WETLAND ECOLOGY AND CONSERVATION

Ecology and Inventory

An analysis of wetland inventory and information sources[1]

CM Finlayson, NC Davidson[2,3], AG Spiers & NJ Stevenson[2,4]

1 Introduction

Over the past few decades many wetland scientists and managers have called for the collection of further information for wetland conservation and management. Knowledge of the location, distribution and character of wetlands, their values and uses, is required at a variety of geographical scales, ranging from local to national and international (Dugan 1990, Finlayson 1996a). Despite the compilation of such information many basic features of wetlands around the world have apparently not been recorded (Finlayson & van der Valk 1995).

Furthermore, the scattered nature of the information that is available has prevented effective assessment of the size and distribution of the global wetland resource (Finlayson & van der Valk 1995). Recognition of this situation by the Ramsar Convention on Wetlands led to the 'Global review of wetlands resources and priorities for wetland inventory' (GRoWI), a review of the state of wetland inventory and the extent to which it can yield information on the size, distribution and status of the global wetland resource (Finlayson & Spiers 1999, Finlayson et al 1999). The review was linked with analyses undertaken in two international workshops. One addressed practical issues for wetland inventory, assessment and monitoring (Finlayson et al 2001a); the other examined information management systems for assessing the conservation and status of wetlands (Davidson 1999). A summary of the review and these analyses is given below.

2 Definitions and concepts of wetland inventory

The global review of wetland inventory used an array of source material since an inventory was considered to be simply a collation of material on wetlands, specifically their location and size, possibly augmented with further information on their biophysical features and management. This broad interpretation of inventory was adopted after considering the report by Finlayson (1996a) who, after differentiating between a wetland inventory and a wetland directory noted that, in reality the terms were often used loosely and interchangeably.

However, due to inconsistency in usage it was necessary to differentiate between inventory, assessment and monitoring of wetlands. The definitions proposed by Finlayson et al (2001b) were adopted.

---

1 More detailed discussion of this research is provided in Finlayson CM & Spiers AG (eds) 1999. *Global review of wetland resources and priorities for wetland inventory*. Supervising Scientist Report 144, Supervising Scientist, Canberra. & in Finlayson CM, Davidson NC, Spiers AG & Stevenson NJ 1999. Global wetland inventory — status and priorities. *Marine and Freshwater Research* 50, 717–727.

2 Wetlands International, Wageningen, The Netherlands.

3 Present address: Ramsar Convention Bureau, Gland, Switzerland.

4 Present address: Ecoscope, Cambridge, United Kingdom.

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 — the collection of specific information for management purposes in response to hypotheses derived from assessment activities. (This definition is taken from that developed for the Ramsar Convention and Mediterranean wetland program; Finlayson 1996b,c.)

Thus, inventory, assessment and monitoring are separate processes, although inexorably linked. This position was also accepted by Costa et al (1996) when developing a protocol for wetland inventory in the Mediterranean. Finlayson et al (1999) and Costa et al (1996) also accepted that whilst inventory provided a basis for monitoring it was not itself a monitoring tool.

3 Information sources, collation and analysis

The information reviewed here is derived chiefly from the international projects noted above and complemented by information contained in draft protocols for an Australian national wetland inventory (Finlayson 1999), so providing a synthesis of the most up-to-date analyses available of inventory information for the world's wetlands. The most comprehensive of the international projects was the global review of wetland resources undertaken on behalf of the Ramsar Convention on Wetlands (Finlayson & Spiers 1999). This comprised separate reports for each of the Ramsar Convention's then seven geo-political regions (with a Middle East analysis reported separately from the remainder of the Asia region), a separate report on continental- and international-scale inventory, and a summary report covering results, conclusions and recommendations at the global scale.

The outcomes from the global review of wetland inventory were combined with information from the other projects to present an overview of the current status of wetland inventory around the globe. The overview was then used as a basis to outline and provide recommendations for standardised inventory methods, information management, and priority directions for improving further inventory.

4 Analysis of wetland inventory

Extent and coverage of wetland inventory

Of the 188 sources examined in detail only 18% were comprehensive wetland inventories; 74% were partial inventories, chiefly in two categories - either inventories of important wetlands only or inventories of particular wetland habitat types only; 9% were sources of information containing wetland inventory but covering a broader scope than solely wetlands, e.g. national soil surveys. Further, only 7% of the 206 countries and territories for which inventory information was sought have an adequate coverage of wetland inventory information (although several other countries do have major inventory programs underway or planned); 68% have only partial inventory coverage (important sites only and/or some habitat types only) and 25% of countries and territories have little or no inventory coverage.

The inadequacy of many inventories was also shown. Inventory methodology was not described in 18% of inventories. Only 30% of inventory sources defined the type of wetlands they included, and for over one-third (34%) no definition could even be inferred. Further, only 52% of sources provided a statement of the objectives of the inventory, and of these only half were undertaken specifically as baseline wetland inventory; and only 49% of sources provided area values per defined wetland type, although some others gave only overall wetland area (not divided by type). 35% proved to be compilations or reviews of existing material (undertaking no new data collection). There was variation in the extent to which inventories also provided information that is categorised as 'assessment' under the above definitions: half (49%) provided wetland status information; but only 21% contained wetland loss or degradation information; and only 8% consistent information on wetland values and benefits.

Extent and distribution of wetlands

Previous attempts to estimate the global extent and distribution of wetlands have been made through a variety of approaches. Such estimates vary considerably (5.6–9.7 million km^2 , Spiers 1999) and appear highly dependent on the type of source material and the definition of wetland used. The broad Ramsar Convention definition of a wetland has been used in many national wetland inventories (41%). There are also many inventories that have been restricted to more specific habitats, or exclude marine wetlands. However, in reviewing wetland inventory information this presented less of a problem than those that did not include a clear definition of the range of habitats being considered.

Spiers (1999) summarised global estimates for different wetland types (natural freshwater wetlands 5.7 million km^2; rice paddy 1.3 million km^2; mangroves 0.18 million km^2; and coral reefs 0.3–0.6 million km^2) and derived an estimate for these habitats only of 7.48–7.78 million km^2. As this estimate does not include a number of widespread and extensive wetland types, notably saltmarshes and coastal flats, seagrass meadows, karsts and caves, and reservoirs, it implies a considerably larger global area than previous estimates. Combining the estimates from the analyses of the individual Ramsar regions also gives a much larger minimum area than previous estimates, ~12.76 million km^2, for global wetlands (table 1). Since, as we have described above, these estimates are derived from extremely patchy inventory information, this implies that the global wetland area is considerably larger. However, given the patchiness of inventory these estimates must be treated as preliminary minimum estimates and indicative only.

Table 1 Regional minimum estimates of wetland area (from Finlayson et al 1999)

Region	Area (million km^2)
Africa	1.21
Asia	2.04
Eastern Europe	2.29
Western Europe	0.29
Neotropics	4.15
North America	2.42
Oceania	0.36

It is not possible to make an objective assessment of the various estimates given because many inventories merely repeat previously gathered information and/or do not clearly describe the accuracy and reliability of the data (Finlayson et al 1999). For example, few inventories have been regularly updated.

5 Standardisation of inventory approaches

The above analyses illustrate the inadequate standardisation of inventory techniques, including the means of recording and reporting the basic information that is necessary for determining, with confidence, the status of wetlands worldwide (Finlayson et al 1999). Many inventories lack basic information, notably the objective or purpose of the inventory, the wetland definition and classification system, the method(s) of data collection, source data for statistics of wetland area and wetland loss, name and affiliation of the compiler for individual site data, etc.

The development of a standardised and flexible framework for wetland inventory will help individual countries to prepare national wetland inventories in a format compatible not only with their objectives but also with the inventory of neighbouring countries. This would greatly improve the capacity for comprehensive wetland inventory on a national and ultimately global scale. Standardised approaches could be derived from existing models, notably those used in the Mediterranean (Costa et al 1996) and the United States (Wilen & Bates 1995). These approaches have been successfully adapted for use in other countries and could provide a basis for a standardised framework and wetland inventory database (Finlayson et al 2001b).

Finlayson et al (1999) also recommended the development of a hierarchical protocol to assist countries in undertaking their inventories cost-effectively through the use of a basic data set to describe the wetland. This should include the location and area and the basic features of the wetland that provide values and benefits to humans. This could include general indicators or descriptors of the water regime, water quality and biota. Adoption of standardised wetland classification systems would greatly assist in comparisons between sites and regions and provide a basis for management decisions that may lead to the collection of more specific information on threats, values and benefits, land tenure and management, and monitoring. Thus, it was further recommended that sufficient information (core data fields) should be derived to enable the major wetland habitats (at least) to be delineated and characterised at least at one point in time (table 2). Additional data fields could be added if required for specific purposes, such as wetland assessment, as recommended in draft protocols for an Australian wetland inventory.

6 Information management

The need to more effectively manage wetland inventory data has been outlined by Finlayson et al (1999). Even the maintenance of a minimum core data set requires considerable care and thought, at least in terms of accessibility and storage and software compatibilities. Finlayson et al (1999) stress that when inventory information is recorded it should be accompanied by clear records that describe when and how the information was collected and its accuracy and reliability. Such records were absent from many of the inventories reviewed in Finlayson & Spiers (1999).

As a minimum, a meta-database should be established and accessible. Regardless of the fields adopted it is essential that the meta-database follows an established data protocol and is readily accessible. The need to immediately develop a standard, versatile meta-database is increasingly widely recognised.

