internal report **287**

Tropical wetlands: Information for environmental training, management and research

Editors
CM Finlayson
AG Spiers

June 1998

supervising scientist

Tropical wetlands: Information for environmental training, management and research

Information base compiled for a training unit in Tropical Wetland Management conducted by *eriss* on behalf of the Northern Territory University

Jabiru, Australia

Edited by

CM Finlayson & AG Spiers

Environmental Research Institute of the Supervising Scientist

Internal Report

Foreword

In 1997 ***eriss*** presented a formal training module on the management and protection of tropical wetlands. This was done in collaboration with the Northern Territory University as a component of their Masters in Tropical Environmental Management. The module covered a two week period and encompassed formal lectures, slide and video presentations, computer demonstrations, laboratory and field exercises, discussion sessions and student projects. Presentations were made by many ***eriss*** staff and invited lecturers from an array of agencies/institutions: Northern Land Council; Parks Australia North; Northern Territory Department of Lands, Planning and the Environment; Department of Law, University of Wollongong; Remote Area Training Unit, Northern Territory University; Gagudju Association; and the Lower Mary River Landcare Group. This made for a very diverse and thought-provoking course.

Throughout the module a large amount of information was presented by the scientific professional and technical staff from ***eriss*** and invited lecturers. This report is a compendium of much of that information. As such it represents an important information resource for wetland training, management and research in tropical Australia. The information is specifically directed towards wetlands of the Australian Wet-Dry tropics but, given the similarities between wetlands of northern Australia and those elsewhere in the tropical regions of the world it also represents a valuable resource for a much broader audience.

The information in the report is presented as a series of formal scientific papers along with transcripts of less formal presentations. The formal and informal papers are interspersed within broad thematic headings. This combination adds a further dimension to the compendium with a variety of material of interest to wetland managers, owners, users and researchers being presented.

The production of this compendium marks the culmination of an extensive effort by many people—the lecturers and authors, laboratory and field assistants, administrative and logistical support staff. We are grateful for their support. We are also grateful for the interaction with and feedback from the students. Thank you to the many people who contributed.

Max Finlayson & Abbie Spiers

Tropical Wetlands: Information for environmental training, management and research

Contents

Information needs for wetland management

CM Finlayson

Environmental Research Institute of the Supervising Scientist,
Locked bag 2, Jabiru, NT 0886

Abstract

Wetland management is today receiving far greater attention within the framework of both general and specific conservation policies. Many jurisdictions have realised the full value of their wetland resources and have begun to implement specific management activities. For these activities they require further information to ensure the resources are managed and used in a wise manner. Information on the current status of wetlands, the extent of wetland loss and degradation, conservation procedures and the success of monitoring strategies is required. This information can be collected through ongoing wetland inventory (incorporating classification) and monitoring programs. Wetland managers in northern Australia can draw upon an increasing amount of information from other regions of the world, but they will still need an interactive inventory process to provide locally relevant information. Management actions also require monitoring to ensure their effectiveness. In turn, monitoring requires the support of management procedures to ensure it is effective and that the outcomes are interpreted and acted upon. A management plan can provide such procedures and ensure that the available information is presented in a form that can be readily used for management actions.

Keywords: wetlands, northern Australia, inventory, monitoring, management planning

1 Introduction

Over the last decade considerable effort has been directed towards the conservation and wise use of wetlands in northern Australia (Jonauskas 1996, Finlayson et al 1997, Fleming 1993, Blackman et al 1993, 1995). However, despite having compiled a general level of knowledge the information base is not even. Whilst reasonable data/information exists for some wetlands and/or threats to wetlands, a comprehensive inventory at the most basic level (encompassing, for example, information on physical and ecological features, values and benefits, land tenure and uses, threats and disturbances, and monitoring and restoration) of all wetlands across this vast region is not available (Storrs & Finlayson 1997, Finlayson et al 1997).

The wise use and conservation of wetlands in northern Australia will be partly reliant on a greatly expanded information base. Information on the ecological character of wetlands, the extent of wetland loss and degradation, conservation procedures and the success of monitoring strategies will be required. In turn, this information base requires linkage and integration with managerial processes – a management planning procedure provides this.

Integral to obtaining this information is the application of the basic, but often controversial process (see Finlayson & van der Valk 1995) of classifying wetlands. Classification and inventory of wetlands are processes designed to provide a summary of knowledge on wetlands and their resources. A review of the basic concepts of wetland classification and inventory is presented along with a summary of the concept of ecological character of a wetland (Dugan &

Jones 1993, Finlayson 1996a) and the importance and role of monitoring (Tomas Vives 1996) and management plans (Davis 1994) for the wise use of wetlands. Management plans are presented in the role of processes that integrate management actions and monitoring to ensure that the ecological character of the wetland concerned is maintained whilst being used for specified values and benefits to society.

