DEVELOPMENTS IN WETLAND INVENTORY, ASSESSMENT AND MONITORING

CM Finlayson, G Begg, CL Humphrey & P Bayliss
Environmental Research Institute of the Supervising Scientist, Jabiru/Darwin, Northern Territory, Australia

ABSTRACT

The main challenge that wetland managers and policy makers face today is to make choices that are sensible, pragmatic and defensible, particularly against a background of ecological and socio-economic complexity and uncertainty, due in large part to a lack of reliable knowledge. However, recent developments in wetland inventory, assessment and monitoring methods may provide an essential framework of knowledge for the wise use of wetlands, whether for conservation, sustainable use or multiple use objectives. Collectively known as a WIAMS (Wetlands Inventory, and Assessment, Monitoring System), we argue that this approach is more comprehensive and, hence, more effective than the conventional WAS (Wetlands Assessment System). It involves a multi-scalar (hierarchical) approach to inventory, best practice assessment protocols within a risk management framework, and a focused monitoring programme which provides feedback on performance in order to obtain outcomes.

Wetlands throughout the world are under increasing threats and pressures from both local and global changes. Hence, over the past two decades, WIAMS are rapidly becoming an indispensable part of the decision-making tool box for wetland managers and policy makers operating from local to global scales. We first review past recommendations and considerations for wetlands inventory, monitoring and assessment, and then identify practical steps for developing effective programmes to obtain reliable information in a cost-effective and timely fashion. We recommend strongly that the WIAMS framework be adopted because it will, at the least, standardise terminology and approaches for obtaining and reporting information which can then be shared with those who cannot afford the luxury of such programmes. We recommend also, that this robust working framework be constantly reviewed and improved.

INTRODUCTION

Wetland inventory, assessment and monitoring have been increasingly addressed in international and national fora in recent years. Much of the international effort has been directed towards supporting the concept of wise use of wetlands advocated under the Ramsar Wetlands Convention and supported by Wetlands International and its partners (Finlayson & Davidson 2001). This has resulted in a number of international meetings and agreements on priorities for wetland inventory, assessment and monitoring. These are reported below as the basis for developing a holistic approach for wetland management through the provision of accurate and reliable information. Such information has been identified as a crucial step for effective wetland management (Dugan 1990, Finlayson 1996a).
In presenting this information we propose the acceptance of standardised terminology and the adoption of comparable approaches for obtaining and reporting information necessary for effective wetland management. In doing this we draw heavily upon information obtained from a number of international wetland projects. Foremost amongst these are:

- a global review of wetland inventories (GRoWI) for the Ramsar Convention (Finlayson & Davidson 1999, Finlayson et al 1999);
- a framework for conducting wetland risk assessment as an integral component of management planning processes (van Dam et al 1999);
- frameworks for monitoring adopted under the Ramsar Convention (Finlayson 1996b) and the Mediterranean wetland initiative (MedWet) (Finlayson 1996c, Grillas 1996, Tomas Vives & Grillas 1996); and
- a framework for a hierarchical approach to wetland inventory in Asia (Finlayson et al 2002a,b).

In support of this proposal we first review past recommendations and considerations for wetland inventory, assessment and monitoring and identify practical steps for developing effective programmes that can supply information in a timely manner for wetland managers. The latter builds on outcomes of workshops held during the 2nd International Conference on Wetlands and Development, Dakar, Senegal, November 1998 (Finlayson et al 2001a).

PREVIOUS CONFERENCE RECOMMENDATIONS

Finlayson & Davidson (2001) provide a summary of the recommendations on wetland inventory, assessment and monitoring agreed in major wetland conferences during the last two decades. These conferences included the following:

- Managing Waterfowl Populations (Matthews 1990) – IWRB, Astrakhan, Russia (former USSR), 2–5 October 1989;
- Managing Mediterranean wetlands and their birds for the Year 2000 and beyond (Finlayson et al 1992) – IWRB, Grado, Italy, 3–10 February 1991;
- Old world and new world wetlands (Mitsch 1994; Finlayson and van der Valk 1995) – Intecol Wetland Conference, Columbus, USA, 13–8 September 1992;
- Waterfowl and wetland conservation in the 1990s – A global perspective (Moser et al 1993) – IWRB, St Petersburg Beach, Florida, USA, 12–19 November 1992; and
- International conference on wetlands and development (Prentice & Jaensch 1997) – Wetlands International, Kuala Lumpur, Malaysia, 9–13 October 1995.

Recommendations from these meetings were broadly consistent and covered six common themes and/or requirements:

- 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 communication networks; and
- Developing means to audit existing effort.

The consistency of the recommendations was attributed in part, to a degree of consistency of attendance and participation of personnel from or associated with Wetlands International (Finlayson & Davidson 2001). However, as the conferences were held in different locations it is likely that many other interests were also represented. Further, the nature of the meetings became much broader with an initial focus on waterbirds extending to waterbirds and their habitats, and then to wetlands and their management. Thus, the outcomes most likely represent a decade of a developing and expanding interest in wetlands and an increasing awareness that wetland inventory, assessment and monitoring was either needed or, where it existed, was inadequate.

Finlayson & Davidson (2001) also reported that there was little evidence that these recommendations had been widely implemented. Whilst many of the recommendations were worthy, they had apparently proved to be unrealistic and possibly over-ambitious given the past and present levels of institutional capacity and capability on the ground. Unfortunately it seemed that the rhetoric and *bon homie* of the conferences (and their workshops) had been difficult to translate into on-the-ground action after the conference. A major exception to the general lack of implementation was provided by the Mediterranean wetlands programme MedWet, which has now contributed substantively to standardising techniques for wetland inventory (Costa et al 1996) and monitoring (Tomas Vives 1996).

