table 3, Denny (1993).

2 Further information from the review of North American wetland inventory sources (Davidson et al 1999a) enables calculation of a total wetland estimate of 241 574 000 ha for North America (Finlayson & Davidson 1999b).

3 Further information from Davidson et al (1999b) enables a total wetland estimate of 414 917 000 ha to be calculated for the Neotropics (Finlayson & Davidson 1999b).

There are apparently huge gaps in knowledge of seagrasses in the South Pacific, Southern Asia, South America and some parts of Africa (L McKenzie, pers comm 1998).

Artificial wetlands (reservoirs, dams, irrigation culverts and canals, fish farms, aquaculture ponds and rice fields) are known to contribute significantly to the global wetland area, and they often provide important habitats for flora and fauna as well as benefits to humankind. Aselmann and Crutzen (1989) calculated the global area of rice paddies as 1.3 million km^2 (130 million ha), of which almost 90% is cultivated in Asia (table 1). It is likely this figure is now outdated: Matthews et al (1991), cited in NASA (1999), provide a map of rice harvest areas worldwide which updates this information.

The GroWI analysis, derived from information in national inventories, came up with a very different estimate (12.76–12.79 M ha) to those derived from global-scale remote sensing (table 1), suggesting that the latter are major underestimates — especially given the major limitations of the national inventory coverage.

3.2 Wetland loss and degradation

The loss of wetlands worldwide has been estimated at 50% of those that existed since 1900 (Dugan 1993, OECD 1996). Without further clarification of this estimate (a definition of wetlands and/or the source data was not provided in references obtained by Spiers, 1999), it is assumed that the 50% wetland loss estimate applies to inland wetlands and possibly mangroves, but is unlikely to include marine wetlands. Much of this wetland loss occurred in northern countries during the first 50 years of the 20th century. Since the 1950s, tropical and sub-tropical wetlands have been increasingly degraded or lost through conversion to agricultural use. Agriculture is the principal cause for wetland loss worldwide. By 1985 it was estimated that 56–65% of available wetland had been drained for intensive agriculture in Europe and North America, 27% in Asia, 6% in South America and 2% in Africa, a total of 26% loss to agriculture worldwide (OECD 1996). As wetland loss to agriculture and other uses is continuing, and indeed intensifying, in regions such as Africa, Asia, and the Neotropics, these figures need to be updated with more quantitative studies.

Impacts are not limited to inland or coastal wetlands: marine wetlands are also under threat. A recent study of coral reefs (WRI 1998) indicated that 58% of the world's reefs are at moderate to high risk from human disturbance. Globally, 36% of all reefs were classified as threatened by overexploitation, 30% by coastal development, 22% by inland pollution and erosion, and 12% by marine pollution.

Moser et al (1996) note that data provided by Ramsar Contracting Parties indicated that 84% of Ramsar-listed wetlands had undergone or were threatened by ecological change.

4 Discussion

On the basis of this and the other regional GRoWI analyses Finlayson and Davidson (1999b) concluded that, based on current information, it is not possible to provide an acceptable figure of the areal extent of wetlands at a global scale. There is little agreement on what constitutes a wetland, and many gaps and inaccuracies in the information. Spiers (1999) notes that all regions of the world — Africa, Asia, Oceania, Neotropics, North America, Western and Eastern Europe — have information gaps and priority areas for wetland inventory. The priority regions are Asia, Africa, Eastern Europe, the Neotropics, and Oceania, all of which urgently require further wetland inventory, and studies on the rate and extent of wetland loss. Attention must also be given to inventory of priority wetland habitats, which include seagrasses, salt marshes and coastal flats, coral reefs, mangroves, arid-zone wetlands, peatlands, rivers and streams, and artificial wetlands.

The work required to establish, update or extend wetland inventory may seem monumental when viewed at a global scale, but it is eminently achievable, if a genuine will exists and a few key processes are targeted for improvement (Finlayson & van der Valk 1995, Scott & Jones 1995). Spiers (1999) discusses issues of communication, cooperation, reporting and inventory format, standardisation of inventory approaches and techniques, electronic data storage and accessibility of wetland inventory information. These issues are further elaborated upon by Finlayson and Davidson (1999b), culminating in a list of recommendations which, if acted upon, will greatly assist the global community to improve wetland inventory and management into the new century.

Key recommendations include:

- All countries lacking a national wetland inventory should undertake one, using an approach that is comparable with other wetland inventories and for which the Ramsar Convention should provide guidance (see below).
- Quantitative studies of wetland loss and degradation are urgently required for much of Asia, Africa, Eastern Europe, South America, the Pacific Islands and Australia.
- Further inventory should focus on a basic data set describing the location and size of each wetland, and its major biophysical features, including variations in area and the water regime. This information should be made available in both hardcopy and electronic formats.
- After acquisition of the basic data, further information oriented to management, on wetland threats and uses, land tenure and management regimes, benefits and values, should be collected. Source(s) of information should be clearly recorded along with comments on its accuracy and availability.
- The Ramsar Convention should support the development and dissemination of models for improved globally-applicable wetland inventory. These should be derived from existing models, for example the MedWet program, that are capable of using both remote sensing and ground techniques, as appropriate. Models should cover appropriate habitat classifications (eg those based on landform categories), information collation and storage, in particular Geographic Information Systems for spatial and temporal data that can be used for monitoring purposes.

5 Acknowledgments

Thanks to everyone who provided references and advice, and to my fellow project officers from Wetlands International. Particular thanks to Dr Max Finlayson, Dr Nick Davidson and Dr Arthur Johnston for the opportunity to present this poster in Dakar, Senegal, and to my husband and family for their understanding and support.

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Status of national wetland inventories in Africa

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Abstract

An analysis of wetland inventory undertaken in Africa was conducted during 1998/99. This was part of a global project to examine the extent of wetland inventory and provide best estimates of the extent of wetlands. The best estimate for Africa was a total area of wetlands estimated as ca. 123 000 000 ha, covering about 4% of the land surface. More than 85% of the area (ca. 107 500 000 ha) of these were inland wetlands, with less than 10% of the area (ca. 10 000 000 ha) described as marine/coastal wetlands and a further 5% (ca. 4 500 000 ha) described as manmade wetlands. However, very few countries had a comprehensive national wetland inventory and many had very little information available. Further, many information sources were inadequate with necessary information (eg dates, wetland types, summary detail) absent. It is also acknowledged that not all sources of information may have been obtained for this analysis and further sources may yet be identified. Many information sources were unpublished and others incomplete. Few inventories (25%) were undertaken by national governmental organisations. A list of recommendations for improving wetland inventory in Africa is presented.

Keywords: wetland inventory, Africa, wetland extent, wetland classification

Introduction

The *Global Review of Wetland Resources and Priorities for Wetland Inventory (GRoWI)* was undertaken for the Ramsar Convention on Wetlands by Wetlands International and the Environmental Research Institute of the Supervising Scientist, Australia (***eriss***) during 1998/9 (Finlayson & Spiers 1999, Finlayson et al 1999). As a major part of this project a review of the existence and status of national wetland inventories was undertaken for each of the (then seven) Ramsar geographical regions. This paper summarises the results for the Africa Ramsar Region. The full report and analysis for Africa (Stevenson & Frazier 1999) and for other regions of the GRoWI study are available at http://www.wetlands.agro.nl/growi.html.

It should be recognised that this analysis is preliminary, owing to the short timescale and extent of resources for the work, and that other inventory sources may exist that were not identified and/or accessed in time for the GRoWI study. Furthermore, a number of wetland inventories have been initiated or expanded upon since the study was undertaken in 1998/9, or are planned, e.g. in Namibia, Uganda, South Africa and Kenya. Where other such inventory material was identified, this is noted in the information that follows. Nevertheless this analysis provides a first continent-wide view of the state of wetland inventory in Africa, and the size of its wetland resource. For details of the conditions and limitations to the quality of the estimates summarised in this paper, see Finlayson and Spiers (1999).

Method

The main aims of the GRoWI work were to collate and analyse existing scattered national wetland inventory information, and from this to identify where adequate inventory information exists and where there are major gaps. This was achieved by identifying and gathering wetland inventory materials and assessing them by means of a common evaluation procedure. Standard metadata information and summaries of wetland areas by inventory and country/territory were compiled as a database and analysed to yield information on a standard set of questions concerning the status of inventory. From this compiled information, best estimates of the area of wetland resource in each African country (or territory) were made. The procedure is summarised in figure 1.

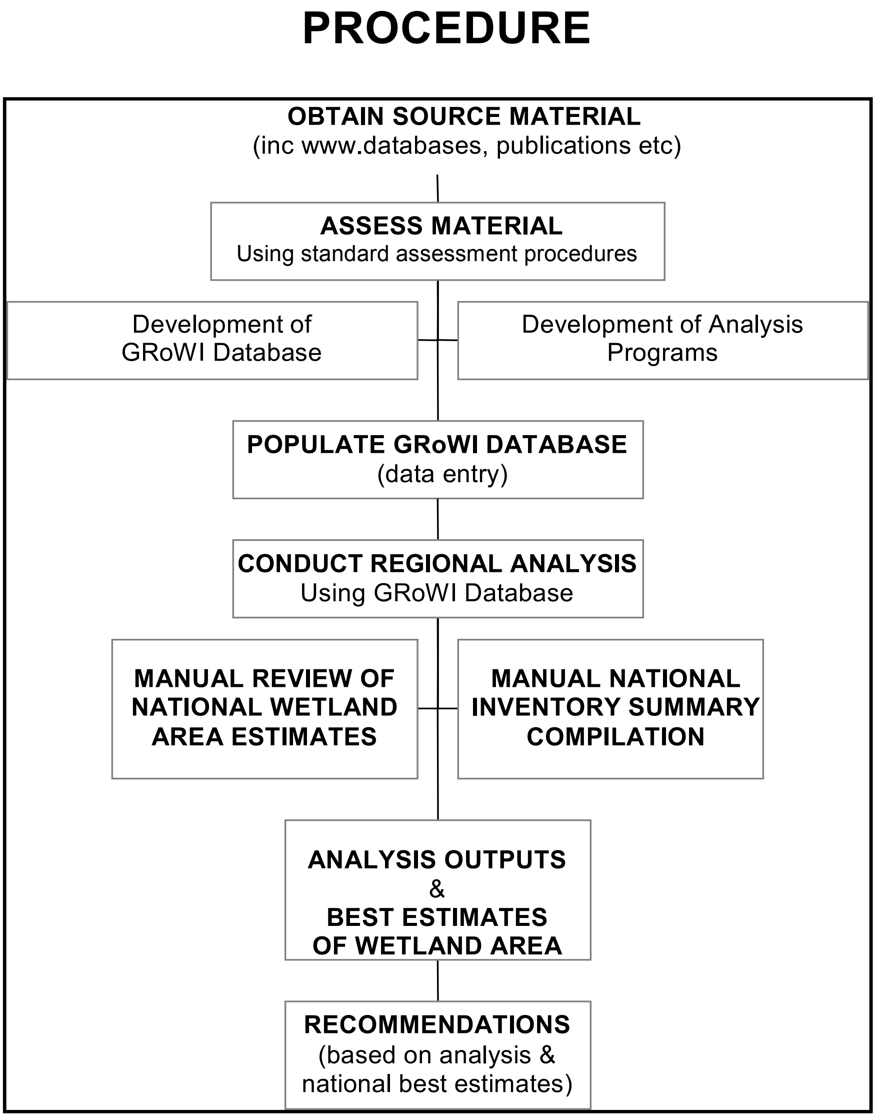

Figure 1 The GRoWI procedure followed in assessing national wetland inventory

Results and discussion

Review of the Africa dataset showed that there have been many wetland inventories and assessments undertaken in Africa, but that these were for different purposes, at differing geographical scales, and at differing levels of detail and coverage of different topics or emphases. In many inventories, a number of wetland types were not covered. For example, wetlands of <10 ha were not generally included, eg in South Africa, Zimbabwe and Zambia. Endorheic pans and seasonal wetlands were similarly poorly covered. The area of many wetlands (especially water bodies) was difficult to assess due to seasonal, annual and intra-annual variations. Human-made wetlands were also infrequently covered.

Overall, it was concluded that in 1998/9 only two African countries (South Africa and Tunisia) had adequate wetland national inventory information, although this required some updating and extension of coverage. Some 26 African countries had some wetland inventory information (either partial geographic coverage or inclusion of only some wetland types), but a further 26 had little or no inventory at the time of the survey (table 1).

Not unexpectedly, states (countries and territories) that had previously (recently) experienced, or were currently in, civil conflict were among those with the greatest paucity of data. These include Angola, Central African Republic, Chad, Ethiopia, Eritrea, Liberia, Libya, Mauritania, Niger, Rwanda and Western Sahara.

In line with the objectives of the study, most sources examined were national-scale inventory, but in the absence of such material some other supra-national sources were used, these amounting to almost one-third (30%) of sources. Inventory material assessed came from a great variety of different sources, both published and unpublished (figure 2), with some 45% being government-based sources, and a further 41% produced by non-governmental organisations. Most (86%) were in English, but this may reflect an inadvertent bias in the success of searching for material in French or other languages. Only 29% were in the form of a formal wetland inventory or directory. Many sources were unpublished, with only 38% being in relatively easily accessible publications. Most inventories (88%) were paper publications, with only 6% held as electronic databases. Few inventories (25%) were undertaken by national governmental organisations, with many having been undertaken by national or international NGOs, universities and research institutes and consultancies.

The information details accompanying the inventories was often incomplete or poorly presented. For example only 39% provided a summary of the work; only 40% listed areal estimates for each wetland type, although 39% did provide such information; and only 11% provided information on wetland loss and/or degradation.

National best estimates of the size of wetland resources were generated for each of the 54 African countries and territories covered by this review (appendix 1). The majority of wetland area estimates examined by this review (though not all) were approximations based on often dated aerial photography, soil and vegetation maps, and limited reconnaissance studies. Information gaps were identified using the best estimates and the results of the database analyses. The total area of wetlands estimated calculated by the Africa dataset (table 2) was ca. 123 000 000 ha, covering about 4% of the land surface. More than 85% of the area (ca. 107 500 000 ha) of these were inland wetlands, with less than 10% of the area (ca. 10 000 000 ha) described as marine/coastal wetlands and a further 5% (ca. 4 500 000 ha) described as man-made wetlands. Inland wetlands have, however, received considerably more inventory coverage than coastal/marine systems so the figures in table 2 for the latter are likely to be underestimates.

Table 1 Preliminary assessment of the status of national wetland inventory information for African countries and territories, based on the GRoWI-Africa dataset

Little or no inventory	Some but incomplete inventory	Adequate inventory, but requires updating and/or more detailed survey
Angola	Algeria	South Africa
Benin	Botswana	Tunisia
Burkina Faso	Cameroon	
Burundi	Republic of Congo	
Cape Verde	Democratic Republic of Congo	
Central African Republic	Cote D'Ivoire	
Chad	Djibouti	
Comoros	Egypt [1]	
Equatorial Guinea	Gabon	
Ethiopia [2]	Gambia	
Eritrea	Ghana	
Lesotho	Guinea	
Liberia	Guinea-Bissau	
Libya	Kenya [3]	
Mali	Madagascar	
Mauritania	Malawi	
Mauritius	Morocco	
Niger	Mozambique	
Rwanda	Namibia [4]	
Sao Tome & Principe	Nigeria	
Seychelles	Senegal	
Somalia	Sierra Leone	
Sudan	Tanzania	
Swaziland	Uganda [5]	
Togo	Zambia	
Western Sahara	Zimbabwe	

1. Considerably more information on Egyptian wetland may exist than was included in the preliminary analysis of the GRoWI dataset, but this information could not be obtained for this analysis.
2. There are plans for a wetlands program in Ethiopia, and this may lead to national wetlands inventory work. No further information was available at the time of this analysis.
3. The Kenyan Wildlife Service has been working on a Wetland Conservation and Training Program, in preparation for a planned national wetland inventory program (1999–2002) to be undertaken by the KWS and the National Environment Secretariat (Ministry of Environment)
4. A national wetland database is being established by the Ministry of Environment and Tourism, Namibia. It currently contains a GIS and Namibian wetlands bibliography, information on Ramsar Sites, and candidate Ramsar sites, as well as simple information on other wetlands, totalling approximately 3000 records. A working version was planned to be available in 1999.
5. Uganda has undertaken a preliminary national wetland inventory, but further information was unavailable for the GRoWI analysis.

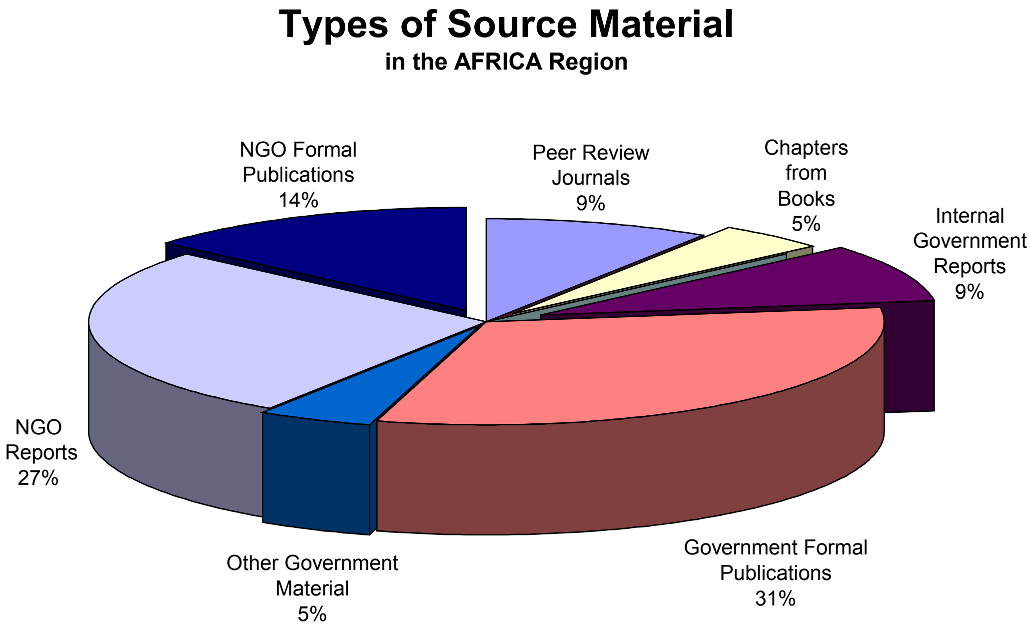

Figure 2 Types of source material used in assessing the status of African wetland inventory

Table 2 Estimates of wetland area in Africa (from Stevenson & Frazier 1999)

No. of countries/territories assessed	54
No. of national datasets identified for Africa	121
No. of national datasets assessed as comprehensive	33
Total area of wetlands (ha)	121 321 683–124 686 189
Marine/coastal wetlands (ha)	8 981 376–11 256 398
Inland wetlands (ha)	107 050 527–107 545 899
Man-made wetlands (ha)	4 590 892–4 657 892
Area of unspecified types of wetland (ha)	698 888–1 226 000

Recommendations made for African wetland inventory by the GRoWI project, many of which reflect also inventory recommendations in other parts of the world, are listed below:

- National wetland policies should be established, and national wetland inventory programs commenced as a priority. These should be organised in such a way as to enable easy updating and review.
- Existing preliminary wetland inventories should be expanded to form national wetland inventories.
- Existing wetland inventory material should be updated in order to assess changes (especially loss or gain). Where it does not already exist, a baseline should be established for measuring future changes in wetland area, function and values, and more baseline wetland inventory activities should be undertaken.
- Specific wetlands types which are currently under represented in inventories (eg wetlands of less than 10 ha in size, dambos and other man-made wetlands, endorheic and temporary wetlands) should be included in any future inventory activities.

- More efforts to integrate wetland surveys with bird surveys should be made, and basic wetland characteristics and function should be recorded. Much bird count related material was identified in this study, but often these contained little useful wetland information. For countries known to have few wetland assessment or management initiatives, it is especially important that ornithologists also examine and provide basic wetland inventory information. The African Waterfowl Census database, which is maintained by Wetlands International–AEME, has enormous potential to assist with this, particularly in at least some countries in West and Central African.
- The results of wetland inventory activities should be adequately advertised and published, particularly on the World Wide Web, or at least disseminated to a wide audience (including libraries).
- Clear objectives for wetland inventories should be identified prior to wetland inventory activities and these should be clearly stated in any wetland inventory documentation and publications.
- Bibliographic databases set up to list information sources of wetlands within a given country/territory should also provide details of where to obtain reference material, and provide contact details. Preferably, a system should be established where persons requiring particular information could contact one agency for this information. A clearing house or document supply centre would be very useful, and would improve information accessibility in Africa enormously. Information availability should not depend on the goodwill and resources of those in possession of particular material, unless they were the original authors.
- The presentation of data should become more accessible by inclusion of summaries and the avoidance of poorly organised bulky text descriptions in favour of tabulated results.
- A summary of findings including wetland type and area should be included in any wetland inventory.
- Wetland definitions and classification scheme used should be clearly stated. Definitions of imprecise terms such as ‘coastal’ and ‘inland’ wetlands should be clearly stated.
- Where only specific wetland types are included in a survey this should be clearly stated, and a definition of this type provided. Inclusions and exclusions should be clearly identified.
- The date of surveys and data compilations should be included, and if studies are part of a longer term program the details of this should be provided.
- The contact details of persons or agencies carrying out wetland inventory activities should always be included, as well as details of how to obtain copies of relevant information.
- Geographic co-ordinates, general location and names (local and other) should be included in wetland inventories, and where possible also a map. This was frequently lacking for much of the material examined for Africa.
- Tomàs Vives (1993) cited in Costa et al (1996) stated that all wetlands, independent of their importance, should be covered by a national wetlands inventory. This is particularly important in African countries, since the identification and designation of internationally important wetlands under the Ramsar Convention is either in its early stages, or has not yet begun, (at the time of the survey only 27 out of 53 countries in this region were Contracting Parties to the Ramsar Convention).
- The functions and values of each wetland site should be identified, including ecological, social and cultural values (Tomàs Vives 1993 in Costa et al 1996).

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Appendix 1 Best estimates of wetland area from national inventory in each African country/territory

	BEST ESTIMATES					COVERAGE INFO	
	Marine/coastal (ha)	**Inland (ha)**	**Artificial (ha)**	**Unspecified wetland type (ha)**	**Total (ha)**	No. of datasets accessed per country/ territory [1]	No. of datasets regarded as comprehensive in cover per country/territory
ALGERIA	121 380–134 380	585 500	8000		714 880–727 880	3	2
ANGOLA	70 000–110 000	400 000	unknown		470 000–510 000	3	1
BENIN	175 790	129 000	unknown		304 790	3	1
BOTSWANA	none	2 243 250	4405		2 247 655	2	1
BURKINA FASO	none	364 958	unknown		364 958	1	1
BURUNDI	none	499 000	unknown		499 000	1	1
CAMEROON	300 000	2 255 613	unknown		2 555 613	4	1
CAPE VERDE	no data	no data	no data		No data	0	0
CENTRAL AFRICAN REPUBLIC	none	3 150 000	unknown		3 150 000	1	0
CHAD	none	12 983 390	1 666 000		14 649 390	1	1
COMOROS	no data	no data	no data		No data	0	0
CONGO — DEM. REPUBLIC OF	37 400	14 551 095	unknown		14 588 495	3	1
CONGO — REPUBLIC OF	740 000	11 686 500	unknown		12 426 500	2	0
COTE D'IVOIRE	292 330	unknown	105 000–172 000		397 330–464 330	3	0

1 Excluding the Ramsar sites and GLCC databases

DJIBOUTI	1000	37 200	unknown		Unknown	2	0
EGYPT	2 634 550	711 200	unknown		3 345 750	2	0
EQUATORIAL GUINEA	27 700	unknown	unknown		27 700	2	0
ERITREA + Ethiopia [2]	58 100	unknown	unknown		58 100	1	0
GABON	175 900–257 500	3 968 875	unknown		4 144 775–4 226 375	5	0
GAMBIA	74 700	106 608	unknown		181 308	5	0
GHANA	117 800	460 050	895 225		1 473 075	4	1
GUINEA	250 000	121 500	unknown		371 500	5	0
GUINEA-BISSAU	200 000–364 900	unknown	unknown		200 000–364 900	4	0
KENYA	96 100	2 641 690	unknown		2 737 790	3	1
LESOTHO	none	unclear	unclear	20 000	20 000	2	0
LIBERIA	42 700	unknown	9000		51 700	3	0
LIBYA	Unknown	unknown	unknown		Unknown	1	0
MADAGASCAR	340 300–371 747	340 000	32 300		712 600–744 047	4	0
MALAWI	none	2 248 150	unknown		2 248 150	1	0
MALI	none	3 560 400	69 000		3 629 400	2	1
MAURITANIA	Unknown	unknown	unknown	668 888–1 196 000	668 888–1 196 000	5	2
MAURITIUS	no data	no data	no data		No data	0	0
MOROCCO	29 300–33 200	27 800–43 800	7500		64 600–84 500	2	2
MOZAMBIQUE	345 900	1 950 785	266 500		2 563 185	2	1?

2 Data exist but for pre-Eritrean independence only: substantial map work would be required to ascertain separate wetland areas coverage data for Ethiopia and Eritrea.

NAMIBIA	6500–9850	1 322 160–1 353 660	7533		1 336 193–1 371 043	3	0
NIGER	None	1 764 950	unknown		1 764 950	1	0
NIGERIA	1 346 775–3 238 000	5 527 060	123 000		6 996 835–8 888 060	4	1
RWANDA	None	348 100	unknown		348 100	1	0
SAO TOME & PRINCIPE	no data	no data	no data		No data	0	0
SENEGAL	508 000	663 000	unknown		1 171 000	5	2
SEYCHELLES	no data	no data	no data		No data	0	0
SIERRA LEONE	170 600	108 820	unknown		279 420	2	1
SOMALIA	91 000	600 000	unknown		691 000	2	1
SOUTH AFRICA	276 367	276 911	201 262		754 540	3	2
SUDAN	93 700	4 155 900	311 500		4 561 100	2	1
SWAZILAND	none	unclear	unclear	10 000	10 000	1	0
TANZANIA	200 000–245 600	8 389 286	85 000		8 674 286–8 719 886	4	2
TOGO	44 400	73 200	unknown		117 600	1	1
TUNISIA	113 084	1 182 915–1 207 915	20 787		1 316 786–1 341 786	3	2
UGANDA	none	4 451 703–4 874 575	unknown		4 451 703–4 874 575	2	1
WESTERN SAHARA	unknown	72 430	unknown		72 430	1	0
ZAMBIA	none	11 733 028	454 200		12 187 228	2	1
ZIMBABWE	none	1 358 500	324 680		1 683 180	2	1
Total estimated wetland cover	**8 981 376–11 256 398**	**107 050 527–107 545 899**	**4 590 892–4 657 892**	**698 888–1 226 000**	**121 321 683–124 686 189**	**121**	**33**

Regional wetland inventory approaches: The Mediterranean example

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Abstract

The Mediterranean region is rich in wetlands of great ecological, social and economic value. Yet these important systems have been considerably degraded or destroyed, a fact that was recognised in a major wetland conference in Grado, Italy in 1991 and which led to the Mediterranean wetland initiative known as MedWet. As a first step in the MedWet initiative a three-year preparatory project was launched in late 1992. This included the development of methods that could potentially improve wetland conservation in the Mediterranean region, with an emphasis on ensuring the wise use of wetlands and stopping and reversing their loss and degradation. One of the actions within MedWet was the development of methods for inventory and monitoring of wetlands, undertaken by the *Instituto da Conservação da Natureza* (Portugal) and Wetlands International. The immediate aims of this program were to assess the status of existing wetland inventories in the Mediterranean region, in order to identify gaps and review the adequacy of the methods in use, and to prepare a standard methodology for future inventories of Mediterranean wetlands. Whilst developing the inventory methodology we recognised the extremely diverse nature of the region and the resources available. We therefore sought to present a methodolgy which was flexible in terms of the level of detail required and which could be used to address a broad array of needs and situations. The inventory tools developed under the MedWet initiative consist of a manual explaining the inventory process, a set of inventory datasheets, a habitat description system, mapping conventions and a database software. These tools have been applied in test sites in each of the five European Mediterranean countries and in Morocco and Tunisia. The Portuguese national inventory will use the tools made available and other countries, such as France and Algeria, are currently using or planning to use these tools.

Keywords: Wetland inventory, Mediterranean, MedWet

Introduction

The Mediterranean region is rich in wetlands of great ecological, social and economic value. Typical Mediterranean wetlands refer to coastal areas and wetlands at low altitude. The lack of tides along most of the coastline also produce river deltas, such as those of the rivers Ebro, Po and Nile (Skinner & Zalewski 1995). Unfortunately these important systems have been considerably degraded or destroyed, a fact that was recognised in the Grado (Italy) Conference in 1991 (Finlayson et al 1992) that led to the Mediterranean wetland initiative known as MedWet. As a first step under this initiative a three-year preparatory project was launched in late 1992 by the European Commission, the Ramsar Convention, the governments of the five countries of European Union within the Mediterranean region and several NGOs (Wetlands International [then known as the International Waterfowl and Wetland Research Bureau], Station Biologique de la Tour du Valat, World Wide Fund for Nature and Greek Biotype/Wetland centre [EKBY]).

This project focused on that part of the Mediterranean region within the European Union (EU) and included the development of methods that could potentially improve wetland conservation in order to stop and reverse the loss of wetlands, as well as to ensure their wise use. Five actions were carried out with each being developed by cooperation between a government and an NGO. One of these was the development of methods for inventory and monitoring of Mediterranean wetlands, developed jointly by the Instituto da Conservação da Natureza (Portugal) and Wetlands International.

The inventory project

The immediate aims of the MedWet inventory program were: (1) to assess the status of existing wetland inventories in the Mediterranean region in order to identify gaps and review the adequacy of methods in use, and (2) to prepare a standard methodology for carrying out inventories of Mediterranean wetlands.

In a first step a review of all wetland inventories, both at national and international levels, was made (Hecker & Tomàs Vives 1995). The results of this review revealed that only a few countries had undertaken a national inventory (Spain, Italy, Tunisia and Greece) and a few had prepared a preliminary inventory, while most did not have an inventory of any sort. Also, the main methods used in each of the inventories was analysed in terms of their classification systems, site selection criteria, wetland delineation criteria, data collection schemes and mapping protocols.

From these conclusions, we recognised the extremely diverse nature of the region and the resources available — this was a major concern and was kept in mind when developing standard methodologies for wetland inventory in the region. Therefore, we have sought to present a methodolgy which is flexible in terms of the level of detail required, and which can be used to address a broad array of needs and situations. In order to prepare the methods, a coordination team was assisted by an advisory group comprising wetland experts from many countries in the region, as well as from other countries.