2 Definition of wetlands

The term 'wetland' groups together a wide range of habitats that share a number of common features, the most important of which is continuous, seasonal or periodic standing water or saturated soils. Despite a number of national/regional wetland surveys (see McComb & Lake 1988, Finlayson & von Oertzen 1993) there is no standard definition of wetlands in Australia (Barson & Williams 1991, Pressey & Adam 1995). The recent *Directory of Important Wetlands in Australia* (Usback & James 1993, ANCA 1996) uses the Ramsar International Wetland Convention definition of a wetland

> *'..... wetlands are areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.'*

Paijmans et al (1985) undertook a national overview of wetlands and used the following definition

> *'... land permanently or temporarily under water or waterlogged. Temporary wetlands must have surface water or waterlogging of sufficient frequency and/or duration to affect the biota. Thus the occurrence, at least sometimes, of hydrophytic vegetation or use by waterbirds are necessary attributes.'*

LWRRDC in a national review of wetland research and development needs (Bunn et al 1997) adopted the Paijmans et al (1985) definition. Thus, when considering wetland classification and inventory it is important to ascertain the breadth of 'wetland' habitat that will be covered (ie determine what definition is being used). In northern Australia the broad-based Ramsar definition is being increasingly used (Finlayson 1995, Storrs & Finlayson 1997).

3 Ecological character

An important obligation under the Ramsar International Wetland Convention is for each Contracting Party to '*designate suitable wetlands within their territory for inclusion in a List of Wetlands of International Importance*'. The Convention also states that wetlands should be Listed according to their '*international significance in terms of ecology, botany, zoology, limnology or hydrology*'. Whilst listing a site as internationally important is an important obligation under the Convention it may not constitute anything more than a passive conservation step. Thus, the Convention also contains an obligation to '*....formulate and implement their planning so as to promote the conservation of the wetlands included in the List.*' and to inform the Ramsar Bureau '*.....if the ecological character of any wetland in their territory and included in the List has changed, is changing, or is likely to change as the result of technological developments, pollution or other human interference*'. Thus, under this Convention there is an obligation to maintain (or restore) the ecological character of Listed sites (and, in fact, of all wetlands).

In 1992 the International Waterfowl and Wetland Research Bureau (IWRB) discussed the concept of ecological character and accepted a working definition that was proffered by Dugan and Jones (1993). The Ramsar Convention Scientific and Technical Review Panel (STRP) refined the definition (Finlayson 1996a) and this is presented below

> *'The ecological character of a wetland is the sum of the wetland's functions, products, and attributes that are derived from the individual biological, chemical, and physical components of the ecosystem and their interactions.'*

This wording reflected an international consensus and was presented as a working definition that could be changed following further discussion. This in fact occurred at the next conference of the Wetland Convention in 1996 and the following working definition was adopted

> *'The ecological character is the structure and inter-relationships between the biological, chemical, and physical components of the wetland. These derive from the interactions of individual processes, functions, attributes and values of the ecosystem(s).'*

The main difference between the definitions is that the first deliberately includes wetland values and benefits (functions, products and attributes) in addition to biophysical features. Thus, the ecological character of a wetland is, in part, defined by the uses made of it by people. In the second instance the direct reference to wetland values has been removed, although it is acknowledged that the use of the wetland can affect the ecological character. This change was made as there was unease at the direct linking of ecological and socio-economic concepts. It is noted, however, that the latter is also presented as a working definition and it could be changed.

Both definitions refers to wetland functions, products and attributes (values and benefits). These terms have been previously described within the Ramsar context (Dugan 1990, Davis 1993, 1994) and are presented below

Functions performed by wetlands include the following: water storage; storm protection and flood mitigation; shoreline stabilisation and erosion control; groundwater recharge; groundwater discharge; retention of nutrients, sediments and pollutants; and stabilisation of local climatic conditions, particularly rainfall and temperature. These functions are the result of the interactions between the biological, chemical and physical components of a wetland, such as soils, water, plants and animals.
Products generated by wetlands include the following: wildlife resources; fisheries; forest resources; forage resources; agricultural resources; and water supply. These products are generated by the interactions between the biological, chemical and physical components of a wetland.
Attributes of a wetland include the following: biological diversity; geomorphic features; and unique cultural and heritage features. These have value either because they induce certain uses or because they are valued themselves.

The combination of wetland functions, products and attributes give the wetland *benefits and values* that make it important to society.