The success of the MedWet programme is heartening, but it should not shield the reality that this success has not been widely replicated. Other regional conferences and workshops have not succeeded in this manner and further wetland inventory, assessment and monitoring are 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.

The workshops held in Dakar, Senegal, 1998 (Finlayson et al 2001a) took this problem into account and attempted to present some practical outcomes that could assist in the development of more effective wetland inventory, assessment and monitoring programmes. 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 earlier workshops. The outcomes of this workshop as presented by Finlayson et al (2001b) are discussed below along with some more recent advances.

CURRENT STATE OF WETLAND INVENTORY, ASSESSMENT AND MONITORING

Finlayson et al (1999, 2001b) report that 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. Broad-scale initiatives include:

- a global review of wetland resources that compiled and analysed information from national wetland inventory resources and evaluated the size and distribution of the global wetland resource (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 (undertaken by Wetlands International through the Biodiversity Conservation Information System (BCIS) network – Davidson 1999);
- the first phase of a project towards a Pan-European wetlands inventory (Wetlands International and the RIZA institute, Netherlands – Nivet & Frazier 2001);
- continuing development and testing of wetland inventory and assessment tools through the MedWet initiative (Costa et al 2001);
- development of a draft framework for wetland inventory by the Scientific and Technical Review Panel of the Ramsar Wetlands Convention based on a resolution adopted by the Convention in 1999 (reproduced in Finlayson & Davidson 2001); and
- development of the Asian Wetland Inventory using approaches derived from the recommendations presented at the workshops held in Dakar and supporting the concepts outlined in the Ramsar framework (Finlayson et al 2002a,b).

The global review of wetland resources identified large gaps in the global wetland inventory effort, with many discrepancies in data management, inadequate documentation, inconsistencies in methods and poor communication of information. Papers presented in Finlayson et al (2001a) also illustrate the extent and limits of wetland inventory, assessment and monitoring in some countries.

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 reported by Finlayson et al (2001b) 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. The collection of time-series information that is not hypothesis-driven from wetland assessment is here termed *surveillance* rather than monitoring.

The relationship between these concepts is shown in Figure 1. 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.

Basically wetland inventory is used to collect information to describe the ecological character of wetlands; assessment considers the pressures and associated risk of adverse change in ecological character; and monitoring, which could include survey and surveillance (Finlayson 1996b,c), provides information on the extent of any change. As all three steps – inventory, assessment and monitoring – are important data gathering exercises we propose that any "Wetland Assessment System (WAS)" comprises components of each. The extent of each component would be determined by individual management needs and the extent of existing information. We also propose, in light of the definitions given above from Finlayson et al (1999, 2001b) that the term "Wetland Assessment System" is redundant and should be replaced with a Wetland Inventory, Assessment and Monitoring System (WIAMS).

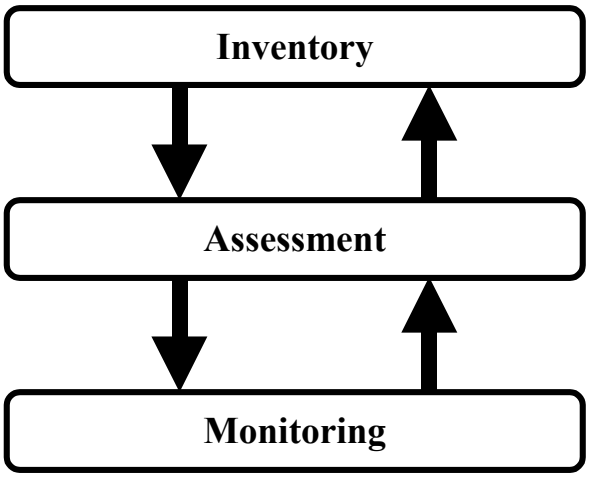

Figure 1. Concepts of wetland inventory, assessment and monitoring (taken from Finlayson et al 1999, 2001b) and proposed for acceptance within the technical guidelines adopted by the Ramsar Wetlands Convention.

PRACTICAL STEPS FOR IMPROVED INVENTORY, ASSESSMENT AND MONITORING

As noted above, recommendations covering practical steps for improving wetland inventory, assessment and monitoring have been proposed at many conferences. A summary of these is presented below along with outcomes of the major activities also reported above.

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 have 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. This information should provide a base for national assessment of wetlands and management priorities.

3. Each inventory and assessment programme 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. 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.

5. The effectiveness of all aspects of wetland inventory and assessment should be addressed through 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 and assessment objectives.

6. Models for effective wetland inventory, using appropriate remote sensing and ground techniques should be compiled and widely disseminated. These should outline useful habitat classifications (eg those based initially on landform and not vegetation parameters), methods and means of collating and storing the information, in particular Geographic Information Systems (GIS) for spatial and temporal data that could be used for monitoring purposes.

7. Wetland monitoring systems should build upon the information provided in wetland inventory and assessment activities. Specific monitoring should be based on a hypothesis derived from the assessment data and be contained within a suitable management structure.

Although we recommend these seven essential steps, we stress the value of: 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 information.

The Ramsar Convention has to date adopted guidelines for the development of effective wetland risk assessment (van Dam et al 1999) and monitoring programmes (Finlayson 1996a). Guidelines for inventory are available in a draft form and will be debated late in 2002 at the 8th Meeting of the Conference of Parties to the Convention. These guidelines can be combined and used to develop a wetland inventory, assessment and monitoring system (WIAMS) that reflects local needs and conditions. A summary of existing guidelines is provided below.

GUIDELINES FOR DEVELOPING WETLAND INVENTORY PROGRAMME

In response to recommendations made in the global review of wetland inventory (Finlayson & Spiers 1999, Finlayson & Davidson 1999, Finlayson et al 1999) the Ramsar Wetlands Convention adopted resolution VII.10 Priorities for Wetland Inventory. Amongst other issues this contained a request 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."