Table 2 Core and recommended additional data fields for wetland inventory and assessment (from Finlayson 1999)

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

7 Priorities for future wetland inventory

Knowledge of the global wetland inventory resource is, on the whole, incomplete. All regions of the world - Africa, Asia, Oceania, Neotropics, North America, and Western and Eastern Europe - have information gaps and priority areas for wetland inventory. Some of these information gaps are urgent with the following being identified (Finlayson & Spiers 1999):

(1) Priority should be given to regions in which the wetlands are least known and considered the most threatened: areas where rapid population growth and development are combining with ineffective or non-existent wetland protection and sustainable-use legislation, to destroy and degrade wetlands at an alarming rate. The priority regions for further wetland inventory and wetland-loss studies are the Neotropics, Asia, Oceania, Africa and Eastern Europe.

(2) To make the task more manageable, priority should be given to encouraging countries that do not yet have a national wetland inventory to commit resources to complete one.

(3) Attention must also be given to the inventory of priority wetland habitats, targeting those for which there is little or no information, and those at greatest risk of degradation and destruction. Priority wetland habitats are as follows.

*Seagrasse*s. In southern Asia, the South Pacific, South America and some parts of Africa, seagrasses are under increasing threat.

Coralreefs. These are an important biodiversity resource that is under continuing threat.

*Salt marshes and coastal flat*s. These have generally not been included in wetland inventories, with few areal estimates and no true global picture being available. They are under increasing threat worldwide, particularly in Africa, Asia and Oceania.

*Mangrove*s. Mangroves are better mapped than other coastal and marine wetlands, but serious inconsistencies exist and more comprehensive inventory is required. This should be used to better determine the mangrove loss that is proceeding at an alarming rate in many parts of Africa, south-east Asia and Oceania.

*Arid-zone wetland*s. These are poorly mapped but increasingly important in the light of escalating population pressures and water demand.

*Peatland*s. These are well mapped in comparison with other wetland habitats. However, they are threatened further in Europe, Asia and North America in particular, despite their importance as a global carbon sink and economic resource, and are poorly known in tropical regions.

*Rivers and stream*s. Rivers and streams are seriously threatened in many regions of the world.

Artificial wetlands. These are increasingly important, with reservoirs, dams, salinas, paddy, and aquaculture ponds being important in many regions, notably Asia, Africa and the Neotropics.

(4) Steps should be taken to develop communciation between wetland users at all levels, from local to global, to ensure that the large amount of work required to establish, update or extend wetland inventory occurs. This is likely to require national action and a genuine will to identify key processes for targeted improvement.

(5) Co-operation between countries and agencies, with the common aim of improving wetland inventory for all wetland habitats, particularly those most threatened, should be enhanced.

(6) When undertaking further wetland inventory every effort should be made to link this with other national and international initiatives, such as the identification and delineation of further sites of international importance.

8 Recommendations

Eight priorities for action were recommended to the Ramsar Convention and accepted by its Contracting Parties in May 1999 (Ramsar Resolution VII.20).

(1) All countries lacking a national wetland inventory should undertake one, using an approach that is comparable with other wetland inventories and for which the Ramsar Convention should provide guidance.

(2) Quantitative studies of wetland loss and degradation are urgently required for much of Asia, Africa, South America, the Pacific Islands and Australia.

(3) Further inventory should focus on a basic data set describing the location and size of each wetland and its major biophysical features, including variations in area and the water regime.

(4) After acquisition of the basic data, further information should be collected with an emphasis on the management of threats to wetlands and uses of wetlands, land tenure and management regimes, and values and benefits of wetlands. Source(s) of information should be clearly recorded along with comments on its accuracy and availability.

(5) Each inventory should include a clear statement of its purpose and the range of information that has been collated or collected, the habitats covered and the date the information was obtained or updated.

(6) The Ramsar Convention should support the development and dissemination of models for improved globally applicable wetland inventory. These should be derived from existing

models and incorporate habitat classifications, and information collation and storage protocols.

(7) The Ramsar Convention should support development of a central repository for both hardcopy and electronic inventories. The meta-data that describe the inventories should be published on the World Wide Web for greater accessibility.

(8) Further support is required for completion of the global review of wetland resources and priorities for wetland inventory; and to develop procedures for regular updating and publishing of inventory information on the World Wide Web.

9 Further developments

The analyses reported here has led to the development of a 'Framework for wetlands inventory' for the Ramsar Convention, which will be considered for adoption at Ramsar's 8th meeting of the Conference of the Parties (COP8) in November 2002. The Framework provides a 13-step procedure for designing a wetland inventory, stressing that the precise nature of inventory chosen will depend on its purpose and objectives, geographical scale, and available resources. So as to assist in such choices, the Framework provides information on existing proven inventory methods, options for wetland classifications, a core recommended dataset, and an approach to identifying appropriate use of remote sensing datasets.

Acknowledgments

A large part of this work was undertaken by a team drawn from Wetlands International and the Environmental Research Institute of the Supervising Scientist *(eris*s), Australia, under contract to the Bureau of the Ramsar Convention on Wetlands, and with financial support from the United Kingdom and Netherlands Governments.

References

Costa LT, Farinha JC, Hecker N & Tomas Vives P (eds) 1996. *Mediterranean wetland inventory: A reference manual*. MedWet, Institutoda Conservação da Natureza, Wetlands International Publication vol 1, Lisbon.

Davidson NC 1999. Wetlands and biodiversity. Creation of global assessment tools for conservation, status, needs and priorities. (BCIS/NORAD wetland pilot project) Phase 1 progress report, February, Wetland 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*, ed R Jaensch, Proceedings of the Regional Workshop on Wetland Protection and Sustainable Use in Oceania, Port Moresby, Papua New Guinea, 6–10 June 1994, Wetlands International-Asia Pacific Publication no 118, Canberra, 185–201.

Finlayson CM 1996b. The Montreux Record: A mechanism for supporting the wise use of wetlands. In *Proceedings of the 6th Meeting of the Conference of the Contracting Parties*, Technical Sessions: Reports and Presentations, Technical Sessions B & D, Ramsar Convention Bureau, Gland, Switzerland, 32–8.

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

Finlayson CM 1999. Protocols for an Australian national wetland inventory. In *Techniques for enhanced wetland inventory and monitoring*, eds Finlayson CM & Spiers AG, Supervising Scientist Report 147, Supervising Scientist, Canberra, 119–145.

Finlayson CM & Spiers AG (eds) 1999. *Global review of wetland resources and priorities for wetland inventory*. Supervising Scientist Report 144, Supervising Scientist, Canberra. (also available on CD)

Finlayson CM & van der Valk AG 1995. Wetland classification and inventory: A summary. In *Classification and inventory of the worlds wetlands*, eds CM Finlayson & AG van der Valk, Advances in Vegetation Science 16, Kluwer Academic Press, Dordrecht, Netherlands, 185–92.

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

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

Finlayson CM, Davidson NC & Stevenson NJ 2001b. Wetland inventory, assessment and monitoring — practical techniques and identification of major issues: Summary. In *Wetland inventory, assessment and monitoring: Practical techniques and identification of major issues*, eds Finlayson CM, Davidson NC & Stevenson NJ, Proceedings of Workshop 4, 2nd International Conference on Wetlands and Development, Dakar, Senegal, 8–14 November 1998, Supervising Scientist Report 161, Supervising Scientist, Darwin, 130–136.

Spiers AG 1999. Review of international/continental wetland resources. In *Global review of wetland resources and priorities for wetland inventory*, eds Finlayson CM & Spiers AG, Supervising Scientist Report 144, Supervising Scientist, Canberra, 63–104. (also available on CD)

Wilen BO & Bates MK 1995. The US Fish and Wildlife Service's national wetland inventory project. 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, Netherlands, 153–69.

Climate change and sea level rise in the Alligator Rivers Region, northern Australia[1]

CM Finlayson, I Eliot[2] & P Waterman[3]

Introduction

In 1995 the Intergovernmental Panel on Climate Change (IPCC) released its Second Assessment Report on the impacts, adaptations and mitigation of climate change with confirmed and dire projections about future scenario (IPCC 1995). (The Third Assessment Report was released in 2001 and confirmed such projections (IPCC 2001)). These reports noted the level of uncertainty with the scientific projections and the possible outcomes for both ecological and social systems. The assessments covered vulnerability to climate change of aquatic ecosystems and to water supply as a specific and important issue.

Coastal wetlands are expected to be highly vulnerable and susceptible to changes in the climate and sea level (IPCC 1995). Changes in temperature and rainfall, sea level rise, and storm surges could result in the erosion of shores and associated habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport and increased coastal flooding. Some coastal ecosystems are at particular risk, including saltwater marshes, mangroves and river deltas as well as non-tidal wetlands (IPCC 1995). The extent of this change will be influenced by the sensitivity, adaptability and vulnerability of the individual ecosystems and locations.

With this background we examined in 1996 the vulnerability of the large and valued freshwater ecosystems of the Alligator Rivers Region which includes Kakadu National Park, northern Australia, to determine if they were at risk from climate change and sea level rise (Bayliss et al 1998, Eliot et al 1999).

Climate change scenario

The major source of information for the prediction of climate change for this assessment was provided by Wasson (1992) and CSIRO (1994). Their projections are summarised in table 1. Scenarios for sea level rise were based on analyses adopted by the CSIRO (1994). Global projections of sea level rise range from 25–80 cm by the year 2100, with the most likely estimate being a rise of 50 cm. By the year 2030 sea level is expected to have risen an estimated 8–30 cm. The estimates require adjustment to allow for regional and site specific conditions to determine the relative sea level change at that place. Specific estimates are not currently available for Kakadu National Park or the wider Alligator Rivers Region.

---

1 This paper is drawn from work published in SSR123: Bayliss B, Brennan K, Eliot I, Finlayson CM, Hall R, House T, Pidgeon R, Walden D & Waterman P 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia.* Supervising Scientist Report 123, Supervising Scientist, Canberra. Sections of it also appear in Eliot I, Waterman P & Finlayson CM 1999. Monitoring and assessment of coastal change in Australia's wet-dry tropics. *Wetlands Ecology and Management* 7, 63–81.