The methodology was based on four main features: it should be (a) standardised to allow consistent use throughout the region and to allow comparisons between inventories, (b) comprehensive, to include all relevant information, (c) flexible, to allow use by entities with diverse resources, and (d) compatible, to assure comparisons and exchange of information with ongoing programs, such as the Ramsar database, the CORINE biotopes and the EU's Natura 2000 network.

The inventory tools developed under the first stage of the MedWet initiative consist of a manual explaining the inventory process (Costa et al 1996), a set of inventory datasheets (Hecker et al 1996), a habitat description system (Farinha et al 1996), mapping conventions (Zalidis et al 1996), and database software (Tomàs Vives et al 1996).

The methodologies developed under the MedWet project are meant to be a set of tools that can be applied in the Mediterranean and contribute to wetland conservation in the region. Although there is the possibility of using these tools to develop and coordinate a regional inventory in the future, these tools have, to date been presented as a standard tool for undertaking wetland inventories at local or national level.

The inventory process

General description and procedures

The inventory is based on three levels of information: the catchment area, the wetland site and the habitat. Information collected at the catchment level avoids repetative inputing of data common to every site within the catchment. The site level includes essential information to be collected at each wetland, while the habitat level entails recording detailed data and provides a baseline for site management and monitoring.

As mentioned above, a preliminary assumption in the preparation of the methodology was that the resources available vary from country to country and sometimes within each country. As such, the flexibility of the method relies on the definition of the different phases of information collection, as decided by the inventory coordinators.

A common set of procedures can be used at any level and these define the basis of the methodology used in the inventory. The five main components identified were: (1) site selection, (2) wetland identification, (3) classification system, (4) data collection and storage, and (5) the mapping procedure. After formulating the objectives of the inventory and identifying the available resources in terms of staff, expertise, equipment and information, decisions can be made on developing the three phases of wetland inventory. The process becomes more comprehensive and complex from phase 1 to phase 3 (table 1).

The first phase involves a *review of existing information*. Compilation of existing data on known sites, using all available sources of information (bibliography, maps, databases) is done. This does not require fieldwork and should be done before the collection of new data. At the end of this phase there will be a list of wetlands with available information, the location of those sites and some data on the biological, social, economic and legal status of the wetlands included. An example of this phase is the preliminary inventory of Portuguese wetlands (Farinha & Trindade 1994).

The second phase is called the *simple inventory*. Here a compilation of additional information about all the sites identified in phase 1 is done, with a higher level of detail, as well as the gathering of information on ‘new’ sites. This may require some fieldwork and moderate resources. This phase is essential as a minimum effort for recognising the wetlands within the area considered and their attributes. Further to the results from the first phase it identifies most wetland sites within the area considered, complete data at site level, wetland area identification for the sites included, compatibility of data with other international programs and assessment of the relative importance of the sites described.

The third and more complex phase, is called the *detailed inventory*. Here, detailed information about each site is compiled and detailed maps, ideally using a GIS are produced. In this phase, the importance of the sites for nature conservation and for local communities should be fully evaluated. Intensive fieldwork and wetland knowledge will be necessary, and more substantial resources are needed. This phase is particularly useful for local management, providing baseline information for planning and monitoring.

Table 1 Phases in the development of a wetland inventory using the MedWet methodology

	Research of existing information	Simple inventory	Detailed inventory
Site selection	Include all the sites for which there is some information	New sites must be located and recorded. Criteria for their inclusion must be set out.	A fully comprehensive inventory should be completed with all the wetlands within the area considered
Wetland identification	No effort is required for precise wetland identification	Wetland identification should be assessed at least for the less obvious boundaries	Precise identification should be undertaken, allowing ecological units to be delineated
Classification system	A detailed wetland classification is not needed, but some general categories or description should be used	A wetland type classification, such as Ramsar is sufficient	A detailed classification system of wetland habitats is required
Data collection and storage	It is important to assess the information existing and to identify the people with knowledge about each wetland site	Standard datasheets and database should be completed	Datasheets and database should be completed in order to allow a comprehensive coverage and output of the information
Mapping procedure	At least a national map with the location of the sites	A sketch map for each site should be included	Detailed habitat maps, ideally using GIS and photointerpretation devices should be produced

Collection of information — datasheets

A set of datasheets were produced in order to provide basic concepts and procedures for the recording of data necessary for the inventory, having in mind three principles: compatibility, uniformity and flexibility.

The datasheets are based on experience and compatibility ensured by the inclusion of information fields required by existing international programs which include wetland inventory (eg Ramsar Convention, Natura 2000). They assure uniformity because the data categories presented in the datasheets (table 2) cover a broad array of information which can be described in a standard way. By flexibility we mean that a selection of fields can be made by the inventory coordinator taking into account the objectives and the resources available (technical, financial and human).

The MedWet methodology for data recording proposes three datasheets, each one corresponding to one level of information: catchment area, wetland site and habitat. These datasheets allow the recording of information at the level of detail required in each case and avoid duplication. To complement them, additional information can be collected in specific forms: flora, fauna, activities and impacts, meteorological data and references.

Table 2 Main data categories included in each of the datasheets for data collection

Catchment area	Wetland site	Habitat
Identification	Identification	Coding
Location	Location	Water permanency
Physiographical information	Description	Area
Population and landcover	Values	Maximum depth
Impacts and threats	Status	Condition of the habitat
		Artificiality of water regime
		pH range
		Description
	Additional datasheets:	
	Flora	
	Fauna	
	Activities and impacts	
	Meteorological data	
	References	

Characterisation of wetlands — classification system

Three classification systems are suggested for use with the inventory methods (Ramsar wetland types, CORINE Biotopes and MedWet Classification System). Although the Ramsar and CORINE systems can be used in a simple inventory, for detailed inventory and mapping it is strongly recommended that the MedWet system which is based on the US wetland classification system (Cowardin et al 1979) is used.

The MedWet classification consists of a hierarchical system for making detailed descriptions of wetland habitats and is intended to describe ecological units that have certain homogeneous natural attributes. The use of these units for mapping purposes, by drawing boundaries, not only provides data for inventory and analysis, but also provides information for monitoring and management.

The MedWet classification develops from systems (marine, estuarine, lacustrine, palustrine and riverine) at the top of the hierarchy, to subsystems (eg tidal, limnetic, littoral), classes (eg water surface, emergent, aquatic bed), and subclasses (eg persistent or non-persistent under class emergent). Furthermore, modifiers can be added, in order to describe the habitat in terms of water regime, salinity and artificiality.

Mapping the wetland sites — photointerpretation and cartography

A mapping procedure was developed in order to spatially identify wetland habitats. The identification and delineation of wetland habitats are based on the MedWet classification and detailed information for its application is available in the format of standard photointerpretation and cartographic conventions.

The method consists of four phases: (1) collection, screening and evaluation of existing data, (2) fieldwork, (3) photointerpretation and production of the final wetland habitat description map, and (4) digital map production using GIS. The work is based on information captured from aerial photographs combined with ground data and pre-existing data.

The production of maps using these methods is time-consuming and requires some investment and resources, but considered crucial for local wetland management.

Storing and analysing the inventory data — the MedWet Database (MWD)

All the information collected with the datasheets can be entered into the MedWet Database (MWD), which allows the storage, analysis and presentation of the inventory information and possible compilation of information at a Mediterranean level. The software mimics as closely as possible the datasheets used for recording the data in the inventory.

The first version of the MWD program was launched in late 1996 and has been produced in the programming language of FoxPro® 2.6 for DOS. This allows the storage of data in DBF files, so they can be easily imported/exported from and to other database software. A second version is being developed in Windows environment, improving data entry time and presentation capabilities.

Output procedures allow the user to produce reports from the MedWet Database, through a wide range of formats. These include outputs in the format designed under Ramsar Convention and Natura 2000 datasheets formats.

Use of the MedWet inventory tools

The methodologies delineated during the three years of the project were tested and refined in pilot studies in Portugal, Spain, France, Greece and Morocco. By the end of this first phase of the MedWet initiative, all the methods were tested in one pilot site in each of the European Union countries in the region (Papayannis & Montemaggiori 1996): Sado estuary (Portugal), Aiguamolls de l'Empordà (Spain), Étang de l'Or (France), Diaccia Botrona (Italy) and Lake Kerkini (Greece).

A second phase of the MedWet initiative took place in subsequent years, applying the MedWet tools in five other countries in the Mediterranean region: Morocco, Algeria, Tunisia, Croatia and Albania. This constituted another opportunity to test and validate the methodologies that had been developed. Other MedWet projects are planned for the near future, expanding the geographical range of the countries using these methods within the Mediterranean.

The methods are being used or are planned to be used in wetland inventories in Portugal, France, Slovenia, Albania, Greece, Algeria and Morocco. Other countries (eg Cambodia, Columbia and South Africa) have also referred to these methods to some extent when developing their own inventory programs.

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Developing a wetland inventory policy and process in Latin America: The Colombian example

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Abstract

A wetland inventory and assessment was made as a basis for development of a national wetlands policy for Colombia (CMWP). Major wetlands were identified from a 1:1 500 000 scale national hydrological map. Of 57 major wetlands in 27 catchments or wetland complexes, wetlands in 16 of these were selected for assessment. Wetland type, ecological status and wetland value for each wetland was scored using the Mediterranean Wetland Inventory System methodology and classifications. Comparison of average scores for ecological status and wetland values showed that wetlands in largely natural condition also had high wetland values and functions, whereas those with poor ecological status had lower values scores. The analyses provide a basis for establishing priorities for the development of national wetland policy and conservation priorities. The study demonstrates that the MedWet inventory system can be readily applied in other parts of the world.

Keywords: national wetland policy, Latin America, wetland inventory

Introduction

At an early stage in the development of a Colombian National Wetland Policy (CNWP) it became clear that improved national wetland inventory was needed. A comprehensive inventory that did not miss important wetlands owing to use of fragmented information sources was identified as necessary for providing a basis for the development of four main CNWP goals:

1 identification and preservation of wetlands of global or regional importance for biodiversity conservation;

2 development of a legal framework for the protection and/or restoration of wetlands affected by development projects;

3 establishment of sustainable wetland use programs; and

4 encouragement of local communities in wetland sustainable management.

Methods

The inventory approach adopted was to compile, as far as possible, standard baseline information to make an assessment of current wetland status, functions and values, which in turn could provide the basis for a program to monitor wetland status. This paper summarises the methods and overall results from this project, which is described more fully in Naranjo (1998) and Naranjo et al (1999).

As a basis for identifying major wetlands for assessment, the country was divided into 6 major eco-regions and then 27 river catchments or wetland complexes with common natural attributes within these eco-regions. For each of these catchments/complexes major wetlands as shown on the official national hydrological map (scale 1:1 500 000), were identified. Information collected for this analysis was restricted to inland wetlands, since in Colombia coastal management is undertaken separately from that for inland systems.

The Mediterranean Wetland Inventory System (Costa et al 1996) was used as the basis for coding the features of each selected major wetland. Each wetland was classified to wetland type subclass, following Farinha et al (1996). The ecological status of each wetland was classified according to Costa et al (1996), with modifications to the natural system being assessed in three categories: hydrological modification, urbanisation/industrial modifications and exploitation of renewable natural resources. Each category was scored on a scale of 0–4, with 0 indicating a large amount of modification and 4 a natural wetland. This scoring system was used in the South American Wetland Assessment (Wetlands International 2001).

Wetland value was assessed following the MedWet methods described by Hecker et al (1996), and also scored in three categories: wetland functions, wetland products and wetland attributes. Again each category was scored on a scale of 0–4, with 0 indicating no value and 4 a high value. Thus a high score indicates that a wetland has a large value for its products and functions.

Average scores for wetlands within each catchment/complex were calculated for each of the three status and three value categories. Total scores for status and for value were then obtained by summing the three category scores for each.

Results and discussion

Overall, 57 major wetlands in 27 catchments/complexes were identified from the hydrological map, but wetlands in only 16 of the catchments/complexes were selected for detailed analysis. The average status and value scores for wetlands in these catchments/complexes are given in table 1. Wetlands in the other catchments or complexes were not assessed because either they were predominantly estuarine/marine, artificial, or because no major wetlands were identifiable from the hydrological map.

Comparison of the ecological status and wetlands values for the different catchments/complexes provides an initial basis for establishing policy and conservation priorities for Colombian wetlands. Figure 1 shows that catchments with wetlands in largely natural condition have important values and functions, and that heavily modified wetland systems provide generally poorer values and functions.

This study also illustrates that the basic methods for wetland assessment developed by the Mediterranean Wetland Inventory System can be readily applied to wetlands in other parts of the world — in this case Colombia — and can be used to establish the basis for setting conservation priorities for wetlands.

Table 1 Average total assessment scores for ecological status and wetland value for major wetlands in 16 catchments/complexes in Colombia

Eco-region	Catchment/complex	Ecological status	Wetland value
Caribbean	Río Atrato	15.8	6.81
	Río Sinú	13.47	8.88
	Depresión Momposina	13.82	7.06
	Bajo Magdalena	13.96	6.77
	Canal del Dique	13.66	9.22
	Alto Río Cauca	14.41	7.94
	Magdalena Medio	14.86	6.27
Pacific	Interior	15.97	5.22
Montane	Central	16	3.44
	Oriental	15.47	6.75
	Macizo Colombiano	15.18	6.64
Orinocoan	Río Vichada	15.92	6.36
	Río Tomo	16	8.11
Amazonian	Río Apaporis	15.62	6.97
	Río Caguán	15.29	7.31
	Río Caquetá	15.52	6.36

Catchments/complexes not included in the analysis: Caribbean: Delta Río Magdalena; Orinocoan: Río Arauca, Río Meta, Río Casanare, Río Guaviare, Río Inírida; Amazonian: Río Vaupés, Río Putumayo, Río Amazonas; Catatumbo: Río Catatumbo

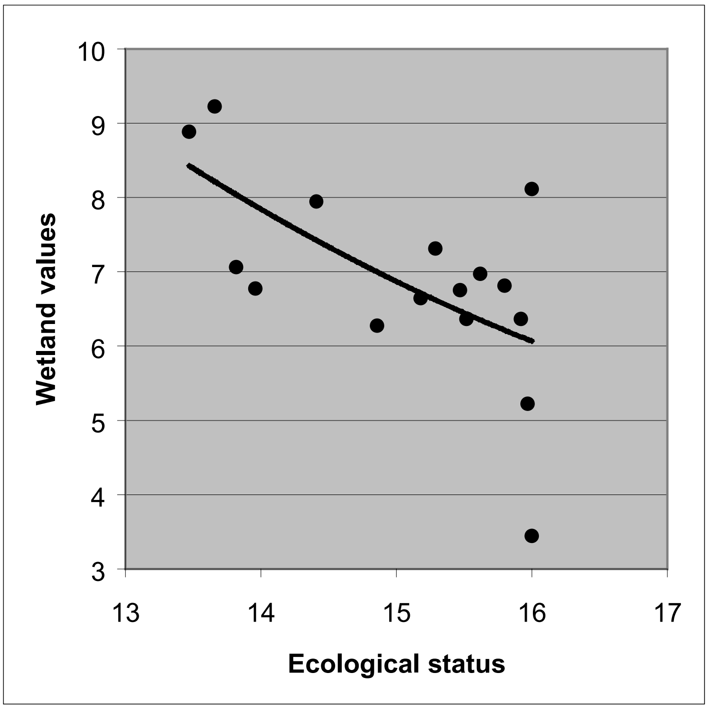

Figure 1 The relationship between the average ecological status and wetland value scores for major wetlands in 16 Colombian catchments/complexes (scores from table 1).
The trend line shows that highly modified wetlands tend to have lower wetland values ($y = 0.0844x^2 - 3.4215x + 39.193$; $R^2 = 0.3771$; $P<0.02$).

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Renforcer les connaissances pour une conservation dynamique des infrastructures naturelles 'zones humides'

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Abstract

The French Government's 'Action Plan for Wetlands', initiated in 1995, aims at stopping the degradation of wetlands, at guaranteeing their preservation through wise management, at encouraging restoration and rehabilitation of important habitats. The Plan has four major fields of action, the first regarding inventories and monitoring and evaluation tools. Advantages and disadvantages of the various approaches which have been implemented are being reviewed with regard to the objectives of the Plan: updating of the lists of sites of international or national importance, creation of the National Wetland Observatory, work of the National Wetland Research Programme, as well as complementary initiatives by public or institutional partners. The French approach is original in that it is based on the deliberate will to consider wetlands as natural infrastructures which should be integrated into policies for land-use planning, modernisation of agricultural practices, tourism and water management. This choice entails the development of models and methods which allow the demonstration of wetlands' ecological functions as well as socio-economic evaluation of the services they provide. How does this work contribute to the design of more efficient intervention measures? Can they be useful in other geographical and political contexts?

Keywords: action plan, wetland inventory, observatory, research, evaluation, functions, values

Résumé

Le Plan d'action gouvernemental français pour les zones humides, initié en 1995, vise à arrêter la dégradation des zones humides, à garantir leur préservation par une bonne gestion, à favoriser la restauration et la reconquête des milieux importants. Il comporte quatre principaux domaines d'intervention, le premier concernant les inventaires et outils de suivi et d'évaluation.

Les avantages et inconvénients des différentes démarches mises en oeuvre sont examinés par rapport aux objectifs du plan: actualisation des listes de sites d'importance internationale ou nationale, création de l'Observatoire national des zones humides, travaux du Programme national de recherche sur les zones humides, ainsi que les initiatives complémentaires de partenaires publics ou associatifs. L'originalité de l'approche française repose sur une volonté délibérée de considérer les zones humides comme des infrastructures naturelles devant être

intégrées aux politiques d'aménagement du territoire, de modernisation agricole, de tourisme et de gestion de l'eau. Cette option implique le développement de modèles et de méthodes permettant la démonstration de leurs fonctions écologiques ainsi que l'évaluation socio-économique des services rendus. En quoi et comment ces travaux contribuent-ils à la conception de mesures d'intervention plus efficaces? Peuvent-ils être utiles dans d'autres contextes géographiques et politiques?

Mots-clés: Plan d'action, inventaire, observatoire, recherche, évaluation, fonctions, valeurs

1 Introduction

Bien que protégées en principe, par différents textes juridiques nationaux et internationaux adoptés progressivement depuis les années soixante, les zones humides françaises n'ont cessé de voir leur situation se dégrader, en dépit d'une reconnaissance croissante, mais encore limitée, de leurs valeurs et de leurs fonctions. Comme dans de nombreux pays de l'Union européenne, en France, la surface en zones humides a diminué d'environ 60% depuis le début de ce siècle. C'est paradoxalement au cours de ces dernières décennies que la destruction a été la plus prononcée (Baldock 1984, CCE 1995).

Alerté de cette situation par différentes organisations de conservation de la nature et par certaines instances scientifiques, et fort du constat qu'il manquait une réelle politique française de conservation et d'aménagement de ces milieux, le Gouvernement français a réagi. En 1991, le Comité interministériel de l'évaluation, présidé par le Premier Ministre, a décidé de faire conduire sur trois ans une évaluation des politiques sectorielles (agriculture, aménagement rural, équipement, tourisme etc) et de protection, ayant un impact négatif ou positif sur les zones humides.

Une Instance spécifique, présidée par un haut fonctionnaire, composée en proportion équivalente d'experts, de représentants des usagers et de responsables de départements ministériels, a été mise en place à cette occasion. Elle a eu pour objectifs: d'identifier les politiques impliquées dans l'évolution des zones humides, d'estimer leurs répercussions, d'analyser les logiques d'action ayant guidé leur mise en oeuvre, d'examiner la cohérence du droit appliqué à ces espaces et de mesurer l'efficacité des moyens de conservation et de restauration de ces milieux. Il s'agissait donc d'établir un constat de l'action publique en faveur ou en défaveur des zones humides, et de dégager des priorités d'actions pour l'avenir afin de remédier à cette situation (Bernard 1994).

Dans un premier temps, l'état des lieux a été dressé à l'aide d'un questionnaire envoyé à un large réseau d'experts et portant sur un échantillon représentatif de 87 zones humides françaises. La deuxième phase d'étude visait à comprendre, à partir d'entretiens, comment les administrations et les collectivités locales gèrent les zones humides et à formuler des propositions visant à améliorer cette gestion. A la suite de ces travaux, l'Instance d'évaluation a élaboré de façon collégiale des conclusions et des recommandations. Le bilan a montré les effets contradictoires des différentes actions sectorielles menées par les administrations. Les experts ont estimé que 67% des zones humides métropolitaines ont disparu depuis le début du siècle, dont la moitié en 30 ans (1960–1990). Ils ont souligné '*que la tendance à la régression est forte et rapide*' (Bernard 1994). Selon eux, le bilan de santé s'est révélé plus alarmant que supposé car, malgré les mesures de conservation existantes, la tendance à moyen terme correspondrait au mieux à un ralentissement de leur dégradation. Ainsi, sur les 87 sites étudiés, 76 sites se sont dégradés, dont douze massivement, neuf sont jugés stables et trois en évolution positive (Lierdeman & Mermet 1994). Les principales causes de la dégradation sont: (*i*) le changement de l'occupation du sol lié à une intensification des pratiques agricoles ou à l'abandon d'usages extensifs, (*ii*) les aménagements touchant le réseau hydrographique et modifiant les régimes hydrauliques, et (*iii*) la détérioration de la qualité de l'eau.

Suite à ces travaux, une des idées maîtresses retenues fut la reconnaissance des zones humides en tant qu' '**infrastructure naturelle**' remplissant des fonctions écologiques et hydrologiques, ayant donc une valeur économique aussi bien que patrimoniale. Il a alors été recommandé d'adopter une stratégie volontaire destinée à inverser les tendances à la dégradation de ces espaces. Pour atteindre cet objectif, l'élaboration d'un plan national d'action pour les zones humides a été envisagée, s'appuyant sur la loi sur l'Eau adoptée en 1992.

2 Le Plan d'action français pour les zones humides

Adopté en 1995 par le Gouvernement, ce Plan a pour objectifs d'arrêter la dégradation de ces milieux, de garantir leur préservation par une bonne gestion, de favoriser la restauration des milieux importants, de reconquérir les sites d'intérêt national. La démonstration de l'intérêt écologique, économique et sociologique des zones humides conduit maintenant à les *considérer comme des* ***infrastructures naturelles*** *qui devront être prises en compte en tant que telles dans les politiques d'aménagement du territoire, de modernisation agricole, de tourisme et de gestion de l'eau*. Le Plan se décline en quatre grands domaines d'intervention complémentaires à mettre en oeuvre simultanément: (*i*) inventorier les zones humides et renforcer les outils de suivi et d'évaluation, (*ii*) assurer la cohérence des politiques publiques, (*iii)* engager la reconquête des zones humides, (*iv*) lancer un programme d'information et de sensibilisation.

Chaque axe comporte une série de mesures et de recommandations. Dans la mesure où de nombreuses destructions ou dégradations de zones humides sont dues à l'ignorance de leur localisation et de leurs rôles réels, le premier de ces volets constitue une étape incontournable.

3 Les programmes visant à mieux connaître les zones humides et à suivre leur évolution

Pour *inventorier les zones humides et renforcer les outils de suivi et d'évaluation*, plusieurs programmes ont été initiés dès 1995. Ils visent à recenser les zones humides d'intérêt international ou national, à développer des inventaires, à mettre en place un Observatoire national des zones humides, et à renforcer les moyens de la communauté scientifique dans le cadre d'un programme national de recherche sur les zones humides (fig 1).

Identifier la ressource en zones humides

La liste des zones humides d'importance internationale

Depuis l'adhésion de la France à la convention de Ramsar en 1986, 18 sites ont été inscrits sur la *Liste des zones humides d'importance internationale*. En 1989, pour favoriser le processus d'inscription, une liste "officieuse" des zones humides d'importance internationale (*shadow list*) comportant 34 sites, établie en fonction essentiellement de critères relatifs aux oiseaux d'eau, avait été adoptée par le Comité français de la Convention de Ramsar. Cette liste méritait d'être actualisée puisque de nouveaux critères ont été adoptés ou révisés lors des Conférences des parties de Montreux (1990), Kushiro (1993), Brisbane (1996). En 1988, elle a été complétée en tenant compte plus particulièrement des critères relatifs aux poissons, mollusques et crustacés (Résolution VI.2) et de la sous-représentation de certains types de zones humides: récifs coralliens, mangroves, herbiers marins, tourbières (Résolution VI.3).

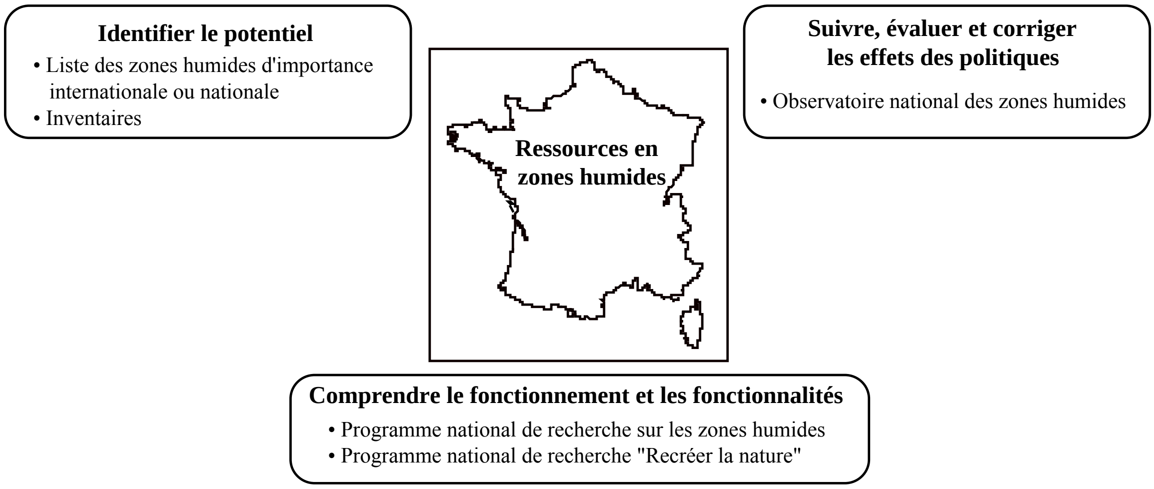

Figure 1 Organisation des actions prévues par le Plan et visant à mieux connaître la ressource en zones humides (Organisation of actions foreseen in the Plan and aiming at increasing the knowledge of wetland resources)

La nouvelle liste 'officieuse' comprend donc 135 sites dont 99 zones humides localisées en métropole, sept dans les départements d'outre-mer, 29 dans les territoires d'outre-mer et îles bénéficiant d'autres statuts. La sélection a été réalisée à partir de l'examen des inventaires existants et de la consultation d'experts (Léthier 1998). Ont été retenus les sites figurant sur la liste de 1989, les zones humides ayant fait l'objet d'un dossier soumis au Comité national Ramsar dont une sélection de sites du Conservatoire du littoral, et les Zones Importantes pour la Conservation des Oiseaux (Directive européenne 'Oiseaux' 1979) à dominante humide (Rocamora 1994). A partir de données bibliographiques et d'avis d'experts, ont été ajoutées des zones humides abritant une sélection d'espèces endémiques, ou en danger: de poissons, de mollusques, de crustacés (critères 4), de reptiles et amphibiens (critères 2); ainsi que des tourbières, récifs coralliens ou herbiers marins de grand intérêt (critères 1). Il s'agit donc d'une sélection sur des critères essentiellement patrimoniaux, la caractérisation de l'importance des fonctions hydrologiques naturelles pour la désignation de sites Ramsar étant encore en discussion (Résolution VI.3).

La liste des zones humides d'importance nationale

Cette liste a pour objectif d'orienter les actions menées dans les zones humides[1] d'intérêt national: suppression des aides publiques aux travaux d'aménagement agricole ou forestier inappropriés, mise en place de contrats pluriannuels de gestion des zones humides, etc. Elle est en cours d'élaboration au Muséum national d'histoire naturelle (MNHN-IEGB). La méthode d'identification correspond à celle déjà appliquée précédemment (exploitation d'inventaires existants, avis d'experts), mais les critères et sources utilisées sont en partie différents. Outre une identification de la valeur patrimoniale selon des paramètres classiques concernant la présence d'espèces et d'habitats protégés ou retenus dans les directives européennes ('Oiseaux', 'Habitats'), a été intégrée, dans la mesure du possible, une évaluation générale du rôle des milieux humides vis-à-vis de la gestion de la ressource en eau (stockage, soutien d'étiage, épuration, ...). Pour ce critère 'hydrologique', ce sont les données provenant des inventaires réalisés, conformément au Plan d'action, par les Agences de l'eau et les Directions régionales de l'environnement (DIREN) lors de l'élaboration des Schémas

1 Selon la définition par de la loi sur l'eau (1992).

Directeurs d'Aménagement et de Gestion des Eaux (SDAGE)[2] qui ont été exploitées. Un total de 257 zones humides remarquables ont ainsi été recensées en métropole (Redaud 1995) et figurées dans la plaquette d'information présentant le Plan d'action (Léthier 1996).

Vers une harmonisation des méthodes d'inventaires de zones humides

Pour des raisons techniques, financières mais aussi stratégiques, le Gouvernement français n'a pas souhaité mettre en oeuvre un inventaire national exhaustif des zones humides selon une méthode définie. De ce fait, divers inventaires ont été initiés par des groupes scientifiques ou associatifs, des administrations (DIREN, Direction départementale à l'agriculture et à la forêt, Direction départementale à l'équipement, ...), et des Agences de l'eau. Ces inventaires thématiques concernent soit des types de zones humides, soit des territoires (région, département, bassin).

Dans ce contexte, le responsable du Plan d'action pour les zones humides, souhaitant une harmonisation des démarches, a créé, en 1998, un groupe de travail *Inventaire des zones humides*. Sa première mission a consisté à faire le point sur les différentes initiatives en cours ou programmées, leurs objectifs, les méthodes utilisées (délimitation, typologie, techniques de recensement, tableaux de bord des SDAGE, ...). Actuellement, des convergences sont recherchées entre l'inventaire national des Zones Naturelles d'Intérêt Écologique, Faunistique, Floristique (ZNIEFF), en cours de modernisation (Maurin et al 1997), et les inventaires de zones humides d'intérêt patrimonial (de Féraudy 1998). A la demande des Agences de l'eau, des travaux sont envisagés en 1999, sur la mise au point de critères (hydrologiques, pédologiques, économiques) permettant de mieux caractériser et d'évaluer les fonctions et services rendus par les zones humides.