The guidelines presented below were developed by the Scientific and Technical Review Panel of the Convention with input from Wetlands International's Specialist Group on Wetland Inventory and Monitoring, and the Environmental Research Institute of the Supervising Scientist (Australia). The draft

guidelines[1], will be debated at the 8th Meeting of the Conference of Contracting Parties to the Convention in November 2002.

The guidelines include 13 steps (Table 1) for assisting interested parties design an inventory that is suited to their needs. It basically comprises a framework for developing an inventory using information provided or obtained by the proponents. It is not a recipe for a specific inventory. As a guide to developing individual inventories information is provided in the draft guidelines on existing inventory methods and habitat classifications, types of remotely sensed data and a procedure for determining which is most appropriate for a particular inventory.

A key feature of the proposed framework is the adoption of the concept of a core or minimum data set sufficient to describe the wetland(s). It is noted that the specific details of this data set are inseparable from the level of complexity and the spatial scale of the inventory. Thus, it is recommended that sufficient information (the core, or minimum, data set) should be collected so as to enable the major wetland habitats to be delineated and characterized for at least one point in time by describing i) the biophysical features of the wetland; and/or ii) the major management issues of the wetland. The decision about whether or not to undertake an inventory based only upon core biophysical data or also to include data on management features will be based on individual priorities and resources. Recommended core data fields for the collection of biophysical and management features of wetlands are listed in Table 2.

GUIDELINES FOR DEVELOPING A WETLAND ASSESSMENT PROGRAMME

The concepts of assessment have also been addressed under the Ramsar Wetlands Convention with an initial emphasis on providing guidance for wetland risk assessment. This was developed to assist with predicting and assessing change in the ecological character of wetlands. A framework that provides guidance on how to go about predicting and assessing change in the ecological character of wetlands and promotes, in particular, the usefulness of early warning systems, was adopted by resolution VII.10 on Wetland Risk Assessment.

The basic model prepared for wetland risk assessment, modified from a generalised ecological risk assessment model, is shown in Figure 2. It outlines the six steps based on the concepts presented by van Dam et al (1999).

1. *Identification of the problem* - identify the nature of the problem and develop a plan for the remainder of the assessment, including the objectives and scope.
2. *Identification of adverse effects* – determine the types of adverse ecological and/or socio-economic effects caused by the problem.
3. *Identification of the extent of the problem* – estimate the extent to which the problem may or does occur.
4. *Identification of the risk* – integrate the results from the above steps.
5. *Risk management and reduction* – make decisions to minimize the risks without compromising other societal, community or environmental values.
6. *Monitoring* – verify the effectiveness of the risk management decisions.

The application of the above risk assessment model has been demonstrated in specific case studies for invasive species (Finlayson et al 2001c, van Dam et al 2001) and altered water allocations within a river basin (Begg et al 2001). It is anticipated that further assessment procedures will be developed or expanded to support this risk assessment model. Importantly it is noted that the risk assessment model builds on information obtained through the inventory procedure and links this with monitoring, shown as the last step in the model.

[1] Available at URL, http://www.ramsar.org/key_sc26_docs_cop8_07.htm.

Table 1. A structured framework and step-wise checklist for planning a wetland inventory

No.	Step	Guidance
1	**State the purpose and objective**	State the reason(s) for undertaking the inventory and why the information is required, as the basis for choosing a spatial scale and minimum data set.
2	**Review 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.
3	**Review existing inventory methods**	Review available methods and seek expert technical advice to: a) choose the methods that can supply the required information; and b) ensure that suitable data management processes are established.
4	**Determine the scale and resolution**	Determine the scale and resolution required to achieve the purpose and objective defined in Step 1.
5	**Establish a core or minimum data set**	Identify the core, or minimum, data set sufficient to describe the location and size of the wetland(s) and any special features. This can be complemented by additional information on factors affecting the ecological character of the wetland(s) and other management issues, if required.
6	**Establish a habitat classification**	Choose a habitat classification that suits the purpose of the inventory, since there is no single classification that has been globally accepted.
7	**Choose an appropriate method**	Choose a method that is appropriate for a specific inventory based on an assessment of the advantages and disadvantages, and costs and benefits, of the alternatives.
8	**Establish a data management system**	Establish clear protocols for collecting, storing and retrieving data, including archiving in electronic or hardcopy formats. This should enable future users to determine the source of the data, and its accuracy and reliability. At this stage it is also necessary to identify suitable data analysis methods. All data analysis should be done by rigorously tested statistical or other quantitative methods, and all information documented. The data management system should support, rather than constrain, the data analysis. A meta-database should be used to: a) record information about the inventory datasets; and b) outline details of data custodianship and access by other users.

9	**Establish a time schedule and the level of resources that are required**	Establish a time schedule for: a) planning the inventory; b) collecting, processing and interpreting the data collected; c) reporting the results; and d) regular review of the programme. Establish the extent and reliability of the resources available for the inventory. If necessary make contingency plans to ensure that data are not lost due to insufficiency of resources.
10	**Assess the feasibility & cost effectiveness**	Assess whether or not the programme, including reporting of the results, can be undertaken within the current institutional, financial and staff situation. Determine if the costs of data acquisition and analysis are within budget and that a budget is available for the programme to be completed.
11	**Establish a reporting procedure**	Establish a procedure for interpreting and reporting all results in a timely and cost effective manner. The report should be succinct and concise, indicate whether or not the objective has been achieved, and contain recommendations for management action, including whether further data or information is required.
12	**Establish a review and evaluation process**	Establish a formal and open review process to ensure the effectiveness of all procedures, including reporting and, when required, supply information to adjust or even terminate the programme.
13	**Plan a pilot study**	Test and adjust the method and specialist equipment being used, assess the training needs for staff involved, and confirm the means of collating, collecting, entering, analysing and interpreting the data. In particular, ensure that any remote sensing can be supported by appropriate "ground-truth" surveys.