2 Department of Geography, The University of Western Australia, Perth, Western Australia, Australia (iane@sunny.gis.uwa.edu.au)

3 Environmental Management Services, Canberra, Australia (waterman@orac.net.au)

Table 1 CSIRO (1994) projections of climate change scenario for 2030 (adapted from Eliot et al 1999)

VARIABLE	PREDICTION
Temperature	Relative to 1990, northern coastal areas will be 1–2°C warmer.
Rainfall	Relative to 1990 rainfall in the NE summer rainfall region is expected to increase by 0–20% with a more intense monsoon.
Extreme events	Extreme events are expected to change in magnitude and frequency more rapidly than the averages – more hot days, floods and dry spells.
Clouds	Preliminary indication of an increase of 0–10% in total cloud cover in tropical areas.
Tropical cyclones	Cyclones could travel further south and their preferred paths may alter but effects on intensity are uncertain. ENSO could affect both the location and frequency.
Winds	Stronger monsoon westerlies are expected in northern Australia and stronger winds will accompany severe weather.
Evaporation	Anticipated 5–15% increase in potential evaporation by 2030.
Sea level	Best estimate for Australia for 2030 AD is about 20 $\pm$ 10 cm above 1990 levels with local variations in magnitude and frequency of extreme events, such as storm surges, waves and estuarine flooding.

Vulnerability assessment

The vulnerability assessment of the wetlands in the Alligator Rivers Region involved six steps in line with the procedure outlined by Kay and Waterman (1993). These were:

- Scoping the issues relating to climate and other changes in the region
- Identification of the natural, cultural, social and economic resources of the region
- Description of the biophysical change processes
- Assessment of the significance of predicted changes
- Determination of the range of responses to predicted changes
- Determination of the actions to be implemented by governmental and community agents

These analyses were aided by the existence of a substantial body of information that had been collected primarily for other environmental assessment purposes (see Bayliss et al 1998).

Resources potentially affected

Natural, cultural, social and economic resources across the Alligator Rivers Region could be affected by climatic and other changes. Specifically, sea level rise, shoreline erosion and saltwater intrusion could degrade both the salt and freshwater wetland resources. This would be manifest in:

- reduction or loss of some components of the mangrove fringe on the coast line;
- extensive loss of *Melaleuca* (paperbark trees) stands on the margins of some wetlands;
- colonisation of mangrove species along creek lines as an accompaniment to salt water intrusion; and
- replacement of freshwater wetlands with saline mudflats.

With changes in the wetland plant communities and habitats there would also be changes in animal populations, particularly noticeable would be changes to the community composition and distribution of bird species found in the freshwater wetlands. Additionally, there would be changes in morphology of the streams and billabongs and in the composition of the fish and other aquatic species. However, detailed analyses of habitat-species interactions have not been done. Changes in the natural vegetation and faunal resources may have cultural, social and economic consequences for the Aboriginal and non-Aboriginal people living in or visiting the area. The cultural resources have both social and economic resource values as they relate to the plants and animals used by the local Aboriginal people.

The cultural, social and economic resources that could be affected by accelerated change should be viewed as indicative of the breadth of factors to be considered, rather than exhaustive. Nonetheless, it serves to indicate the extent of possible changes to the resources of the park and the wider region.

Significance of potential change

There is a very substantial body of information describing geologic and especially, recent historic changes to the coast and wetlands of the region (see summary in Bayliss et al 1998). Oceanographic processes in the nearby marine ecosystems contribute to many of the changes and are manifested by high rates of shoreline erosion, changing tidal regimes within the river systems and contribution to saltwater intrusion into freshwater ecosystems. Changes resulting from these processes are seen in reduction of the fringing mangroves along the shoreline, expansion of the samphire and saltflat areas, colonisation of mangroves along estuarine levee banks, and the headward erosion of tidal creeks. However, the significance of such change has not been fully assessed.

Ecologic processes affected by environmental change include the expansion and contraction of plant communities with consequent effects on animal habitats. Again, insufficient knowledge of the interaction between wetland plant communities and changes in hydrological and depositional conditions makes prediction of the significance of long-term effects difficult. Wetland plant communities are viewed as being widespread in the region and highly dynamic in terms of variability in species composition, structure of the community and geographic spatial extent. The plant species are widespread at pan-regional and regional scales and no communities or individual species of rare or endangered species have been recorded. Similarly, animal species are widespread and no rare and endangered species are known from areas that could be affected by environmental change.

Pastoralists farming lands adjacent to the region have registered concerns over increasing encroachment of saline waters into freshwater wetlands that are used for seasonal pastures (Woodroffe & Mulrennan 1993). The potential loss of existing economic activities has been judged as significant given the attention directed towards remedial measures (Applegate 1999).

Management of a changing environment

Six broad environmental management issues were identified through the issue scoping process used for the vulnerability assessment. Many of the issues are common to the coastal margins of the Australian wet-dry tropics in general and underlie the possible management responses required to address the expected extent of ecological change in the wetlands. These issues and their implications are described below.

1 Perceptions and values

There has been no systematic examination of perceptions and values with respect to management of the region. However, societal perceptions and values manifest in the level of awareness of the possible effects of climatic and associated changes, as well as in attitudes held with regard to the hazards and threats to the environment resulting from climate change. Raising awareness of the implications of climate change is an important first step in changing governmental and community perceptions of the implications of climate change.

2 Hazard and risk

Natural hazards of the region include extreme weather events — tropical cyclones, monsoonal depressions, heavy rainfall, extended Wet seasons, excessively high temperatures and prolonged droughts; flooding, channel avulsion and bank erosion; inundation of coastal plains by storm surge; and coastal erosion, shoreline retreat, chenier migration and saltwater intrusion. Questions of responsibility and accountability may need to be addressed when changes due to particular hazards disrupt orderly use of coastal resources for habitation, industry and commerce, recreation and conservation.

3 Governance

Governance in the region and neighbouring catchments is currently not geared to deal with environmental change of the type and magnitude that is currently occurring. Issues are dealt with on a sectoral basis rather than in an integrated, intergovernmental and cross-sectoral manner (Finlayson et al 1998). However, environmental change is manifested across the biophysical region irrespective of jurisdictional boundaries. Governmental structures and community-based management mechanisms need to provide a consistent and appropriate response for system management, rather than simply addressing problems at a sectoral level.

4 Strategic management

Strategic management has two interrelated components, regional development and resource conservation. Regional development has strong economic connotations and raises questions about the best use of wetland areas. For example, the areas to the west of the Park are considered as important areas for seasonal pastures and measures have been proposed to prevent saltwater intrusion (Applegate 1999). In contrast, representatives from the fishing industry consider that the wetlands need to be retained as natural systems that support recruitment of commercial fish species. There is clearly a need for the broad community to resolve such conflict within the context of a regional development strategy that encompasses adequate conservation of resources.

5 Acquisition and custodianship of information

The acquisition and custodianship of information has been recognised as a key issue within Kakadu National Park as it is likely to impinge on:

- the strategic management of the responses to climate and other environmental change;
- research and monitoring needed to document the processes of change; and
- evaluation of the effectiveness of any management measures taken.

Lack of appropriate data and information causes poor decision-making and contributes to inappropriate management of coastal resources. An investment must be made in data and information with the object of reducing uncertainty, improving decision making, enhancing management capability and ensuring that unnecessary funds are not spent on ill conceived and poorly researched projects. Bayliss et al (1998) provide a summary of the information collated during the vulnerability assessment, in particular that from the wetland habitats most likely to be affected by climate change. This led to Eliot et al (2000) collating further data on the coastal environment and placing this within a management context. Whilst a large amount of data and information is available it has not always been possible to readily access this or use it for further assessment. Issues of data management have also been addressed and reported (Finlayson & Bayliss 1997, Eliot et al 2000).

6 Environmental research and monitoring

Ongoing environmental research and monitoring is required in the region to provide data and information for:

- further understanding of the processes and extent of environmental change;
- development of management strategies and action plans;
- implementing management prescriptions;
- auditing the effectiveness of management actions; and
- assessing performance of the overall management processes.

Research and monitoring should be broad in scope and include examination of social issues. The latter would include measures to raise the general level of awareness of natural variation in the environment of the region. Natural systems research is needed to document the processes of change and their effects on the biophysical environment. Such research will require a high level of innovation in order to integrate the cultural implications of change.

Requirements for management

As with broader environmental management a number of general principles can be applied when dealing with sea level rise. These include:

- avoid development in areas that are vulnerable to inundation;
- ensure that critical natural systems continue to function naturally; and
- protect human lives, essential properties and economic activities.

Though principles are applicable in the broader context of environmental change, their interpretation requires more detailed consideration of local factors and processes affecting environmental well being.

Institutional arrangements that are already in place for the region and adjacent wetlands (Finlayson et al 1998) may need to be developed to meet the governmental and community requirements for integrated management of the coastal wetlands. Current arrangements tend to focus on the specific issues confronting individual agencies or departments within a specific sphere of government. The intra- and inter-governmental dimensions of the issues identified for the coastal wetlands require an innovative approach because of the scale of the problems, and because they cross-jurisdictional boundaries.

References

Applegate RJ 1999. Saltwater intrusion and the Mary River wetlands of the Northern Territory. In *An international perspective on wetland rehabilitation*, ed W Streever, Kluwer Academic Publishers, Dordrecht, The Netherlands, 113–119.

Bayliss B, Brennan K, Eliot I, Finlayson CM, Hall R, House T, Pidgeon R, Walden D & Waterman P 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia*. Supervising Scientist Report 123, Supervising Scientist, Canberra.

Eliot I, Waterman P & Finlayson CM 1999. Monitoring and assessment of coastal change in Australia's wet-dry tropics, *Wetlands Ecology and Management* 7, 63–81.