Suivre, évaluer et corriger les effets des politiques

L'Observatoire national des zones humides (ONZH) est confié à l'Institut Français de l'Environnement (Ifen 1998). Le ministère de l'Environnement a assigné à l'ONZH cinq missions : faire le point sur la situation actuelle des zones humides, coordonner et améliorer le suivi de leur évolution, développer la capacité d'expertise française dans ce domaine, aider à l'élaboration et au suivi des politiques sectorielles (agriculture, équipement...) et de la politique de préservation, dans le cadre du renforcement de la concertation ministérielle, diffuser les informations recueillies.

Les principes sous-jacents à la constitution de cet Observatoire se déduisent de son objectif principal : **l'évaluation écologique et socio-économique des effets de politiques** pour fournir des éléments permettant aux responsables administratifs et politiques de les réorienter.

Compte tenu du but ultime du projet, il semble plus judicieux et efficace de concentrer l'effort sur les principaux processus à l'origine de la dégradation ou de l'amélioration des zones humides et de proposer des moyens d'évaluer leurs effets sur un échantillon de sites.

Le parti pris de départ étant la valorisation des bases de données et des réseaux d'informateurs existants, les résultats de divers programmes de suivi des changements écologiques (plans de gestion d'espaces protégés), des réseaux de mesures physico-chimiques, sont à prendre en compte dans la mesure où ils apportent des informations pertinentes. Les méthodes et protocoles produits doivent avoir pour principales caractéristiques d'être simples, robustes et flexibles, afin d'intégrer au fur et à mesure les progrès des connaissances.

2 Les SDAGE, prévus par la loi sur l'eau, ont pour objectif de fixer les orientations fondamentales d'une gestion équilibrée de la ressource en eau dans les six grands bassins hydrographiques de France métropolitaine.

A partir du diagnostic de l’état de 94 zones humides d’importance majeure, appréhendées globalement comme des entités fonctionnelles correspondant à des infrastructures naturelles, il s’agit de mettre en place un suivi de leur évolution en fonction de changements des activités humaines. Un atlas, comprenant une carte et un tableau de bord pour chacune des zones humides, est en préparation. La carte provient de l’exploitation des données de CORINE Land cover recoupées avec les contours d’espaces inventoriés (ZNIEFF, ZICO) ou protégés. Les informations du tableau de bord sont extraites d’une base de données, adaptée de celle mise au point pour le programme Medwet (Costa et al 1996). Cette base est renseignée à partir des fiches remplies lors de l’évaluation des politiques publiques, qui ont été actualisées et complétées, notamment par les bases de données de l’Ifen. Les principales rubriques traitées correspondent à la présentation du site, son type, le périmètre d’observation, des renseignements administratifs, physiques, sociologiques et économiques, des données sur les protections, la faune, la flore, les pressions et les enjeux, les évolutions prévisibles. Ces informations seront également utilisées pour le suivi des zones humides des SDAGE.

Simultanément, le Muséum national d’histoire naturelle apporte un appui méthodologique en effectuant des études et des recherches en amont à la conception de l’Observatoire, sur la mise au point d’indicateurs par catégories d’activités ou par thématiques jugées prioritaires (Barnaud et al 1996). Le principe commun retenu pour mener à bien ces travaux est de traiter des thématiques en relation avec des politiques sectorielles (fig 2). Ces dernières sont appréhendées:

- soit individuellement, tels les effets du développement de la populiculture (Fouque 1996), des extractions de granulats (Dubien et Bouni 1996), des activités cynégétiques (Schricke et al 1997) ;
- soit de manière groupée, telle l’évolution des prairies humides, milieu bien représenté dans les sites de l’Observatoire et ayant subi une dégradation intense due aux changements des pratiques, en particulier agricoles (Dubien et al 1998), ou l’évaluation des conditions hydrologiques des sites en raison d’aménagements hydrauliques et de prélèvements d’eau (Poinsot 1998).

L’accent est mis sur la formulation des questions relatives aux enjeux majeurs pour aboutir à la proposition d’indicateurs d’évolution dont l’application permet en retour de renforcer ou de modifier les politiques incriminées. Des études générales visant à fournir des éléments utiles à l’ONZH complètent le dispositif: analyse d’opérations comparables à l’étranger (Bouni & Dubien 1996) ou d’autres observatoires nationaux (Bouni & Cattan 1997).

Comprendre le fonctionnement et les fonctionnalités

Le Programme national de recherche sur les zones humides (PNRZH)

Le Plan d’action prévoit la mise en place, au sein d’une structure scientifique fédérative (GIP HydrOsystèmes), ‘*d’un pôle de recherche interdisciplinaire sur les zones humides*’, dont l’objectif est d’approfondir ‘*en particulier les fonctions socio-économiques et les conditions du maintien et de la restauration des zones humides*’. Dans ce but, un programme de recherche, doté d’un budget de 15 600 000 FF, a été initié. Il vise à conforter la notion "d’infrastructure naturelle" appliquée à ces milieux. A cette occasion, un partenariat fort entre Agences de l’eau et ministères concernés (Environnement, Agriculture, Équipement) a été établi par la signature d’une convention cadre d’une durée de trois ans (1997–2000). Deux instances complémentaires (Comité scientifique, Comité de pilotage) assurent la prise en compte des points de vue des scientifiques et des praticiens de la gestion des zones humides.

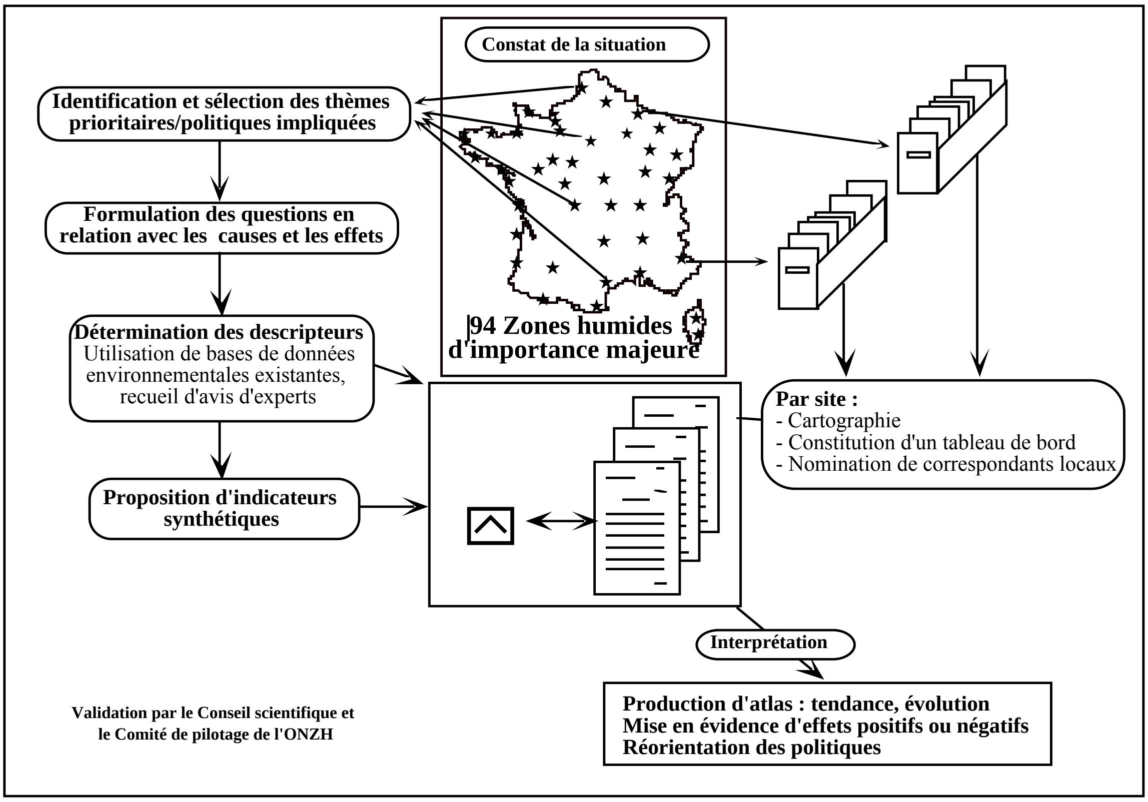

Figure 2 Présentation schématique de la démarche adoptée et préfiguration du dispositif de l'Observatoire national des zones humides (Diagram showing the approach which has been adopted, and foreshadowing the organisation of the National Wetland Observatory)

Les quatre principaux axes de recherche retenus dans l'appel d'offres concernent des travaux sur la structure et le fonctionnement des zones humides, leur rôle écologique et leur importance économique, les interactions Nature-Société propres à ces milieux, les modes d'action pour leur conservation ou restauration (http://www.oieau.fr/hydrosys). Les critères d'évaluation des 20 projets retenus sont en rapport avec l'intérêt scientifique et appliqué du sujet, son caractère interdisciplinaire et innovant ou son parti pris de valorisation des acquis, l'intégration de la mise au point d'outils et de systèmes d'aide à la gestion (Barnaud 1997).

Les questions abordées permettront de préciser et déterminer la manière dont les grands types de zones humides remplissent des fonctions écologiques et hydrologiques permettant aux sociétés d'en tirer des bénéfices. Elles doivent également fournir le moyen de hiérarchiser les priorités d'actions de conservation et de gestion durable dans le cadre de l'application de la réglementation, et de réorienter les politiques,... Outre un appui scientifique à l'ONZH, le PNRZH a pour ambition de faire progresser de manière significative les connaissances sur le fonctionnement des zones humides (modèles, principes, théories) ainsi que la conception d'outils méthodologiques et pratiques d'aide au diagnostic, aux plans de gestion (SAGE) et de conservation (espaces protégés).

Le Programme national de recherche "Recréer la nature"

Initié par le ministère de l'Environnement, d'un montant de 6 900 000 FF pour une durée de trois ans (1996–1999), il contribue également à renforcer les connaissances dans le domaine de la restauration des zones humides (Barnaud & Chapuis 1997, Barnaud et al 1998). Son objectif est de comprendre les processus écologiques et socio-économiques caractérisant les opérations de restauration. Au total, vingt projets ont été sélectionnés couplant des équipes scientifiques et des opérateurs, huit traitent des zones humides (deux sur les annexes de systèmes fluviaux, trois sur les marais-marécages, deux sur les tourbières, un sur les gravières) et deux autres, des récifs coralliens (Réunion, Polynésie). Les résultats attendus appartiennent au domaine de la connaissance (mise au point de méthodes, de modèles transposables) et de la pratique (conception d'outils, de techniques utilisables dans le cadre des mesures compensatoires aux aménagements).

Des initiatives complémentaires

D'autres actions, non détaillées ici, sont menées par la communauté scientifique, par les ONG ou par des administrations et établissements publics dans l'objectif de mieux connaître les zones humides et leur fonctionnement. Il s'agit, entre autres, des opérations réalisées par les réseaux d'espaces protégés dans le cadre de programmes européens ou régionaux, ou par les Agences de l'eau qui, dans leur dernier programme quinquennal, ont accordé une place importante aux zones humides (études, acquisition foncière, gestion, sensibilisation). Par exemple, l'Agence de l'eau Seine-Normandie a commandé des études sur la cartographie de l'intérêt fonctionnel des zones humides de son bassin vis-à-vis des ressources en eau (BURGEAP 1995) et une évaluation des services rendus par ces milieux (Laurans et al 1996, Amezal 1997).

4 Analyse du dispositif, ses points forts et ses faiblesses

Le champ couvert par la panoplie d'actions visant à l'amélioration des connaissances, des recensements aux recherches, en passant par les inventaires et le suivi, se révèle vaste. Par ailleurs, certaines opérations ne fourniront des résultats concrets que dans deux à trois ans et d'autres se trouvent encore au stade de projet. Dans sa configuration actuelle, le dispositif présente des avantages, mais aussi des inconvénients.

Les aspects positifs

Il faut souligner la logique et le **réalisme** de ce volet du Plan d'action qui se traduit par le choix de **démarches pragmatiques et modestes** ne nécessitant pas d'importants moyens, sauf en recherche. Par une mise en perspectives de données existantes mais de qualité inégale, des résultats probants ont été obtenus dès 1996, tel l'inventaire des zones humides remarquables des SDAGE. D'autres pays, les États-Unis ou l'Espagne, par exemple, ont opté pour la mise en place d'un inventaire national exhaustif, souvent coûteux en temps et financièrement. Cet outil est sans doute utile mais ne constitue pas forcément une garantie pour une meilleure préservation des zones humides comme l'ont montré les controverses sur la définition et la délimitation de ces milieux aux États-Unis, au cours des années quatre-vingt-dix (Barnaud 1998).

Le choix d'une **valorisation maximale** des acquis a également obligé les commanditaires et les experts à bien formaliser les problématiques et à faire un effort de communication rapide des résultats. Un autre avantage de la démarche concerne la mobilisation d'un ensemble de réseaux constitués de scientifiques ou de praticiens dans le but de mettre en commun leurs acquis. Dans ce contexte, les échanges riches et parfois houleux ont stimulé la dynamique d'ensemble.

Les retombées en termes de **réorientation des politiques** sont évidentes pour certains thèmes et plus diffuses pour d'autres. Par exemple, le travail méthodologique sur les indicateurs de suivi des activités populicoles (ONZH) a induit la diffusion, par le ministère de l'Agriculture, d'une circulaire destinée aux professionnels du domaine, texte expliquant qu'il ne faut pas planter de peupliers dans les secteurs présentant des caractères marqués d'hydromorphie, et exposant les précautions à prendre lors des plantations (distance aux berges, agencement des parcelles, ...). Certaines Agences de l'eau ont initié des programmes ambitieux d'acquisition et de gestion des zones humides jouant un rôle vis-à-vis de la ressource en eau.

Le Plan, prévu à l'origine sur une décennie, n'en est encore qu'à **mi-parcours**. Pourtant, des synergies entre les différents volets apparaissent déjà et ont pour effet de modifier la manière de concevoir certaines politiques, tout du moins au niveau central. Cependant, malgré de nombreuses initiatives locales, sur le terrain, là où se font les aménagements, les progrès sont parfois moins évidents et la cohérence de l'action publique, prise en défaut.

Les aspects négatifs

Les principaux inconvénients du dispositif concernent sa **lourdeur inhérente à son ambition**. Mener de front l'ensemble des volets du Plan oblige à prévoir, par mesure, des possibilités d'intégration de résultats acquis par ailleurs, donc des méthodes relativement souples et adaptables. S'ajoute la diversité des cas de figure rencontrés en France compte tenu du nombre de régions biogéographiques couvertes et du linéaire côtier, sans parler des DOM-TOM.

Plus gênant est le sentiment de frustration lié à la **faiblesse des moyens affectés** pour agir directement sur le terrain. De même, le Plan donne l'impression en partie justifiée de ne considérer que les zones humides bénéficiant d'une certaine aura au détriment des petits habitats dont le rôle en termes de biodiversité et de fonctionnalité est pourtant démontré. D'un point de vue fondamental, les lacunes de connaissance restent encore flagrantes notamment lorsqu'on tente de caractériser les fonctionnalités et d'établir des critères, des typologies, intégrant les fonctions écologiques *sensu lato* et les valeurs des zones humides. Le PNRZH n'apportera pas de réponses à toutes les questions. Le problème rencontré à ce propos réside dans la difficulté à développer des recherches interdisciplinaires, à mobiliser les spécialistes de certaines disciplines, en particulier des sciences humaines, sur les questions prioritaires. Des dérives sont d'ailleurs déjà perceptibles, telle la mise au point d'opérations de terrain fondées sur des interprétations de résultats de recherche relatifs aux fonctions écologiques et services rendus, alors qu'il s'agit d'hypothèses.

Les limites des différentes actions présentées ci-dessus sont connues. Tout d'abord, l'utilisation trop systématique de l'approche '*inventaire des inventaires*' pose le problème de l'actualisation de l'information et de son adaptation aux objectifs visés. Ensuite, le recours à l'avis d'experts empêche la standardisation des méthodes. Ainsi, la caractérisation des fonctions hydrologiques reste pour le moment peu qualifiée et encore moins quantifiée. Ces critiques s'appliquent à l'établissement des listes d'importance internationale ou nationale, mais également à la conception de l'ONZH. De surcroît, les listes correspondent à un repérage des zones les plus intéressantes et riches en habitats humides, sans délimitation précise et valeur réglementaire. Leur désignation au titre de Ramsar ou l'affectation de moyens pour leur protection et leur gestion, étape capitale du processus, relève entièrement de la volonté politique. Par ailleurs, l'approche développée pour l'ONZH implique l'accumulation au cours du temps d'un corpus de connaissances dont l'exploitation et l'interprétation doivent être acceptées par les partenaires du Plan d'action. Le pas de temps permettant d'une part, de disposer d'indicateurs crédibles et, d'autre part, de réagir en modifiant les politiques le plus rapidement possible, reste à définir. Dans un autre registre, la construction d'un '*langage commun*' aux producteurs et aux utilisateurs de données semble nécessaire. Il pourrait prendre la forme d'un dictionnaire national des données sur les zones humides, l'atlas de l'Observatoire correspondant à une première étape de cette réflexion.

Ces travaux contribuent-ils à la conception de mesures d'intervention plus efficaces?

Nous avons examiné les principales opérations visant à accroître les connaissances sur les zones humides en faisant ressortir les points essentiels permettant d'atteindre les objectifs majeurs du Plan d'action : arrêter la dégradation des zones humides en général, garantir par une bonne gestion leur préservation durable, favoriser la restauration des zones humides importantes et reconquérir les sites d'intérêt national (tableau 1).

Tableau 1 Les apports des actions de connaissance et de suivi aux objectifs du Plan
(**Table 1** Contributions of the research and monitoring actions to the objectives of the Plan)

Objectifs **Actions**	**Stopper la dégradation**	**Préserver — Gérer**	**Restaurer — Reconquérir**
Listes des zones humides d'importance internationale ou nationale	Reconnaissance d'un intérêt dépassant les enjeux locaux Contrôle accru des activités négatives	Désignation de sites Ramsar Mise en place de mesures de protection et de plans de gestion	Identification des points faibles/types de milieux protégés Affectation prioritaire de moyens
Inventaires	Information sur l'existence et la localisation des zones humides	Mise en oeuvre de programme d'acquisition et de gestion	Possibilité de hiérarchiser les priorités d'intervention
Observatoire national des zones humides	État des lieux Mise au point et suivi d'indicateurs de dégradation et d'amélioration	Mise en évidence des incohérences Orientation des politiques	Évaluation de priorités d'intervention
Programme national de recherche sur les zones humides Programme national de recherche 'Récréer la nature'	Identification des principaux facteurs agissant sur le fonctionnement Mise au point d'outils méthodologiques et techniques	Analyse des relations entre acteurs, des stratégies de conservation et de gestion Mise au point de systèmes d'aide à la décision, à la planification	Test des méthodes d'évaluation et de restauration

Le véritable bilan de ces programmes se mesurera sur le terrain grâce aux résultats obtenus en termes de conservation et de reconquête des zones humides. Faire connaître l'existence de ces milieux et conforter les arguments permettant de démontrer leur rôle en tant qu'infrastructure naturelle, quel que soit la superficie ou le type considéré, nous paraissent être le meilleur moyen de rendre effective leur prise en compte dans la planification au même titre que d'autres infrastructures (routes, voies ferrées, barrages écrêteurs de crues ou soutien d'étiage, réservoirs, stations d'épuration, espaces verts, ...).

4 Transposition et adaptation de la démarche à d'autres contextes nationaux

L'originalité de l'approche française tient à la stratégie adoptée pour mener à bien l'évaluation des effets des politiques dont les résultats ont été avalisés par l'ensemble des partenaires concernés (Mermet 1996). Par contre, l'organisation du Plan d'action gouvernemental en quatre volets complémentaires, allant de la recherche à la communication, en passant par les mesures réglementaires et les actions de reconquête sur le terrain, n'a rien de fondamentalement innovant. Il est important de signaler qu'il s'appuie sur les structures existantes (DIREN, Agences de l'eau, espaces protégés ou gérés, ...) et se déroule à moyens humains et matériels constants, programmes de recherche mis à part.

Ce schéma doit pouvoir être transféré à d'autres situations avec des adaptations mineures. Toutefois, au cas par cas, il s'agit de trouver un subtil équilibre entre le degré d'urgence des menaces, le besoin d'approfondir les connaissances, le souhait justifié d'exhaustivité et l'efficacité des actions de conservation sur le terrain. Les décisions à forts enjeux économiques se prennent souvent très rapidement, alors que la collecte et l'interprétation des données nécessitent du recul.

Une des principales caractéristiques de la démarche présentée ici reste son coût modeste, économie permise par la valorisation des acquis et le nombre relativement important de professionnels de disciplines variées travaillant sur les différentes zones humides du territoire.

L'option choisie, consistant à analyser les mécanismes et les processus à l'origine d'une dégradation ou d'une amélioration sur un échantillon restreint de sites, permet d'éviter la mise en place de systèmes lourds et coûteux. Il est ensuite possible d'extrapoler les résultats obtenus à d'autres zones présentant des caractéristiques similaires, en se basant sur des inventaires, comprenant une typologie adéquate, travaux qui peuvent être menés en parallèle.

Dans la situation des pays en développement où ce type de démarche serait adoptée, elle mériterait, à notre avis, d'impliquer de façon beaucoup plus prononcée les **communautés locales** utilisant traditionnellement les zones humides. En effet, l'intérêt actuel de ces milieux découle en bonne partie des relations et interactions déployées au cours du temps entre les sociétés humaines et ces territoires. Les préoccupations et connaissances des utilisateurs devraient donc se trouver, plus encore que dans notre exemple, au centre de tout programme visant à améliorer les connaissances pour la conservation et la gestion des zones humides.

Plus généralement, l'attention est attirée sur le fait que l'acquisition de connaissances supplémentaires à propos du fonctionnement de ces zones et de leurs valeurs associées peut présenter le risque de favoriser l'orientation de certaines politiques vers l'optimisation d'une seule des fonctions remplies (épuration, stockage d'eau) au détriment des autres (biodiversité, alimentation de nappe). Il semble donc crucial d'anticiper ces pressions éventuelles afin de veiller à ce que l'intégralité des fonctions, seule garantie réelle de maintien des milieux sur le moyen terme, soit préservée.

Enfin rappelons que les programmes d'inventaires ou de recherche ne doivent pas servir d'alibi à l'inaction et qu'inversement l'action ne peut se concevoir dans l'arbitraire. Parfois, les connaissances sont disponibles et transposables en termes opérationnels mais la volonté politique fait défaut.

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Wise use and conservation of wetlands in Guangdong Province, PR China

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Abstract

By using information derived from general field investigations, social and historical data, and remote sensing, wetlands in Guangdong Province (China) have been divided into different types according to the classification system of the Ramsar Wetlands Convention. The functions, ecological situation, environmental conditions, present use and status, and ecological problems of these wetlands are discussed. Measures for the rational use, management and conservation of wetlands, and the development of an automatic monitoring system for the wetland environments and resources are recommended.

Keywords: wetland management, wetland functions, wetland inventory, wetland conservation, Guangdong Province, China

1 Introduction

Wetlands are distinctive ecological systems that globally reflect high levels of diversity. They are not only rich in natural resources, but also have important functions for regulating the environment, such as storing flood water, recharging groundwater, preventing soil erosion and drought, controlling and regulating the climate, and purifying the environment. Therefore scientists often call wetlands the 'kidney' of the earth. Because they shelter many species, especially many rare and endangered species, they are also a genetic 'storehouse', and possess high value for scientific research, education and economic uses.

Unfortunately, socio-economic development and population growth have resulted in more and more wetlands being over-exploited. Natural resources and biodiversity have been seriously damaged because of the non-rational use of wetlands, including excessive cultivation in tidal areas, hunting, introduction of invasive species and pollution. It is urgent that the remaining wetlands are protected and those that have been previously destroyed rehabilitated.

The Government of the People's Republic of China devotes much attention to the protection of wetlands and a Programme for Chinese Wetland Conservation Actions was drawn up in 1995. Since then a comprehensive investigation of Chinese wetlands has been undertaken in order to know what is the real situation with wetlands in China, ie a wetland inventory including an assessment of management problems, has been undertaken and measures have been taken to protect and manage wetlands. The investigation of wetlands in Guangdong is part of the Chinese wetland program and is described in this paper.

The Ramsar Wetlands Convention (1971) and the Investigation Programme of Chinese Wetlands (Ministry of Forests of the Peoples Republic of China 1995) provide the scientific basis for the investigation of Guangdong wetlands. The American report on wetlands and classification of deepwater habitats (Cowardin et al1979), wetlands in China (Lu 1990), conservation and research of wetlands in China (Lang et al1998), protection of Chinese wetlands (Chen 1996) and many other publications about wetlands also provide information in support of this research. The wetland investigations covered wetland types, area, distribution, ecological characteristics, environmental condition, present use, conservation and disruption.

2 Research methods

The investigation was undertaken using three methods, as listed below:

- Collection of social and historical data on the wetlands;
- Conventional field investigations;
- Monitoring based on remote sensing.

For remote sensing, a Landsat TM image was received in December 1995 and adopted as the baseline map and combined with data from conventional field investigations before a classification system for Guangdong wetlands was developed. After testing and verifying with field work an annotated map was drawn from the remotely sensed image. This was at a scale of 1:25 000 and provided the basis for wetland monitoring. Finally, the areas of different types of wetlands were calculated. The scheme of remote sensing monitoring is shown in figure 1.

3 Results

Variety and area of wetlands

Because of its location in the tropics and subtropics in the south of China and its long coastline, Guangdong has high rainfall and is therefore rich in water resources. Rivers and streams criss-cross the province and discharge through flat and low-lying deltas. The environment and the resources present exceptional advantages and the area of wetlands is vast and encompasses a number of habitat types.

Based on the classification system of the Ramsar Wetlands Convention (Scott 1989) and the analysis undertaken using information on the geology, geomorphology, topography and vegetation, the wetlands can be divided into 5 large types, 16 types and 47 subtypes (fig 2). The total area of wetlands in Guangdong covers more than 3 827 297 ha, that is 21% of the total area. Among these are coastal wetlands (760 431 ha), river mouth wetlands (298 234 ha), bay wetlands (463 543 ha), delta wetlands (594 656 ha), riverine wetlands (1 346 873 ha), and lakes (363 559 ha). There are also 14 000 ha of mangroves within the coast, bay or river mouth wetlands; this type of wetland deserves more attention.

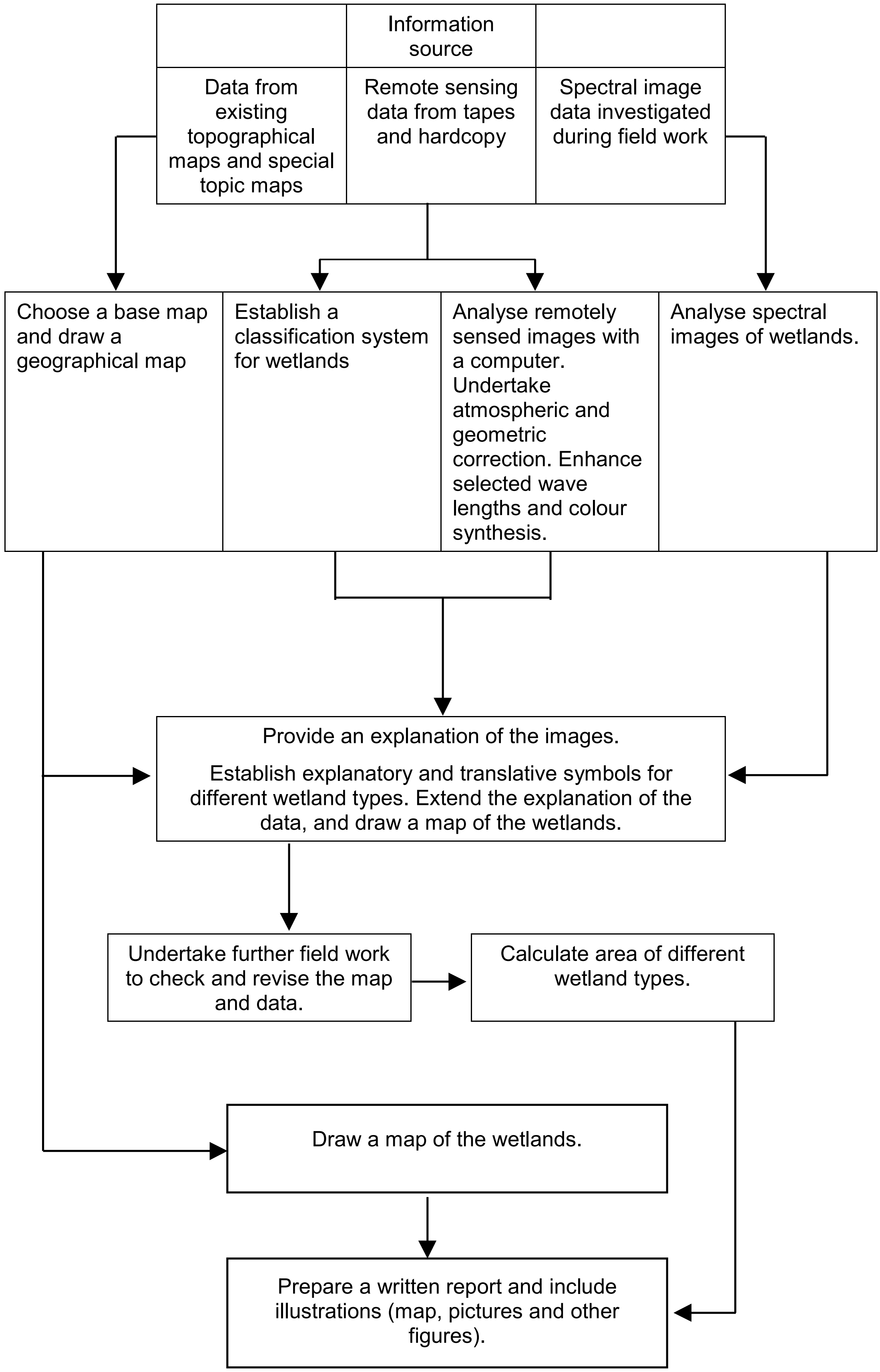

Figure 1 Working plan for remote sensing technique monitoring of wetlands in Guangdong, China

Wetlands in Guangdong	Coastal wetlands	Sandy and muddy beach
		Gravel beach
		Shallow sea areas
		Lagoons (Coastal saltwater lakes)
		Coastal freshwater lakes
		Saltwater swamps
	River mouth and bay wetlands	River mouths
		Bays
		Deltas
	Interior river wetlands	Long-term rivers and streams
		Flood lands
	Interior lake wetlands	Natural lakes
		Man-made lakes
	Interior swamp wetlands	Mountainous region swamps
		Hills swamps
		Flatland swamps

Figure 2 Classification system of wetlands in Guangdong Province, China

Ecological situation

Numerical data show that in Guangdong Province there are 181 species of wetland hygrophytes, belonging to 68 families and 129 genera. Among these are 7 species of Bryophytes, 14 species of Pteridophytes and 160 species of Angiosperms. The second category of wetland vegetation is fresh water hydrophytes, with 38 families, 69 genera and 106 species, among which there are 63 Graniferous species, 37 species of Dicotyledons, and 6 species of Bryophytes. The mangrove vegetation is another type with 19 families, 32 genera and 33 species. Among these 7 families, 10 genera and 10 species are considered 'real' mangroves with 5 families, 7 genera and 7 species being considered 'semi-mangrove' species. Another 9 families, 14 genera and 16 species are know as 'companion' species of mangroves.