Table 2. Core (minimum) data fields for biophysical and management features of wetlands

Biophysical features

- Site name (official name of site and catchment)
- Area and boundary (size and variation, range and average values) *
- Location (projection system, map 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)
- Climate – zone and major features (average rainfall, temperature range, relative humidity, prevailing winds)
- Soil (structure and colour)
- Water regime (natural or artificial, periodicity, extent of flooding and depth, source of surface water and links with groundwater)
- Water chemistry (salinity, pH, colour, transparency, nutrients)
- Biota (vegetation zones and structure, animal populations and distribution, special features including rare/endangered species)

Management features

- Land use – local, and in the river basin and/or coastal zone
- Pressures on the wetland – within the wetland and in the river basin and/or coastal zone
- Land tenure and administrative authority – for the wetland, and for critical parts of the river basin and/or coastal zone
- Conservation and management status of the wetland – including legal instruments and social or cultural traditions that influence the management of the wetland
- Ecosystem values and benefits (goods and services) derived from the wetland – including products, functions and attributes (see Resolution VI.1) and, where possible, their services to human well-being (see Resolution VI.23 and VII.8) and whether or not the benefits derived from wetlands are sustainable.
- Management plans and monitoring programmes – in place and planned within the wetland and in the river basin and/or coastal zone (see Resolutions 5.7, VI.1, VII.17, [and VIII.xx])

* These features can usually be derived from topographical maps or remote sense images, especially aerial photographs.

GUIDELINES FOR DEVELOPING A WETLAND MONITORING PROGRAMME

A framework for assisting with the design of a monitoring programme was developed in unison for the Ramsar Wetlands Convention (Finlayson 1996b) and for the Mediterranean Wetland Programme (MedWet) (Finlayson 1996c). The concepts that support the framework are outlined in resolution VI.1 which addressed a number of issues including monitoring change in the ecological character of wetlands.

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). As such it is not prescriptive and it does not provide a recipe for a particular type of problem wetland type. It presents a series of steps for designing a monitoring programme which can be tailored to individual needs.

In presenting this framework it is stressed that not all monitoring programmes are effective. For example, monitoring programmes that are data rich and information poor are not likely to be effective. Effectiveness is further reduced if the programme provides misleading information. At the outset the likely outcomes of the monitoring programme should be considered, including an assessment of the likely threshold of change

that can be tolerated (both system and social tolerance), or the likely responses that may be needed (van Dam et al 1999).

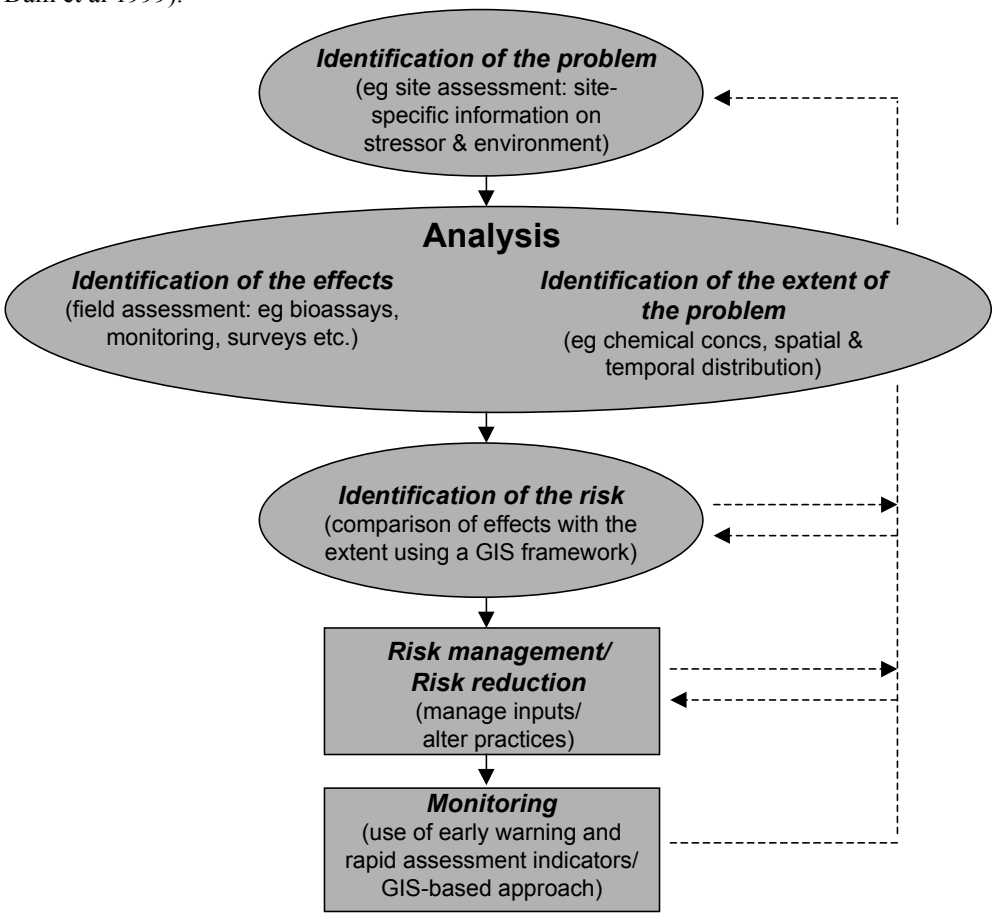

Figure 2. Wetland risk assessment model recommended by the Ramsar Wetlands Convention resolution VI.1, after van Dam et al (1999)

Key aspects of the framework are described below, adapted from material presented by Finlayson (1996b,c) and from background sources. A summary of the points to consider when using the framework is given in Table 3.