The above terms provide a theoretical basis for describing the ecological character of a wetland, but do not assist with the practical issues of describing the character – what is an adequate level of baseline description and can this be used as a basis for assessing the significance of any change? Thus, there is a level of consensus (but not agreement) on the key concept (ie definitions) of ecological character, but the harder questions relating to the ecological meaning of change when it is detected have yet to be agreed. Monitoring can provide the necessary

information, but it does not necessarily provide the basis for interpreting the significance of change.

Within the context of the International Wetland Convention change in ecological character was considered as meaning adverse change. (It was noted that positive change could occur and that this was already covered by the management planning and restoration guidelines developed by the Ramsar Convention.) This concept is captured in the definition of change in ecological character proposed by Dugan & Jones (1993) and slightly modified by STRP (Finlayson 1996a)

> *'Change in ecological character of a wetland occurs as the result of technological developments, pollution, or other human interferences with the biological, chemical, and/or physical components of the ecosystem (and/or the interactions between them), to such an extent that a reduction and/or an ongoing imbalance occurs in any of those functions, products and attributes which give the wetland benefits and value to society'.*

However, even with this definition we are no closer to ascertaining what exactly constitutes an unacceptable ecological change. To define an unacceptable ecological change we need to firstly establish the values and benefits of the wetland, assess the ecological status of these and then monitor them to ascertain when (if) an adverse change is likely to or has actually occurred. At a superficial level this may seem a straight forward exercise, but in reality, all three steps are bedevilled by technical and/or socio-economic difficulties that can undermine the management, including monitoring, and wise use and conservation of wetlands (Hollis et al 1992, Finlayson 1994, 1996b, Hollis & Finlayson 1996).

The same comments apply to the definition of change in ecological character adopted by the Convention in 1996

> *'Change in the ecological character of a wetland is the impairment or imbalance in any of those processes and functions which maintain the wetland and its products, attributes and values.'*

Thus, there is broad agreement on the basic need to assess and describe the ecological character of a wetland, but further attention is required to assessing the significance of any change. For the latter to occur, further attention to inventory (that provides the basic description of the wetland) and monitoring (that describes the extent of any change) is required.

4 Wetland classification

The classification of wetlands is beset with difficulties (Finlayson & van der Valk 1995) and these seemingly multiply when a regional or an international approach is sought (Scott & Jones 1995). The purpose of wetland classification is to standardise and define the terms being used to describe the various wetland types. At an international level a uniform set of terms is needed (Cowardin & Golet 1995, Scott & Jones 1995, Zoltai & Vitt 1995). Pressey & Adam (1995) argue that at a local or national level this may not be necessary, although there would seem to be little argument that the adoption of standardised terms and definitions has definite advantages for comparative and broad planning purposes (Cowardin & Golet 1995, Hughes 1995, Zoltai & Vitt 1995).

Scott & Jones (1995) issued a warning concerning the level of sophistication required for classification in relation to the amount of information required for management. Careful consideration of the need for information and the requirements for management purposes are points strongly made by Pressey & Adam (1995). The important point in classifying wetlands

is not the detail of the classification, but the usefulness of the classification for management purposes.

Many national wetland classifications now exist (see Cowardin & Golet 1995, Lu 1995, Pressey & Adam 1995, Semeniuk & Semeniuk 1995, Zoltai & Vitt 1995). These invariably incorporate local terms and definitions that are not necessarily known or accepted elsewhere. For national purposes this may not be a major problem, but for comparisons and management at an international level these differences may present difficulties. However, even at the national level it can be extremely difficult to develop a classification that is acceptable to all wetland scientists and experts (Cowardin & Golet 1995, Lu 1995, Pressey & Adam 1995).

An overview of the classification of northern Australian wetlands has been provided by Finlayson & von Oertzen (1993). They list four completely different approaches (table 1) and can now be complemented by two further systems (Semeniuk 1987, Semeniuk & Semeniuk 1995, 1997, ANCA 1996). The inconsistencies within classifications similar to that adopted by the Ramsar Wetland Convention (such as that used by ANCA 1996) have been pointed out by Semeniuk & Semeniuk (1995, 1997).

Inconsistencies identified in wetland classifications
• not all types of wetlands are clearly or unambiguously described
• repetition of types that are named 'marshes'
• some wetlands remain ill-defined and encompass a number of types
• mixed criteria are used to separate wetlands

In order to overcome such inconsistencies Semeniuk & Semeniuk (1995, 1997) propose a geomorphic approach to wetland classification based on landform setting and hydroperiod. It is systematic with a hierarchical use of descriptors added to core wetland types.