Wetland animals in Guangdong include 40 species of amphibians, 62 species of reptiles, 28 species of mammals and 201 species of birds belonging to 19 orders and 45 families, and many insects. The bird species, *Ciconia ciconia* and *Aquila heliaca*, are included in the highest level of conservation protection with another 21 species in the second level.

Investigation of wetland insects has been rarely carried out, except in the Futian mangrove wetlands in Shenzhen. Based on preliminary investigations, there are 96 species of insects, belonging to 10 orders and 59 families. There are also 7 species of spiders. The zooplankton species of Guangdong wetlands are diverse with about 7 phyla, 67 families, 201 genera and 381 species. Among these are 66 species of protozoa, 96 species of coelenterates and 201 species of arthropods.

The benthic fauna of the wetlands is plentiful with about 16 phyla, 391 families, 658 genera and 881 species, among which there are 19 species of sponges, 48 coelenterate species, 7 species of flat worms, 158 annelids, 308 molluscs, 125 arthropods and 90 echinoderms.

Wetland algae are also diverse with 628 species in total. Among these are 257 species of macroalgae and 371 species of phytoplankton.

Coastal wetland fish include beach fish and shallow sea fish with 56 families, 96 genera and 147 species. There are 296 river fish species, belonging to 17 orders, 45 families and 156 genera, and there are more than 60 species of continental lake fish, belonging to 8 orders and 15 families.

Environmental conditions

In a geological sense the Guangdong wetlands have been largely influenced by the Quaternary period, especially in the coastal area.

Due to the tropical and subtropical location the average lowest temperature in January is around 8–10°C. In the south of Leizhu Peninsula the lowest temperature reaches 16°C while in East Guangdong, the lowest temperature recorded is -7.3°C. From July to September, the temperature is higher with an average in July of 28°C. The highest temperature recorded is 42°C in North Guangdong.

The average annual rainfall is 1600–1800 mm with the highest measured being 2600 mm. There are 1314 rivers in Guangdong with a total length of 25 290 km. The total average runoff in 23 years is 1 800 000 m^3.

The water quality in most rivers meets the National Standard, except the Zhujian River in Guangzhou area. The water surface of lakes and reservoirs cover 687.25 km^2 with a total storage capacity of 1850 million m^3. The water quality is good in general, except for the Kongping Reservoirs that are polluted by an iron mine and Zhaoqing Star Lakes that are eutrophified. The quality of most coastal water is fine except for some of the items such as COD, oil, Cu and Zn. Many brooks in the Pearl River Delta are seriously polluted.

Use of wetlands and ecological-economical problems

As a very important natural resource, wetlands have been used for shipping, generating electricity, aquaculture, food and vegetable production. More and more wetlands have been exploited, especially the river mouths, bays and coastal wetlands, for food, aquaculture products and urban development. Since the 1990s, the area of the Pearl River Delta has lost 15% of its wetlands for urban development. Mangrove wetlands have been severely affected. In the 1990s, mangroves covered only 18% of the area covered in the 1950s. Many mangroves were cleared for fish ponds or rice fields, but because of the existence of acid sulphate conditions the production of rice and aquaculture were both unsuccessful. For example, in 1986, about 700 ha of mangrove wetlands were converted to ponds to breed prawns in Dianbai County, but after two years, all the prawns had died and the ponds left to waste.

As a result of mangrove destruction, the capacity to resist disasters such as typhoons or tidal surges has been weakened. Embankments, farmlands and villages have been seriously damaged by strong typhoons and tidal surges. In 1966 an embankment 30 km long and farmlands were destroyed by a typhoon, and the economic losses amounted to 16 million yuan. Another ecological problem caused by destroying mangroves is the ease with which saltwater intrudes into farmlands, which affects the growth and yield of crops.

Destruction of mangroves also affects the biodiversity. For instance, according to an investigation made in 1995, an area of 148 ha (49% of the total area) of the Futian mangrove wetlands in Shenzhen City were destroyed in order to build an industrial park, an expressway, and a TV broadcasting station. As a result, compared with 1993 data the bird biodiversity has declined — terrestrial bird species by 40%; breeding species by 71%; rare and endangered terrestrial species by 39%; waterbirds by 30%; rare and endangered waterbird species by 55% and total bird species by 36%. Further, because insectivorous bird species decreased by 41%, the *Avicennia marina* mangrove forest has been plagued by insects for many years in succession.

Last but not least, the destruction of other wetlands, such as rivers, lakes, reservoirs, swamps and grass marshland, also affects the capacity to protect the local area in times of flood or drought.

Protection status

Many nature reserves have been established in Guangdong with 17 wetland nature reserves. They cover a total area of 16 533ha, which is 4.3% of the total area of wetlands in the province (table 1).

Table 1 Overview of nature reserves in the Guangdong wetlands

Name of the nature reserve	Level	Date	Area (ha)
Zhanjiang Mangrove Natural Reserve District	national	1990	12 000
Shenzhen Mangrove Natural Reserve District	national	1984	304
Neiling Ding Island *Marcaca mulata* Natural Reserve District	national	1984	498
Huidong Green Turtle Natural Reserve District	national	1986	1400
Liuqi Rive Forest Park	national	1982	833
Xingfeng Jiang Forest Park	national	1993	4479
Donghai Island Forest Park	national	1993	1333
Dangan Island *Macaca mulata* Natural Reserve District	provincial	1990	270
Shangchan Island *Macaca mulata* Natural Reserve District	provincial	1990	1300
Dayia Bay Aquatic Products Natural Reserve District	provincial	1990	102 880
Haikang Pearl Shell Natural Reserve District	provincial	1983	25 880
Nanao Mirant Natural Reserve	provincial	1990	260
Xingang *Cervus unicolor* Natural Reserve District	provincial	1976	33
Gongping Migrant Natural Reserve District	city	1996	3333
Maoming Mangrove Natural Reserve District	city	1997	3333
Naozhu Island Aquatic Products Natural Reserve District	city	1984	1500
Conghua Hot Spring Natural Reserve District	city	1988	2800

4 Conclusions

- Research methods are numerous and varied, including advanced techniques and remote sensing techniques.
- Wetlands in Guangdong Province are numerous and varied and cover 21% of the total area and provide many important functions.
- Wetlands in Guangdong contain many natural resources and are excessively rich, notably in species. Rare and endangered species are in need of immediate protection.
- The underlying geological structure of Guangdong wetlands has its origins in the Quaternary period. The climate is warm and the rainfall abundant. The water quality of

rivers, lakes, reservoirs and the coast zone is good, but the Pearl River in Guangzhou area, Gongping Reservoir, Zhaoqing Star Lakes and many criss-crossing brooks are polluted to varying degrees.

- There are 17 nature reserves, representing 4.3% of the total area of Guangdong wetlands.
- In Guangdong wetlands, the following ecological problems can be encountered: coastal wetlands have been urbanised, or used for aquaculture ponds and rice fields; many ponds and rice fields have ended in failure; one of the consequences of mangrove destruction is a much weaker capacity to resist disasters like typhoons and tidestorms; another consequence is a loss of biodiversity. Destruction of other wetlands has affected the local capacity to manage flood and drought.

5 Recommendations

Strengthening wetland conservation

The first and most important thing to do is to protect and manage rationally the forest vegetation in the upper reaches of the fresh water wetlands, in order to protect the water quality, maintain the water supply and counter floods and drought. The sustainable use and protection of wetland water resources will be a fundamental issue in the future. Secondly, mangrove wetlands should be protected. Mangroves are very important for the people of Guangdong, notably because the province has a long coastal line (430 km). Thirdly, it is important to preserve the wetland biodiversity. Wetlands cover only 6% of the surface of the earth, but they contain 20% of the world's species. That is why more nature reserves should urgently be set up. Lastly, wetlands should be protected within a landscape context.

Maintaining the functions of wetlands

Reclamation of wetlands for cultivation and urbanisation should be stopped. In the future, they should be used to store and supply water, purify the environment, shelter birds and other animals, for ecotourism, scientific education and research.

Enhancing wetland monitoring

Automatic monitoring systems for wetland environment and resources must be developed. Remote sensing and GIS techniques should be employed for setting up an information system on wetland resources and environment (WREIS). Changes in wetland areas, environmental quality and resources should be monitored and forecast in time. These data could provide a scientific basis to build a management index system for wetlands.

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Proposed classification system for the South African National Wetland Inventory

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Abstract

South Africa has begun developing a wetland inventory program, coordinated on a national scale and employing a standardised methodology and classification system. In order to facilitate the mapping phase of the inventory and enhance the value of data gathered, a classification system for South Africa's wetlands has been developed. This is based on the Cowardin system used by the United States National Wetland Inventory, but has been adapted to accommodate the full range of South African wetland diversity. A significant departure from the original Cowardin system is the separation of endorheic (pan or playa) ecosystems from other lacustrine and palustrine habitats. Palustrine wetlands have also been distinguished into four subsystems, based on position in the landscape. This should enhance the value of the classification for purposes of conservation and management. A field verification protocol is currently being developed to test the proposed classification system.

Keywords: wetland inventory, wetland classification, wetland mapping, South Africa

Introduction

The urgent need for an inventory of South Africa's wetlands has long been recognised. The lack of such spatial information has consistently been identified as an obstacle to the development, implementation and monitoring of wetland conservation strategies at national, provincial and local levels. With estimated losses of wetland area in South Africa in excess of 50% (Kotze et al 1995), the generation of information on the distribution and status of the country's wetlands has become a priority.

The South African Wetlands Conservation Program of the Department of Environmental Affairs and Tourism has undertaken the task of developing and coordinating an inventory program. Although a number of wetland mapping projects have previously been conducted in several parts of the country, they have been localised in coverage and have lacked a common basis for comparison. The national inventory will overcome these problems by applying throughout the country one set of standards and methods and one classification system.

Several tasks have been completed in order to lay the foundations for wetland mapping on a national scale. A catalogue, or meta-database, of wetland inventory work that has been done in South Africa has been compiled, containing details of each survey, including where it was conducted, what was listed and where it can be obtained. An important step in the conceptual design of the inventory was the convening of a national workshop, attended by those organisations which will be the major users of the products of the inventory. These included conservation authorities, universities, research and non-governmental organisations and government departments working with agriculture, water resources and land-use planning. Input from these stakeholders was essential, as the ability of the inventory to meet its objectives will hinge on the effective application of its products in decision-making processes.

During this workshop it was decided to adopt for South Africa the classification system used by the United States National Wetland Inventory, known as the Cowardin system (Cowardin et al 1979). This decision was based on user needs and expectations of the inventory, as well as desirable traits of the Cowardin system, such as its broad and open structure. This adaptability will permit the classification to be applied with precision to local conditions, after minor alteration (Morant 1983). Modifications to the system have subsequently been proposed, in order to accommodate the full range of South African wetland diversity. These modifications are discussed in detail in the following sections.

Proposed modifications to the Cowardin system

The modified Cowardin wetland classification system proposed for use in the South African wetland inventory is presented in figure 1, to the level of Class. The following modifications have been made to the original system.

Addition of intermittent subsystems to riverine system

The riverine system has been divided into five subsystems, whereas the Cowardin system makes use of four. The addition is the result of Cowardin's intermittent subsystem being divided into lower and upper intermittent. These subsystems will accommodate wetlands in channels containing flowing water for only part of the year. This will allow the distinction made between upper and lower perennial subsystems, on the basis of gradient and water velocity, to be extended to the intermittent subsystem.

With much of South Africa experiencing a semi-arid climate, non-perennial riverine ecosystems are common, hence the division of the broad category of intermittent. Valuable information would otherwise be lost by grouping together, under the heading of Intermittent, ecosystems with similar hydrological regimes but widely differing physical and ecological attributes.

Division of Palustrine system into four subsystems

In contrast to the Cowardin system, which did not further subdivide the Palustrine system, the South African classification proposes to create four subsystems, based on the position of the wetland in the landscape. This hydrogeomorphological approach is considered valuable because it takes into account the important influence that geomorphology has on local surface and groundwater movement patterns and the degree to which wetlands are open to lateral exchanges of sediments, nutrients and other pollutants (Kotze et al 1994).

The four subsystems defined are:

Flat: wetlands occurring on areas of comparatively level land (slope less than 1%) with little or no relief, but not directly associated with either a valley bottom or floodplain feature.

Slope: wetland habitats occurring on areas with a gradient of greater than 1%, but not directly associated with either a valley bottom or floodplain feature.

Valley bottom: wetland habitats occupying the lower end of the topographical continuum from upland to valley bottom. They are not necessarily associated with a river channel.

Floodplain: wetland habitats falling within areas which are:

- adjacent to a well-defined river channel;
- built of sediments during the present regimen of the stream; and
- covered with water when the river overflows its banks during a 1-in-10 year magnitude flood event.

Floodplain wetlands were explicitly distinguished in order to allow an ecologically-meaningful distinction to be drawn between wetlands which have particular hydrological relationships with riverine systems by virtue of their position on floodplains, and those with no association with, or directly connected to, a river channel. In terms of information for conservation and management purposes, this is a valuable distinction. It was decided to place floodplain wetlands within the Palustrine rather than the Riverine system, as these wetlands share hydrological, geomorphological and ecological features more characteristic of the former system, although these attributes are strongly influenced by the latter.

The use of the 1-in-10 year flood line to delineate floodplains matches the definition used in the Conservation of Agricultural Resources Act, which regulates cultivation in wetlands. This compatibility of definitions will optimise the usefulness of the inventory and classification for a wide range of applications.

Addition of Endorheic system

Wetlands of the Endorheic system are commonly referred to as pans in South Africa, and as small closed basins or playas in geomorphological literature. Being located largely in dry regions, they display characteristic patterns of ephemeral and irregular inundation (Allan et al 1995). The Endorheic system comprises wetlands that would otherwise be classified as Palustrine or Lacustrine, but which possess all of the following additional characteristics: circular to oval in shape, sometimes kidney-shaped or lobed; flat basin floor; less than 3 m deep when fully inundated; and closed drainage (lacking any outlet).

The Endorheic system has been added to Cowardin's original complement of five systems in recognition of the significant ecological role played by pans in southern Africa, especially those in arid areas (Goudie & Thomas 1985). The addition of another system is a significant departure from the original framework, but was viewed as necessary in order to adequately accommodate these ecosystems. Using the Cowardin system in its original form, it is not possible to distinguish pans from other Lacustrine and Palustrine wetlands. In their adaptation of the Ramsar wetland classification system for South African conditions, using the Cowardin system as a template, Cowan and van Riet (1998) also included endorheic systems at the highest classification level.

Endorheic wetlands were added at system level because, by the original classification, these ecosystems would fit into both Palustrine and Lacustrine systems, depending on size. This would have made it impossible to capture all pans within one subsystem under either Palustrine or Lacustrine. More importantly, the basis for division of systems into subsystems is primarily hydrological differences, such as water depth and permanence (Cowardin & Golet 1995). Although endorheic ecosystems are primarily influenced by hydrological variability, they share a number of additional determinant factors (Allan et al 1995). To assign Endorheic at the level of subsystem would place most of the emphasis on hydrologic aspects and ignore the range of geomorphologic, chemical and biological features that are common to these ecosystems. The system level, which describes the overall complex of hydrological, geomorphological, physical, chemical and biological features that certain groups of wetlands share (Cowardin & Golet 1995), therefore seems a more appropriate level of the hierarchy at which to introduce endorheic ecosystems.

Conclusion

The classification system as proposed above has yet to pass the crucial stage of field testing. Ideally this will take the form of a mini-inventory exercise covering selected areas which contain a representative variety of wetland types. How effectively the classification accommodates the range of wetland habitats encountered during this trial will determine its suitability for application in a full-scale national wetland inventory.

The regionalisation of the classification will also be explored. In the system as it currently exists, a given taxon has no particular regional alliance; its representatives may be found in one or many parts of the country. However, regional variations in climate, geology, soils and vegetation are important in the development of different wetland habitats, and issues of management and utilisation can also be expected to vary correspondingly. For these reasons, there is a need to recognise regional differences. Several bioregional classification systems (eg Cowan 1995) exist in South Africa which can potentially play this role.

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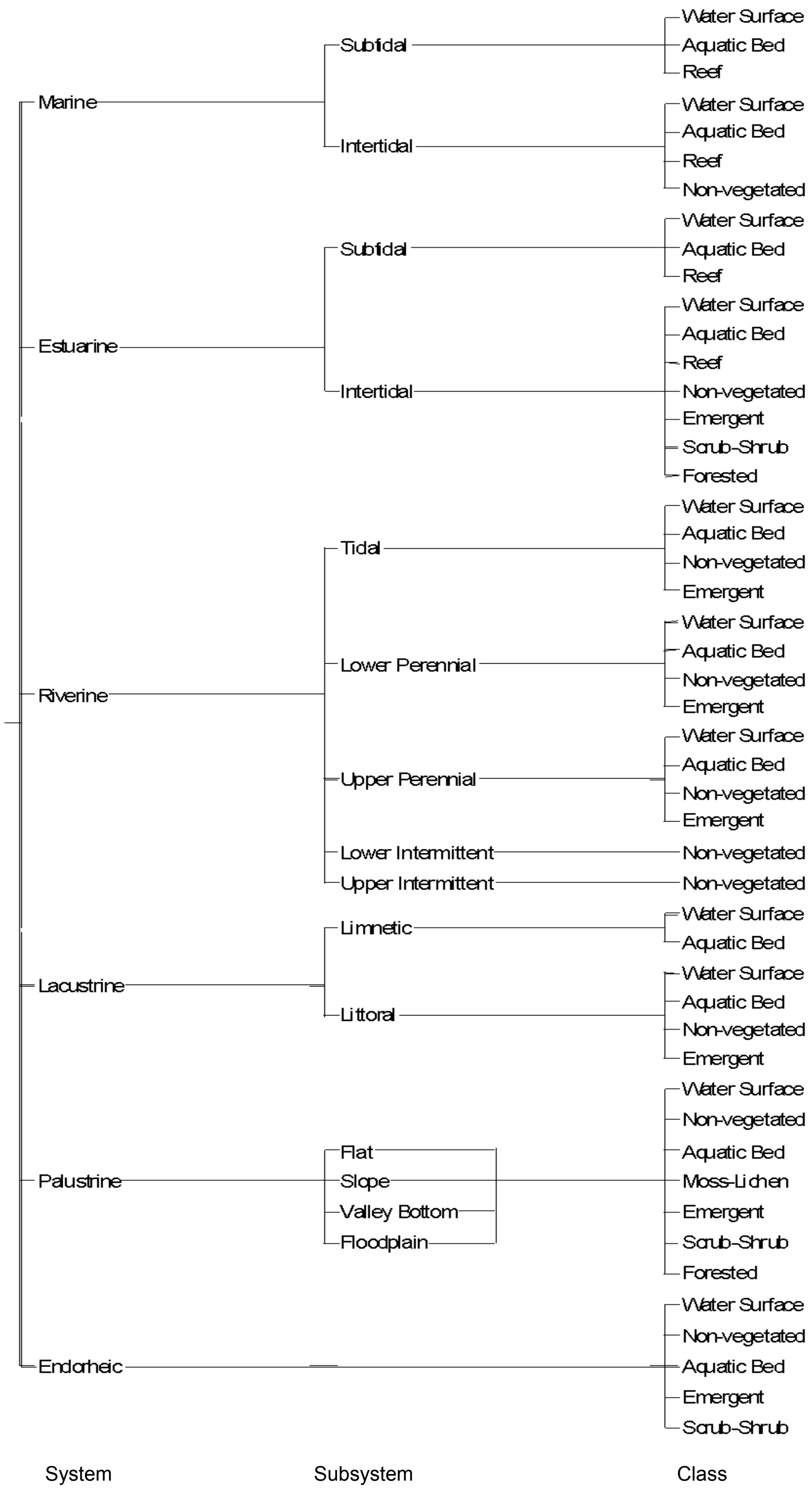

Figure 1 Proposed South African wetland classification system, to Class level

Monitoring coastal wetlands in a highly dynamic tropical environment

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Abstract

The Alligator Rivers Region in the wet-dry tropics of northern Australia has been selected by government and collaborating agencies as a key study area for the monitoring of natural and human-induced coastal change. The Region contains the floodplain wetlands of Kakadu National Park which have been recognised internationally for their natural and cultural heritage value.

A coastal monitoring program for assessing and monitoring environmental change in the Alligator Rivers Region has been established at the Environmental Research Institute of the Supervising Scientist. This program has developed a regional capacity to measure and assess change on the wetlands, floodplains and coastline within the region. Field assessment and monitoring procedures have been developed for the program. The assessment procedures require use of georeferencing and data handling techniques to facilitate comparison and relational overlay of a wide variety of information. Monitoring includes regular survey of biophysical and cultural processes on the floodplains; such as the extension of tidal creeks and mangroves, shoreline movement, dieback in *Melaleuca* wetlands, and weed invasion of freshwater wetlands. A differential Global Positioning System is used to accurately georeference spatial data and a Geographic Information System is then used to store and assess information. The assessment and monitoring procedures can be applied to the wet-dry tropics in general.

These studies are all particularly pertinent with the possibility of greenhouse gases causing global warming and potential sea-level rise, a major possible threat to the valued wetlands of Kakadu National Park, and across the wet-dry tropics in general.

Keywords: Coastal wetlands, tropical wetlands, monitoring, wet-dry tropics, management, differential Global Positioning System, coastal monitoring

1 Introduction

The Alligator Rivers Region (ARR) (fig 1) is located in the wet-dry tropics of northern Australia approximately 150 km east of Darwin. The Region contains the floodplain wetlands of Kakadu National Park. It is an area of internationally acclaimed natural and cultural heritage value. Several major rivers and large areas of coastal plain drain onto the wetlands and into van Diemen Gulf. These wetlands are already undergoing major ecological changes and, by nature of their elevation and hydrology, are likely to be particularly vulnerable to climatic and other change. (Bayliss et al 1997, Finlayson et al 1997, Eliot et al 1999).

The major part of the ARR (fig 1), of which Kakadu forms a significant part, is drained by the South Alligator and East Alligator Rivers with the smaller West Alligator and Wildman Rivers draining the north-western portion of the Region. The combined catchment area of the four major rivers is approximately 28 000 km^2, about 8000 km^2 greater than the size of Kakadu National Park.

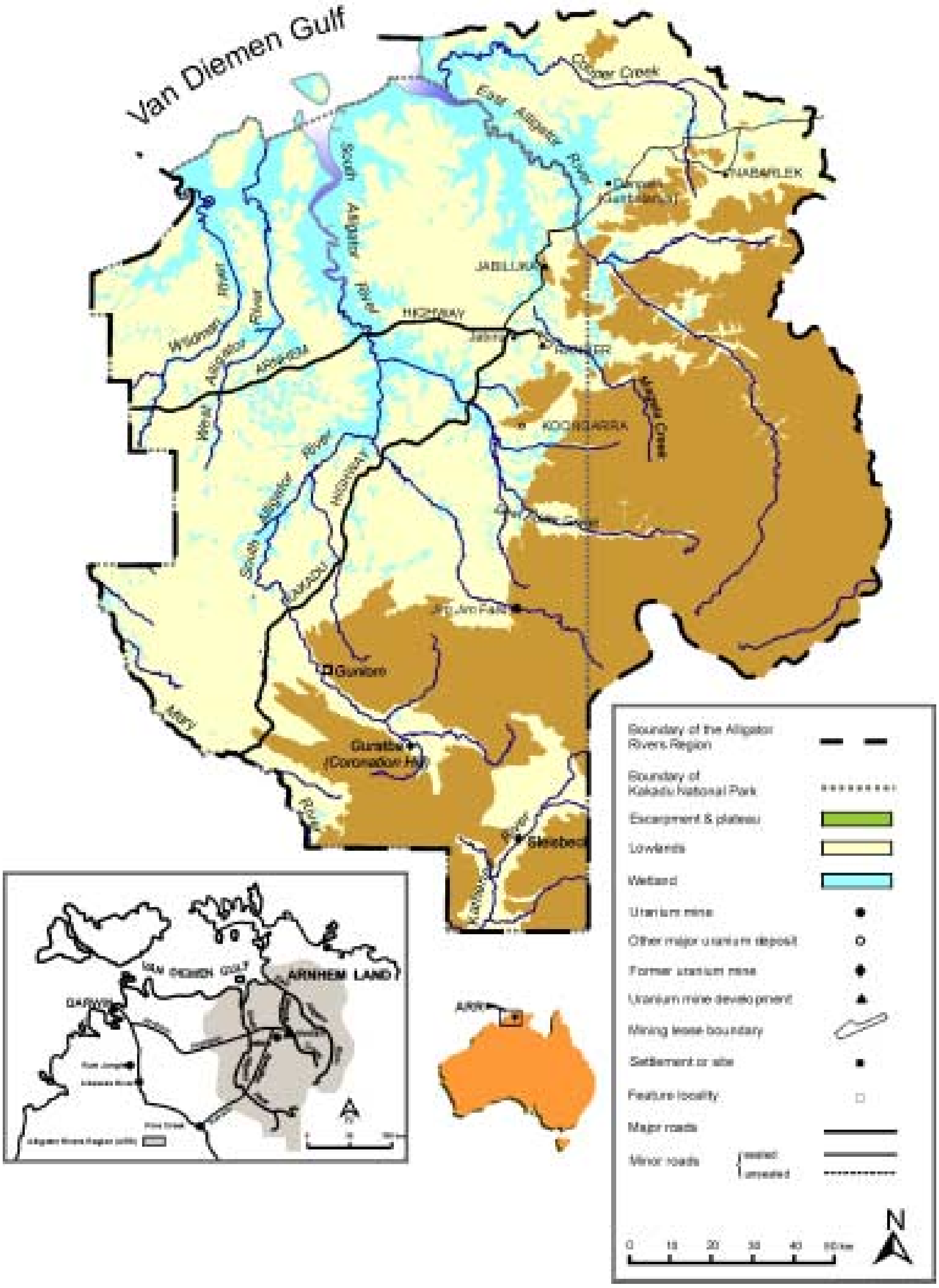

Figure 1 Alligator Rivers Region map

The broad coastal plains of the ARR lie in a narrow band of elevation, 3–4 metres above Australian Height Datum and close to the mean high water spring tide level. On the South Alligator River they fall approximately 50 cm in over 70 km from the escarpment. As a result, small fluctuations in river discharge and sea level associated with variation in climate are likely to have far reaching effects on riverine processes, particularly on the tidal hydrology of the streams and the distribution of vegetation on the floodplains. This has been demonstrated through detailed research into the evolution of the floodplains and through systematic accounts of major ecological changes that are currently taking place in the wetlands of the Region (Finlayson & Woodroffe 1996, Bayliss et al 1997, Finlayson et al 1997).

The development of a coastal monitoring program in the ARR was initiated as a follow up to a project conducted under the federally supported Australian Coastal Vulnerability Case Studies as a component of a federal coastal action plan. A report titled 'Vulnerability assessment of the possible effects of predicted climate change and sea-level rise in the Alligator Rivers Region, Northern Territory, Australia' (Bayliss et al 1997) was produced as a component of the national program.

The coastal monitoring program was established to investigate the impacts on the wetlands and coastal floodplains of the ARR, due to climate change and sea-level rise via:

- an assessment of past and current physical (creek expansion, sedimentation, stratigraphy) and biophysical (shoreline retreat, mangrove distribution and productivity) changes in the coastal zone and predictions of likely further change to these areas; and
- determination of the extent of change to the ecological character of the region due to predicted climate change and sea-level rise.

The initial aims of the coastal monitoring program are:

- to provide a survey framework for georeferencing and storing spatial information; and
- to collate existing baseline information on coastal change and management.

These aims will be achieved through more specific objectives which are to:

- develop a regional capacity to measure and assess change on the floodplains and coast of Kakadu National Park, its catchment area, the wider Alligator Rivers Region, and in the wet-dry tropics in general;
- increase Australia's capacity in the monitoring of coastal change through establishment of a coordinated monitoring program which can function as a benchmark for monitoring in the wet-dry tropics and eventually in low-lying coastal areas subject to seasonal episodic flooding; and
- provide a regional and local benchmark against which to measure environmental changes in the Magela Creek system, which could be attributed to mining and other human activities.

2 Material and methods

Monitoring framework

Establishment of Global Positioning System (GPS) capability and its linkage with GIS to store the information were identified as the initial main tasks to establish a survey framework for the coastal monitoring program.

Global Positioning System

A sophisticated Ashtech differential GPS system (dGPS) was purchased to facilitate the development of an accurate georeferencing capability and monitoring framework for the ARR. GPS receivers use a coordinate system, known as World Geodetic System 1984 (WGS1984) and normally require a minimum of four satellites to accurately determine a position. Accuracy using a single receiver (standard) handheld GPS is usually in the 10–20 metre range, however, this is vastly improved by using two or more receivers. Differential GPS is used to collect and process data using two or more receivers that track the same satellites simultaneously. One receiver is located over a known reference point (eg a benchmark) and the position of unknown points is determined relative to the reference point. Accuracy varies from sub-centimetre level to within 100 metres depending on how the signals are collected and processed.

A permanent GPS base station has been established at Jabiru Airport, to increase the accuracy of the dGPS. This base station is part of the Australian Fiducial Network (AFN) coordinated by the Australian Surveying and Land Information Group (AUSLIG). The site positions will form a framework for the Geocentric Datum of Australia as defined in 1994 (GDA94). GDA94 is a new coordinate system that will be gradually implemented in Australia up to the year 2000. For all intents and purposes, it is the same as WGS1984.

GIS development

A GIS will be used to store and analyse data from all monitoring and research programs and in particular the coastal monitoring program. Thus it is fundamental to have an effective strategy for data management and information storage, management and exchange for all projects undertaken in this program and for the data management systems to be in place before projects are begun.