The framework outlined above was developed for the Ramsar Wetland Convention and has been specifically tested in the MedWet programme (Tomas Vives 1996).

DEVELOPMENT AND IMPLEMENTATION OF MULTI-SCALAR APPROACHES FOR WETLAND INVENTORY, ASSESSMENT AND MONITORING

The above guidelines have been agreed as the basis for developing coherent approaches for wetland inventory, assessment and monitoring. That is, the guidelines provide the basis of a holistic approach to determining the status of and extent of change (if any) in wetlands. In the process of developing these guidelines the issue of scale was regularly raised. This has been possibly most clearly articulated for inventory (Finlayson et al 2001b), but could equally apply to assessment and monitoring.

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

Table 3. Summary of key points to consider when designing a wetland monitoring programme

Identify the nature & extent of the problem(s) or the issue(s)	State clearly and unambiguously in relation to the known extent and most likely cause, identify the baseline or reference situation that exists or is required, and establish the most likely threshold of change that could be socially acceptable.
Set the objective	Based on the step above and provides the basis for collecting the information through attainable and achievable time periods for monitoring and to support managerial responses.
Establish the working hypothesis(es)	Supports the objective and can be tested by the methods adopted, including statistical analyses in line with acceptable levels of change identified before the monitoring commences.
Choose the methods & variables	Specific for the problem and able to provide sufficient information to test the hypothesis(es) need to detect the presence of, and assess the significance of, any change. Thus, they are suitable for obtaining the results necessary to identify or clarify any change and for showing the most likely cause or need for further investigation.
Assess the feasibility & cost effectiveness	Determine whether or not the programme (including reporting of the results) can be done regularly and continually within the context of the management planning processes and financial resources available. Assess factors that influence the sampling programme such as: 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. 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 analysing and interpreting the data. 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 sampling methods before the project begins, including the necessary documentation required. For example, 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.

	Samples should be processed within a timely period and all data documented such as: date and location; names of staff; processing methods; equipment used ; and all changes to the protocols.
Analyse the samples	Sample and data analysis should be done by rigorous and tested methods and all information documented such as: 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 written in a clear and concise manner and indicate whether or not the hypothesis(es) has been supported. It contains recommendations for management action, including further monitoring.
Evaluate the project	Formally and openly review the effectiveness of all procedures and where necessary adjust or even terminate the programme. The latter should not be seen as a failure if it is shown to be done for valid reasons.

- global – presence/absence in specific continents and islands,
- continental – distribution of regions within continents or islands dominated by wetlands,
- regional – scale of predominance of specific wetland types,
- local – individual wetlands, and
- site – variability within wetlands.

These ideas have been further developed and expressed in a draft protocol for wetland inventory in Australia (Finlayson 1999) and extended with protocols for an Asian wetland inventory (Finlayson et al 2002a,b). The basis of the latter is outlined below.

The Asian Wetland Inventory (AWI) has been developed with multiple goals in mind. These take into account the need for information at multiple scales (ie local to global) and include the need to (after Finlayson et al 2002a,b):

- develop standardised field data collection sheets;
- provide core data/information on Asian wetlands to support international conventions and treaties on wetlands, climate change, biodiversity, migratory species and desertification, and their implementation by governments;
- analyse long-term trends in Asian wetlands and their natural resources;
- enable regular revisions and updates of information on wetlands of national and international importance in Asia; and
- disseminate these analyses for wider consideration and use in sustainable development and conservation of wetland resources.

The key feature of the AWI is the production of hierarchical and map-based outputs at four levels of detail. The level of detail is related to the scale of the maps that are contained within a standardised GIS format with a minimum core data set. The hierarchical approach comprises a progression in scale from river basins to individual sites (Figure 3). The initial analysis (level 1) comprises delineation of geographical regions (major river basins & islands) in Asia and encompasses a description of the geology, climate and ecology of each based on existing information sources. Level 2 analysis comprises delineation of wetland regions within each geographic region. This is done on the basis of similar climatic, geologic, hydrologic and

vegetation features. Level 3 analysis comprises grouping and description of wetland complexes within each region on the basis of more detailed information. Finally, Level 4 analysis comprises detailed description of individual wetland habitats. The above approach results in the production of more detailed information on wetlands as the inventory progresses from Levels 1 to 4.

At all levels of analysis the usefulness of existing information is assessed and used as a basis for determining whether or not further analysis or collection of information is necessary. It is likely that the analyses will be undertaken as described below:

- **Level 1** – desk study to describe the broad geologic, climatic and ecological features of each geographic region using existing datasets, such as those nowadays available on the world wide web;
- **Level 2** – desk study to identify the wetland regions within each geographic region using information already collated on geology, climate, hydrology and vegetation;
- **Level 3** – fieldwork and analysis to identify the physical, physico-chemical and biological features of wetland complexes within each wetland region; and
- **Level 4** – detailed fieldwork and analysis to describe the physical, physico-chemical and biological features of each wetland habitat within each wetland complex. This includes information on plant and animal assemblages and species, land and water use and wetland management.

Data collection and analysis is based on standardised procedures, although flexibility is not discouraged where deemed useful, and data management formats. Proforma data sheets for each level of analysis have been developed and are accompanied by guidelines for collecting the required information (Finlayson et al 2002c).