Eliot I, Saynor M, Eliot M & Finlayson CM 2000. *Assessment and monitoring of coastal change in the Alligator Rivers Region, northern Australia*. Supervising Scientist Report 157, Supervising Scientist, Darwin.

Finlayson CM & Bayliss B (eds) 1997. *Data management systems for environmental research in northern Australia: Proceedings of a workshop held in Jabiru, Northern Territory, 22 July 1995*. Supervising Scientist Report 124, Supervising Scientist, Canberra.

Finlayson CM, Thurtell L, Storrs MJ, Applegate R, Barrow P & Wellings P 1998. Local communities and wetland management in the Australian wet-dry tropics. In *Wetlands in a dry land: Understanding for management*, ed WD Williams, Biodiversity Group, Environment Australia, Canberra, 299–311.

IPCC 1995. *Climate change 1995: Impacts, adaptations and mitigation of climate change: Scientific-technical analyses*. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC 2001. *Climate change 2001: Impacts, adaptation, and vulnerability*. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Kay R & Waterman P 1993. Review of the applicability of the common methodology for assessment of the vulnerability to sea level rise to the Australian coastal zone. In *Proceedings of the IPCC Eastern Hemisphere Workshop on Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*, eds R McClean & N Mimura, Tsukaba, Japan, 237–248.

Suppiah R, Hennessy K, Hirst T, Jones R, Katzey J, Pittock B, Walsh K, Whetton P & Wilson S 1998. *Climate change under enhanced greenhouse conditions in northern Australia. Final Report 1994–1997*. CSIRO Division of Atmospheric Research, Aspendale, Australia.

Wasson RJ (ed) 1992. *Modern sedimentation and late quaternary evolution of the Magela Creek Plain*. Research report 6, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Woodroffe CD & Mulrennan ME 1993. *Geomorphology of the lower Mary River plains, Northern Territory*. Australian National University, North Australia Research Unit and the Conservation Commission of the Northern Territory, Darwin NT.

A review of wetland conservation issues in the Northern Territory[1]

MJ Storrs[2] & CM Finlayson

1 Introduction

The ecological character of wetlands of the Northern Territory (NT) has been described in a general sense and the major threats or management problems identified (Finlayson et al 1988, 1991, Finlayson & von Oertzen 1993). These reviews and reports on specific localities also identified major gaps in knowledge of basic ecological processes and threats to wetlands and, in the more isolated areas, even the character and extent of wetlands. Despite a general level of knowledge the information base is not uniform. Whilst reasonable data/information exists for some wetlands and/or threats to wetlands, a comprehensive inventory of all wetlands in the NT is not available.

A comprehensive review of wetland conservation and management issues for wetlands in the Northern Territory (Australia) was prepared by Storrs and Finlayson (1997) as a discussion paper for the development of a wetland conservation strategy. (A strategy was finalised and published by the Parks and Wildlife Commission of the Northern Territory (2000)). The conservation value of wetlands and the threats that they face were identified and described within a framework of sustainable utilisation of resources and maintenance of biological diversity. A summary of this paper is presented here.

2 Geographic setting

The NT lies between latitudes 11°S and 26°S an encompasses a large proportion of tropical Australia. The 1 347 x 10^6 km^2 area of the NT is divided into three broad landforms: i) the tropical northern zone that contains large rivers with wide coastal plains with permanent and seasonal wetlands; ii) the central semi-arid zone of uncoordinated drainage that contains seasonal and intermittent wetlands; and iii) the southern lowland zone of coordinated drainage that contains intermittent and episodic wetlands.

The NT comprises two broad climatic zones. In the north, the warm-hot wet season commences late in the year (Nov-Dec) and lasts for 3–4 months. The remainder of the year is cooler and mostly dry. South-easterly trade winds and a high pressure belt dominate the climate in the south. During the warm months (the temperate summer months) the south-east trade winds are interrupted by intrusions of moist air from tropical low-pressure troughs to the north. Most of the annual rainfall comes from violent convectional thunderstorms. Overnight frost can occur at sites in the south.

---

1 A more detailed discussion of this topic is found in Storrs MJ & Finlayson CM 1997. *Overview of the conservation status of wetlands of the Northern Territory*. Supervising Scientist Report 116, Supervising Scientist, Canberra.

2 Northern Land Council, PO Box 42921, Casuarina, NT 0811, Australia.

3 Current knowledge of wetland resources

For convenience of summarising the information on wetlands of the NT the geographic area has been divided into three broad administrative regions — northern, central and southern regions. Given difficulties with systems used to classify wetlands a simplistic and interim classification was adopted for this review (table 1). Storrs and Finlayson (1997) also provide maps that show the distribution of plants species generally associated with wetland habitats.

Table 1 A simplistic and interim classification system for wetlands of the Northern Territory. The general occurrence of wetland categories within the three broadly delineated regions of the NT is also shown.

Wetland categories		Region of the NT
1	Coastal salt marshes	Northern/Central region
2	Mangrove swamps	Northern/Central region
3	Freshwater lakes and swamps	Northern/Central/Southern region
4	Floodplains	Northern region
5	Freshwater ponds	Northern/Central/Southern region
6	Seasonal and intermittent saline lakes	Southern region

It was not possible, based on current inventory information, to accurately depict the extent of wetlands across the NT. Maps produced by Paijmans et al (1985) whilst not specifically delineating discrete wetlands were used to illustrate a number of key points about the distribution of wetlands in the NT that reflect the general landforms and climate:

- general low occurrence of permanent swamps and lakes;
- permanent and near permanent wetlands occur along the coast and in the northern area;
- episodic lakes and land subject to inundation are spread across the central and southern regions; and
- generally dry wetlands occur across most of the central and southern regions

Storrs and Finlayson (1997) list the many major datasets on wetland features held by NT government agencies and used this along with past reviews of northern Australian wetlands to describe the major known features of wetlands in the NT.

4 Conservation status of wetlands

Generic comments on the conservation status of wetlands in the NT and the pressures that they face are described below. It is stressed that further assessment, monitoring and even audit of the conservation status of the wetland habitats and ecosystems is still needed.

Invasive plants

Major weed species include *Acacia nilotica* (prickly acacia), *Cenchrus ciliaris* (buffel grass), *Eichhornia crassipes* (water hyacinth), *Salvinia molesta* (salvinia), *Parkinsonia aculeata* (parkinsonia), *Prosopsis limensis* (mesquite), *Tamarix aphylla* (athel pine), *Brachiaria mutica* (paragrass), *Echinochloa polystachya* (aleman grass), *Hymenachne amplexicaulis* (olive hymenachne) and *Mimosa pigra* (mimosa).

Paragrass and other pasture species such olive hymenachne, present a particularly difficult problem given that pastoralists desire them while conservation and fisheries authorities are concerned over their potential to alter the ecological character of wetlands. Paragrass is highly invasive and has spread across many wetlands in northern Australia, aided by deliberate plantings. The major weed species is undoubtedly mimosa which has spread across coastal floodplains in an arc extending from the Moyle River in the west to the Arafura Swamps in Arnhem Land (Harley 1992). It covers an estimated 80 000 ha. Research efforts have centred on finding suitable biological control agents with a number having been released. Integrated control programs are also in place and incorporate biological control along with the use of herbicides, mechanical removal (chaining), burning and revegetation.

Invasive animals

Major invasive animals include *Bubalus bubalis* (Asian water buffalo), *Sus scrofa* (pig), *Bufo marinus* (cane toad), *Equus caballus* (horse) and *Equus asinus* (donkey), *Camelus dromedarius* (camels), and *Oryctolagus cuniculus* (rabbit). Prior to the 1980s feral Asian water buffalo proliferated on the coastal floodplains of the NT and were considered responsible for widescale destruction of the native vegetation by direct grazing, trampling and wallowing, and indirectly by destroying levee banks and contributing to premature drainage of freshwaters (Finlayson et al 1988). However, throughout the 1980s the feral herds to the west of Arnhem Land were almost eradicated as part of a national program to prevent diseases being transferred to domestic stock. They still exist in large numbers in Arnhem Land.

Feral pigs are widespread and have caused widespread damage around the edges of wetlands. There is also evidence they have proliferated following the removal of the buffaloes from the floodplains (Corbett 1995). Control of pigs is widely regarded as difficult in certain types of terrain. Camels concentrate around salt lakes and clay pans in the southern region of the NT while horses and donkeys are prevalent in the southern and central regions. The extent of their impact on wetlands is unknown. The impact of grazing by rabbits severe in the southern region and tapers off northwards. Excessive grazing can devastate the vegetative margins of ephemeral lakes and pools. Of increasing concern are the cane toads that have moved westwards from Queensland into the NT. There is major concern and uncertainty about the effect they will have on native fauna.

Fire and burning regime

Fire is a conspicuous element of the landscape in the northern part of the NT and burning patterns have changed considerably in recent decades. Andersen (1996) questions the emphases of some fire management regimes and along with other authors points out that the ecological consequences of burning patterns are, on the whole, inadequately known. Roberts (1996) refers to the wealth of traditional Aboriginal knowledge on fire and burning regimes in relation to food availability. In some landscapes there is a deliberate policy that attempts, amongst other objectives, to re-establish some semblance of traditional Aboriginal burning (Ryan et al 1995, Roberts 1996). Vast areas of the central and southern regions of the NT are also burned on a regular basis, including many intermittently or episodically flooded wetlands.

Overgrazing

Soil erosion, due largely to poor land management including overgrazing has resulted in extensive degradation of waterholes, stream banks and the riparian vegetation (Winter 1990). Heavily grazed wetland communities tend to converge floristically and introduced pasture species are known to replace the native grasses (Liddle & Sterling 1992). In addition to changes in the vegetation changes in primary production also have an adverse effect on fisheries production in estuaries (Griffin 1996). Overall, however, little is known about changes due to grazing.