Establishing baseline information

Baseline information and historical records provide an indication of where changes have occurred, perhaps are ongoing, and sites where research should be undertaken in future. Such information is required for a wide range of environmental parameters. Baseline information is currently being collected for the following parameters:

- meteorologic records;
- oceanographic records;
- hydrologic and river gauging records;
- shoreline movement and storm surges;
- mangrove distribution and species identification;
- salt flats and saline intrusion;
- history of land use and environmental change;
- sediments and stratigraphy; and
- remote sensing and landscape change.

Mapping

The dGPS was used to map the present morphological and biological features of an area near the mouth of the East Alligator River (Point Farewell) to establish an accurate (georeferenced) environmental baseline from which ongoing monitoring can proceed. The site is located on the southern coastline of van Diemen Gulf in the estuarine funnel of the East Alligator River. This site was chosen after a local traditional land owner drew attention to a stand of dead *Melaleuca* trees.

Field work was completed over several days using the dGPS receiver (rover) mounted on a four wheel (quad) bike in conjunction with the base station receiver located over a temporary benchmark (there were no existing benchmarks nearby). Spatial information was obtained by recording the data as the quad bike was driven around areas of biophysical interest, such as stands of mangroves, dead trees and salt flats. When more accurate vertical data (elevation) was required a point reading was taken. The data was processed on return to the laboratory and entered into the GIS. A diagram of the processed information showing the attributes that were mapped in the field is shown in figure 2.

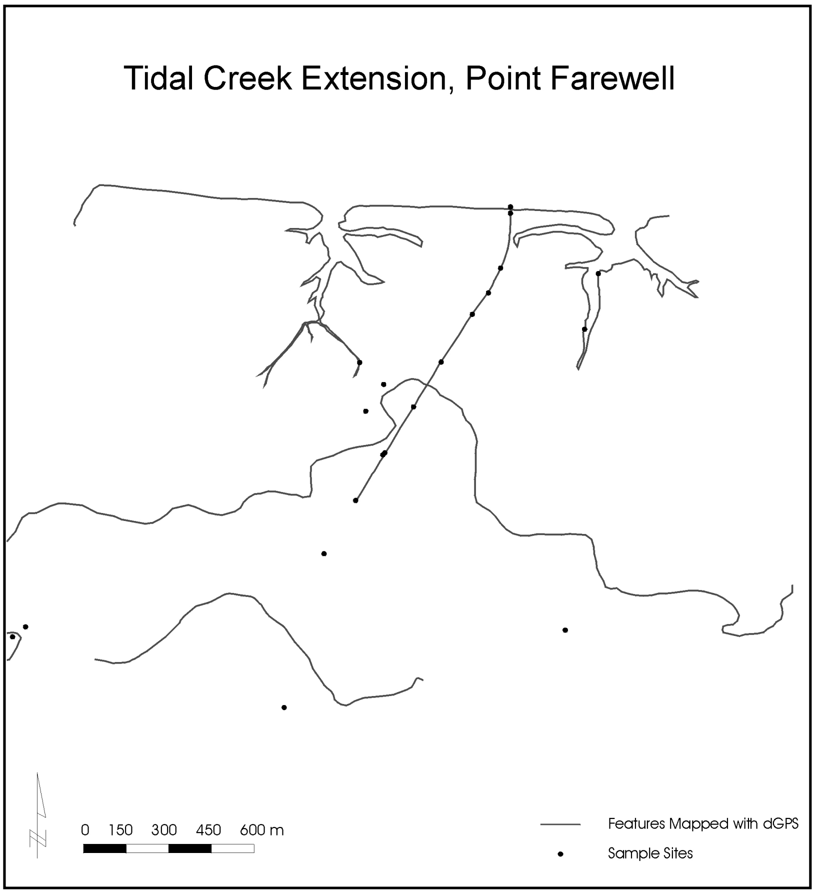

Figure 2 Differential Global Positioning System map of various features at Point Farewell

Other areas that were mapped using the dGPS included:

- Kapalga — An area of dead *Melaleuca* forest on the South Alligator floodplain located on the cuspate bends of the South Alligator River, approximately 55 km (straight line) from the river mouth. Examination of aerial photographs for the years 1950 to 1991 (Cobb 1997) indicated extension of one main tidal creek network into a freshwater swamp, resulting in *Melaleuca* dieback.
- Munmarlary — This site was selected by Cobb (1997) after examination of aerial photographs for the years 1950 to 1991. The photography indicated extensive growth of tidal creeks and mangrove encroachment within the confines of a palaeochannel swamp on the left (west) bank of the South Alligator River whilst there was little evidence of the trend occurring on the right (east) bank. Access to the left bank of the tidal creek was difficult so field mapping using the dGPS was conducted on a tidal creek extending from the right bank. Aerial photographs indicated that the creek selected was stable, but mangrove colonisation had increased since 1950.

3 Results

A variety of fundamental information has already been collected on the floodplains. Geomorphologic and stratigraphic records compiled by Wasson (1992) and Erskine and Saynor (2000) have been used to establish the landform and hydrological setting in which contemporary environmental change is taking place (Bayliss et al 1997). Studies of wetland vegetation in the region describe the distribution and community composition of mangroves on the South Alligator (Woodroffe et al 1985) and East Alligator (Hegerl et al 1979) Rivers, and the floodplains of the South Alligator River (Taylor & Friend 1984) and Magela Creek (Williams 1979, Sanderson et al 1983, Finlayson et al 1989). Other information on the vegetation is available from studies of feral buffalo (Williams & Ridpath 1982), exotic plants (Cowie et al 1988) and general plant taxonomy (Cowie & Finlayson 1986, Brennan 1996). An overview of vegetation in the region has been provided by Finlayson and Woodroffe (1996). Little attention has been given to the vegetation of the salt flats and freshwater lakes although these are areas likely to be markedly affected by change in climate, storm impact and extension of tidal creeks.

Environmental changes in the region are also initiated by land use and may influence future land use strategies for the area. In particular, change such as the introduction of pest species, altered fire regimes or environmental degradation may continue to impact upon the area long after the land use has altered. For example, the role of buffalo and introduced pasture grasses in land degradation and environmental change is acknowledged and continues to be a matter of concern in the region since removal of the animal from the region in the late 1980s (Finlayson & von Oertzen 1996).

Understanding the history can assist in recognising the extent of landscape differentiation and its underlying cause, hence providing a baseline for monitoring further change. Major land uses in the ARR currently include mining, fishing, tourism, use by traditional custodians and conservation. The region is often the subject of intense political debate and public interest due to its diverse natural and cultural values and vast mineral wealth. Historical land use and potential environmental impacts in the region are being assessed as a part of monitoring programs that operate at both a local site and landscape scale.

The latter include investigation of the implication of climate change and sea-level rise on the wetlands in the region. Saltwater intrusion though tidal-creek extension has been identified as a major coastal problem in the ARR (Bayliss et al 1997, Eliot et al 1999). Whilst trends in saltwater intrusion have been well documented in the literature for the nearby Mary River plains (Woodroffe & Mulrennan 1993, Finlayson et al 1997) and observed in the ARR, the geographic extent of the problem and the spatial variations in the rates of change had not been determined in detail.

4 Discussion and conclusions

Many of the biophysical surveys completed on the floodplain prior to establishment of the current dGPS and GIS-based monitoring program lack detailed georeferencing. An exception is the survey of Heggerl et al (1979) which referenced the location of vegetation transects along the coast and marked their end-points for future reference. Other surveys have been tied to interpretation of maps and aerial photography or have been developed from satellite imagery where the level of accuracy is tied to the techniques of data acquisition. Nevertheless, much of the information gathered in these surveys is invaluable for i) the historical insight it provides into patterns of change, and ii) its potential for further elaboration in relation to current and future land use. To maximise this potential the information should be collated in a geo-referenced framework and the reliability of each data set established. In this context, Finlayson and von Oertzen (1996) have identified a requirement for tighter mapping and data control. This is afforded by recent developments in differential GPS and GIS, developments that have been fostered by the institute and the coastal monitoring program.

The dGPS has successfully been used to map various features such as saltwater intrusions, mangroves, wetland areas, basin cross-sections and tidal creek extensions. The ability to georeference such features within a GIS will be a valuable tool within the framework of future coastal monitoring in the region. This capability provides a basis for 'benchmarking' future environmental change in the region. This is particularly pertinent in respect of global warming and potential sea-level rise which are predicted to result in major changes in the highly valued wetlands of the region (Bayliss et al 1998).

The ARR has and continues to provide excellent opportunities to document environmental change as it has a sound history of applied environmental research and management in relation to its widely recognised cultural and natural heritage. In this respect it can also provide a model for other areas in the wet-dry tropics in Australia and elsewhere. The infrastructure developed to accurately georeference (or locate) and map many of the geomorphic and biological features on or associated with the coastal wetlands of the region will be an integral part of ongoing monitoring of coastal wetlands in this highly dynamic tropical environment.

Acknowledgments

Thanks are owed to many people. The development of a Coastal Monitoring Program in the ARR was funded by the Portfolio Marine Group of Environment Australia. Parks Australia North allowed access to many sites and provided a lot of background information. Martin Hendy (AUSLIG) provided valuable help with the dGPS and base station equipment. Ray Hall undertook various tasks including, data acquisition, liaison with government and private organisations. Gary West and Alex Bakunowicz (Department of Lands, Planning and Environment) and Lyall Camp (AUSLIG), provided information on benchmarks. The work of a multitude of field assistants, Ray Hall, Ann Bull, Ben Bayliss, Stephanie Cobb and Darren Bell, is also gratefully acknowledged. Diagrams were provided by Ben Bayliss and Ann Bull.

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An evaluation of wetland assessment techniques and their applications to decision making

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Abstract

In the United States, wetland assessment, or the evaluation of the ecological condition and/or function of wetlands, most frequently occurs when those wetlands are proposed to be either impacted or lost as a result of development. The need to consider ecological value and function in the decision making process has led to the development of a wide variety of techniques for wetland assessment. The earliest techniques which were developed were considered to be rapid assessment procedures, which are most often used to evaluate single sites and to provide project-specific analyses. Some rapid assessment procedures, such as the Wetland Evaluation Technique (WET), which was developed by the US Army Corps of Engineers, considered broad groups of functions which included fish and wildlife habitat value, but also included flood control, groundwater recharge/discharge and value of the site for recreation and education. All of these techniques, however, are limited in their application. Most involve either qualitative results with little predictive value, or include subjective considerations based on best professional judgement. More recent techniques, such as the Hydrogeomorphic Method for Wetland Assessment (HGM) are based on peer-reviewed mechanistic models which are data-based, but which are difficult to apply and consider.

All of the methods evaluated ignored macro-scale, landscape and system-level functions, which are critical for cumulative impacts assessment and for the conservation of biodiversity. More recent assessment efforts are being driven by efforts to protect watersheds as a whole, rather than the specific sites within these watersheds. As a result, more current assessment techniques evaluate populations of wetlands against identified reference wetlands in that landscape, which allows more objective comparisons of functional performance. This paper examines the most commonly used wetland assessment procedures and compares their uses for resource management, restoration and landscape-level conservation.

Keywords: wetland assessment, rapid assessment, hydrogeomorphic method, landscape-level assessment, bioindicators

Introduction

In the past thirty years, there has been an increased public awareness of the values and benefits of wetlands to society. In the United States, this has produced changes in national policy, which include increased regulation of wetlands as well as both public and private conservation efforts to protect, acquire, enhance and restore these resources. At the same time, wetland areas are under increasing pressure from development and urbanisation within watersheds. Both resource management concerns, as well as regulatory needs, often force choices among the different, sometimes conflicting uses. The need to make decisions about wetlands has thus created a need for information on the value, both from an ecological and a societal standpoint, of these wetland resources; hence the need for wetland assessment. This paper uses examples from the United States to examine methods which are currently available for wetland assessment, evaluates their applications and shortcomings, and provides recommendations for approaches to wetland assessment based on the information needs and goals identified.

In the United States, the US Congress directed the US Fish and Wildlife Service (USFWS) in 1986 to develop a nationwide inventory of wetlands, in order to provide information to the public and to the government on the location and types of wetlands in the US. This National Wetlands Inventory (NWI), which is approximately 89% complete (USFWS 1998) has identified the location of wetlands in the US using stereoscopic pairs of infrared photographs. Fieldwork is then performed to confirm, or 'ground-truth' photographic data and collect additional data, from which the wetlands are ultimately mapped. The inventory further classifies wetlands by type based on substrate or soil type, dominant hydrologic regime, vegetation community and aquatic habitat type, among other things (USFWS 1998). NWI maps are not intended to provide wetland boundaries for regulatory purposes, but rather to provide information to the public about the possible locations and types of wetlands in a given geographic area. Information arising from the National Wetlands Inventory indicates that the United States has lost over half of the wetlands which historically existed in the lower 48 states, most frequently as a result of drainage for agriculture (Dahl 1990).

The development of inventory data is a type of assessment: it provides information identifying the locations, areal extent and types of wetlands existing within a landscape. The term assessment, however, as it is most commonly used, implies a more detailed evaluation of how a specific wetland or range of wetlands functions. Assessment may also involve an evaluation of the condition, or ecological integrity, of the wetland system.

In discussing wetland assessment, we often speak in terms of wetland functions and wetland values. Wetland functions are defined as physical, chemical, or biological processes occurring within wetland systems. Wetland values are attributes of wetlands which are perceived as valuable to society. Wetland functions are therefore able to be more objectively assessed or measured, while wetland values are inherently subjective and may be difficult to assess. Nevertheless, decision making is a valuative process and consequently must consider wetland values in weighing decision alternatives and consequences. Consideration of wetland value is often indirectly imbedded in the assessment process as well, because the choice of which functions to assess is often made based on the perception of which wetland functions are most important.

There are a wide variety of applications for which information on wetland function and condition may be used. The most common uses of assessment to date have been: 1) The evaluation of wetlands proposed for fill for development; 2) Evaluation of impacts for planning purposes; 3) Evaluation of wetland restoration potential for conservation programs; 4) Determining wildlife habitat potential for properties proposed for acquisition for wildlife management purposes, or where changes in land management are proposed to occur.

The commonest use of wetland assessment to date has been for the evaluation of impacts to wetlands from development. The placement of fill material into wetlands and other waters, which results in wetland loss, is regulated by §404 of the Clean Water Act and requires a permit from the US Army Corps of Engineers. The §404 regulations direct that, for a permit to be granted, it must be demonstrated that the placement of fill is unavoidable and that it has been minimised to the maximum extent possible. If these criteria have been met, the permit applicant must mitigate for any unavoidable impacts that the fill may have on the aquatic ecosystem. This typically involves some form of wetland creation, enhancement, or restoration within the affected ecosystem; its purpose is to compensate for wetland value lost to the system as a result of fill. In order to objectively determine whether wetland loss can be compensated by mitigation, the functions performed by the wetland proposed to be impacted must be determined. An additional policy directive within the wetland regulatory program proposes that there should be no net loss of wetland functions and values. This has augmented the need for an objective protocol to assess wetland functions, so that not only the feasibility, but also appropriate amounts and types of compensatory mitigation may be determined when wetlands are proposed to be impacted and/or lost. These regulatory imperatives may indirectly guide planning processes as well, since the evaluation of plan alternatives must consider future permit requirements for each alternative evaluated.

In response to the desire to achieve the goal of no net loss of wetland function, there have been over forty different methods developed in the last decade alone which are designed to assess wetlands (Bartoldus 1999). They range in level of rigor from those based on *ad hoc* consensus among professionals to more sophisticated peer-reviewed mechanistic models. Consequently, these techniques differ greatly in the level of detail, objectivity and repeatability of the results. There is also considerable variability in the range of wetland functions that are considered by any given technique. Some methodologies are narrowly focused and may only consider a single or a small related group of functions such as fish habitat, bird habitat, wildlife habitat, flood storage, etc (Bovee & Milhous 1978, US Fish and Wildlife Service 1980, Heinemann 1981, Morris & Bowden 1986, Cable et al 1989, Whitlock et al 1995); others look at a broader range of wetlands functions concurrently, such as flood storage capacity, sediment stabilisation, nutrient uptake, primary production export and fish and wildlife habitat (Larson 1976, Adamus 1983, Hollands & Magee 1985, Adamus et al 1987, Abbruzzese et al 1990, Amman & Stone 1991, Bartoldus et al 1992, US Army Corps of Engineers 1993, 1995, Bartoldus et al 1994, Ruby et al 1995, Miller & Gunslaus 1997). Some of these techniques have components to consider wetland values as well as functions. Because wetlands are such complex systems, however, there is no single technique, no matter how comprehensive, which can evaluate all functions performed by a given wetland.

Generally speaking, assessment methods fall into approximately four general types of approaches:

1 *Inventory and classification*. These are objective techniques which describe the areal extent and/or types of wetlands within a given landscape. This includes such information as the National Wetland Inventory maps, watershed-based GIS data, and remote sensing data.

2 *Rapid Assessment Protocols*. These are mostly low-cost techniques in which the data necessary to perform the assessment may be gathered in a short period of time. Rapid assessment protocols tend to focus mostly on single wetlands or small populations of wetlands. The results are likely to be either completely qualitative, or involve a large extent of subjective ('best professional judgement') information.

3 *Data-driven Assessment Methods*. These are usually expensive to develop, often model-based, but provide a high degree of reproducibility. The results often have predictive value.

4 *Bioindicators/Indices of Biotic Integrity.* These techniques involve a selected set of variables, which are measured across wetland types. The variables may be evaluated separately, or used to develop multimetric indices, which can be used to measure the condition or ecological integrity of a wetland and can be used as environmental triggers to identify long-term changes. They do not provide a reliable assessment of functional capacity.

Some of the methodologies may incorporate elements of more than one type of approach.

Rapid assessment methodologies have been and continue to be the most commonly used methodologies. One of the most widely used of the multi-function rapid assessment methods is known as the Wetland Evaluation Technique or WET 2.0 (Adamus et al 1987, Adamus et al 1991). This technique was developed through the US Army Corps of Engineers for use in making wetland permit decisions. WET is a broad-brush tool, which uses the presence or absence of a large set of wetland characteristics as correlative predictors of wetland functions. It is not designed to provide quantitative measurements of functional performance; rather, it is designed to predict the *qualitative likelihood* (high, medium or low) that a wetland performs given functions, to an unspecified degree. These functions include groundwater recharge, groundwater discharge, floodflow alteration, sediment stabilisation, sediment/toxicant retention, nutrient removal/transformation, aquatic diversity and abundance, wildlife diversity and abundance, recreation, and uniqueness/natural heritage, as well as species-specific fish and wildlife habitat assessments. For most of these functions, the protocol evaluates both the effectiveness, or the ability of the wetland to perform the function based on its structure, as well as the opportunity that the wetland has to perform the function. The relationships between characteristics and functions which WET uses are well-supported in the scientific literature and the rationale for WET is exceptionally well documented (Adamus et al 1991). WET was originally developed for the US Federal Highway Administration (Adamus 1983), and was used to do a 'broad brush' evaluation of relative impacts to wetlands for different highway location alternatives. It provides an excellent procedure for rapid screening of different alternatives which would affect wetlands in a landscape, and looks at a broad array of wetland functions. It is not, however, suitable for assessing the actual extent of wetlands impacts, or the type, location, or amount of mitigation that would be necessary to compensate for functions lost due to impacts. Furthermore, some of the predictors used in WET, particularly with respect to fish and wildlife habitat, differ in different regions of the US, and so do not always accurately predict habitat use likelihoods. Finally, while the results summary is fairly simple, the decision trees used to reach those results are quite complex, which tends to make the rationale for the end results somewhat obscure.

In contrast, a less complex, consensus-based assessment method known simply as the Highway Methodology has been used to assess wetlands in connection with planning and permitting of highway projects in the New England region of the US (US Army Corps of Engineers 1993, 1995). This method also does not yield quantitative results; however, it documents the rationale for the assessment results in a manner that is completely transparent. It also includes components which assess whether a wetland is likely to provide selected wetland values. While this method is not suitable for providing evaluation of losses for determining compensation ratios, it is simpler to use than WET and was designed for the region in which it is being used, so that it may be more sensitive to region specific wildlife habitat potential.

Another commonly used protocol for rapid assessment, which is used to evaluate fish and wildlife habitat within a given ecological community was developed by the US Fish and Wildlife Service (1980). This method, known as the Habitat Evaluation Procedure (HEP), uses a consensus-based field evaluation based on species-specific conceptual models for habitat use. HEP was originally developed for the evaluation of wildlife habitat potential for lands being considered for acquisition for wildlife management purposes. It provides a semi-quantitative measure of the number of habitat units per acre that a community can provide for each species evaluated. Because HEP can assess habitat value for a planned future condition as well as existing conditions in a given community, it has been used to assess the value gained from compensatory mitigation. The species models used in HEP are conceptual, based on ecological characteristics of the species which have been reported in the literature. HEP also allows for modifications to the models to better reflect regional differences in the habitat use of the species. Unfortunately, the procedure is easily affected by bias on the part of the field evaluators, both in terms of which species are selected for evaluation and in terms of the weights assigned to the habitat features. The relative ease with which the evaluation may be biased requires a greater degree of scrutiny in the weighing of results in the decision-making process.

Each of these rapid assessment techniques has limitations to their use. The data input for WET is more objective, and involves much less subjective judgement on the part of the evaluators. However, the results of WET cannot be used to compare the degree of functional performance of a wetland to any other wetland within a system, because there is no measure of function, only a prediction about whether that function may be performed. Both HEP and the Highway Methodology assess wetlands by using a consensus process; this means that the results are subjective, are not likely to be reproducible, and may be severely biased if the evaluators lack sufficient background to perform the assessment. This inherent subjectivity means that the results of such assessments cannot be reliably compared across large populations of wetlands or for the same wetlands over time, because the evaluative process is not directly reproducible.

The recognition that greater objectivity as well as reproducibility in wetland assessment was needed has led to reliance in certain decision making processes on more data-based analytical methods. Most such methods tend to be limited to single wetland functions; for example, HEC models (Hydrologic Engineering Center, US Army Corps of Engineers 1988) are techniques used for quantifying the hydrologic impacts of a project on a site and on the surrounding area, in order to evaluate flooding risks from development. Because these methods are data-intensive and often involve the use of a model, they are usually expensive and time consuming to perform; however, the outputs have good predictive value and reliability across wetland types. The narrow focus of these techniques limits their applicability to special problems and does little to address the need for objective information about a wide variety of wetland functions.

The decisions made by the §404 Regulatory program increasingly require not only some means of quantifying functional performance, but also need to address a wide variety of wetland functions. Brinson (1993) began to address this need with the development of the Hydrogeomorphic Classification Method (HGM), which has since evolved into a technique (Smith et al 1995) which can be used to measure a large suite of wetland functions in a quantifiable, consistent manner across a large geographic region. HGM is a reference-based technique, which develops a model for measuring wetland functions based on wetlands which are established as standards within that landscape. First, the wetlands are classified by hydrology and geomorphic setting into subclasses. The assessment protocol is then established by measuring functions across a set of wetlands of the same hydrogeomorphic subclass within a geographic region (called the reference domain) to determine the range of performance, for those functions in wetlands within the landscape. These functional profiles are used to develop functional indices, which estimate the capacity of a wetland to perform a function relative to other wetlands of the same hydrogeomorphic type in the reference domain. These are based on reference standards, which are defined as the conditions under which the highest *sustainable* level of function is achieved across the suite of functions performed by wetlands of that subclass. The protocol is developed by a designated team of experts and is subjected to both peer review and public comment before the model is finalised. Thus, HGM provides an objective means by which functional performance can be measured, objectively compared across geographic areas and evaluated.

The Corps of Engineers proposed a National Action Plan for the adoption of HGM as the national standard for wetland assessment for use within the regulatory program (US Army Corps of Engineers 1996), which stated that the goal would be to develop sufficient models over the subsequent two years so that HGM could be used in 80% of the permit cases. As of this date, there are not sufficient models to apply HGM as an assessment method in most parts of the US, nor is the protocol for its use sufficiently documented to allow the development of consistent functional models.

HGM has a number of fundamental strengths which set it apart from other assessment techniques. Perhaps its greatest strength is that model development is an iterative process, which allows for refinement and validation based on data and expert review. As an approach, HGM is both objective and quantitative. It uses reference wetlands to provide objective bases for standards of comparison — something which is clearly missing from almost all other assessment techniques. Once the model is developed, the assessment of a specific wetland would be expected to be relatively rapid, consistent, and reproducible. However, the cost of model development is high and the results of the assessment and the functions measured are both complex and rather obscure, and may not capture functions of importance as defined by established management objectives. Finally, HGM does not adequately evaluate highly impacted wetlands such as those wetlands in urban settings. Reference standards are based on the highest *sustainable* level of functional performance. Owing to their location within the landscape, urban wetlands may be performing functions (eg sediment removal) at a level higher than the reference standard and would have a significant benefit to the watershed because of their location within it. The application of HGM would result in a low functional rating for such a wetland because both positive and negative deviations from the reference standard are set lower than the standard. Such performance is not likely to be sustainable in the long term but nonetheless results in much greater benefits. Unfortunately, wetlands which receive low functional indices do not receive the same priority for protection as those which would receive high functional indices; as such, they may be at greater risk of destruction. This challenge is currently being worked on by the US Army Corps of Engineers Waterways Experiment Station.

A data-based approach which also evaluates wetlands across large geographic landscapes is the development and use of Bioindicators, or Indices of Biotic Integrity (IBIs). This type of approach was developed to rapidly evaluate the condition of streams and open waters (Yoder 1991a,b, Davis et al 1996, Karr & Chu 1997), and has only recently been evaluated as an approach to evaluating wetland conditions. The intent of each of these techniques is not to evaluate an entire suite of functions, but rather to pinpoint those which are characteristic of a specific set of environmental conditions, and to use their presence as indicators of condition and over time, as indicators of ongoing impacts. Species which are sensitive to degradation, for example, would act as indicators of high quality environmental condition. The loss of such species would be an indication that change is occurring and being triggered by environmental degradation. Karr and Chu (1997) indicate that careful program design can result in indicators that are both biologically useful and statistically robust. These techniques do not measure or evaluate functional capacity; however, the use of bioindicators and IBIs offer a promising approach where the goal of assessment is not assessing functional capacity but rather ecological condition of a wetland. As our focus in wetland protection becomes based more on watershed management, the measurement of condition assumes increased importance. It takes considerable time and data to develop a reliable suite of indicators; however, it is not necessary to evaluate many different functions, so development of bioindicators and IBIs is likely to be less costly than the development of HGM models.

Rapid assessment protocols evaluate individual wetlands; models such as HGM and IBIs provide assessment of wetlands in context of the geographic landscape. The evaluation of landscapes can be performed using GIS (Johnston et al 1988). The only assessment approach that addresses evaluation of wetlands at the landscape level is called the Synoptic Approach to Wetland Designation (Leibowitz et al 1992) and has been used in a few cases in the northwestern United States (Abbruzese et al 1990). This approach ranks watersheds using landscape level data such as GIS-based maps to evaluate watersheds for a variety of functions in terms of their capacity and sensitivity to wetland loss. It has not been used widely and its drawbacks are not fully evident; however, it can offer a useful approach for the evaluation of cumulative impacts.

Each of these approaches evaluates wetland functions differently; however, assessment methodologies do not exist at all for the evaluation of larger, landscape level effects. At the landscape level, wetlands interact with one another; they provide refugia for wetland animals within the landscape and seed banks for wetland vegetation; they are able to serve as sources for species dispersal and migration to other wetlands within the landscape. They provide support for migratory species. In addition, in areas such as urban settings where wetlands are scarce in the landscape, their relative contributions to habitat support, regional biodiversity and watershed-wide hydrologic functions assumes a disproportionate importance. Most landscape approaches emphasise wetland size and contiguousness as being significant from a landscape perspective. The contributions of large wetlands to biodiversity has been previously documented, and certainly continuity across a landscape is important for migratory support. However, a simulation study by Gibbs (1993) found that the loss of small wetlands (less than one acre in size) from a landscape resulted in significant regional extinction rates for some bird and many amphibian species because the interwetland distance became too great to allow outward migration of displaced individuals. Consequently, the role of small wetlands in contributing to regional biodiversity at the landscape level may have been underestimated. The maintenance and support of biodiversity may be one of the most critical landscape level effects which has been left largely unassessed in any systematic way.

Not every decision making process requires the same level of information. Qualitative information may be perfectly adequate if the only consideration is to screen alternatives for feasibility. On the other hand, when unique, rare, or regionally/globally significant wetlands are at serious risk of loss or damage, detailed data may be necessary to evaluate the impacts of present or proposed damage. In addition, little attention has been given toward the development of reliable techniques to assess cumulative impacts to wetlands. As we move toward a greater emphasis on comprehensive, watershed-based protection, this becomes even more important in planning for sustainable uses of these resources.

Toward that end, I offer the following recommendations for improving the way that we incorporate wetland assessment into our decision-making processes:

1 At the outset of the decision making process, clear goals for both immediate and long-term management of wetlands must be established. The level and focus of the information needs for assessment purposes cannot otherwise be determined.

2 There needs to be a clear understanding by the decision maker of what the chosen methodology will not provide, as well as what it will. The choice of what to leave out of the assessment must be able to be addressed within the scope of the decision.

3 Reference sites should be established regardless of whether any technique is systematically adopted by resource managers. Reference sites provide objective standards for both the measurement of functional capacity, even in assessment methods which rely on best professional judgement and consensus. They also provide reality-based targets for wetland restoration efforts and allow for long-term monitoring of wetland dynamics within the landscape. The most useful sites would be those which are under public ownership and/or long-term management, such as long-term ecological research sites, since these are most likely to be protected.

4 Techniques for the systematic effects of landscape-level effects, particularly the relative contributions of wetlands to regional biodiversity, need to be established. Without such protocols, we will be unable to realistically evaluate cumulative impacts of actions involved in our decisions.

5 Inventory data should be collected wherever possible if biodiversity is to be considered realistically in decisions. The increased availability and decreasing costs of GIS systems makes management of such information simpler. Partnerships between resource managers and non-governmental groups, academia and the public could be productive means of increasing the availability of these data.

6 Finally, we need to realise that there is no 'magic bullet' when it comes to objective assessment. The choice of methods is often dictated strictly by the available resources; however, a tiered approach, which could incorporate rapid assessment to screen alternatives and perhaps incorporate a more detailed approach for analysis of a preferred option, could provide a way to maximise the value of the information.

Note: The information presented in this paper has not been submitted to the US Environmental Protection Agency for the agency peer review process. All opinions and recommendations expressed herein are those of the author and do not necessarily represent the opinions or policy of the USEPA.