5 Wetland inventory

The information collected through wetland inventories is nowadays regarded as a necessary prerequisite for wetland conservation and management at a holistic level, involving planning on a national, regional and international scale (Dugan 1990, Hollis et al 1992, Taylor et al 1995, Hughes 1995, Naranjo 1995, Scott & Jones 1995). An inventory is regarded by Dugan (1990) as the first step in assembling an information base for wetland management. In fact, Contracting Parties to the Ramsar Convention undertake to compile an inventory as part of the process of developing and implementing a national wetland policy for the wise use of all wetlands on their territory. Strategically developed wetland inventory (or inventories) should provide managers and/or policy makers with the information base that they require not only to manage individual wetlands or threats, but to also place the conservation value of wetlands within the context of broadscale (catchment, regional or even national) land use and sustainable development priorities.

To be effective in promoting the conservation of wetlands these inventories must be available to and understood by all those formulating and implementing wetland management policies (Naranjo 1995, Pressey & Adam 1995, Wilen & Bates 1995). Thus, they must be framed in a manner suitable for management purposes. Additionally, to remain useful tools for management they need to be regularly reviewed and updated (Naranjo 1995, Scott & Jones 1995, Wilen & Bates 1995). Information categories often used in wetland inventories are shown in table 2. Many of the categories do not relate directly to biophysical information, but are management oriented.

Inventories are useful in the first stages of developing effective wetland conservation programs (Taylor et al 1995, Hughes 1995, Naranjo 1995, Scott & Jones 1995, Wilen & Bates 1995). They can assist in the identification of conservation priorities, establish the basis for monitoring the ecological status of wetlands, promote awareness of wetland sites and management issues, and facilitate exchange of information and comparisons between sites and regions. As importantly, information gathered for inventories can also illustrate the economic value of wetlands and provide valuable data for resource utilisation decisions.

Inventories are particularly valuable for assessing wetland loss and degradation (Taylor et al 1995, Hughes 1995, Lu 1995, Wilen & Bates 1995). Information on rates of wetland loss and reasons for this loss have proved invaluable for promoting awareness and developing conservation and restoration programs (Hollis & Jones 1991, Hughes 1995, Wilen & Bates 1995). Once the basic information on wetland occurrence, distribution and status has been collated it is essential that it is utilised as the basis of further conservation effort before it becomes dated and not seriously regarded by conservation officials (Naranjo 1995). However, even when inventories are available they may only be of limited use (Hughes 1995, Naranjo 1995). This is particularly so where the information is not comprehensive or is restricted in scope and coverage, or is not brought to the attention of governmental officials responsible for setting policies that affect wetlands.

It is not possible, based on current inventory information, to accurately depict the extent of wetlands across all of northern Australia. A broadscale inventory is lacking, although much information has been collated in the national wetland directory (ANCA 1996). The existence of datasets on wetlands in the Northern Territory was identified by Storrs & Finlayson (1997), but an inventory does not exist. Similarly, in northern Western Australia there has been a recent attempt to collate existing information on major wetlands (Watkins et al 1997), but not a comprehensive inventory. There is much more information on northern Queensland wetlands and this is becoming available (Blackman et al 1993, 1995)

Without a complete inventory of wetlands, management for conservation and sustainable utilisation of wetlands will, in part, continue to be underpinned by an *ad hoc* information base. This is an unsatisfactory situation given the status of wetlands in northern Australia and the value now being placed on them (Finlayson et al 1997, Storrs & Finlayson 1997).

Costa et al (1996) summarised the conclusions of a Mediterranean analysis of wetland inventory. The key points from this summary are given below as a guide to compiling a wetland inventory. Additionally, Costa et al (1996) point out that the undertaking of an inventory allows the development of networks of experts concerned with wetlands, the stimulation of cooperation for undertaking conservation actions, and the promotion of awareness of wetland values and benefits.

Objectives of a 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
• to provide a tool for planning and management

In order to achieve these objectives the following recommendations were made.

Recommendations to achieve the objectives of an Inventory
• use standardised methods for classification, data collection and storage, delineation and mapping
• incorporate qualitative and quantitative data to provide a baseline for monitoring wetland change and loss
• facilitate analysis of loss of wetland functions
• be regularly updated
• be easily disseminated and made available to wetland managers, decision-makers and the general public.

For the above to be achieved careful planning and testing of techniques is required. A secure funding source is needed and all changes to protocols should be well documented and assessed. Critically, any limitations on the use of the information should be made apparent at the outset.

6 Monitoring

Environmental monitoring has received more and more attention in recent years. At a global level this has arisen as awareness of the extent of environmental degradation and habitat loss has increased. Wetlands have not been exempt from this general and widescale degradation (see, for example, cases described in Finlayson et al 1992). Such is the concern at the extent of global wetland degradation that more and more effort is being directed towards developing effective management processes and responses to problems. In many instances this effort is being held back by a lack of relevant information on the nature of the problem, the cause of the problem and the effectiveness of management procedures and actions. Effective monitoring programs can help overcome these deficiencies.