Tourism and recreational activities

The environmental impact of tourism and recreational activities on wetlands has not on the whole been specifically investigated. The notable exceptions are possibly the effect of boats in specific locations, the pressure of recreational fishing on barramundi (*Lates calcarifer*) stocks, and the hunting of geese by non-Aborigines. However, the pressure from such activities needs to also consider infrastructure and associated disturbance. Anticipated increased tourism and extension of recreational activities is expected to increase pressure on wetlands. Hunting of geese by non-Aborigines has recently undergone increased regulation and has been subjected to intensive research and monitoring.

Pollution and contaminants

Water pollution, in particular that associated with mining has received a large amount of attention. The former mining activities at Rum Jungle are the subject of extensive rehabilitation effort while the Ranger uranium mine is the subject of a strict testing and monitoring regime (Humphrey et al 2000). Pesticides and fertilisers are used extensively in agricultural projects and for weed control on coastal wetlands, but little information is available on their impact on wetlands. Pollution from sunscreens, soaps and insect repellents may become a problem in small permanent waterholes frequented by tourists, as could fuel spillage from boats. Lead poisoning of waterfowl from ingested shotgun pellets is a problem at hunting reserves in the northern region (Whitehead & Tschirner 1991). Salinity is possibly the major concern in the coastal freshwater wetlands (Jonauskas 1996). Bayliss et al (1997) consider that many of these wetlands are under threat from sea level rise in association with the Greenhouse Effect.

Water regime and physical modification

Water regulation and physical modification of wetlands in the NT occur, but not to the same extent as in eastern Australia. Small barrages and dams are being constructed, but at this stage these are not considered to be excessively detrimental, although at times these issues have been hotly debated (Julius 1996). The clearing of mangroves for port, industrial and/or residential purposes has also aroused controversy. The proposed development of irrigated agriculture has raised concerns over water logging, sedimentation and discharges of polluted water.

5 Current uses of wetlands

The NT Government has adopted a policy of multiple land use for wetland management and encourages different land uses in balance with conservation objectives. Current uses include: pastoralism, grazing and some horticulture, commercial fishing, tourism and recreation, especially amateur fishing, crocodile egg harvesting, commercial pig harvesting, safari style buffalo hunting, conservation and nature reservation, and traditional subsistence. Land uses are more intensive in the seasonally inundated and very productive wetlands near Darwin in the northern coastal region than in the wetlands of the semi-arid and arid areas.

Pastoralism has been by far the most extensive land use in the NT. The wetland areas are the most nutrient rich and mesic areas and thereby produce the best forage for livestock.

However, there has been much debate on the efficacy of pastoral activities in the arid zone of Australia with periodic calls for the removal of grazing from at least some areas. Tourism and recreation are increasingly important land uses based on natural and cultural values. The recreational fishing industry is well established in the coastal wetlands with barramundi being favoured species (Julius 1996, Griffin 1996). Commercial fishing also occurs with barramundi and mud crabs being targeted.

New commercial uses of wetlands are being developed, such as wildlife utilisation (eg goose and crocodile egg collection), expanded tourism (eg hunting or photographic safaris or cultural and wildlife tours) agriculture and horticulture. Many of these activities are being investigated on wetlands owned by Aboriginal people.

Major issues

Based on information collated in the review a number of generic strategic issues for successful management of wetlands in the NT have been identified (Table 2). These have been expressed within the context of the specific objectives of the Conservation Stategy for the NT (NT Government 1994).

Table 2 Strategic issues for wetland conservation in the NT

Conservation strategy objective	Strategic issues for wetland conservation
Understanding	Develop and maintain a comprehensive inventory database for all wetlands, including protocols to ensure it is updated at regular intervals
	Characterise and quantify the importance of the physical and ecological interactions and linkages that occur between wetlands
	Characterise the processes that maintain the ecological character and values and quantify the importance of ecological benefits of wetlands
Public awareness	Develop community awareness of the extent, values and benefits of wetlands.
Protection and management	Implement catchment-wide land use planning processes that encompass wetlands and ensure the maintenance of their ecological character and values and benefits
	Enhance the reservation and management of wetlands within a systematically developed protected areas network that is representative of the diversity of wetland habitats, species and values and benefits
	Instigate specific management arrangements for wetland conservation and sustainable utilisation regardless of land tenure
	Enhance the level of control over and planning of grazing activities, especially in the central and southern regions
Monitoring	Develop and implement monitoring programs that describes the ecological character of wetlands to provide early warning of any potential adverse change.
Restoring	Assess the extent of ecological degradation caused by specific pest species and develop appropriate control measures based on rigorous risk assessment.
	Undertake immediate control measures for effective management of salinisation and other effects associated with climate change, especially in the northern region.
	Undertake immediate control measures for effective management of grazing in all wetlands.
Reviewing	Develop and implement a regular and systematic reporting process on the state of wetlands.

In developing these strategies a large emphasis was placed on integrated land use and planning policies. It is doubtful that these could be effectively developed and implemented without the adoption of an integrated and multi-sectoral approach to wetland management.

References

Andersen AN 1996. Fire ecology and management. In *Landscape and vegetation ecology of the Kakadu region, Northern Australia*, eds CM Finlayson & I von Oertzen, Kluwer Academic Publishers, Dordrecht, Netherlands, 179–195.

Bayliss B, Brennan K, Eliot I, Finlayson CM, Hall R, House T, Pidgeon R, Walden D & Waterman P 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia*. Supervising Scientist Report 123, Supervising Scientist, Canberra.

Corbett LK 1995. Does dingo predation or buffalo competition regulate feral pig populations in the Australian wet-dry tropics? An experimental study. *Wildlife Research* 22(1), 65–74.

Finlayson CM, Bailey BJ, Freeland WJ & Fleming M 1988. Wetlands of the Northern Territory. In *The conservation of Australian wetlands*, eds AJ McComb & PS Lake Surrey Beatty and Sons, Sydney, 103–116.

Finlayson CM & von Oertzen I 1993. Wetlands of northern (tropical) Australia. In *Wetlands of the World 1: Inventory, ecology and management*, eds DF Whigham, D Dykjova & S Hejny, Kluwer Academic Publishers, Dordrecht, Netherlands, 195–243.

Finlayson CM, Wilson B & Cowie ID 1991. Management of freshwater monsoonal wetlands: Conservation threats and issues. In *Educating and management for wetland conservation*, eds R Donohue & B Phillips, ANPWS, Canberra, 109–117.

Griffin RK 1996. Barramundi and the Mary River wetlands. In *Making multiple landuse work: Proceedings of the Wetlands Workshop*, 6–7 December 1994, Darwin NT, ed P Jonauskas, Department of Lands, Planning & the Environment, Palmerston NT, 45–49.

Harley KLS 1992. *A guide to the management of* Mimosa pigra*.* CSIRO, Canberra.

Humphrey, C.L., Thurtell, L., Pidgeon, R.W.J., van Dam, R.A. and Finlayson, C.M. 1999. A model for assessing the health of Kakadu's streams. *Australian Biologist* 12, 33-42.

Jonauskas P (ed) 1996. *Making multiple landuse work: Proceedings of the Wetlands Workshop*, 6–7 December 1994, Darwin NT, Department of Lands, Planning & the Environment, Palmerston NT.

Julius A 1996. What price the fish? In *Making multiple landuse work: Proceedings of the Wetlands Workshop*, 6–7 December 1994, Darwin NT, ed P Jonauskas, Department of Lands, Planning & the Environment, Palmerston NT, 83–85.

Liddle DT & Sterling EA 1992. The integration of pastoralism and conservation on the coastal wetlands of the Northern Territory. In *Australian rangelands in a changing environment*, Proceedings of the 7th Biennial Conference of the Australian Rangeland Society, Cobar, 129–136.

Northern Territory Government 1994. *A conservation strategy for the Northern Territory.* Government Printer of the Northern Territory, Darwin.

Paijmans K, Galloway RW, Faith DP, Fleming PM, Haantjens HA, Heyligers PC, et al 1985. *Aspects of Australian wetlands*. Division of Water and Land Resources, Paper 44, CSIRO, Australia.

Parks & Wildlife Commission of the Northern Territory 2000. *A strategy for conservation of the biological diversity of wetlands in the Northern Territory of Australia*. PWCNT, Darwin NT.

Roberts SJ 1996. Fire on the *Gapalg* (floodplain): Contemporary Aboriginal and other burning patterns in Kakadu National Park, Northern Australia. In *Fire in wetlands: A management perspective*. Proceedings of the Tall Timbers Fire Ecology Conference 19, Tall Timbers Research Station, Tallahassee, Florida.

Ryan P, Russell-Smith J & Durieu R 1995. Long term satellite monitoring of fire regimes in Kakadu National Park, Northern Territory, Australia. In *NARGIS 95: Proceedings of the 2nd North Australian Remote Sensing and Geographic Information Systems Forum*. Darwin, 18–20 July 1995, Supervising Scientist and the Australian Urban and Regional Information Systems Association Inc [Monograph No 11], AGPS, Camberra, 13–20.

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

Whitehead PJ & Tschirner K 1991. Lead shot ingestion and lead poisoning of Magpie Geese (*Anseranas semipalmata*) foraging in a northern Australian hunting reserve. *Biological Conservation* 58, 99–118.

Winter WH 1990. Australia's northern savannas: A time for change in management philosophy. *Journal of Biogeography* 17, 525–529.

Ecological character of two lagoons in the lower Volta, Ghana[1]

CM Finlayson, C Gordon[2], MJ Storrs[3] & Y Ntiamoa-Baidu[4,5]

Introduction

The socio-economic benefits of coastal lagoons in Ghana to the local people are very apparent — large quantities of fish and crabs are caught and traded; reeds and other plants are cut for thatch and for weaving mats; vegetables are grown in sandy garden beds irrigated by water drawn by hand from wells along the edges of the lagoons; and salt is extracted by both intensive and extensive methods. In recent years, the immense conservation value of the lagoons has also been recognised (Ntiamoa-Baidu & Grieve 1987, Ntiamoa-Baidu 1991, 1993, Piersma & Ntiamoa-Baidu 1995, Ntiamoa-Baidu et al 1998).