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Assessment and monitoring of wetlands for conservation and development in dry lands: A case study of Kajiado District, Kenya

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Abstract

African wetlands constitute an important natural resource base and are actively utilised by rural communities for socio-economic activities. However, vital information on their functions, values, uses and threats is lacking in many parts of the continent. This makes it difficult to plan for wetland conservation and to integrate conservation and development goals at a local level. This paper presents the results of a two-year study of wetlands in Kajiado district (36°30'E, 2°10'S), a semi-arid area in southern Kenya. The physical inventory of wetlands was carried out using topographic maps (scale 1:50 000) and aerial photographs of the district together with field surveys undertaken during the period March 1996–April 1998. Biological inventory was carried out by sampling higher plants and animals on each major wetland.

Data on wetland values, uses, threats and conservation initiatives was gathered through direct and indirect methods. 80% of Kajiado district (21 105 km^2) is semi-arid. Wetlands cover about 2% of the total area, most of them occurring in the high water potential areas of Ngong Hills, Mau-Nguruman escarpments and Mt. Kilimanjaro. Fifteen wetlands ranging in size from 10 to 15 000 ha were found and comprised lakes, rivers, swamps, marshes, floodplains, natural springs, man-made dams, ponds and pans. Water quality and quantity varied considerably between wetlands and between seasons. Species diversity was relatively low in marshes and swamps but even lower in saline lakes and seasonal rivers. Permanent fresh water wetlands provided water for domestic and livestock consumption and for irrigation. Subsistence fisheries and livestock grazing took place in some permanent freshwater wetlands. Aquaculture for fish production and control of water-based disease vectors was a rapidly growing community activity. The primary threats to wetlands were due to pollution, siltation and colonisation by exotic species. The results of this study indicate that wetlands play a vital role in conserving biological diversity, supporting human life and economic activities in the dry lands of Africa.

Keywords: wetlands, Kajiado, assessment, utilisation, threats, conservation

Introduction

Wetlands are lands that are transitional between terrestrial and aquatic systems where the watertable is usually at or near the surface of the land or the land is covered by shallow water (Cowardin et al 1979, Roggeri 1995). In the context of arid and semi-arid environments, wetlands are transitional areas that are permanently, seasonally or occasionally waterlogged with fresh or saline water, including both natural and man-made areas that support characteristic fauna and flora (Mermet 1986, Dugan 1990). In Kenya, wetlands occur in relatively small but widely distributed patches. They cover 2.5% of the country's total surface area of some 583 645 km^2 but their total area has been declining by approximately 7% per annum primarily due to drainage for agriculture (Gichuki 1995).

Semi-arid lands (dry lands) cover approximately 72% of Kenya's total land area. Wetlands in those dry lands cover approximately one percent of the land and are important focal points for human and animal activities. They are important refugia for wildlife and livestock, especially during prolonged dry periods. Pastoral communities that live in the dry lands depend on wetlands for water, forage and minerals. Wetlands also play a vital role in the hydrological cycle and in stabilizing the underground watertable, thus making underground water accessible to people through shallow wells and boreholes.

In order to manage these ecosystems sustainably we need to have current information on their conservation status, ecological variability, values and functions. Unfortunately, very little information is documented about the wetland types, their distribution, the species diversity and biological communities as well as socio-economic values of wetlands in dry lands of Africa. This study was intended to generate useful information for conservation and development planning at sub-national level. Its aims were to undertake an inventory of wetlands, determine their values and uses by the local community, identify threats and propose possible conservation measures in Kajiado District, Kenya.

Study area

This study was carried out in Kajiado district, which is located in the southern part of the Eastern Great Rift Valley in Kenya. The district has an area of 21 105 km^2 and is situated between latitudes 36° 5'E and 37° 55'E and between longitudes 10° 10'S and 30° 10'S. The area is characterised by plains, valleys and volcanic hills and is situated at an elevation of between 600 m (metres above sea level) to about 2500 m. The climate of the district is influenced by altitude, especially Mount Kilimanjaro, Ngong Hills, Chyulu Hills, Loita Hills and Mau Hills. Most of Kajiado District is semi-arid with poorly developed and shallow soils (vertisols), which are commonly known as black cotton soils. The soils have high clay content and are susceptible to waterlogging. The temporal rainfall distribution is bimodal with an annual average of 600 mm but increases with land elevation from 500 mm in the plains to 1250 mm in the highlands. Heavy rain falls on hills, escarpments and mountains where it permits intensive agriculture. Temperatures and potential evapotranspiration vary with altitude and range from 12°C and 1700 mm in the highlands to 34°C and 2500 mm in lowlands respectively.

The population of the district is approximately 382 000 people (G.O.K 1996). The district is primarily inhabited by the Maasai people who practice nomadic pastoralism and subsistence agriculture in well-watered areas. Sedentary farming communities occupy highland areas such as Ngong Hills, Nguruman escarpment and lower slopes of Mount Kilimanjaro in Loitokitok area. Human population density was highest in Ngong (36 persons/km^2) followed by Loitokitok (18 persons/km^2) in 1996. Land degradation especially destruction of natural forests and wetlands was also most apparent in those parts of the district.

Water resources in the district are scarce. There are few permanent rivers and springs. The major lakes are shallow, alkaline and relatively small. Wetlands are closely associated with permanent rivers, springs and lakes and are characterised by large seasonal variations in size. Wetlands occur in the form of swamps, marshes, springs, seasonal and temporary pools. Wells, pans, dams and fishponds are also numerous although no proper survey of them has been carried out. Information on surface water hydrology is scant and no water pollution monitoring has been undertaken. Except for the wetlands in wildlife refugia which are managed by Kenya Wildlife Service, there is no authority responsible for conservation of wetlands in the district (NES 1996).

Methodology

A physical inventory of wetlands in Kajiado District was conducted by the project executants with the assistance of fisheries and water development officers and the local people. The wetlands were located using topographic maps of scale 1:50 000 and followed by ground truthing. The altitude, latitude and longitude of wetlands surveyed on the ground were determined using Global Positioning System (GPS) and topographic maps. The area of target wetlands was estimated from a sketch map drawn using measurements made with a range finder (TMO-500-X) or tape measure and a compass. Alternatively estimates of wetland size were made from aerial photographs and recently published Survey of Kenya maps.

Sampling stations for aquatic fauna and flora, as well as for water quality were randomly selected along the shallow parts and edges of each wetland. Physical-chemical water characteristics were determined at each station. These included water pH, temperature, conductivity and water depth. Water transparency was determined by secchi disk while dissolved oxygen was measured using the Winkler method (APHA 1975).

Groups of higher animals, which included mammals and birds, were assessed through observations and the spot count method (Verner 1985) using pairs of binoculars and a telescope. Reptiles, amphibians, fish and aquatic macro-invertebrates were assessed using standard sampling equipment and methods (Southwood 1978). The results of this biological inventory are reported elsewhere (Gichuki et al 1998). Information on wetland use was gathered through direct observations and interviews with local land owners. The latter were mature individuals who were residents and interacted with target wetlands. Information from respondents was recorded in a pre-designed questionnaire. Existing threats to wetlands, conservation measures being undertaken and proposed development activities were noted.

Results

Physical inventory

The permanent wetlands of Kajiado District cover approximately 421 km^2 (equivalent to 2% of the total surface area). The district has five shallow lakes, 59 permanent streams and springs, 135 water storage dams and pans and 381 shallow wells and boreholes. Permanent wetlands play a vital role in recharging with water underground aquifers. Most of the district's water resources are underground and hence, the local population depends largely on shallow wells and boreholes for their domestic and livestock water needs.

Seasonal wetlands were widely scattered and tended to vary considerably both in size and location. The distribution of all wetlands, however, was strongly influenced by the drainage pattern, local topography, soil and geological characteristics. The main wetlands are found within three major drainage basins. These are the Athi (10 553 km^2) Rift Valley (7260 km^2) and Amboseli (3292 km^2) (see fig 1). The wetlands in the Athi basin are associated with River Mbagathi which originates on Ngong Hills (2459), River Kiboko which originates on Endoinyo Narok (2025 m) and River Tsavo which originates on the northern slopes of Mount

Kilimanjaro (5895 m). These rivers supply water into River Athi, one of Kenya's two major rivers that drain into the Indian Ocean.

The Rift Valley is an internal drainage basin whose coverage width is 60 km. The main wetlands in the valley are the alkaline Lake Magadi (95 km^2), moderately alkaline Kwenia (4 km^2), Kabongo (3.6 km^2) and Loonkujit (1.8 km^2). There are also hot springs, especially south of Lake Magadi and on the northern shores of Lake Natron. Apart from shallow lakes and pans, there are also freshwater marshes, mudflats and a floodplain associated with the River Ewaso Ngiro (South). That floodplain (80 km^2) has abundant tall grass and marshes that regulate river flow into Lake Natron. The River Ewaso Ngiro receives water from the Mau Hills (3098 m), the Loita Hills (2249 m) and the Nguruman escarpment located on the western shoulders of the Rift Valley.

Amboseli basin is also an internal drainage basin situated north of Mount Kilimanjaro. Lake Amboseli (140 km^2) is the main wetland, which though seasonal, receives regular water supply from River Namanga. The river originates on Meto Hills (2200 m) and flows through a marsh at Namanga town and through dry woodland before it enters the lake. The basin also receives both surface runoff and underground water supply from Mount Kilimanjaro. The seepage of underground water in the basin maintains a series of freshwater marshes, swamps and springs on the eastern shores of the lake. In addition, there are also seasonal wetlands, such as Kimana pans which fill with water during the long Wet season.

Wetland development

The wetlands in Kajiado district occur in a variety of landscape positions (table 1). Low gradient of the land and low water permeability are favorable conditions for formation of a wetland. These conditions, which result in impeded drainage, exist in the central parts of the district where shallow black cotton soil overlies impervious rocks. Most of the wetlands in that part of the district are shallow and highly seasonal.

The hydrological conditions of wetlands in the study area varied from permanent inundation by shallow water (eg Lake Magadi), or permanent soil saturation (eg Amboseli Swamps) to periodic inundation (eg Lake Kwenia) or periodic soil saturation (eg Ewaso Ngiro floodplain). The varied hydrological regimes associated with wetlands in the drylands of southern Kenya produce diverse environmental conditions to which different species of plants and animals are adapted.

Table 1 Landscape positions in which wetlands occurred in Kajiado District, Kenya

Landscape position	Characteristic topography
Low-lying areas subject to periodic flooding	River valleys, floodplains and estuaries
Gentle slopes in areas of groundwater discharge or seepage	Springs and seepage slopes
Isolated depressions surrounded by uplands	Lakes, ponds and pans and seasonal pools
Flat areas without drainage outlets	Seasonal pools and holes collecting surface runoff
Flat or sloping areas adjacent to a body of water	Fringing marshes and seepage wetlands below dam walls

Note: Landscape categories follow those suggested by Tiner (1993)

It was found that as soil wetness decreased, plant composition gradually changed from a typical wetland community of herbaceous vegetation to a transitional community where typical wetland plants intermixed with terrestrial plants, including woody vegetation. This pattern of vegetation change or succession was clearly apparent in the Ewaso Ngiro floodplain. Newly established dams were colonised by herbs but the colonisation process was very slow. For instance, the mean plant cover on walls of five 20 year old dams established in Kajiado District was 37.3%, suggesting that natural plant colonisation and succession was a relatively slow processes.

Fluctuation in size and water regime

One of the main features of wetlands in this semi-arid district is their fluctuation in size and water regime. The changes in some physical characteristics of major wetlands surveyed in November 1997 (wet period) and March 1998 (dry period) are shown in table 2. Altitude varied from 600 m at Lake Magadi to nearly 2000 m at Ngong Swamp. The wetland surface area during the dry period decreased by between 15.8% (Lake Magadi) and 35.0% (Lake Kwenia). Other wetlands such as Lake Amboseli, Lake Kabongo and Ngong Swamp shrunk by about 30% during a five month period. Shrinkage of the lakes continued until Lakes Amboseli and Kwenia dried up.

Table 2 Change in altitude, and seasonal variation in surface area and water temperature between wet and dry periods in major wetlands of Kajiado District, Kenya. The wet period data are for November 1997 while the dry period data are for March 1998.

		Wet period		Dry period	
Wetland name	**Altitude (m)**	**Area (km^2)**	**Temp (^{o}C)**	**Area (km^2)**	**Temp (^{o}C)**
Lake Magadi	600	95.0	34.0	80.0	36.0
Lake Kwenia	1072	4.0	29.5	2.6	32.5
Lake Amboseli	1151	140.0	33.0	98.0	34.0
Lake Kabongo	1500	4.0	30.0	2.9	32.0
Ngong Swamp	1980	5.4	28.5	3.8	30.0

Water surface temperature was higher in Lake Magadi and Lake Amboseli than the other wetlands surveyed in both wet and dry periods. Marginal increases in water surface temperature were noted during the dry period at Lakes Kwenia (3°C), Lakes Magadi (2°C) and Kabongo (2°C). Fluctuations in wetland size were attributed to high ambient temperature and the associated high rates of evaporation and evapotransporation. Seasonal wetlands that occurred in shallow depressions or flat areas without drainage outlets, were widespread in Kajiado District during the long rains in April and May. However, most of them dried up before the short rains in November and December.

During the long rains, wetlands occurred widely in the upland areas of Athi basin where heavy clay soil overlies impervious basement rocks. The principal effect of the short rains in the study area was to expand permanent wetlands, especially riverine wetlands in the lower courses (eg River Ewaso Ngiro floodplain). The short rains also contribute to the formation of temporary pools and pans that did not last through the long Dry season, between January and March.

Physical and chemical water characteristics

The physical and chemical characteristics of the water in major wetland types in Kajiado District are shown in table 3. The water in the endorrheic lakes Magadi and Natron as well as the associated hot springs in the Rift Valley basin was shallow, with a mean depth of less than half a metre. Water transparency was also generally low being less than 20 cm. The mean water temperature, conductivity and pH were generally high in those alkaline lakes and hot springs. Lakes Magadi and Natron have high concentrations of sodium chloride, sodium bicarbonates and phosphorus. The lakes were also characterised by low levels of dissolved oxygen.

The water of lakes Kabongo and Kwenia was moderately alkaline. The lakes were also shallow, the mean depth being 40 cm. Lake Amboseli was larger and its water was marginally warmer than the water of the other two lakes. However, there was no significant difference between the mean temperature and dissolved oxygen between the five lakes. Lakes Kabongo and Kwenia had notably lower pH, electrical conductivity and water transparency than Amboseli, Magadi and Natron. Dissolved oxygen levels fluctuated more in Lakes Kwenia and Kabongo than other alkaline lakes.

The water in swamps and rivers was deeper and cooler than the water in lakes and pans. The pH level tended to be lower in swamps than rivers but local variations were apparent within each wetland type. The mean electrical conductivity ranged from 0.1 mS in River Oloiboitoto to 1.51 mS in Sosian Swamp. Because of site variations, however, it could not be confirmed whether electrical conductivity was higher in swamps than rivers. Freshwater swamps with submerged and floating aquatic vegetation had higher values of dissolved oxygen than rivers without aquatic vegetation. Similarly, water transparency values were higher in freshwater swamps than in rivers, especially during the wet period when river water was highly turbid.

Man-made wetlands were a common feature of the landscape in the semi-arid lands of southern and eastern Kenya. In Kajiado District, man-made dams were built for domestic and farm water supply, fish rearing and waste water treatment. Pokeny dam in central Kajiado and Entosopian fishpond near Nguruman escarpment contain freshwater and fish. The water of Pokeny dam was deeper, cooler, more transparent and in a larger basin than that of Entosopian pond. Differences in pH, electrical conductivity and levels of dissolved oxygen between Pokeny dam and Entosopian pond could be associated with local differences in water source, rock type and the sizes of the two wetlands.

Serena and Sampu Lagoons were established for wastewater treatment. Serena Lagoons are located in Amboseli National Park and receive wastewater from the Serena tourist hotel. Sampu lagoon is located on the outskirts of Kajiado town and receives waste water from an abattoir. In spite of the fact that the two wetlands were at different locations and altitudes, and receive different types of waste, there was no difference in surface water temperature. The measured pH was slightly higher in Sampu Lagoon than Serena Lagoons, but electrical conductivity and dissolved oxygen were, however, significantly higher in Sampu than Serena Lagoons. The two sites had emergent aquatic plants, particularly at the edges. The water in Sampu Lagoon was, however, significantly less transparent than that of Serena. The differences in the water characteristics of two wetlands primarily derive from the nature of the influent and local hydrological conditions.

Table 3 The physical and chemical characteristics of water in major wetland types in Kajiado District

Type	Wetland	Mean depth (cm)	Temperature °C	pH	Conductivity mS	Dissolved oxygen	Turbidity
Lakes							
	Lake Amboseli	41	33.0	11.1	0.4	1.86	7.0
	Lake Magadi	35	36.0	9.7	>20	2.56	14.0
	Lake Kwenia	30	29.0	7.6	0.94	1.22	1.4
	Lake Kabongo	38	31.0	8.5	1.32	1.18	39.4
	Lake Natron	46	36.5	10.5	<20	2.22	19.6
Swamps							
	Maji ya Kioko	105	26	8.8	0.53	2.18	30
	Enkong Narok	97	24	6.4	0.18	1.04	30
	Sosian	65	26.3	10.5	1.51	1.6	clear
	Injiri	71	21.7	6.8	0.21	2.08	clear
	Longinye swamp	145	27.9	10.7	0.36	2.23	9.5
Rivers	River Engare Narok	27.5	26.8	5.2	0.29	1.32	clear
	River Ewaso Ngiro	78.7	25.3	7.9	0.33	1.4	>100
	River Oloiboitoto	29.6	23.2	10.3	0.1	1.25	29.6
	River Rombo	22.5	25.9	10.5	0.36	1.5	clear
Dams/ponds							
	Serena Lagoons	140	26.9	7.25	0.5	0.61	24.5
	Sampu Lagoon	110	26.1	9.7	6.81	1.33	12.2
	Pokeny dam	200	21.06	7.75	0.22	3.5	19.6
	Entosopian pond	120	27.8	8.7	0.11	2.75	11.5

Wetland values and uses

In Kajiado District, wetland resources as well as their attributes and functions contribute to the socio-economic development of the local communities (table 4). About 60% of the people rear livestock (cattle, sheep, goats and donkeys). These people have established traditional links with wetlands that provide specific products and services.

Table 4 Socio-economic values of wetlands in Kajiado District, Kenya

Wetland values	Value score	Characteristic wetland
Resources		
Agriculture	2	Rombo Swamp/Nguruman seepage
Fisheries and aquaculture	1	Ewaso Narok/Loitokitok fishponds
Forage	3	Ewaso Ngiro floodplain
Food products	1	Mist wetlands
Medicinal products	1	Kimana Swamp
Water supply	3	Amboseli Swamp, Nguruman
Tourism	2	Amboseli National Park, Lake Magadi
Mining	3	Lake Magadi and Amboseli
Salt licks		
Attributes		
Biological diversity	1	Amboseli National Park
Cultural heritage	1	Amboseli, Lake Kwenia
Functions		
Groundwater recharge	3	Amboseli Swamp
Groundwater discharge	1	Shombole Swamp
Flood control and flow regulation	2	Kiserian, Shombole swamps
Sediment retention	2	Shombole and Rombo Swamps
Soil erosion control	1	Kiserian and Rombo Swamps
Water treatment	1	Sampu/Serena wastewater lagoons

Score: 3 important, 2 common, 1 present

Wetland values modified after Dugan (1990) and several other authors

Agriculture

Wetlands are valuable for subsistence agriculture both directly and indirectly. The presence of water during the Dry season permits irrigation of food crops and horticultural crops. The soil in reclaimed marshes and floodplains is moist and fertile and permits flood-recession agriculture. Nutrients are replenished by silt brought by flood waters. This type of agriculture is possible on the Ewaso Ngiro floodplain where traditional cereal crops can be grown after the flood recedes. Wetland dependent agriculture, primarily for the production of vegetables and fruits, is common at Rombo, Loitokitok, Kiserian, Nguruman, Ngong and Namanga. Food crops from those areas are consumed locally while the surplus is marketed in Nairobi.

Fisheries

Wetlands in Kajiado District have ample potential for development of subsistence fisheries and aquaculture. Permanent rivers and swamps offer fishing opportunities, especially River Ewaso Ngiro and Amboseli swamps. In addition, 35 landowners and seven primary schools have productive fishponds. In 1996, for instance, the District generated US $10 688 from the sale of fish caught in natural wetlands and US $5000 from the sale of fish obtained from ponds and dams. Traditionally, the Maasai community despises and, hence, do not eat fish. However, the value of fish lies in their ability to control mosquitoes, leeches and snails, which are vectors of human and livestock diseases.

Livestock grazing

Herbaceous and woody vegetation found in wetlands remains productive throughout the year and constitutes an important grazing resource for the pastoral communities in Kajiado District. The major wetlands used for livestock grazing are Amboseli Swamps, Lake Kabongo, Lake Kwenia and Ewaso Ngiro floodplain. These four major wetlands cover a total area of 15 600 ha and support about 80 000 head of cattle a year. The floodplains of rivers Kiboko, Namanga, Esokota and Rombo are also important livestock grazing areas during the Dry season. Livestock owners lead their herds of cattle, sheep, goats and donkeys to wetlands where nutritious forage and water are available during the dry season when upland reserves are exhausted. Flooding of lowland wetlands forces stock farmers to move to upland areas where health conditions are better for people and livestock.

Plant food and medicine

Communities that live in drylands obtain a wide variety of food and medicinal products from wetlands. Ponds and fresh leaves of certain riverine *Acacia* spp are used to prepare special traditional foods. Fruits of various plants, such as *Rhus natalentsis* and *Ficus sycomorus*, are used for a variety of purposes (eg food or making alcoholic drinks). Seeds of various types of wild sorghum and wild millet are also cooked and eaten. These indigenous foods sustain the community during periods of severe drought and famine. A wide range of medicinal plants for the treatment of human and livestock ailments are obtained from wetlands. Community members have immense knowledge of plants or parts of plants that have medicinal values but this area of ethnobotany is important for biodiversity conservation and development of aquatic resources and hence requires a separate study.

Freshwater supply

In drylands, water is a critical resource that is needed for social and economic development. In Kajiado District, surface water is scarce and hence most of the local people depend on underground water resources that are accessed through shallow wells, boreholes and springs. Underground water yields vary from 0.01 to 35.77 m^3 per hour. In areas close to wetlands the underground water table is shallow and hence shallow wells provide adequate water supply for families and their livestock. The people use the water for their own consumption and for household and farm (eg drinking by livestock) needs. Numerous dams and water pans have been constructed in various parts of the district to provide water to people, livestock and wildlife. Rain water harvesting pans have been introduced in a few places, especially in schools and other institutions.

Mining of raw industrial material

Mining of minerals is an important economic activity in Kajiado District. The most important mining activity is exploitation of soda ash in Lake Magadi. The lake has large quantities of solid trona (sodium bicarbonate, sodium chloride and other derivatives). Magadi Soda Company the lease holders produces a wide range of marketable material, primarily for the export market. The raw materials produced by the company are used in the manufacture of table salt, glass, industrial acids and food preservatives. Sand was mined in dry riverbeds while building stones, including marble plates, were mined in a few areas where suitable rock formations were available.

Tourism and biodiversity conservation

Kajiado District is rich in wildlife, particularly the large mammals such as elephant, buffalo, hippopotamus, lion, leopard as well as zebra, giraffe and wildbeast. There is therefore ample potential for wildlife conservation and development of eco-tourism. Among the wetland areas that presently support eco-tourism are Amboseli Swamps, Shombole swamp, Lake Magadi and the associated hotsprings. Spot fishing is a popular activity in Rivers Kiboko and Ewaso Ngiro, as well as in man-made dams with introduced species of fish.

The existence of wetlands in Amboseli National Park is crucial to the survival of wildlife, people and their livestock. Amboseli National Park is a Biosphere Reserve that was recognised by UNESCO for its primary role of protecting the physical environment and wildlife and preserving the life styles of the indigenous Maasai people. Apart from Amboseli, there are other cultural heritage sites, such as Lake Kwenia, which has traditionally served as a salt lick for wildlife and livestock.

Environmental service

The wetlands of Kajiado District perform a wide range of functions that generate benefits to local people. Wetlands retain sediment and filter water, making it suitable for domestic and farm use. Lake edge wetlands protect lakeshores against soil erosion by water current. Similarly, riverine wetlands regulate river flow and control floods. Excess water collecting in the swamps during heavy rain is stored and slowly released to underground aquifers. The functions of wetland recharge and discharge are important for the stabilisation of underground water table.

A number of villages in Loitokitok, Nguruman and Ngong drain their wastewater into small natural swamps. The use of constructed or natural wetlands for wastewater treatment is a relatively new concept in southern Kenya (Nzeng'yia & Gichuki 1997). Tourist lodges (eg Serena Lodge) in Amboseli National Park drain wastewater into wetlands after it is discharged from conventional water treatment systems. The wetlands purify wastewater making it fit for consumption by wildlife and livestock. Use of wetlands to treat wastewater from slaughter houses is uncommon but it is practiced at Sampu slaughter house in Kajiado town.

Ecosystem monitoring

Development activities that impact on wetlands and water resources have been increasing rapidly in Kajiado District during the last 20 years. The integrity of aquatic ecosystems in the district is therefore being gradually threatened by land-based human and livestock activities. During this study, ecosystem-monitoring activities were initiated in Amboseli and Magadi ecosystems. The activities included taking basic measurements of water quality and carrying out inventories on species composition, diversity and presence of indicator species. The two ecosystems showed marked differences in water quality, water supply regime and in the structure of plant and animal communities.

Amboseli basin was characterised by freshwater swamps and springs and alkaline water in Lake Amboseli. Magadi had highly alkaline sediments and hence most of the lake and in the hot springs was alkaline. While freshwater was available for domestic and livestock use in Amboseli, much of the water in Magadi basin was unsuitable for human and livestock use so freshwater is piped from Nguruman escarpment to Magadi town. Both Amboseli and Lake Magadi are closed basins with substantial underground water supply.

As in other alkaline lakes of the Eastern Rift Valley, Lake Magadi is relatively poor in biodiversity. The lake and the associated hot springs have an endemic cichlid fish, (*Oreochromis alcalicus grahami*) which is of great conservation value but of no commercial value. Except for abundant chironomid worms, the lake is poor in aquatic invertebrates. Amboseli, on the other hand, has four species of fish, two of which are of commercial value. Fish, invertebrates and water-dependent birds were found to be suitable indicators of changing ecosystem integrity. The rapidly growing population and rapid expansion of villages near wetlands and other water sources has serious implications on the ecological integrity of aquatic systems in Kajiado District. A long-term program of monitoring of wetlands and water resources should therefore be developed and implemented in the district and in other dry lands.

Threats to wetlands

The major threats to wetlands in Kajiado district were siltation, water abstraction and pollution. Improper activities such as vegetation destruction, heavy grazing and trampling were noted in many wetlands. Unplanned settlements in water catchment areas were noted around Posimoru forests and Oletukat areas. Most urban centres in Kajiado do not have proper sanitation and waste water treatment plants. Pollution from domestic waste was noted in Magadi, Kajiado and Loitokitok towns, Amboseli National Parks and in Olkirimatian area. Unplanned water abstraction for agriculture was common along the Endosopian, Embakasi and Rombo Rivers.

Modern and traditional mechanisms of conserving wetlands

Wetlands in Kajiado district are either under government, private, communal or trust land. Customary law governs utilisation of communally owned wetlands in the district. Wetlands under private and trustlands are found in adjudicated lands where title deeds have been issued. Access to these wetlands is restricted and they are managed by individual landowners. Government lands comprise forest reserves, game reserves and national parks. Wetlands under these areas are managed by central government or its agencies (eg Kenya Wildlife Service, Forest Department) and are exclusively reserved for wild animals although they are open to normal usage by the local people. A few water springs, swamps and marshes are sacred sites. For example, Oloyiankalani spring in Kajiado district was protected through customary law as an important site for community ceremonies and rites.

This study established that the Maasai people have a strong attachment to wetlands and recognise their vulnerability and have participated in their conservation. They employ a number of practices that result in the restoration and conservation of wetlands. The Maasai occupy uplands during Wet seasons and wetland basins and valleys during Dry seasons. For instance, seasonal migration of people and livestock from upland areas to and from River

Ewaso Ngiro and Lake Kwenia is a common practice. This practice (known as trans humance) allows sustainable utilisation of forage materials and promotes co-existence between livestock and wild herbivores.

Customary rules govern the utilisation of communally owned wetlands by restricting direct utilisation and encouraging zonation. Boreholes and wells were observed to be well spaced out and in some places watering points were located away from the water sources so as to minimise trampling of vegetation and over-grazing by livestock.

Discussion and recommendations

Significance of wetland inventory

Assessment of wetlands is an important initial step in improving the quality and quantity of available information (Dugan 1990). The information derived from inventory activities relating to water quality and biological resources in Kajiado District should be used for conservation and development planning as well as management of water, wildlife, livestock and forest resources.

The findings of the inventory work have generated valuable information for wetland management. This includes designation of wetlands of national or international importance (Ramsar 1971), identification of suitable indicator species and promoting public awareness of wetland issues and sustainable utilisation of resources such as water, fish, wildlife and livestock. The results of the study are expected to find wider use or application in other drylands of eastern Africa.

Wetlands in dry lands form an important life support system (Child et al 1984). They are important refugia for wild animals including thousands of migratory waterbirds. Seasonal wetlands are extremely rich in ephemeral invertebrate fauna and flora (Ng'weno 1992). In Kajiado District, wetlands occur in a wide range of landscape positions and are focal points of both human and animal activities. Because of the various resources that wetlands contain, they are susceptible to unsustainable use, thereby threatening their rich biodiversity and ecological process.

Arid and semi-arid lands are characterised by environmental variability. In Kajiado, that variability was apparent in the fluctuations in wetland size and water regime, as well as in the seasonal movement of people, large game and livestock. Availability of fresh water is a crucial factor influencing the distribution and activities of people, livestock and wild animals, especially during the Dry season (Mungai 1992). Understanding the functional dynamics of wetlands in dry lands and the various ways in which wetlands are affected by and affect local communities are important for effective management.

Socio-economic values

Wetlands in dry lands are endowed with essential natural resources which are used to fuel social and economic development. In Kajiado, wetlands cover only 2% of the district's surface area but contribute up to 40% of the total income deriving from local natural resources (Government of Kenya 1996). Freshwater is available in wetlands as well as in shallow wells and boreholes. Wetlands contribute to groundwater recharge and discharge, a function that is crucial to the maintenance of an adequate and accessible underground water supply.