In a general sense monitoring addresses the issue of change or lack of change through time and at particular places. Thus **monitoring** can be defined as *the systematic collection of data or information over time*. It differs from **surveillance** by assuming that there is a specific reason for collecting the data or information (see Spellerberg 1991, Hellawell 1991, Furness et al 1994). Thus, whilst it is built upon survey and surveillance, it is more precise and oriented to specific targets or goals (Hellawell 1991, Spellerberg 1991).

Survey is an exercise in which a set of qualitative observations are made but without any preconception of what the findings ought to be.
Surveillance is a time series of surveys to ascertain the extent of variability and/or range of values for particular parameters.
Monitoring is based on surveillance and is the systematic collection of data or information over time in order to ascertain the extent of compliance with a predetermined standard or position.

The effectiveness of monitoring varies considerably. An effective monitoring program is not necessarily complex nor expensive. Effectiveness is gauged by the relevance and timeliness of the data or information collected which, in turn, are influenced by the design of the program.

A framework for assisting with the design of a monitoring program has been presented by Finlayson (1996a,c). The framework applies to all forms of monitoring (eg changes in the area of a wetland, the ecological health of a wetland, or the underlying reasons behind the loss of wetlands). The framework is not prescriptive. It is not a recipe for a particular type of problem or a particular type of wetland – this would be presumptuous given the many differences

between sites, the problems and the resources available. It presents a series of steps that will assist those charged with designing a monitoring program make decisions suitable for their own situation. A person using the framework will make these decisions based on some degree of knowledge and/or expertise. The framework is not a substitute for knowledge or expertise.

Before an effective monitoring program can be implemented the objectives of the program must be clearly identified and agreed. In an ideal situation, this should be a straightforward and cooperative process between managers (who make decisions) and scientists (who provide expert advice and interpret the data). In a simple sense, the managers would outline the need for a monitoring program and the scientists recommend the most appropriate techniques and, by an iterative process, an approach that has both scientific rigour and meets the management objectives will be developed. Conflict could arise if, in outlining the objectives, the managers are constrained or influenced by other than scientific considerations. Under such circumstances it must be remembered that any deficiency in the objectives will influence all other components of the program (Spellerberg 1991).

In a general sense, monitoring is needed to prevent further unchecked exploitation and degradation of wetlands. Thus, there is a need to assess the impact of human development and minimise ecological change. Success in such programs will depend on our ability not only to detect and monitor changes in the quality of wetlands, but also to provide early indications of likely change and thereby take action to prevent this change from occurring. A monitoring program that simply shows that change (including habitat loss) has occurred can have immense educational and public awareness value and demonstrate environmental trends, but programs that enable steps to be taken **before** such change (or loss) occurs are urgently needed. Without these programs the extent of ecological change (and loss) referred to above will continue unabated.

With all monitoring techniques there is a need to establish a starting point or to obtain baseline data that identifies the key functions and values of the site. Thus, the functions and values of a particular site need to be defined. Spellerberg (1991) considers baseline data to be information collected from the same place and on the same basis as subsequent data and that this is different to reference data which may have been collected from the same site by a different method or even from a different site. Reference data should only be used where it is not possible to obtain valid baseline data. To obtain a direct analysis of the extent and ecological significance of change a valid baseline is needed. However, for all sorts of reasons, it may be necessary to use the more indirect method of comparing to reference data. This still has value, but care should be used when inferring from one method to another or from one site to another.

Even a well designed monitoring program could have little value if the information that is collected is not utilised or does not influence the management process for that locality or site. Ideally, the locality or site will be subject to an interactive and holistic management plan that provides the means of responding to the information obtained from the monitoring program. If a formal or official management plan does not exist or is not being effectively implemented it is critical that mechanisms to make use of the information collected from a monitoring program are identified and developed.

The diagram in figure 1 (adapted from Constable 1991) outlines the connection between a formal management procedure and an environmental monitoring program. In this case monitoring provides the means of measuring the output of the management procedure – that is, it provides the means of measuring the (observed) state of the environment and the extent to which it may have been altered. If the management objectives are not being met the existing

legislation or regulations that affect the site (or location) are used to adjust the management activities. In the rather ideal procedure shown in figure 1, the monitoring program can be established either before or after a particular management activity is implemented. If monitoring is conducted before a particular management decision is taken it is essential that the information collected is then used to influence the management activities.

7 Management planning

> *'Wetlands are dynamic areas, open to influence from natural and human factors. In order to maintain their biological diversity and productivity and to allow wise use of their resources by human beings, some kind of overall agreement is needed between the various owners, occupiers and interested parties. The management planning process provides this overall agreement.'* (Davis 1993).