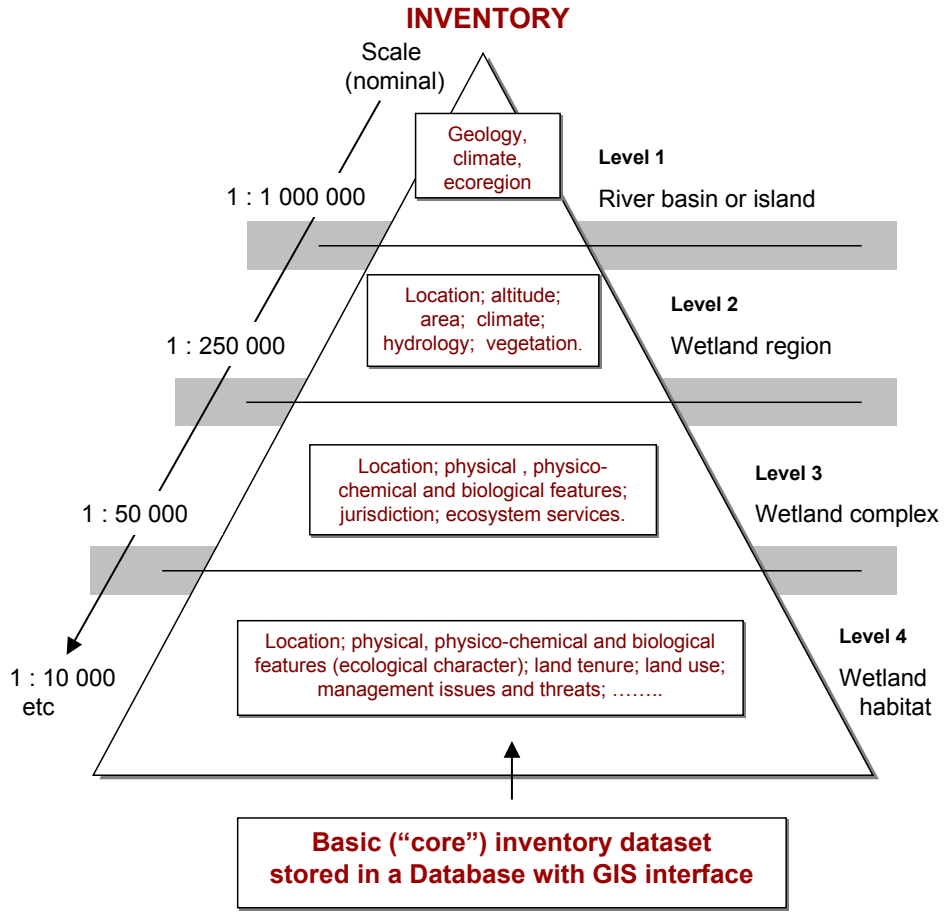

Figure 3. Hierarchical approach to wetland inventory

The hierarchical or multi-scalar approach can also be linked with other data collecting exercise such as those proposed in the Millennium Ecosystem Assessment (Reid 2000). It is important to realise that while a hierarchical framework has been proposed it is not essential to work through all levels of detail. The hierarchical approach has been developed in response to existing needs to obtain information at different levels and detail, and also serves to demonstrate the clear linkages between scales. It is possible to obtain data at any level within the hierarchy whether or not other levels have been or will be addressed. A key point of this approach, however, is the adoption of compatible data fields and data management procedures to allow maximum use of the data whether this is immediately planned or not. The global review of wetland inventory demonstrated that a large amount of data was reused, often without sufficient attention to its limits or constraints on interpretation (Finlayson et al 1999, Finlayson & Spiers 1999).

It is anticipated that similar multi-scalar procedures will be developed for wetland assessment and monitoring. These procedures will likely build on the multi-scalar information collected under the inventory process and provide managers and others with analyses suitable for the scale of investigation. A concept for a multi-scalar, interrelated wetland inventory, assessment and monitoring scheme is provided in Figure 4. The concept is an extension of those provided in Figures 1 and 3, acknowledging that assessment and monitoring also require information gathered at different scales.

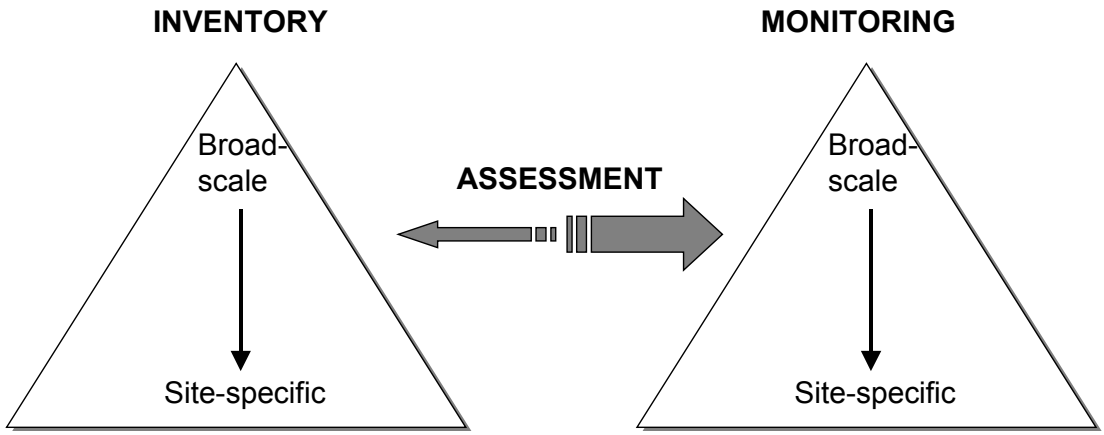

Figure 4. Concept of a multi-scalar, interrelated wetland inventory, assessment and monitoring system

Assessment and monitoring at broad scales may be required to:

1. evaluate larger, landscape level features or effects, and/or
2. provide assessments over catchment, regional or larger scales.