However, it became evident to authorites in Ghana, that the values and benefits provided by the lagoons were under increasing threat from over-exploitation and degradation. In response to this situation the Ghana Coastal Wetlands Management Project (CWMP) was implemented by the Ghana Wildlife Department (now Wildlife Division of the Forestry Commission) as part of the Ghana Environmental Resource Management Project, funded by the Global Environmental Facility (GEF). The general aim of the CWMP was to create an enabling environment so as to manage five coastal wetland sites. The basic rationale for the project was to maintain the ecological integrity of the lagoons and to enhance the benefits derived from the wetlands by local communities.

In support of this aim we provide a description of the ecological character of the Keta and Songor lagoons in the Lower Volta region of Ghana (fig 1). The detailed information collected in this study is presented by Finlayson et al (2000). Here we provide information on the climate, hydrology, chemistry, and the aquatic/wetland invertebrate fauna and the flora, and identify the major threats to the sustainable use of the lagoons.

Methods

Sampling of each lagoon and the surrounding wetland vegetation was based on a stratified grid drawn at intervals of 1' latitude and longitude (ie ≈ 1.8 x 1.8 km). The points of intersection of the grid were used as the basis for selecting sites for sampling. Samples were also collected from the Angor channel that connects the Keta lagoon with the Volta estuary.

---

1 More detailed discussion of this research is provided in Finlayson CM, Gordon C, Ntiamoa-Baidu Y, Tumbulto J & Storrs M 2000. *The hydrobiology of Keta and Songor lagoons: Implications for coastal wetland management in Ghana*. Supervising Scientist Report 152, Supervising Scientist, Darwin.

2 Volta Basin Research Project & Zoology Department, University of Ghana, Legon, Accra, Ghana.

3 Formerly ***eriss*** (current address: Northern Land Council, PO Box 42921, Casuarina, NT 0811, Australia).

4 Zoology Department, University of Ghana, Legon, Accra, Ghana; Ghana Wildlife Society, Accra, Ghana.

5 present address: WWF International, Avenue du Mont-Blanc, 1196 Gland, Switzerland.

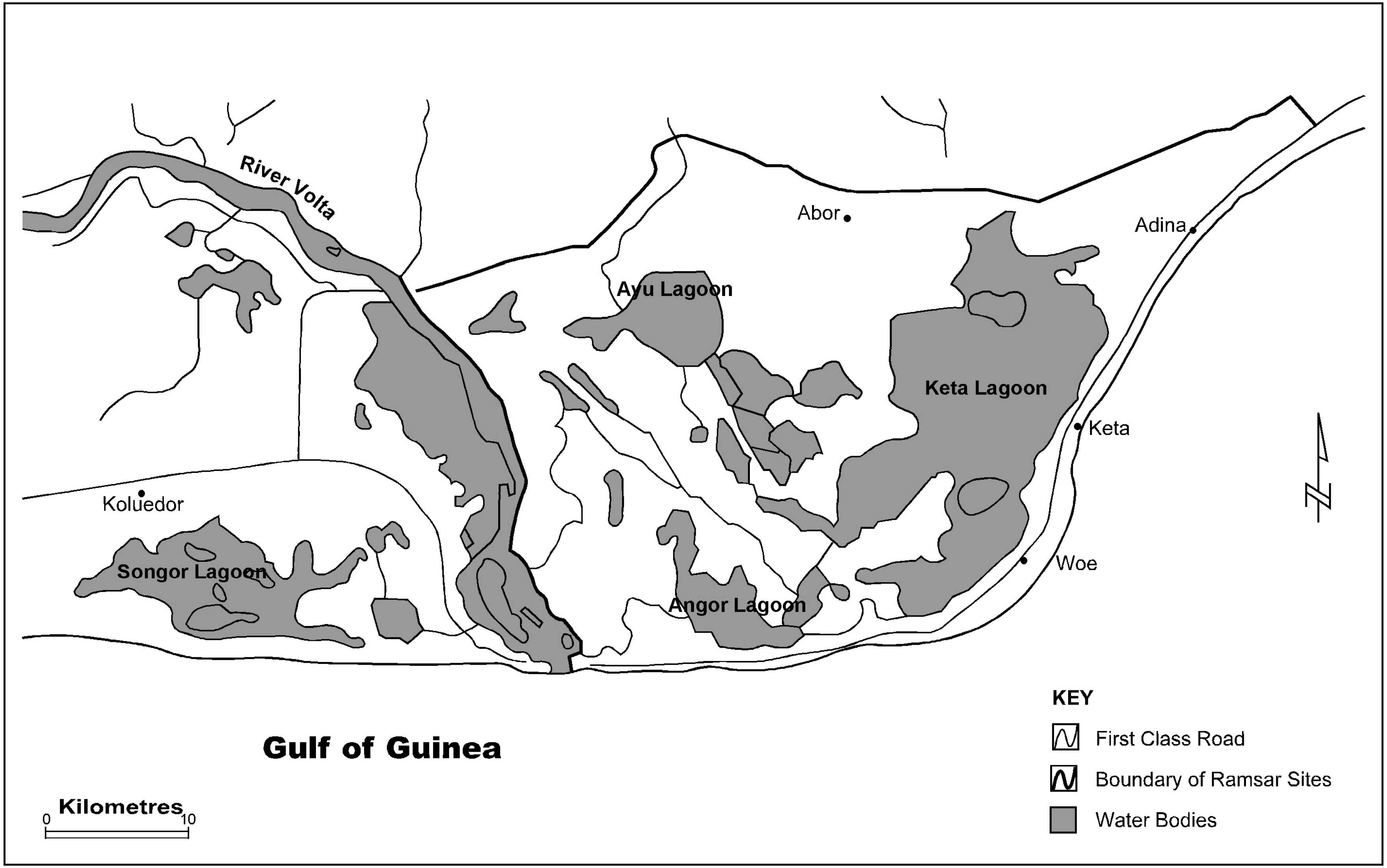

Figure 1 Location of Keta and Songor lagoons alongside the lower Volta River in eastern Ghana

For logistic convenience, the sampling strategy was divided into two components — one aquatic and the other wetland/terrestrial. All intersecting grid points within the lagoons were used for aquatic sampling (ie physico-chemical and biological parameters). The wetland sampling was based on a series of grid points located along the landward side of the lagoon shorelines. The details of the sampling strategy and location of all sites are shown in Finlayson et al (2000).

Ecological character of Keta and Songor lagoons

Climatic conditions

The study area lies within the dry equatorial climatic region of coastal Ghana which has two clearly defined seasons, the Dry season and the Rainy season. The Rainy season exhibits two peaks of rainfall, the main one occurring between April and June and the minor one between September and October. June is normally the wettest month. The mean annual rainfall is 892 mm, although it has been lower in the past decade. The prevailing wind direction is from the southwest (the southwest monsoons). Mean monthly averages of daily wind speed range between 21.1 to 29.0 km h^{-1}. However, high velocity winds (110 km h^{-1}) of short duration have been recorded in Accra. Average temperatures range between 23ºC and 31ºC with August usually being the coldest month.

Hydrological conditions

In general, stream flow in the area is seasonal, and corresponds to the seasonal variation in rainfall. A few coastal streams drain the area above the Keta lagoon which is about 24 km long and 12 km wide with an area of 272 km^2 and volume of 5 560 270 m^3 with water depths ranging from 0.08–0.75 m. The major streams apart from the Volta River include the Todzie River, which discharges into the Avu lagoon just north-west of Keta lagoon, and the Belikpa River, which discharges directly into the Keta lagoon. The Keta lagoon is connected to the Volta system by the Angor channel which is currently being dredged due to blockage by weeds and sediments.

The Volta River drains two-thirds of the country and is dammed first at Akosombo and then at Kpong. Before 1964, the year the dam at Akosombo was created, records on the Volta at Sogakope showed that water levels increased from 1.4 m in the Dry season to about 6.6 m in September or October. Discharge also varied between over 10 000 m^3 s^{-1} after the rains to less than 50 m^3 s^{-1} in the Dry season. After the construction of the Akosombo dam, however, water levels and flows were more uniform.

A few coastal streams drain the area above the Songor lagoon. The Sege River has a catchment area of about 75 km^2 and drains the north-western part of the Songor lagoon. There are no flow records for this river. The other major stream draining into Songor lagoon flows through Hwakpo. Songor lagoon covers an area of 115 km^2 and extends for about 20 km along the coast and 8 km inland behind the narrow sand dune. In general the lagoon normally dries in the Dry season and a sand dune is physically broken to allow seawater to flow into the lagoon at high tide. It is subsequently closed and the water evaporates under natural conditions throughout the year. The part of the lagoon, which is not managed for salt extraction mixes with freshwater from the catchment and undergoes natural evaporation until it dries completely.

Water chemistry

The pH of the water in Keta lagoon was neutral to alkaline (6.7 to 9.7 range) and in Songor slightly acidic to alkaline (5.2 to 8.3). The fairly high carbonate content of the water (generally 100 to 170 CO_4 mg L^{-1}) may have buffered any pH changes that could have resulted from biotic activity. Temperature in these shallow lagoons was always high, the mean often exceeding 30ºC. There was very little temperature difference between the surface and bottom. Unlike other water bodies in Ghana the water was not super-saturated with dissolved oxygen. The surface waters are generally well oxygenated throughout the night with lower levels at depth. It is assumed that wind action plays a greater role than photosynthesis in establishing the dissolved oxygen profiles.