In other words, the management plan provides the basis for maintaining the ecological character of a wetland and to allow wise use of the resources by the owner and/or agreed users. In developing a management plan the following issues need consideration:

• It is a way of thinking which involves recording, evaluating and planning and is subject to constant review and revision and is therefore flexible and dynamic.
• It involves three basic steps of describing the features of the site/area, defining operational objectives and taking necessary management actions.
• Preparation of an elaborate plan is not an excuse for inaction or delay.
• Review of the plan may lead to revision of the site description and operational objectives.
• It should be a technical, not a legal document, although it may be supported by appropriate legislation.

Although conditions and resources vary at individual sites the general considerations may be applied widely.

The format of a plan may need to meet various legislative requirements, but it will generally contain a preamble and three major sections (table 3) – description of the site; evaluation and objections; and action plan/prescriptions. Technical staff will normally participate in all three stages with policy staff reviewing the first two stages before approving finances and implementation of the third stage.

The above may sound all very simple, but there are pitfalls, such as making the plan too complicated, making the plan the goal rather than the tool, making the plan inflexible and not allocating resources to ensure the plan can be implemented. Importantly, the plan should provide the means of obtaining and using the information needed for effective management of the wetland.

8 Conclusion

Collation of wetland information for northern Australia has been greatly enhanced in recent years, mainly through the national wetland directory. However, resource and conservation agencies across northern Australia have not agreed a definition of wetlands and a classification system. These steps need addressing before a comprehensive wetland inventory can be successful. Individual jurisdictions may proceed independently and gather inventory information, but this will not provide a national picture. Processes to assist in the development of an inventory are readily available and should be used, after due assessment for local

relevance. The inventory will require due attention and agreement on a classification system and be supported by effective monitoring that is dependent on the existence of adequate baseline or reference information.

The information requirements should be identified and supported by a site management plan that ensures that the objective of maintaining the ecological character of a site is supported by appropriate actions. The management plan provides the linkage between processes to gather information and to ensure that it is used in a timely and effective manner.

9 References

ANCA 1996. *A directory of important wetlands in Australia*. 2nd edn, Australian Nature Conservation Agency, Canberra.

Barson MM & Williams JE 1991. *Wetland inventory – towards a unified approach*. Bureau of Rural Resources, Canberra.

Blackman JG, Gardiner SJ & Morgan MG 1995. Framework for biogeographic inventory, assessment, planning and management of wetland systems – the Queensland approach. In *Wetland research in the Wet-Dry tropics of Australia*, ed CM Finlayson, Supervising Scientist Report 101, Supervising Scientist, Canberra, 114–122.

Blackman JG, Spain AV, Preece HJ & Whiteley LA 1993. Queensland. In *A directory of important wetlands of Australia*, eds S Usback & R James, Australian Nature Conservation Agency, Canberra, 6.1–6.115.

Briggs SV 1981. Freshwater wetlands. In *Australian Vegetation*, ed RH Groves, Cambridge University Press, Cambridge, 335–360.

Bunn SE, Boon PI, Brock MA & Schofield NJ 1997. *National wetlands R&D program: scoping review*. Land and Water Resources Research and Development Corporation, Canberra.

Constable, AJ 1991. The role of science in environmental protection. *Australian Journal of Marine and Freshwater Research* 42: 527–538.

Costa LT, Farinha JC & Hecker N 1996. Introduction. In *Mediterranean Wetland Inventory: A Reference Manual, Vol 1*, MedWet/Instituto da Conservacao da Natureza/Wetlands International Publication, Rome/Lisbon/Wageningen, 11–14.

Cowardin LM & Golet FC 1995. U.S. Fish and Wildlife Service 1979 wetland classification – a review. In *Classification and Inventory of the World's Wetlands*, eds CM Finlayson & AG van der Valk, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Davis TJ (ed) 1993. *Towards the Wise Use of Wetlands*. Ramsar Convention Bureau, Gland, Switzerland.

Davis TJ (ed) 1994. *The Ramsar Convention Manual: A Guide to the Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. Ramsar Convention Bureau, Gland, Switzerland.

Dugan PJ (ed) 1990. *Wetland conservation – a review of current issues and required action*. IUCN, Gland, Switzerland.

Dugan PJ & Jones TA 1993. Ecological change in wetlands: A global view. In *Waterfowl and wetland conservation in the 1990s – A global perspective*, eds M Moser, RC Prentice & J van Vessem, IWRB Special Publication No 26, Slimbridge UK, 34–38.

Finlayson, C.M. 1994. Monitoring ecological change in wetlands. In *Monitoring Ecological Change in Wetlands of Middle Europe*, eds G Aubrecht, G Dick & RC Prentice, Stapfia 31, Linz, Austria and IWRB Special Publication No 30, Slimbridge, UK, 163–180.