Landscape-level effects may result as a consequence of wetland loss due to fragmentation of the landscape, climate change, fire, or widespread invasion by weeds and feral animals. Thiesing (2001) criticised the lack of assessment methods available at the landscape level for wetlands in the USA, noting that wetlands interact with one another, provide refugia for wetland animals within the landscape and seed banks for wetland vegetation. They also serve as sources for species dispersal and migration to other wetlands within the landscape, providing habitat for migratory species such as waterbirds or fish, as well as maintenance and support of biodiversity. Indeed, for biodiversity and conservation assessments at the site-specific level, landscape-level studies are essential to provide contextual information (distribution and abundance).

Additionally, assessments over catchment, regional or larger scales are an essential management requirement. For example, in Australia and New Zealand they are applied in national water quality assessment programmes for:

- rapid, cost-effective and adequate first-pass determination of the extent of a problem or potential problem (eg as applied to broad-scale land-use issues, diffuse-source effluent discharges or information for State of Environment Reporting or audits);
- screening of sites to identify locations needing more detailed investigation; and/or
- remediation programmes being conducted over broad geographical areas (catchment, regional or larger scales) (see ANZECC & ARMCANZ 2000).

Assessment and monitoring of course, will also be required at specific sites where, in general, stronger inference and greater sensitivity to disturbance become more important requirements. Humphrey et al (2002) discuss these applications further, providing attributes and examples of monitoring techniques used for broad-scale and site-specific assessments.

Detailed monitoring at broad scales is usually not possible because of excessive costs and so monitoring at this scale must be cost-effective and sufficiently rapid to generate adequate first-pass data over large areas. The data may be adequate for management purposes or they may help managers to decide what type of further information may be required and from where (ANZECC & ARMCANZ 2000). Typically, rapid assessment methods are applied at broad scales, including rapid biological assessment and remote sensing. For specific sites, however, more detailed, quantitative monitoring may be required, utilising designs that provide stronger inference about a putative impact (Humphrey et al 2002). Parker (2001) describes a number of study designs for monitoring wetlands, each applicable to a particular spatial scale of a study.

REFERENCES

ANZECC & ARMCANZ 2000. *Australian and New Zealand guidelines for fresh and marine water quality*. National Water Quality Management Strategy Paper No 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Begg GW, van Dam RA, Lowry JB, Finlayson CM & Walden DJ 2001. *Inventory and risk assessment of water dependent ecosystems in the Daly basin, Northern Territory, Australia*. Supervising Scientist Report 162, Supervising Scientist, Darwin NT.

Costa LT, Farinha JC, Tomas Vives P & Hecker N 1996. *Mediterranean wetland inventory: A reference manual. MedWet Publication*. Instituto da Conservacao da Naturez, Lisboa, and Wetlands International, Slimbridge, UK.

Costa LT, Farinha JC, Tomas Vives P, Hecker N & Silva EP 2001. *Regional wetland inventory approaches – the Mediterranean example*. In Wetland inventory, assessment and monitoring - Practical techniques and identification of major issues: Introduction and review of past recommendations, eds CM Finlayson, NC Davidson & NJ Stevenson (eds), Supervising Scientist Report 161, Supervising Scientist Division, Environment Australia, Darwin, Australia. pp 31-39.

Davidson NC 1999. Wetlands and biodiversity. Creation of global assessment tools for conservation, status, needs and priorities. BCIS/NORAD. Wetland pilot project. Phase I progress report, February 1999, unpublished report, Wetlands International, Wageningen, The Netherlands.

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

Finlayson CM 1996a. Information required for wetland management in the South Pacific. In *Wetland conservation in the Pacific islands region*, Proceedings of the regional workshop on wetland protection and sustainable use in Oceania, R Jaensch (ed). Port Moresby, Papua New Guinea, June 1994, Wetlands International-Asia/Pacific, Canberra, 185–201.

Finlayson CM 1996b. The Montreux Record: A mechanism for supporting the wise use of wetlands. In *Proceedings of the Sixth Meeting of the Conference of the Contracting Parties of the Convention on Wetlands, Technical Sessions: Reports and presentations*, Ramsar Convention Bureau, Gland, Switzerland, 32–37.

Finlayson CM 1996c. Framework for designing a monitoring programme. In *Monitoring Mediterranean wetlands: A methodological guide*, ed P Tomas Vives, MedWet publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal, 25–34.

Finlayson CM 1999. Protocols for an Australian national wetland inventory. In CM Finlayson & AG Spiers (eds), Techniques for Enhanced Wetland Inventory, Assessment and Monitoring. Supervising Scientist Report 147, Supervising Scientist Group, Canberra. 119-145.

Finlayson CM & Davidson NC 1999. Summary report. In *Global review of wetland resources and priorities for wetland inventory*, eds CM Finlayson & AG Spiers, Supervising Scientist Report 144, Supervising Scientist Group, Environment Australia, Canberra, 1–13.

Finlayson CM & NC Davidson 2001. Wetland inventory, assessment and monitoring–Practical techniques and identification of major issues: Introduction and review of past recommendations. In CM Finlayson, NC Davidson & Stevenson NJ (eds) 2001a. *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. pp 1-10.

Finlayson CM & Spiers AG (eds) 1999. *Global review of wetland resources and priorities for wetland inventory*. Supervising Scientist Report 144, Supervising Scientist Group, Environment Australia, Canberra.

Finlayson CM & van der Valk AG 1995. *Classification and inventory of the world's wetlands*. Advances in Vegetation Science 16, Kluwer Academic Press, Dordrecht, The Netherlands.

Finlayson CM, Hollis T & Davis T (eds) 1992. *Managing Mediterranean wetlands and their birds*. Proceedings of an IWRB International Symposium, Grado, Italy, February 1991. IWRB Special Publication No. 20, Slimbridge, UK.

Finlayson CM, Davidson NC & Stevenson NJ (eds) 2001a. *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.