Wetlands support subsistence agriculture, especially the growing of early maturing crops, such as cereals, vegetables and fruits. The pastoral communities of drylands have immense knowledge of traditional food plants and medicinal plants that derive from wetlands. That knowledge has been acquired and tested over many generations of deliberate interactions with wetlands. The Maasai community of Kajiado, have developed traditional mechanisms and technology of utilizing wetlands in a sustainable manner (Miaron 1997).

There is ample potential for harvesting of rainwater and storing it in suitable reservoirs. This would reduce pressure on wetlands, especially in areas where zonation of wetland usage is unfeasible. In both natural and man-made wetlands, there is potential for development of small-scale fisheries and aquaculture. In Kajiado, the individual and communal landowners have agreed to rear fish because of the need to control aquatic vectors of human and livestock diseases. Other incentives for fish farmers should be developed and implemented. Fish aquaculture in natural and man-made waters can be a suitable means of using wetlands wisely.

Mining of sand and other products, such as solid trona, is an activity that generates monetary income and supports local and national economy. In Kajiado, mining of soda ash is a major industry in Lake Magadi. Mining of river sand, building stones, marble and other minerals also generates monetary income. These economic activities provide employment and livelihood for several hundred people in Kajiado District. However, sand mining in dry riverbeds lowers the underground water table. In order to continuously check and control the impacts of mining and disposal of waste products, it is necessary to devise a consistent water and ecosystem monitoring program.

Wild animals tend to congregate in wetlands where freshwater is available. Tourist lodges and hotels, as well as villages and market centres are also located near wetlands where fresh water is available. Encroachment of wetlands by human settlements and pollution from such areas threaten aquatic animals, plants and water resources. This was apparent in Magadi, Nguruman, Kiserian and other areas of the Kajiado district. This seems to be a common trend in other semi-arid lands in Kenya.

Wetland threats and conservation

Human population trends and patterns of economic development in Kenya's drylands have made it imperative that significant changes be made in the way wetlands are managed. The demand for goods and services by a rapidly growing human population cannot be sustained by the existing traditional management systems (Gakahu 1997, Gichuki 1997).

In Kajiado District, wetlands are threatened by human encroachment (drainage) over-exploitation of plant and water resources, pollution from human settlements, introduction of exotic species and destruction of water catchment areas. Population over-spill from densely populated areas to drylands and the changing life-styles of the pastoral communities have serious negative effects on the future of wetlands in drylands. Freshwater resources are already scarce and are likely to be even more endangered (Liniger 1995).

The traditional mechanisms of protecting wetlands and managing water, browse and livestock resources cannot withstand today's population pressure. Ecosystem management principles must be adopted and linked to economic development goals as well as the global environmental issues of preventing desertification and minimising the impacts of climate change. The drylands of Africa are the granaries of the future and wetlands are important to the realisation of that dream. Since most communities that live in drylands have retained their traditional lifestyles, modern approaches to environmental management should draw lessons from existing local knowledge and technologies. Co-management of wetlands between state and community is necessary especially in dry lands where land is still communally owned.

Acknowledgment

This project was supported by the Eastern African Program of Research on Sustainable Use of Dryland Biodiversity under the auspices of the Swedish International Research and Development Agency (SIDA). Their financial support is gratefully acknowledged. We are also indebted to our research colleagues Mr Collins Handa, Stephen Mathai and Stephen Muoki for their assistance in the field and the laboratory. Ms Rose Warigia typed the manuscript and we are grateful for the assistance.

The Royal Netherlands Embassy (Nairobi) and Kenya Wildlife Service kindly provided a travel grant that enabled the first author to attend the International Conference on Wetlands and Development in Dakar, Senegal, where this paper was presented.

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Priorities for wetland biodiversity conservation in Africa

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Abstract

The peoples of the African continent and its related islands are naturally preoccupied by water issues, since water is the determining element for the availability of natural resources throughout Africa. Most African people rely directly on natural resources for drinking water, food, shelter, health and domestic energy supply. Wetland ecosystems provide key goods, services, functions and water resources. Priorities for wetland conservation are varied and complex and derive from individual concerns such as those of a local fisherman to the global targets and objectives of international agreements such as Agenda 21 and the Ramsar Convention on Wetlands (Ramsar, Iran, 1971).

However, African countries share common interests in relation to wetland biodiversity conservation. The main problems and threats that face wetland biodiversity conservation in Africa stem from insufficient knowledge of wetlands and their importance, insufficient political conviction, poor policies and strategies, lack of suitable legislative frameworks leading to insufficient programs and activities for protection of wetland functions and values. A common dilemma faced by policy makers and decision makers is balancing the short-term benefits derived from unsustainable land use practices versus the medium and long-term benefits derived from long-term programs that sustain wetland functions and values.

In response to these challenges, wetland inventory and assessment, water and wetland policies/strategies, legislation and regulation, pollution control, economic valuation techniques, training and environmental education and public awareness are some of the areas where efforts are being made to conserve wetland biodiversity in Africa. This paper explores those priority actions that are likely to overcome or alleviate the major problems associated with the loss of biodiversity due to wetland ecosystem degradation.

Keywords: Wetland biodiversity, Africa, Ramsar Convention

Introduction

Successful wetland biodiversity conservation in Africa is being challenged by poor policies and a lack of suitable legislative frameworks as a result of insufficient political conviction or 'will' to formalise wetland conservation. Commonly, dilemmas are faced when evaluating options that are either beneficial in the short term — but are derived from unsustainable practices — or accrue benefits only in the mid-long term — but sustain wealthy and productive wetland ecosystems. This paper examines some of the issues around this dilemma. Particular attention is given to how African countries can mobilise existing knowledge and capacity so as to foster political conviction and activate decisions for wetland conservation and wise use.

There is growing awareness of the importance of wetlands (Costanza et al 1997) and increasing recognition that wetlands are amongst the most economically valuable of ecosystems. Table 1 summarises the global economic importance of wetlands and other ecosystems. Wetlands provide ecosystem services estimated to be worth at least $14 785 ha/yr, a substantially higher value than any other ecosystem. Furthermore, this value refers to a narrower definition of 'wetland' than that adopted by the Ramsar Convention. For this full range of wetlands the total value of ecosystem services is in excess of US$14.9 trillion per annum, some 45% of the global total (Ramsar Convention Bureau 2000a).

Table 1 The economic value of global ecosystem services (from Costanza et al 1997)

Ecosystem	Area Million ha	Value US$/ha/yr	Global Value US$trillions/yr
Open ocean	33 200	252	8.4
Coastal	3102	4052	12.6
Tropical forest	1900	2007	3.8
Other forests	2955	302	0.9
Grasslands	3898	232	0.9
Wetlands	330	14 785	4.9
Lakes and rivers	200	8498	1.7
Cropland	1400	92	0.1
Total annual worth of the services provided by the Biosphere			33.3

However, despite this global importance of wetlands, these ecosystems are still perceived as wastelands by decision-makers in many African countries. Some water users consider wetlands as competitors for water. At its 1998 Regional Pan-African Meeting, Contracting Parties to the Ramsar Convention recognised that 'in many cases, the greatest threat to wetlands is land use which does not take water conservation objectives into account, since the shortage of lands makes wetlands a target for gaining land through drainage'. The approach recommended under the Convention, to encourage the incorporation of water resource management when dealing with wetland biodiversity conservation, is one potential solution to this problem. In this context, the conservation and wise use of wetland biodiversity need to be addressed through the wider perspective of the sustainable use and management of both land and water resources.

Major issues linked to wetland conservation in Africa

The major challenge facing wetland conservation in Africa is how to identify and apply efficient incentives which serve to maintain and improve the livelihood of local people dependent on wetland areas while safeguarding wetland functions, values and attributes (including biodiversity). In this regard, land use patterns and water management for economic development are important issues to be addressed.

To address this it is essential for policy-makers to know where their wetlands are and what is their importance in terms of values and functions, ie to have adequate national wetland inventory and assessment.

However, even where such information exists a further barrier to achieving sustainable wetland use is that in many African countries there are numerous national institutions and interest groups dealing with land use and water issues at local, national and international levels. In addition, wetland issues are quite often considered as a sectoral matter under the responsibilities of a single national institution. As a result, there is an urgent need to establish mechanisms to co-ordinate the work being carried out on wetland conservation and wise use at national and regional levels. The Ramsar Convention offers a framework for international co-operation and encourages the establishment of National Ramsar (or wetland) Committees which should include representatives from other government sectors, NGOs and local communities.

A number of ecological, socio-cultural, economic and political constraints need to be addressed through those co-ordinating mechanisms. In response to these constraints, the Ramsar Convention and its Partners Organisations (BirdLife International, IUCN, Wetlands International and WWF), are being instrumental in urging African countries to work towards the conservation of wetland ecosystems in the Africa region. This is directed to a focus on economic valuation of wetlands; development of incentives to foster public and decision makers' awareness; training; environmental education and communication in order to raise the profile of wetland issues among young people; water or wetland policies; legislation and regulation; community empowerment; community capacity building — to promote an enabling environment; pollution control; initiatives related to climate change; invasive alien species control; threatened species conservation; and programs on adaptive management of ecosystems in response to a changing environment.

Identifying priorities for wetland biodiversity conservation in Africa

Identifying priorities for wetland conservation is a complex exercise since it involves a number of interests ranging from local concerns to global goals. In addition, the decision about priorities can be made on different grounds: scientific, social and economic, or political grounds. African decision-makers are mainly politicians and as such they prefer to make decisions on political grounds. However, economic and social considerations can considerably influence political decisions. Therefore, to promote the conservation of wetland biodiversity in Africa, we need to encourage actions which lead to a better understanding of socio-economic relationships between wetland resources and the various interests of stakeholders which in turn can be used to persuade politicians and incite them to take action for wetland conservation.

Hence, it is important to identify and collaborate with interest groups which have direct dependency on wetlands such as fishermen for whom wetland biodiversity is the primary source of their income and food security. Empowering those interest groups can be an efficient move for promoting partnership between these stakeholders and political decision makers. African political leaders are very receptive to any actions that can contribute to food security. As a result, identifying and implementing pertinent options, which combine food security and biodiversity conservation, are critical steps to be taken for wetland biodiversity conservation in Africa. In this respect, it is useful to recognise the rights of local communities over the biodiversity that exists on wetlands they manage and use, and the rights over their traditional knowledge and practices. The value to local people of sustainable use should be promoted through an appropriate combination of the best traditional knowledge/practices and the latest technical and scientific understanding.

The promotion of wise use concepts and practices is of critical importance. A number of actions have to be taken to create an enabling environment that is likely to support and encourage the efforts of different stakeholders, policy makers and decision makers.

Consequently, wetland policy/strategy development and legislative review are essential tools to adopt in each country. At present, Uganda is the only African country, which has a National Wetland Policy in place along with a National Wetland program to implement it. However, it is encouraging to note that Ghana has recently developed and adopted a National Wetland Strategy and the following countries are drafting Wetland Policies: Benin, Botswana, Kenya, Namibia, South Africa and Zambia.

It is worth noting that the following countries do not have a Wetland Policy: Algeria, Burkina Faso, Chad, Congo, Côte d'Ivoire, Democratic Republic of Congo, Federal Republic of Comoros, Guinea, Mali, Morocco, Niger, Senegal, Tunisia and Togo. However, wetland issues are also considered through Biodiversity Strategies and Action Plans in Algeria, Burkina Faso, Chad, the Gambia, Malawi, Mali and Niger. In Tunisia, the conservation and wise use of wetlands form part of water management policy. National Environmental Action Plans are integrating wetland issues in the Democratic Republic of Congo, the Federal Republic of Comoros, Guinea, Senegal and Togo.

Thus there is a clear need to co-ordinate the work of environment-related conventions in each country and to create a synergy for the effective implementation of these international treaties. This can be developed at a national level through assisting African Contracting Parties in implementing the Memoranda of Co-operation between the Convention on Wetlands and the other environment-related conventions and notably the Joint Work Plan between the Convention on Biological Diversity and the Ramsar Convention.

African Contracting Parties to the Ramsar Convention recognise that the greatest threat to wetlands in Africa arises from inappropriate land use practices. Given the fact that wise use of natural resources is a complex issue, African countries need some guidelines on various aspects of this concept. In response to this need, the Ramsar Convention has published its 'toolkit' of nine Wise Use Handbooks (Ramsar Convention Bureau 2000b), which draws together the numerous guidelines approved by its recent Conferences of Parties, together with supporting case studies. Amongst this guidance a new priority is stressed, that of integrating wetlands and biodiversity conservation into river basin management (Wise Use Handbook 4). This approach seeks to integrate conservation and wise use of wetlands into national, provincial and local planning and decision making on land use, groundwater management, catchment/river basin and coastal zone planning, and all other environmental management. Since a critical requirement for this approach is the involvement of all stakeholders at the river basin scale, there is a need for joint action plans on shared wetlands/catchments and concerted action at national level.

Fortunately, it is worth noting that many African countries are more and more committed to decentralisation of governance and decision making to local levels. When the local administration is involved in taking responsibility for wetland management in a given country, there is an opportunity for local communities to be involved in decision-making processes. Guidance on local community and indigenous people's participatory management is included in Ramsar's Wise Use Handbook 5 (Ramsar Convention Bureau 2000b). At regional level, where a river basin is shared between two or more countries, the establishment of an international river commission can facilitate the development of a common vision for the efficient management and use of shared wetlands.

Key questions to be answered for wetland biodiversity conservation in Africa

In identifying priorities for wetland biodiversity conservation, it is useful to consider three key questions:

- Where are the important wetlands in Africa?
- What types of wetland should priorities focus on: threatened wetland types, rare wetland types, wetlands with rare and endangered species, wetlands with endemic species, wetlands with a high diversity of species and/or wetlands which are important commercially?
- What are the most important features to be conserved for any particular wetland?

Where are the important wetlands in Africa?

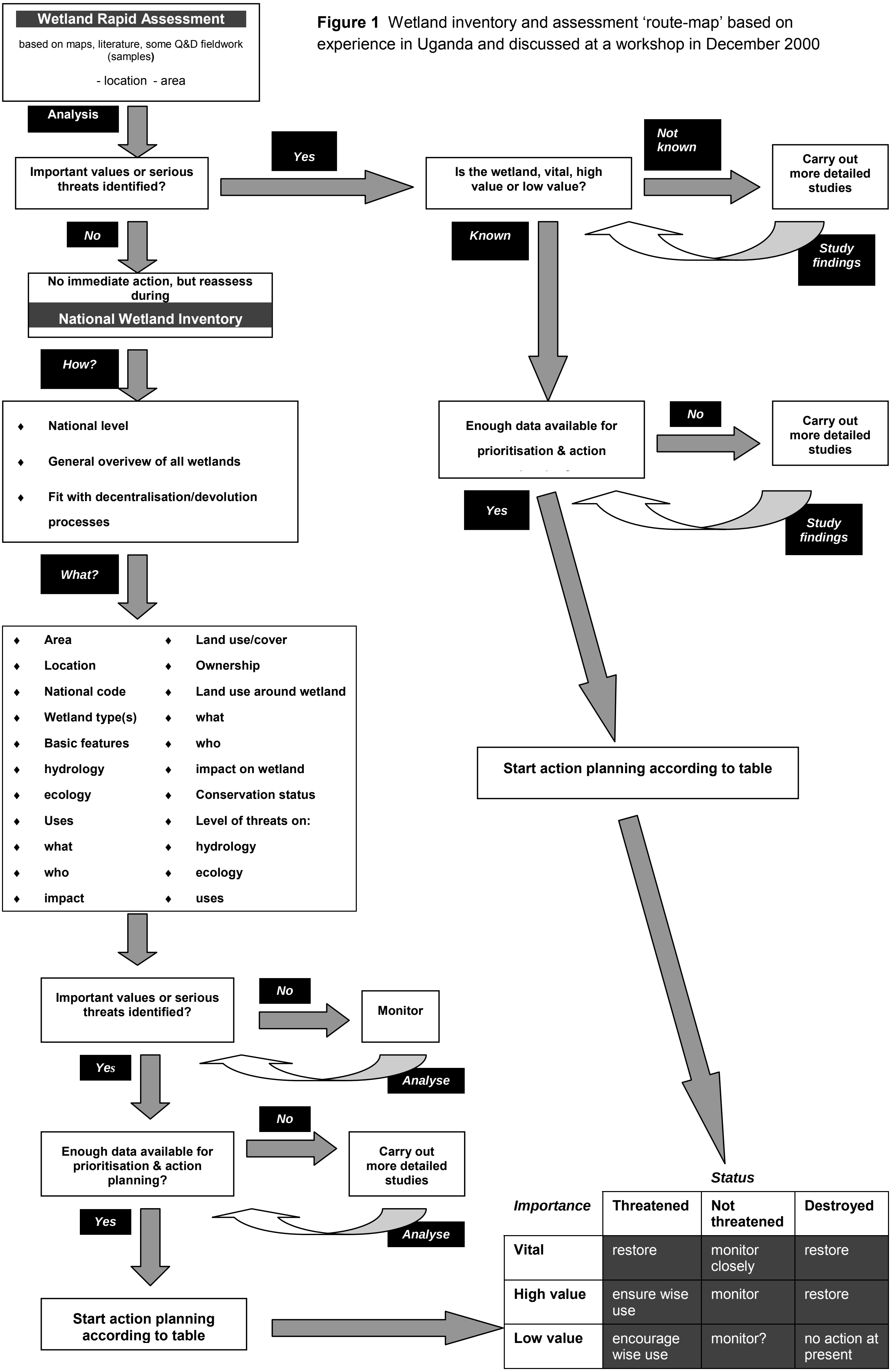
As yet very few African countries have complete national inventories to allow them to assess the full range of wetland types present and to permit identification of the most important wetlands for biodiversity conservation (see also Stevenson and Frazier, this vol.). An analysis of National Reports from Ramsar Contracting Parties for their 7th Conference of the Parties (Costa Rica 1999) indicated that Botswana, Malawi and Tunisia are the only African Parties who had completed a national inventory for their wetlands. Zambia's was reported as nearing completion and Kenya has many wetland inventories that are being developed at various sectoral levels. Namibia indicated that a national inventory is in preparation and that a first edition would be available before the end of 1999. Côte d'Ivoire, Ghana, Kenya, Mali, Morocco, Senegal, South Africa, the Gambia and Uganda have comprehensive national wetland inventories planned for the near future. Ten countries have directories of 'important' wetlands: Botswana, Côte d'Ivoire, Egypt, Kenya, Morocco,Namibia, Senegal, Uganda, Tunisia and Zambia.

In addition to lack of baseline wetland inventory there is a general lack of assessment and monitoring, so it is difficult to assess trends in wetland degradation at national and regional levels.

Ramsar's 7th Meeting of the Conference of Parties (Costa Rica 1999) placed a high priority for countries to undertake national wetland inventories, which the Conference considered as the essential information base from which to develop policies and implementation of wetland wise use. Comprehensive inventory can, however, be costly and time-consuming and so difficult to achieve in developing countries. To help develop cost-effective approaches and prioritisation of inventory, assessment and monitoring a recent workshop (Uganda, December 2000) brought together wetland experts from seven African countries who developed a 'route-map' designed to guide practitioners through the inventory and assessment process.

The workshop examined the need for wetland inventories in relation to wise wetland use at national and local levels. Important issues discussed during this workshop including the choice of wetland inventory types, the various methods and approaches, training needs and suitable institutions for training. The workshop was also an opportunity to learn from the practical experience of undertaking inventory and assessment in Uganda and other countries. A route-map based on the Uganda's experience was adopted (fig 1). A significant feature of the route-map is the relationship between rapid assessment and national inventory. The route-map recommends that rapid assessment is undertaken as the first step, before waiting for the completion of a national wetland inventory.

Figure 1 Wetland inventory and assessment 'route-map' based on experience in Uganda and discussed at a workshop in December 2000



Importance	Threatened	Not threatened	Destroyed
Vital	restore	monitor closely	restore
High value	ensure wise use	monitor	restore
Low value	encourage wise use	monitor?	no action at present

What types of wetland should priorities focus on: threatened wetland types, rare wetland types, wetlands with rare and endangered species, wetlands with endemic species, wetlands with a high diversity of species and/or wetlands which are important commercially?

A comprehensive wetland inventory in each country would go some way to providing the basis for answering this. Under the criteria for the selection and designation of Wetlands of International Importance, included in Ramsar's *Strategic framework and guidelines for the future development of the List of Wetlands of International Importance*, published as Wise Use Handbook 7 (Ramsar Convention Bureau 2000b), Parties are expected to designate wetlands from almost all these categories — and many important wetlands will have at least several of these features. Since Ramsar site designation criteria are based on ecological and biodiversity features, 'commercial importance' is not a selection criterion in its own right, but identification of the values and functions of designated wetlands forms an important basis for developing appropriate management planning.

Suggestions have been made as to activities that should be undertaken as a priority whilst countries are completing their national wetland inventories. The report *WWF Priorities and Guidelines for the Conservation of Freshwater Ecosystems in the Africa and Madagascar Region* (WWF International 1997) provides some useful suggestions. It recommends that a variety of representative freshwater ecosystems should be targeted as a priority, including the Niger River, Lake Malawi, Lake Tanganyika (Tanzania), Lake Barombi (Cameroon), Lake Nawampassa (Uganda), Lake Kanyaboli (Kenya) and Lake Nabugado (Uganda). The flooded grassland and savannas of particularly the inner delta of the Niger River in Mali and the Okavango in Botswana are also priority target wetlands. Since 1999, WWF's *Living Waters Campaign* has been working with the Ramsar Convention to assist countries in accelerating the designation of some of these and other major wetlands in Africa as Ramsar sites. As a result of this support, Algeria has added 10 new sites to the List of Wetlands of International Importance, including typical desert wetland types which are so far under represented in the Ramsar List. Cameroon, Central African Republic, Chad, Niger, Nigeria and Guinea are also in the process of designating new Ramsar sites through the financial assistance of WWF International.

Undertaking programs for wetland biodiversity conservation should not, however, be delayed because of insufficient baseline information. Taking action should go in parallel with inventory development, so as to make the best use of existing information. In this respect, it should be noted that the 'directories of important wetlands' which already exist in at least ten African countries have not so far been used adequately to identify priority sites for biodiversity conservation. Ramsar site designation has progressed very slowly in Africa. By January 2001, of the 1050 Ramsar sites worldwide, only 95 (8.96 %) were in Africa, although since many of the sites are large (including the world's largest Ramsar site, the Okavango Delta) the area designated in Africa (19.7 million hectares) is 24.41% of the total designated area. This lack of designation is certainly not an indication that there are few important wetlands in Africa, since many other wetlands are known to qualify for designation. Further priority, and helping increase national capacities, for designation is important, since designation is just the first step in then ensuring that the use and management of these key wetlands are sustainable.

What are the most important features to be conserved for any particular wetland?

The range of potential solutions for safeguarding Africa's vital wetlands is diverse and they should be integrated so as to be able to combine the satisfaction of basic needs of people while ensuring biodiversity conservation. It is essential to identify the various responses to soil and wetland degradation and apply the best existing practices to maintain soil fertility, wetland functions and values. To that end, the following guiding principles (WWF International 1997) should be used:

- promote healthy and productive wetland ecosystems with an emphasis on measures to be taken for pollution control, toxics and excess nutrients.
- focus on maintaining ecological processes in areas of high biodiversity, or high conservation value in terms of biodiversity and functional links with important forests or coastal systems.
- address the interdependence of human and nature with respect to water resources, by taking into account the hydrological cycle, ecosystem needs and human development imperatives.

Conclusions: Some tactics to be applied

In order to promote wetland biodiversity conservation in Africa, economic policies and strategies that decrease local community food security should be avoided. Perceived gaps in wetland information and understanding should not be used as a reason for inaction. Our understanding of possible solutions to soil and wetland degradation should be improved and the relevant application of local strategies should be encouraged.

To achieve wetland biodiversity conservation, building partnership is essential in order to be able to mobilise existing knowledge on wetlands, existing capacity and funding mechanisms at local, national, regional and global levels. At the local level, partnership is needed between various interest groups in order to have a better understanding of the major issues surrounding wetlands and to prevent conflicts. At the national level, building partnership means strengthening solidarity among national institutions and reaching consensus on prioroties and actions. At an international level, partnership should help mobilise expertise and financial assistance to promote sustainable use practices in wetland management.

Finally, it is necessary to remain realistic about the feasibility of policy/strategy implementation and law enforcement. It is essential to take into account the ecological, socio-cultural, economic and political context in each country so as to be able to make the best use of existing human capacity and financial resources.

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Inventory of important wetlands in Lithuania: a case study of a country in transition

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Abstract

A country-wide inventory of important wetlands was undertaken in Lithuania in 1996–1999, covering more than 80 wetlands with a total area of about 130 000 ha. Intensive field surveys (land-based, aerial- and boat-surveys) were performed at all sites. The Ramsar Information Sheet and data recording methodology was used as the basis for the structure of the inventory. Results of the field surveys revealed more than 29 wetlands that met the Ramsar criteria for identification of wetlands of international importance. Five wetlands were proposed for immediate inclusion into the national Ramsar list: the Girutiškis mire complex, the Rūdninkai mire complex, the northern part of the Kuršių Marios lagoon with the adjacent meadows, lakes of the Meteliai Regional park and inshore marine waters at the Palanga coast. A special Lithuanian Wetlands Database was created and duplicate copies forwarded to the regional and local authorities responsible for land reform and further management of wetlands. Results of the inventory were compiled in a special publication 'Important Wetlands in Lithuania' (1999). Successful completion of this program will enable more effective and ongoing practical implementation of recommendations concerning the protection and further management of important wetlands during a continuing period landuse reform and other economic developments.

Keywords: wetlands, inventory, Ramsar sites, database, Lithuania

1 Introduction

Lithuania contains rich wetland resources with mires and bogs covering about 5% of the land area (*The cadastre*, 1995). Large mire complexes (such a Čepkeliai, Rūdninkai, Kamanos, Viešvilė, Girutiškis) are almost unchanged natural areas that have never been exploited for agricultural or forestry purposes, and as such represent the kind of natural environment that used to be present in Western Europe prior to the agricultural revolution. There are 2834 lakes larger than 0.5 ha which amount to 87 643 ha in total (Kilkus, 1986). Many lakes are surrounded by wet forests, raised bogs or seasonally flooded meadows. Large areas of land are covered by various human-made wetlands (water reservoirs, fish ponds, etc) — there are 400 artificial wetlands larger than 5 ha and over 10 000 smaller ponds, reservoirs (Basalykas 1965). Among 758 rivers (longer than 10 km) and numerous streams there are many unregulated or moderately modified rivers with naturally flooded land. The total length of unregulated natural rivers and streams is about 17 000 km. Preservation of such areas of extraordinary biological richness is particularly important for many breeding species of birds. Coastal wetlands (including inshore marine waters, the brackish Kuršių Marios lagoon, and the Nemunas River delta with adjacent seasonally flooded meadows) which are located along the Eastern Atlantic Flyway, are extremely important sites for migratory and wintering populations of waterfowl.

Many important wetlands in Lithuania are at least partly protected. The present system of protected areas consists of 4 Strict Nature Reserves (where all human activities and public access are prohibited), 5 National Parks (where most human activities are regulated), 30 Regional Parks (all activities are regulated in specific conservation areas) and 300 managed reserves. The total protected area (all categories) now covers about 11% of Lithuania (Lapelė 1997).

Most of the protected areas were established when all the land belonged to the state. The political and economic changes that have taken place in Lithuania during recent years have resulted in intensified forestry, and privatisation or re-privatisation of land. As a consequence numerous wetlands can be transferred to private ownership. In such conditions it is necessary to urgently perform an inventory of important wetlands and particularly of the areas meeting the criteria of the Ramsar Convention. Information of this sort is crucial when undertaking land use reform such as is occurring in the new economic climate of Lithuania. A wetland inventory is a pivotal first step towards protecting key and important wetlands, and is fundamental to applying the 'wise use' concept for wetlands.

Lithuania joined the Ramsar Convention in 1993 and 5 key wetlands were designated as national Ramsar sites: Čepkeliai, Kamanos, Viešvilė, Žuvintas Strict Nature Reserves and Nemunas River Delta Regional Park. Their total area covers 50 443 ha (Švažas et al 1999). A preliminary inventory of other important wetlands in Lithuania was performed in 1994–1995 when 9 sites (total area over 30 000 ha) were identified (Balčiauskas & Švažas 1998). However, as there was still a critical lack of detailed information about most of the key wetlands a country-wide inventory of all important wetlands was initiated in 1996. This program was supported by Migratory Birds of Western Palearctic (OMPO). The objectives of the project performed in 1996–1999 were as follows:

- to undertake an inventory of the key wetlands, using the Ramsar criteria and wetland classification;
- to produce detailed maps of all important wetlands, plotting important elements of each site;
- to develop a national wetlands database providing a relevant tool for local decision-makers responsible for wetlands management; and
- to publish a report 'Important Wetlands in Lithuania' (both in Lithuanian and in English).

2 Material and methods

More than 80 wetlands (their total area — about 130 000 ha) were investigated between 1996–1999 (fig 1). These comprise the following wetland types: mire complexes, bogs and marshes of all types, peatlands, wet forests, large shallow lakes, stretches of rivers with naturally flooded land, natural wet meadows and swamps, coastal wetlands with adjacent seasonally flooded meadows, large fish-ponds and human-made reservoirs. Intensive field surveys (land-based, aerial- and boat-surveys) were performed in all selected wetlands. The Ramsar Information Sheet (RIS) and date recording methodology was used as the basis for the structure of the inventory. All valuable wetland elements (important habitats, localities of rare flora and fauna, physical, hydrological, socio-cultural features) as well as threats/disturbances were recorded and plotted on maps. Some habitats were investigated more thoroughly, as a result of biodiversity investigations, performed at a local level. However, the main objective of these studies was to survey breeding and migratory bird populations.

The Ramsar criteria for representative or unique wetlands, general criteria based on animals or plants and specific criteria based on waterfowl were used for the designation of wetlands of international importance. Wetlands of national importance were designated based on a set of important criteria (biodiversity of habitats and species, naturalness of each site, rarity of habitats or species, regional typicalness of the wetland, size of each selected site, etc.). A wetland database designed under DBMS Paradox for DOS, with a mapping module DMAP for DOS (from Alan J. Morton, UK) was developed for this inventory project.