Finlayson CM (ed) 1995. *Wetland research in the Wet-Dry tropics of Australia*. Supervising Scientist Report 101, Supervising Scientist, Canberra.

Finlayson CM 1996a. The Montreux Record: A mechanism for supporting the wise use of wetlands. In *Ramsar Convention, Proceedings of 6th Conference of the Contracting Parties of the Convention on Wetlands, Technical Sessions: Reports and Presentations*, Ramsar Convention Bureau, Gland, Switzerland, 32–38.

Finlayson CM 1996b. Development impact on wetlands: why monitor? In *Development and Wetlands*, Wetlands International, Kuala Lumpur, Malaysia (in press).

Finlayson CM 1996c. Framework for designing a monitoring program. In *Monitoring Mediterranean Wetlands: A Methodological Guide*, ed P Tomas Vives, MedWet Publication; Wetlands International, Slimbridge, UK and ICN, Lisbon, 25–34.

Finlayson CM & van der Valk AG (eds) 1995. *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Finlayson CM & von Oertzen I 1993. Wetlands of northern Australia. In *Wetlands of the World I: Inventory, Ecology & Management*, eds DJ Whigham, D Dykyova & S Heijny, Kluwer Academic Publishers, Dordrecht, The Netherlands, 195–243.

Finlayson, CM, Hollis GE & TJ Davis (eds) 1992. *Managing Mediterranean Wetlands and Their Birds*. IWRB Special Publication No 20, Slimbridge, UK.

Finlayson CM, Hall R & Bayliss B 1997. *Regional review of wetland management issues: Wet-Dry tropics of northern Australia*. LWRRDC National Wetlands R&D Program, LWRRDC Occasional Paper, Canberra (in press).

Fleming M 1993. Northern Territory: Introduction. In *A directory of important wetlands in Australia*. Australian Nature Conservation Agency, Canberra, 5.1–5.2.

Furness RW, Greenwood JJD & Jarvis PJ 1994. Can birds be used to monitor the environment? In *Birds as Monitors of Environmental Change*, eds RW Furness & JJD Greenwood, Chapman & Hall, London, 1–14.

Hellawell JM 1991. Development of a rationale for monitoring. In *Monitoring for Conservation and Ecology*, ed FB Goldsmith, Chapman & Hall, London, 1–14.

Hollis GE & Jones TA 1991. Europe and the Mediterranean Basin. In *Wetlands*, eds CM Finlayson & M Moser, Facts on File, Oxford.

Hollis GE & Finlayson CM 1996. Ecological change in Mediterranean wetlands. In *Monitoring Mediterranean Wetlands: A Methodological Guide*, ed P Thomas Vives, MedWet Publication; Wetlands International, Slimbridge, UK and ICN, Lisbon, 5–24.

Hollis GE, Patterson J, Papayannis T & Finlayson CM 1992. Sustaining wetlands: policies, programs and partnerships. In *Managing Mediterranean Wetlands and Their Birds*, IWRB Special Publication No. 20, Slimbridge, UK, 281–285.

Hughes JMR 1995. European wetland inventories and classifications: current status and future directions. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Jonauskas P (ed) 1996. *Proceedings wetlands workshop: Making multiple landuse work.* Department of Lands, Planning & Environment, Northern Territory Government Publishing Service, Palmerston.

Lu J 1995. Ecological significance and classification of Chinese wetlands. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Masini RJ 1986. Inland waters of the Pilbara. A report on a field study carried out in March–April 1983. Unpublished report to the Department of Conservation and the Environment, Perth, Australia.

McComb AJ & Lake PS 1988. *The Conservation of Australian Wetlands*. Surrey Beatty & Sons Pty Limited, Sydney.

Naranjo LG 1995. Wetland inventories and conservation in South America: an overview. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Paijmans K, Galloway RW, Faith DP, Fleming PM, Haantjens HA, Heyligers PC, Kalma JD and Loffler E 1985. *Aspects of Australian wetlands*. Division of Water and Land Resources Paper No 44, CSIRO, Australia.

Pressey RL & Adam P 1995. A review of wetland inventory and classification in Australia. *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Scott DA 1993. *A directory of wetlands in Oceania*. IWRB, Slimbridge, UK and AWB, Kuala Lumpur, Malaysia.

Scott DA & Jones TA 1995. Classification and inventory of wetlands: a global overview. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Semeniuk CA 1987. Wetlands of the Darling System – a geomorphic approach to habitat classification. *Journal of the Royal Society of Western Australia* 69, 95–111.