The water was also basically without true colour. However, due to the strong wind action and the shallow nature of the lagoons, the transparency was often reduced to less than 10 cm. The transparency was reduced in areas where there was a large clay fraction in the sediment and high in areas where there were submerged aquatic plants.

Conductivity values range from under 2 mS cm^{-1} to over 80 mS cm^{-1}. The presence of hypersaline subsurface water was noted in several areas, especially in Songor lagoon. Sodium and chloride dominate the ionic composition of the water in Keta lagoon ranging from 4373 ± 1788 mg L^{-1} and 10 207 ± 8527 mg L^{-1} respectively. This is to be expected given the proximity to the sea. The trace metal concentrations in the water in Keta lagoon was usually below the limits of detection (0.03 mg L^{-1}) for lead and copper and ranged from 0.04–0.09 mg L^{-1} for zinc. Phosphorus concentrations ranged from 0.03 to 0.10 P-PO_4 mg L^{-1}.

Aquatic ecology

The phytoplankton consisted primarily of benthic diatoms that have been dislodged from the bottom of the lagoons, plus a few true planktonic diatom species. These species are typical of shallow lagoons and most likely make a significant contribution to the primary production. Some blue-green alga species made up the remainder of the biomass. Both lagoons harboured diatoms characteristic of high salinity close to seawater or even higher. The only freshwater or brackish water species present were found in the samples from the Angor channel connecting Keta lagoon to the Volta. The two lagoons are characterised by separate diatom assemblages, although many species are common to both.

The total chlorophyll concentrations in Keta ranged from undetectable to 145 µg L^{-1} with a mean of 20 ± 21 µg L^{-1} and in Songor lagoon from undetectable to 86 µg L^{-1} with a mean of 24 ± 19 µg L^{-1}. In Keta chlorophyll *a* was generally present in greater concentrations than *b* or *c* whereas in Songor chlorophyll *b* was more prevalent in some, but not all sites. These figures suggest that the lagoons are highly productive.

As would be expected from temporary waters with extremes of salinity and temperature, the zooplanktonic diversity in the two lagoons was not high. The situation was further complicated by the shallow nature of the waters sampled, leading to the appearance of several epibenthic species in the water column. Three main groups were found in the plankton sampling: Ostracods, Copepods and Amphipods. Zooplankton were found in all parts of the lagoon.

The macroinvertebrate fauna was dominated by three groups of organisms: annelids, molluscs and crustacea. For this type of waterbody, the insecta seemed under represented. This may be due to the large numbers of fish that are found in the lagoons and the salinity of the water. In Keta lagoon the mollusc *Tivela* sp. was most common in the macro-benthos followed by the gastropod *Tympanotonos* sp. In Songor, polychaetes were the most common organisms. The macro-zoobenthos reached remarkable numbers at some sites, oligochaetes were found in numbers exceeding 70 000 per m^2. The distribution and relevant abundance of *Nereis* and *Tympanotonos* are presented in figures 2 and 3.

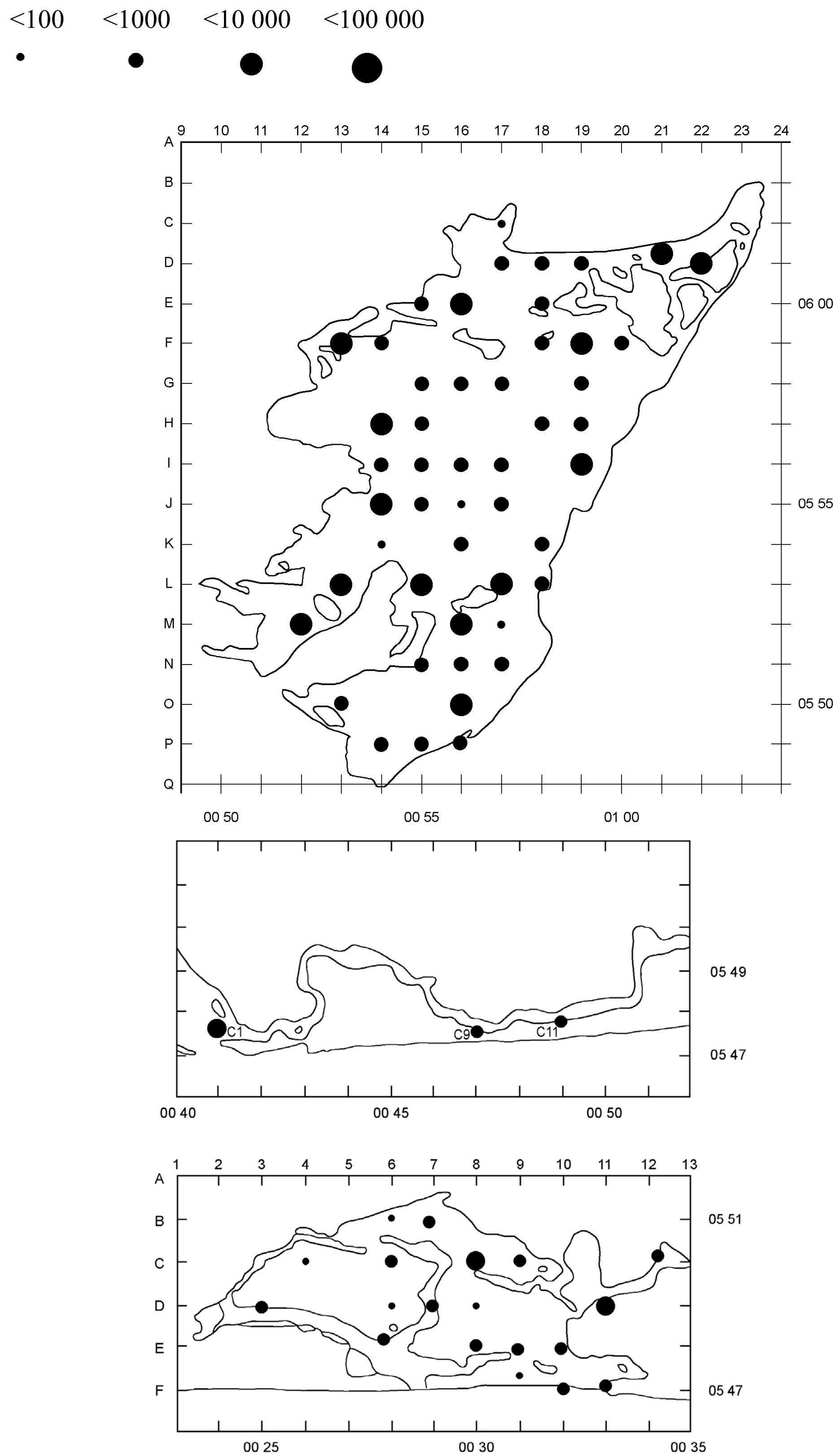

Figure 2 Distribution and abundance of *Nereis* sp. in Keta lagoon (top), Angor channel connecting Keta lagoon to the Volta River (middle) and in Songor lagoon (bottom)

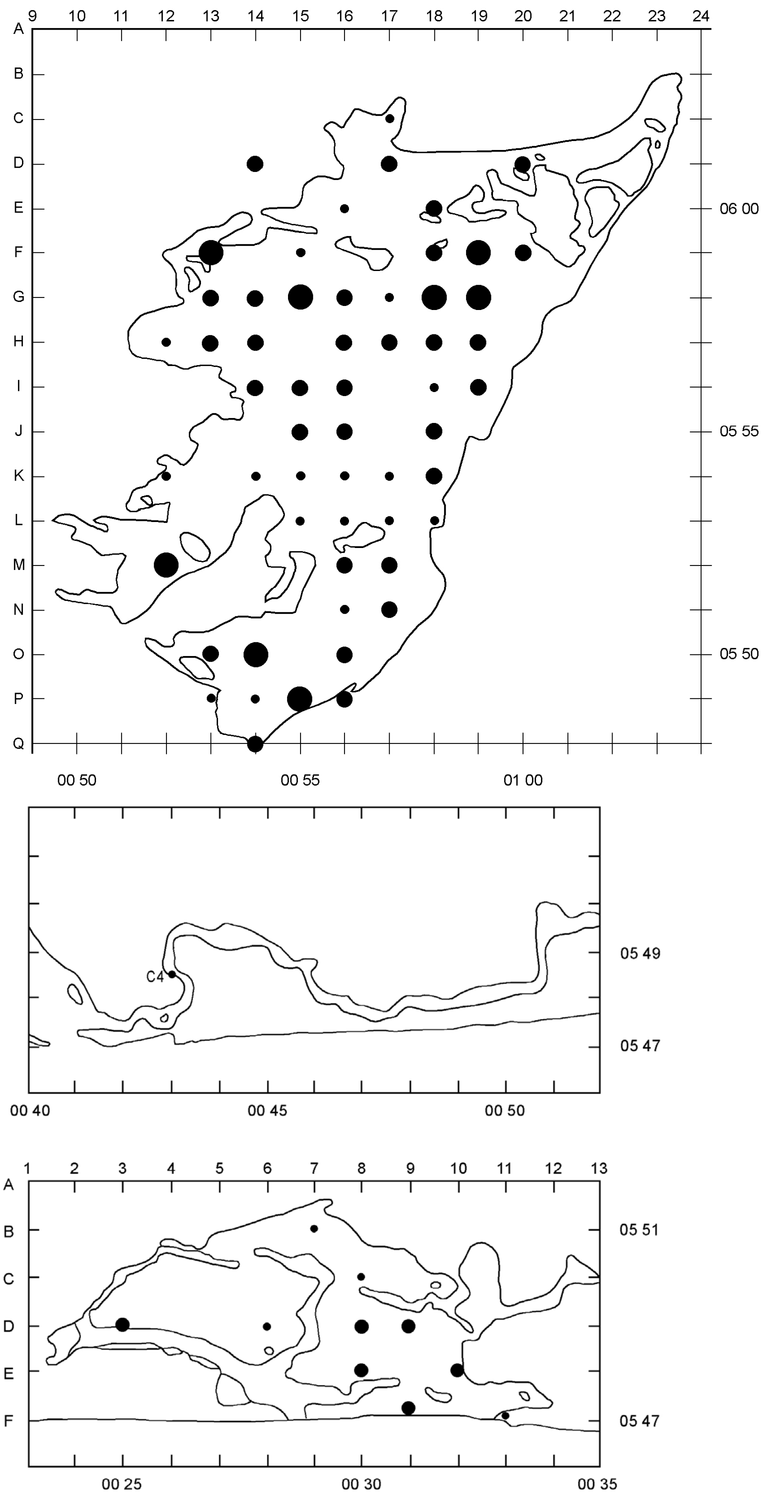

Figure 3 Distribution of *Tympanotonos* in Keta lagoon (top), Angor channel connecting Keta lagoon to the Volta River (middle) and in Songor lagoon (bottom)