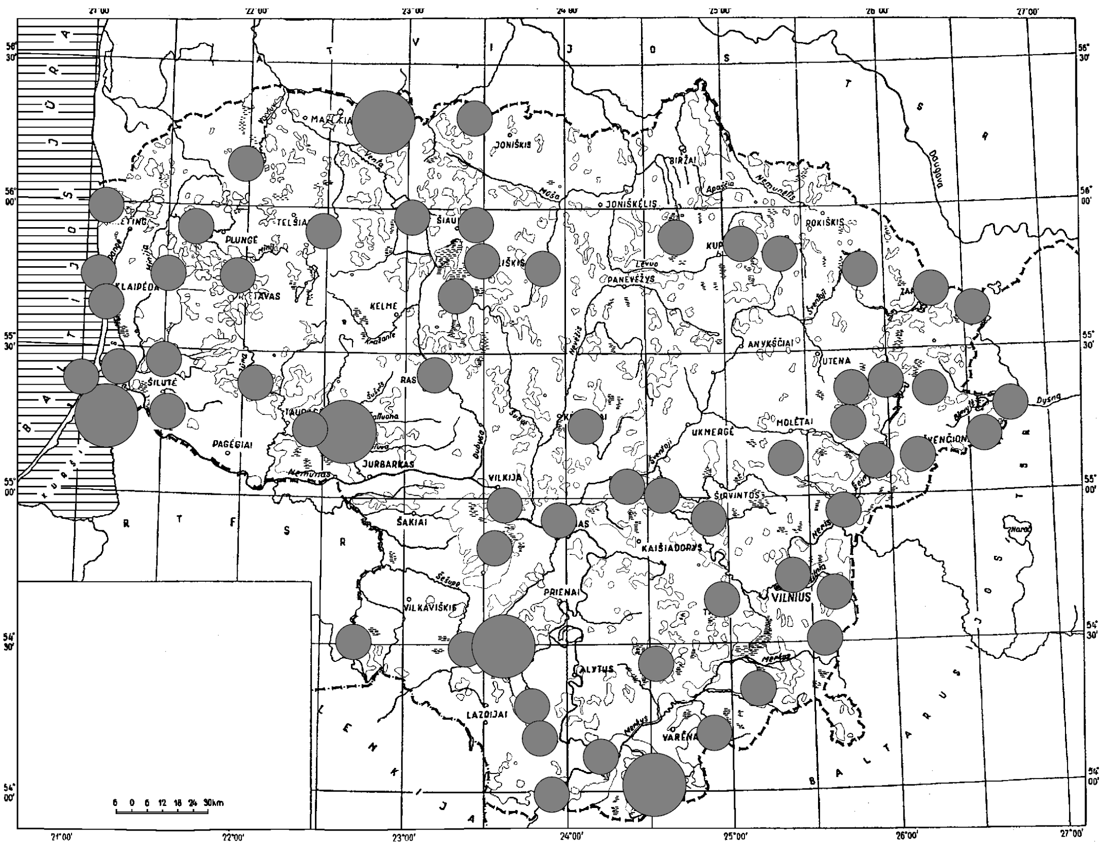

Figure 1 Network of wetlands under investigation in 1996–1999; existing Ramsar sites are represented by the larger sized dots.

3 Results

Results of the field surveys performed between 1996 and 1999 revealed 29 Lithuanian wetlands which met the Ramsar criteria for identification of wetlands of international importance (see table 1 & fig 2) and have significant biodiversity importance.

The first 5 wetlands on this list were proposed for immediate inclusion into the national Ramsar list, while other selected wetlands will remain as potential Ramsar sites representing nationally important wetlands. All remaining wetlands covered during this survey (53 sites) will be included in the network of the most valuable nature areas of national importance.

The results of this countrywide survey have confirmed the importance of Lithuanian coastal wetlands for migratory and wintering populations of waterfowl. Internationally important concentrations of 11 migratory wildfowl species were recorded in the coastal wetlands. Particularly valuable are the seasonally flooded meadows and pastures surrounding the Nemunas River delta area. Internationally important staging concentrations of whooper swan (*Cygnus cygnus*), Bewick's swan (*Cygnus columbianus bewickii*), white-fronted goose (*Anser albifrons*), lesser white-fronted goose (*Anser erythropus*), gadwall (*Anas strepera*) and pintail (*Anas acuta*) were recorded on the seasonally flooded meadows near the Sausgalviai, Žalgiriai, Plaškiai settlements and near the town of Šilute (Švažas et al 1997, 1998). This area is among the most important key staging sites for migratory whooper swans in Europe. Large flooded areas distinguished by a mosaic of habitats provide extremely favourable feeding and roosting sites for migratory populations of wildfowl.

Table 1 Wetlands, which meet several Ramsar criteria for the identification of wetlands of international importance, especially as waterfowl habitat

Girutiškis mire complex
Rūdninkai mire complex
Northern part of the Kuršių Marios lagoon with the adjacent meadows
Lakes of the Meteliai Regional Park
Inshore marine waters at the Palanga coast
Aukštasis Tyras Reserve
Reiskių Tyras Reserve
Lakes Biržulis and Stervas with the adjacent meadows
Pasruojė fish ponds with the adjacent meadows
Plynoji Reserve
Kauno Marios Reservoir
Novaraistis Reserve
Mūšos Tyrelis Reserve
Praviršulio Tyrulis mire complex
Sulinkiai peatland
Tyruliai Reserve
Imškai Reserve
Žaltytis Reserve
Alionys Reserve
Baltasamanė Reserve
Lake Papis and Baltoji Vokė fish ponds
Kanio Raistas mire complex
Lakes Kretuonas and Kretuonykštis
Pušnis mire complex
Notygalė Reserve
Antalieptė Reserve
Smalvas Reserve
Lake Drūkšiai

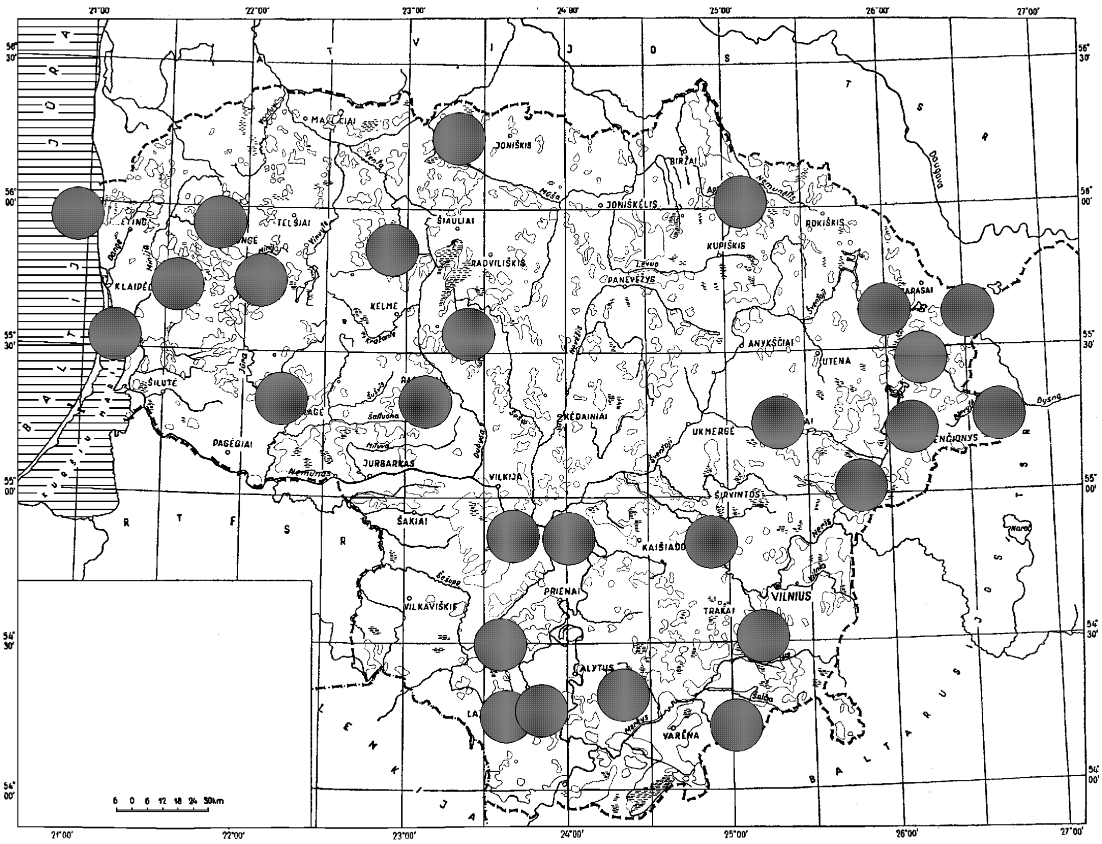

Figure 2 Potential Ramsar sites in Lithuania

Large concentrations of staging Bewick's swans, goldeneyes (*Bucephala clangula*) and goosanders (*Mergus merganser*), exceeding the 1% Ramsar threshold, were recorded in the northern part of the Kuršių Marios lagoon. This brackish lagoon is also a key wintering site for wintering goosanders, supporting up to 17% of the whole north-west Europe population (Švažas et al 1994, Žalakevičius et al 1995). A mosaic of wide, naturally flooded meadows located along the eastern coast of the lagoon are particularly important breeding sites for the globally threatened aquatic warbler (*Acrocephalus paludicola*) and numerous rare species of shorebirds. The whole wetland complex (including the brackish, shallow lagoon with coastal wet meadows) meets at least several Ramsar criteria.

A further potential Ramsar site identified was the shallow inshore marine waters along the coast of Palanga town. The Palanga site is one of the most important wintering areas for the globally threatened Steller's eider (*Polysticta stelleri*) in Europe (Nygard et al 1995, Švažas 1997). This site, distinguished by highly diverse and productive benthic communities, regularly supports more than 20 000 wintering waterfowl of various species.

In addition to coastal wetlands, more than 20 potential inland Ramsar sites were identified. These have been grouped into several categories, as follows:

- bogs and swamps of all types, including wet forests;
- shallow lakes with adjacent territories, including wet meadows;
- water reservoirs and ponds;
- fish ponds;
- former peat-lands (fully or partially exploited with various stages of restoration.

Economical difficulties during the recent period of political and economic transition have caused a sharp decline in inland fisheries activities in Lithuania. Numerous fishponds have been partly abandoned (for 1–2 years or longer; in some cases ponds are flooded every second year). Shallow ponds have become rapidly overgrown with aquatic vegetation and banks have become overgrown with shrubs and reed-beds. However, the combination of partly and fully flooded ponds, well-developed coastal vegetation and numerous sandy islands provides excellent habitats for breeding, feeding and staging waterbirds (Švažas & Stanevičius 1998). A comparatively high number of threatened bird species was recorded on the fishponds (149 species/46 threatened species in Papis lake and Baltoji Vokė fish ponds, 151 species/31 threatened species in Pasruojė fish ponds). Ponds are also characterised with notable findings of threatened plants (Pasruojė), insects and amphibians (Papis lake and Baltoji Vokė fish ponds). The population of fire-bellied toad (*Bombina bombina*) at Baltoji Vokė fish ponds is important on a European scale (several thousands of individuals spawning), (Balčiauskas & Balčiauskienë 1998, Balčiauskienë & Balčiauskas 1998).

Abandoned peat-works represent a unique habitat in Central Europe. In Lithuania, fully exploited or partly exploited peat-lands were abandoned without artificial restoration. These peat-lands were flooded due to Beaver (*Castor fiber*) activity or due to fire-fighting actvities during the initial phase of the natural restoration process. As a result, large open shallow areas containing a mixture of reed-beds, shrubs, wet meadows and fragments of flooded peat were formed. Beaver activity is the natural agent, keeping these territories open for a long time. So far, such sites have a low biodiversity value (the plant communities were destroyed during peat extraction), but as natural restoration progresses they should become more valuable with a high insect and birds diversity (Balčiauskas et al 1996).

The forest swamps, wet forests and surrounding habitats of Rūdninkai complex (comprising Lake Kernavas, a mire and native ancient deciduous forest) have high biological value. Some 20 threatened plant species, 6 threatened mammal species, 24 threatened bird species, 1 threatened reptile species and several insect species (threatened, rare or even new to Lithuania) were recorded here.

An important part of the wetland inventory was the creation of the special Wetlands Database (Balčiauskas & Švažas 1998). The relational structure of the Wetlands database files and the primary key fields of its data tables are shown in figure 3. The database includes the following information:

- data on important wetlands in each region/district;
- data on species and communities in each district/wetland;
- system of recommendations at the species or the community level, including land use and conservation measures; and
- data visualisation (maps at several levels: from national to local and up to individual wetland).

Copies of the wetlands database were forwarded to the regional and local authorities responsible for land reform and further management of wetlands.

The database makes it possible to add, edit or delete information on species, communities and habitats (wetlands) and to make changes in the system of recommendations. The data is compatibility with databases available in Windows format. As this system is not GIS-based the possibility of exporting the data has also been foreseen.

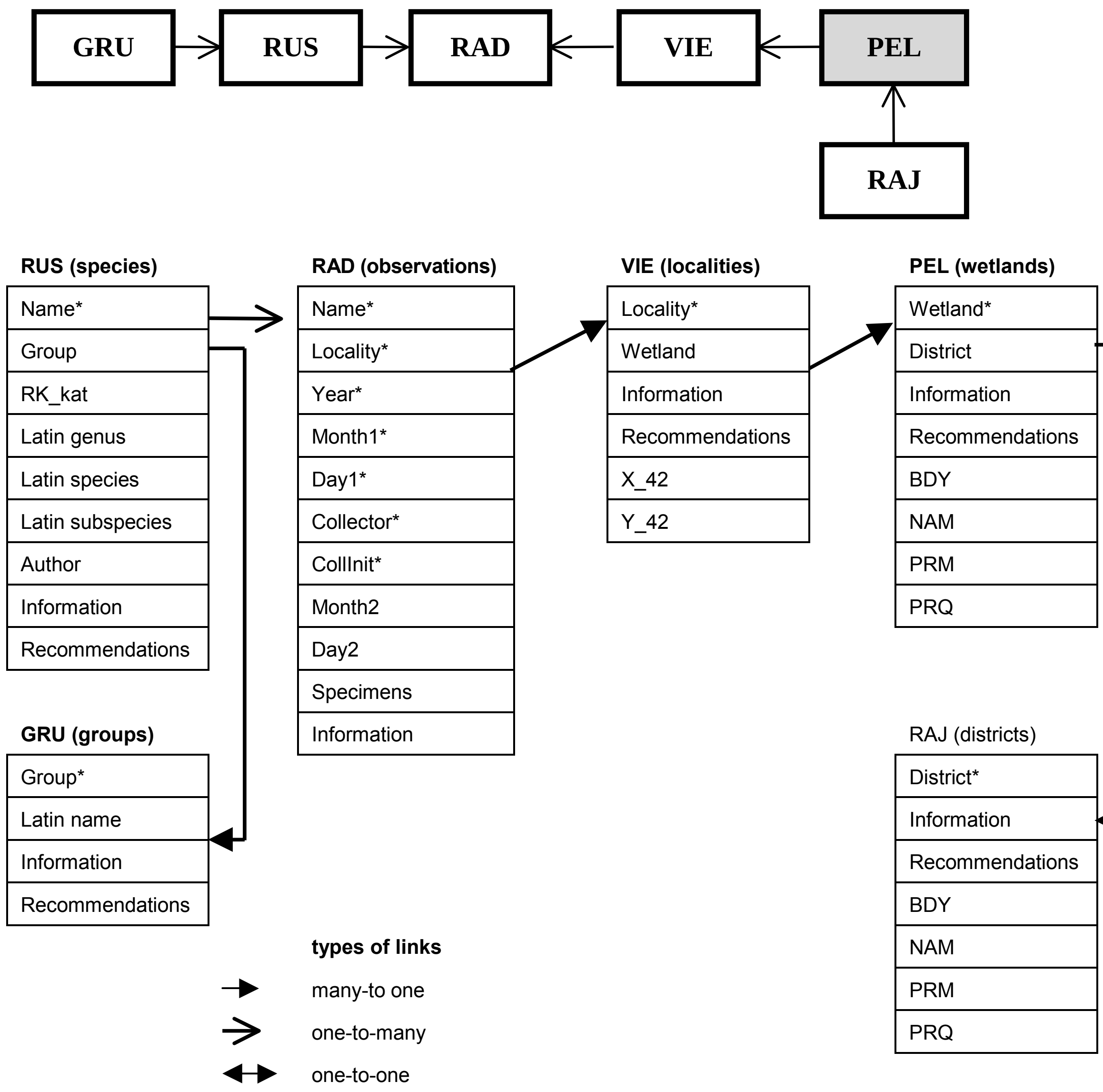

Figure 3 Relational structure of the data files or the wetland database. Files with lists of higher taxa (GRU), species (RUS), observed/collected specimens (RAD), lists of localities (VIE), wetlands (PEL), districts (RAJ), the latter two with boundary data. The links between data fields are shown as arrows.

4 Conclusions

An inventory of important wetlands in Lithuania was performed during the recent and continuing period of land reform and major changes in the nature protection system (including legislation, network of protected territories and their management). Results of these investigations revealed 29 Lithuanian wetlands that met the Ramsar criteria for wetlands of international importance. Several potential Ramsar sites are still not protected and are threatened by various developments, while some protected sites that were established do not incorporate some of the most valuable nature areas.

The map outputs have been adapted for presentation at the national scale, district scale and local scale (fig 4).

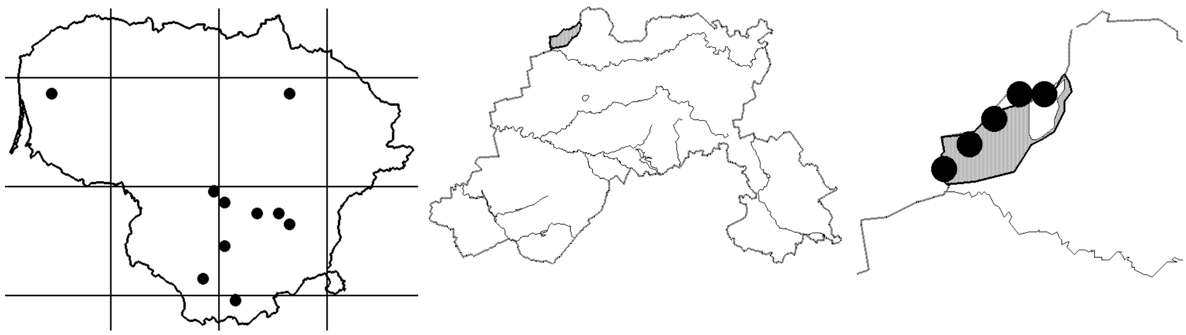

Figure 4 Map output of the database: a) national scale, b) scale of administrative district (with localisation of one specified wetland), c) local scale (with data on species observations in certain wetland; different habitats are separated by color)

A high priority for this program was to provide all necessary information concerning the key wetlands to the regional and local authorities, responsible for nature management. All data collected and analysed during this countrywide survey (including all characteristics of important wetlands in each region/district, distribution of rare species of fauna and flora, recommendations including land use and conservation measures, maps of all levels) were compiled in a special publication, which will serve as important tool for wetlands management and protection.

Copies of the newly established Wetlands Database were distributed to organisations responsible for conservation of wetlands in specific districts/regions. The end-user interface was made as simple as possible, to make the database available even for people with minimum computer skills. Therefore we expect that the results of the inventory will enable effective and ongoing practical implementation of recommendations for the protection and further management of important nature areas during the ongoing period of economic and political transition.

Acknowledgments

The countrywide inventory of important wetlands in Lithuania was undertaken as a result of the enthusiastic voluntary work of a large team of ornithologists, ecologists, foresters and amateur naturalists. This program would not have been possible without the support of the 'Migratory Birds of the Western Palearctic' (OMPO). Wetland database design and implementation was strongly supported by Dr E Budrys.

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Wetland inventory, assessment and monitoring — practical techniques and identification of major issues: Summary

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Background and objectives

Inventory, assessment and monitoring are vital components of effective wetland management. Together they provide the essential data and information that support management decisions (Dugan 1990, Finlayson 1996a). Furthermore, they provide feedback on management actions and implementation of principles and frameworks to ensure that they deliver the information necessary for managers and other decision makers. With the recognition that inventory, assessment and monitoring cannot be treated separately from management processes, increasing attention has focused on the design and implementation of effective and integrated programs. For inventory, a global review of wetland inventories (GRoWI), that recommended future good practice and priorities, has been conducted for the Ramsar Convention (Finlayson & Spiers 1999, Finlayson et al 1999) and guidebooks for wetland inventory produced by the MedWet Mediterranean wetland program (Costa et al 1996). For assessment, the Ramsar Convention has developed a framework for conducting wetland risk assessment as an integral component of the management planning processes (van Dam et al 1999). For monitoring, general principles and frameworks have been developed, for example under the Ramsar Convention (Finlayson 1996b) and the MedWet program (Finlayson 1996c, Grillas 1996, Tomàs Vives & Grillas 1996).

This workshop as part of the 2nd International Conference on Wetlands and Development reviewed past and current projects for wetland inventory, assessment and monitoring and developed recommendations for further implementation.

The main objectives were to:

- promote the inventory, assessment and monitoring of wetlands, through discussion of practical approaches, methodologies and techniques;
- identify the working tools needed to improve delivery of wetland inventory and assessment; and
- to identify priorities for wetland inventory and assessment in support of biodiversity conservation in Africa.

Issues arising

Previous recommendations

Several major wetland conferences (Astrakhan, Russia 1989 — Matthews 1990; Grado, Italy 1991 — Finlayson et al 1992; St Petersburg Beach, USA 1992 — Moser et al 1993; Columbus, USA 1992 — Mitsch 1994; Kuala Lumpur, Malaysia 1995 — Prentice & Jaensch 1997) have produced recommendations for improved wetland inventory, assessment and monitoring. These recommendations have been broadly consistent and cover:

- collecting long-term data on wetlands;
- standardising techniques, guidelines and manuals;
- providing training;
- reviewing gaps and co-ordinating data collection;
- developing and using networks; and
- developing means to audit existing effort.

There is little evidence that these have been widely implemented. However, the development of methodols for the MedWet Mediterranean wetland program has contributed substantively to standardising techniques etc and the GRoWI project can be seen as a first attempt to review gaps and develop means to audit existing effort and to provide further guidance on standardisation of techniques. Some past recommendations, whilst worthy, now appear unrealistic given the level of response, possibly due to the level of institutional capacity to enact them. Thus, recommendations with suggested mechanisms for their implementation are needed.

Current state of wetland inventory, assessment and monitoring

There is a wealth of wetland inventory, assessment and monitoring activity under way at a great variety of scales — from global through regional and national scales to wetland site-based work (Finlayson & Spiers 1999). Broad-scale initiatives include:

- the *Global Review of Wetland Resources (GRoWI)* compiled and analysed from national wetland inventory resources and designed to evaluate the size and distribution of the global wetland resource and to make recommendations for future national inventory and assessment priorities (undertaken by Wetlands International for the Ramsar Convention — Finlayson & Spiers 1999, Finlayson et al 1999);
- a pilot project designed to recommend and develop standard wetland inventory and assessment tools to meet the needs of sustainable wetlands management worldwide (Wetlands International through the Biodiversity Conservation Information System (BCIS) network);
- the first phase of a project towards a Pan-European wetlands inventory (Wetlands International and the RIZA institute, Netherlands); and
- continuing development and testing of wetland assessment tools through the MedWet initiative.

The GRoWI project has identified large gaps in global wetland inventory effort, with many discrepancies in data management, inadequate documentation, inconsistencies in methods and poor communication of information.

A key issue is the development, use and management of wetland databases, since inventory information compiled in electronic form is potentially more amenable to updating and the creation of time-series information. The MedWet database tools were identified as a valuable starting point for future wetland database initiatives, and are already being adapted and used in other regions. However, more clarity is needed as to the purpose and use of each inventory and the essential data fields that should be collected for different purposes. A working group of the Ramsar Convention on Wetlands Scientific and Technical Review Panel (STRP) is now reviewing (i) the purposes and uses of inventories; (ii) the core data elements that should feature in an inventory for each purpose and use; and (iii) the additional data elements necessary for delivering particular management objectives (CM Finlayson & NC Davidson pers comm).

Distinctions between wetland inventory, assessment and monitoring

It is important to distinguish between inventory, assessment and monitoring when designing data gathering exercises, especially since they require different categories of information. The distinctions are often confused. Working definitions are:

> *Wetland Inventory*: the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities.
>
> *Wetland Assessment:* the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities.
>
> *Wetland Monitoring:* Collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. (Note that the collection of time-series information that is not hypothesis-driven from wetland assessment should be termed *surveillance* rather than monitoring.)

The approach and the scope of activity for inventory, assessment and monitoring as separate components of the management process differ substantially but these are not always well distinguished in implementation projects. Importantly, wetland inventory and wetland monitoring require differing types of information and, whilst wetland inventory provides the basis for guiding the development of appropriate assessment and monitoring, wetland inventories repeated at given time intervals do not constitute 'monitoring'.

Conclusions

The papers presented at the workshop provided a basis for addressing the objectives (as given above) and for subsequent discussion. The official rapporteurs noted the key points of agreement and these are shown below.

1. There is extensive past, current and planned wetland inventory activity worldwide. However, for global purposes the state of wetland inventory is best described as dismal, with information particularly poor in Oceania, South and Central America, Africa, Asia

and eastern Europe (although there are notable exceptions in these regions). The extent and quality of wetland inventory coverage in Africa is similar to other regions, as are the issues and priorities for future inventory and assessment activity.

2. The coverage of most inventories is restricted (eg to only some wetland types, or to important sites only): comprehensive wetland inventory exists only for a few countries. Some wetland habitats are particularly poorly covered by existing inventories.
3. As well as the global lack of basic national wetland inventory information, wetland loss and degradation has not been adequately assessed, and information on economic values of wetlands has seldom been collected (and where it has is usually inadequate).
4. The purpose and use of wetland inventory activities is often unclear, and leads to over-ambitious and time-consuming wetland inventory programs that lack focus and that have seldom produced the information required for management purposes.
5. Much of the wetland inventory information collected to date has been largely descriptive, and/or stored in forms which cannot easily be manipulated to provide answers to fundamental questions, such as the spatial extent of wetlands and how many wetlands exist.
6. Presentation of inventory data is often poor, and essential information such as the context, aims and objectives, dates, and methods are frequently omitted from inventory documentation and other outputs.
7. There are many different wetland inventory, assessment and monitoring methodologies and techniques in use: a widely accepted basic standardised approach and standardised methodologies is not available. This creates difficulty in comparing information across national and international scales and limits global assessment of wetland extent, status, trends and management.
8. Some standard regional methodologies, notably that developed by MedWet for the Mediterranean region, are available and the MedWet tools are already being adapted for use in other parts of the world — there is good potential for further development of standards derived from MedWet and other available tools.
9. Complex wetland inventory data collection methods (such as information derived from satellite imagery and airborne video techniques) are increasingly frequently utilised, but are not always properly targeted, or used effectively.
10. Insufficient use of allied sources of information (eg waterbird, fisheries, water quality and agricultural information bases; and local peoples' information and knowledge) is made in most wetland inventory, assessment and monitoring processes.
11. Dissemination of wetland inventory, assessment and monitoring data is often very limited, with poor or restricted access, so that it is not readily accessible to those involved in the decision making process: improved access to data management tools, and the establishment of 'clearing house' mechanisms for wetland management information is needed.
12. Although wetland inventory is an essential prerequisite for wetland management, the methods used for most existing inventories will not, if repeated over time, yield monitoring information, since they do not collect the data elements necessary for monitoring. Identification of the key data elements necessary for specific wetland assessment and monitoring management objectives, and in particular those needed for evaluation of wetland loss and degradation, is needed.

Recommendations

Recommendations cover three approaches: maximising the use and availability of existing information; developing standard frameworks and mechanisms, made as simple and versatile as possible and based on clear evaluation of purpose and need; and using these approaches to support filling of the extensive gaps in existing inventory coverage. Implementation projects to help deliver the workshop recommendations are underway or being developed by Wetlands International and its Wetland Inventory and Monitoring Specialist Group and with partner organisations.

1. All countries that have not yet conducted a national wetland inventory should do so, preferably using an approach that is comparable with other large-scale wetland inventories already underway or complete. These should focus on a basic data set that describes the location and size of the wetland and the major biophysical features, including variation in the areas and the water regime.
2. Once the basic data has been acquired and adequately stored more management oriented information on wetland threats and uses, land tenure and management regimes, benefits and values can be added. When such information is recorded it should be accompanied by clear records that describe when and how the information was collected and its accuracy and reliability.
3. Each inventory should contain a clear statement of its purpose and the range of information that has been collated or collected. This extends to defining the habitats being considered and the date the information was obtained or updated.
4. Improved links should be established between wetland inventory databases and other existing database sources containing relevant information for assessment and monitoring of these wetlands, notably species datasets (eg waterbirds) and fisheries, water quality and agricultural datasets.
5. Wetland inventory information for particular countries and regions should be used to determine priority wetland habitats for conservation and intensive management. Quantitative studies of wetland loss and degradation are urgently required for much of Asia, Africa, South America and the Pacific Islands.
6. Priority should be given to improving the global inventory for wetland habitats that are currently poorly covered in most parts of the world, notably seagrasses, coral reefs, saltmarshes and coastal tidal flats, mangroves, arid-zone wetlands, rivers and streams and artificial wetlands.
7. The effectiveness of all aspects of wetland inventory should be addressed through standardisation, ie a standardised framework and a generic wetland inventory database, designed to be as flexible as possible for use in all regions of the world and to accommodate various inventory objectives.
8. Models for effective wetland inventory, using both remote sensing and ground techniques, as appropriate, should be compiled and widely disseminated. These should outline appropriate habitat classifications (eg those based initially on landform and not biological parameters), methods and means of collating and storing the information, in particular Geographic Information Systems for spatial and temporal data that could be used for monitoring purposes.
9. All further wetland inventories should be stored and published electronically in addition to the normally produced hardcopy. This should improve accessibility and allow for

regular updating of information. Ideally the meta-data at least should be published on the World Wide Web to make it easily accessible. Consideration should be given to the development of a central repository for both hard-copy and electronic inventories.

Acknowledgments

The report from this workshop was prepared from notes taken by four official rapporteurs — Isabell von Oertzen (Cambodian Wetland Inventory Project), Ian Eliot (University of Western Australia), Scott Frazier (Wetlands International) and Jurgen Volz (Water Storage Corporation Brabantse Biesbosch, Netherlands). The formal sessions were chaired by Luis Naranjo (Universidad del Valle, Colombia; and Wetlands Inventory and Monitoring Specialist Group), and Abdoulaye Ndiaye (Wetlands International). The rapporteurs, chairs, speakers and participants are warmly thanked — the workshop was interactive and the discussion unrestrained.

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