Semeniuk CA & Semeniuk V 1995. Geomorphic approach to classifying wetlands in tropical north Australia. In *Wetland research in the Wet-Dry tropics of Australia*, ed CM Finlayson, Supervising Scientist Report 101, Supervising Scientist, Canberra, 123–128.

Semeniuk V & Semeniuk CA 1997. A geomorphic approach to global classification for natural inland wetlands and rationalisation of the system used by the Ramsar Convention – a discussion. *Wetlands Ecology & Management* (in press).

Stanton JP 1975. *A preliminary assessment of wetlands in Queensland*. CSIRO Division of Land Use Research Technical Memorandum 75/10, Canberra.

Storrs MJ & Finlayson CM 1997. *Overview of the conservation status of wetlands of the Northern Territory*. Supervising Scientist Report 116, Supervising Scientist, Canberra.

Spellerberg IF 1991. *Monitoring Ecological Change*. Cambridge University Press, Cambridge.

Taylor ARD, Howard GW & Begg GW 1995. Developing wetland inventories in southern Africa: a review. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Tomas Vives P (ed) 1996. *Monitoring Mediterranean Wetlands: A Methodological Guide.* MedWet Publication; Wetlands International, Slimbridge, UK and ICN, Lisbon.

Usback S & James R (eds) 1993. *A directory of important wetlands in Australia.* Australian Nature Conservation Agency, Canberra.

Watkins D, Brennan K, Lange C, Jaensch R & Finlayson M 1997. Management planning for Ramsar sites in the Kimberley region of Western Australia. Unpublished report to the Department of Conservation and Land Management, Western Australia.

Wilen BO & Bates MK 1995. The US Fish & Wildlife Service's national wetland inventory project. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Zoltai SC & Vitt DH 1995. Canadian wetlands: their classification and responses to environmental gradients. In *Classification and Inventory of the World's Wetlands*, Advances in Vegetation Science 16, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Table 1 Wetland classification schemes used in northern Australia

Basis of classification	Region	Reference
Hydrologic	Queensland	Stanton 1975
Vegetation structure and floristic	Australia	Briggs 1981
Hydrologic and vegetation	Australia	Paijmans et al 1985
Physical	Pilbara	Masini 1986
Geomorphic, hydrologic and vegetation	Australia	ANCA 1996
Geomorphic	Australia	Semeniuk & Semeniuk 1997

Table 2 Data categories used by Scott (1993) in the directory of wetlands of Oceania

Category	Information
Title	Name and reference number
Location	Geographical coordinates
Area	Area and/or length of rivers
Altitude	Average
Overview	Summary description of site
Physical features	Hydrology, soils, water quality, climate
Ecological features	Main habitats and vegetation
Land tenure	Ownership of wetland and surrounding land
Conservation measures taken	Details of protected areas
Conservation measures proposed	Further proposals
Land use	Human activities
Possible changes in land use	Development plans and ideas
Disturbances and threats	Existing and possible threats
Hydrological and biophysical values	Principal features
Social and cultural values	Principal values
Noteworthy fauna	Important species
Noteworthy flora	Important species
Scientific research and facilities	Major research activities and facilities
Conservation education	Existing programs and facilities
Management authority and jurisdiction	Responsible authority(ies)
References	Key published literature
Reasons for inclusion	Reason(s) designated as important

Table 3 Recommended components of a management plan (Davis 1994)

- Preamble
  - Concise statement of broad governmental policies concerned with the plan.
  - Statement of the Ramsar obligations of maintaining the ecological character of a listed site
- Description
  - Establishes the basis for monitoring to identify any subsequent changes at the site.
- Evaluation and Objectives
  - Evaluation
    - Assessment of the major features of the site
  - Long-term management objectives
    - Concise expression of intent and derived from the evaluation process.
  - Factors influencing the achievement of long-term objectives
    - Internal natural factors such as vegetation succession and variations in water level.
    - Internal human-induced factors such as erosion, disturbance and pollution.
    - External natural factors such as climate change, variations in current and sea level.
    - External human-induced factors such as sedimentation and pollution.
    - Factors arising from legislation or tradition such as treaties or access rights.
    - Physical considerations such as inaccessibility.
    - Available resources such as finance and a skilled workforce.
  - Identification of operational objectives
    - Taking into account factors that affect the achievement of long-term objectives.
    - Establishment of the limits of acceptable change.
- Action Plan/Prescriptions
  - Workplan
    - Provides management options derived from the operational objectives.
  - Projects
    - Prescriptions to achieve the individual tasks to required for the operational objectives.
    - Establishes record keeping and administrative procedures.
  - Work programs
    - Derived from the individual projects.
  - Reviews
    - Assessment of the success of the workplan, projects and work program.

Figure 1 Connection between a formal management procedure (plan) and an environmental monitoring program (based on Constable 1991).