Finlayson CM, Davidson NC & Stevenson NJ 2001b. Wetland inventory, assessment and monitoring – Practical techniques and identification of major issues: Summary. In CM Finlayson, NC Davidson & NJ Stevenson (eds) 2001a. *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.

Finlayson CM, Davidson NC, Spiers AG & Stevenson NJ 1999. Global wetland inventory – Status and priorities. *Marine and Freshwater Research* 50, 717–727.

Finlayson M, van Dam R, Walden D & Storrs M 2001c. Risk assessment for managing the tropical weed *Mimosa pigra*. In: Assessment and Management of Alien Species that Threaten Ecosystems, Habitats and Species. Abstracts of keynote addresses and posters presented at the sixth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, Montreal, Canada, 12-16 March 2001. CBD Technical Series No. 1. Secretariat of the Convention on Biological Diversity, Montreal, Canada. pp. 17-19.

Finlayson CM, Howes J, Begg G & Tagi K 2002a. A strategic approach for characterising wetlands – the Asian wetland inventory. Proceedings of Asian Wetland Symposium, Penang, Malaysia, 27-30 August, 2001. (in press).

Finlayson CM, Howes J, van Dam R, Begg G & Tagi K 2002b. The Asian Wetland Inventory as a tool for providing information on the effect of climate change on wetlands in Asia. Workshop on climate change and wetlands, Kushiro, Japan, 20-21 September 2001. In press.

Finlayson CM, Howes J, Begg GW, Tagi K & Lowry J 2002c. A manual for an inventory of Asian wetlands. Asian Wetland Inventory regional workshop, Phnom Penh, Cambodia, 8-9 April 2002. In draft.

Grillas P 1996. Identification of indicators. In *Monitoring Mediterranean wetlands: A methodological guide*, ed P Tomas Vives, MedWet publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal, 35–59.

Humphrey CL, Bayliss P & Finlayson CM 2002. Possible approach towards developing a wetland inventory, assessment and monitoring scheme in Australia: A case study from the wet-dry tropics. *In: Murugadas TL (Compl) 2002. Proceedings of workshop on developing a proposed framework for a wetland inventory, assessment and monitoring system (WIAMS) in Malaysia (eds. Sundari R, Davies J and Humphrey C)*, Kuala Lumpur, Malaysia, 18-19 April, 2002, Wetlands International – Malaysia Programme (in press)

Matthews GVT (ed) 1990. *Managing waterfowl populations*. Proceedings of an IWRB Symposium, Astrakahn, USSR, 2–5 October 1989. IWRB Special Publication No. 12, Slimbridge, UK.

Mitsch WJ (ed) 1994. *Global wetlands – Old world and new*. Elsevier, Amsterdam.

Moser M, Prentice RC & van Vessem J (eds) 1993. *Waterfowl and wetland conservation in the 1990s – A global perspective*. Proceedings of an IWRB Symposium, St Petersburg Beach, Florida, USA, 12-19 November 1992. IWRB Special Publication No. 26, Slimbridge, UK.

Nivet C & Frazier S 2001. *A review of European wetland inventory information*. Preliminary (incomplete) report prepared in the framework of 'A Pilot Study towards a Pan-European Wetland Inventory', a cooperative project between Wetlands International – Africa, Europe, Middle East and the Dutch Institute for Inland Water Management and Waste Water Treatment (RIZA).

Parker AK 2001. *Methods for evaluating wetland condition: Study design for monitoring wetlands*. EPA 822-R-01-007d. US Environmental Protection Agency, Office of Water, Washington, DC.

Phinn S, Hess L & Finlayson CM 1999. An assessment of the usefulness of remote sensing for wetland monitoring and inventory in Australia. In *Techniques for enhanced wetland inventory, assessment and monitoring*, eds CM Finlayson & AG Spiers, Supervising Scientist Report 147, Supervising Scientist Group, Canberra, 44–82.

Prentice RC & Jaensch RP (eds) 1997. *Development polices, plans and wetlands*. Proceedings of Workshop 1 of the International Conference on Wetlands and Development, Kuala Lumpur, Malaysia, 9–13 October 1995, Wetlands International, Kuala Lumpur.

Reid WV 2000. Ecosystem data to drive hard choices. Issues in Science and Technology XVI, 37-44.

Thiesing MA 2001. An evaluation of wetland assessment techniques and their applications to decision making. In CM Finlayson, NC Davidson & NJ Stevenson (eds) 2001a. *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, 87-96.

Tomas Vives P (ed) 1996. *Monitoring Mediterranean wetlands: A methodological guide*, MedWet publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal.

Tomas Vives P & Grillas P 1996. Techniques for monitoring. In *Monitoring Mediterranean wetlands: A methodological guide*, ed P Tomas Vives, MedWet publication, Wetlands International, Slimbridge, UK and ICN, Lisbon, Portugal, 61–72.

Van Dam RA, Finlayson CM & Humphrey CL 1999. Wetland risk assessment: A framework and methods for predicting and assessing change in ecological character. In *Techniques for enhanced wetland inventory, assessment and monitoring*, eds CM Finlayson & AG Spiers, Supervising Scientist Report 147, Supervising Scientist Group, Environment Australia, pp 83–118.

Van Dam R, Walden D, Begg G & Finlayson M 2001. Ecological risk assessment of the cane toad, *Bufo marinus*, in Kakadu National park, Australia. In *Assessment and Management of Alien Species that Threaten Ecosystems, Habitats and Species*. Abstracts of keynote addresses and posters presented at the sixth meeting of the Subsidiary Body

on Scientific, Technical and Technological Advice, Montreal, Canada, 12-16 March 2001. CBD Technical Series No. 1. Secretariat of the Convention on Biological Diversity, Montreal, Canada. pp. 21-23.