The Keta lagoon and the swamps that surround it contained 109 aquatic macrophyte species compared with 57 in Songor and the swamps that surround it. This is likely due to the drier and more saline conditions that occur around the latter. The most dominant aquatic macrophytes are the large emergent species *Typha domingensis, Scirpus littoralis* and the rampant grass *Paspalum vaginatus* with above ground biomass (dry weight) values of 1270 ± 790, 674 ± 358, and 1278 ± 868 g m^{-2} respectively. These species were most common in the freshwater zones around both lagoons (fig 4).

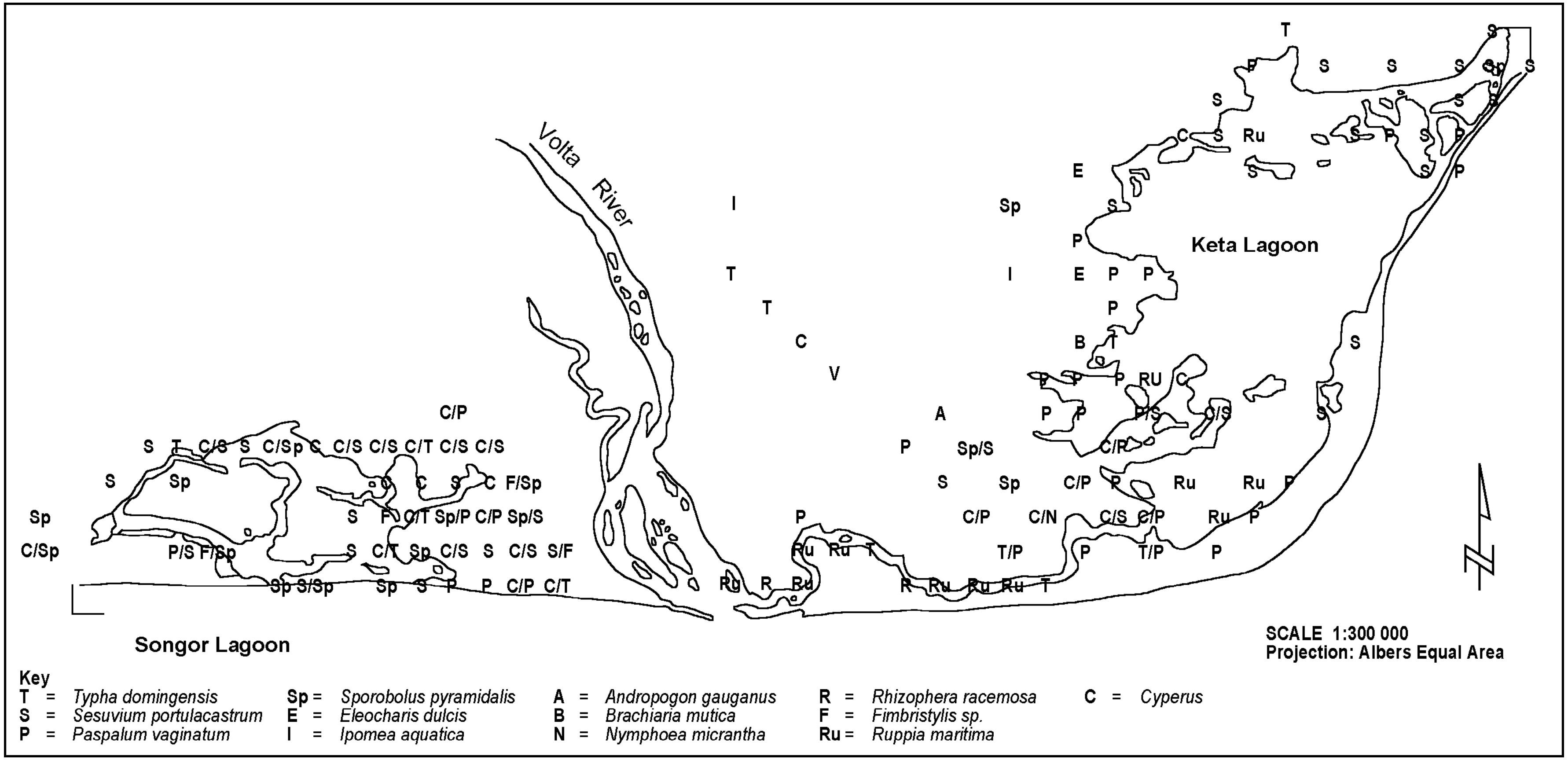

Figure 4 Distribution of aquatic macrophytes around Keta and Songor lagoons

The drier and saline areas around each lagoon are characterised by a *Sesuvium portulacastrum* and *Sporobolus pyriamidialis* association. The diversity of the vegetation around Keta lagoon was shown in transects that generally had *Ruppia maritima* at the waters edge or in the shallow water, followed by *Sesuvium*, then zones dominated by *Paspalum vaginatum, Cyperus articulatus* and/or *Scirpus littoralis,* or *Typha domingensis*. Much of Songor lagoon, especially the western half of the lagoon contained salt ponds and little vegetation.

Management of Keta and Songor lagoons

The description of the ecological character of the lagoons and the development of monitoring programs are components of a management strategy for the long-term sustainable use of the lagoons. The major threats to the lagoons were identified and grouped under four broad categories: water regime; water pollution; physical modification; and exploitation and loss of production as a basis for identifying more specific issues (table 1).

Table 1 Priority pressures in Keta and Songor lagoons

	Wetland	
Priority	**Keta**	**Songor**
1	Erosion and damage from erosion control measures	Expansion of urban infrastructure
2	Flooding and damage from flood control measures	Hunting marine turtles
3	Reclamation of land	Disposal of solid waste-refuse
4	Pollution from sewage	Over-exploitation of fish
5	Pollution from fertilisers	Blockage and diversion of freshwater

As the two lagoons are very large it would be impossible to carry out the same sort of sampling intensity that was used in the baseline study for a monitoring program. A stratified random approach is recommended for monitoring based on further analysis of the pressures occurring in each lagoon. The listing of pressures shown in table 1 does not contain any quantitative data — such information is required before the monitoring projects are implemented. On the whole, the sampling methods described in the report by Finlayson et al (2000) are suitable for further monitoring if supported by an adequate sampling schedule.

It was also recommended that further work be carried out in order to gain an in-depth understanding of the lagoons and how they function, especially in relation to the many goods and services that are derived from the lagoons by local people. It is anticipated that local people would have a wealth of information on such issues and could advise managers and researchers alike. Further, it is recognised that some basic research is required as a base for management decisions, especially those relating to long-term sustainable use of the resources in the lagoons. This is in line with the general goal of gathering information that can be used to ensure the lagoons are used in a sustainable manner.

Acknowledgments

A large number of individuals were involved in this project. Thanks must first go to Mr Bill MacFarlane, Mr HO Ankrah and Mr F Seku for their technical assistance in the field. They were ably supported by staff from the Ghana Wildlife Society and Ghana Wildlife Department. The Ghana National Petroleum Company granted permission to use the Camp at Anloga. And we thank the Ghana Wildlife Department who through the Ghana Coastal Wetlands Management Project invited us to carry out this study.

References

Finlayson CM, Gordon C, Ntiamoa-Baidu Y, Tumbulto J & Storrs M 2000. *The hydrobiology of Keta and Songor lagoons: Implications for coastal wetland management in Ghana*. Supervising Scientist Report 152, Supervising Scientist, Darwin.

Ntiamoa-Baidu Y & Grieve A 1987. Palaearctic waders in coastal Ghana 1985/6. Wader Study Group Bulletin 49 Supplement & IWRB Special Publication 7, Slimbridge, UK, 76–78.

Ntiamoa-Baidu Y 1991. Seasonal changes in the importance of coastal wetlands in Ghana for wading birds. *Biological Conservation* 57, 139–158.

Ntiamoa-Baidu Y 1993. Trends in the use of Ghanaian coastal wetlands by migrating Knots *Calidris canutus*. *Ardea* 81, 71–79.

Ntiamoa-Baidu Y, Piersma T, Wiersma P, Poot M, Battley P & Gordon C 1998. Water depth selection, daily feeding routines and diets of waterbirds in coastal lagoons in Ghana. *Ibis* 140, 89–103.

Piersma T & Ntiamoa-Baidu Y 1995. *Waterbird ecology and the management of coastal wetlands in Ghana*. NIOZ Report 6, Texel, The Netherlands.

Wetland scientists — involvement in training, community awareness and exchange of information

CM Finlayson

Introduction

Across northern Australia local communities have increasingly become involved in wetland management. This has occurred through the development of structured processes, such as those in place in Kakadu National Park (Wellings 1995, Lindner 1999) and less formalised processes, such as those in place in parts of Arnhem Land (Storrs 1999a,b, Szabo 1999). The nature and intent of these processes has varied enormously, generally in response to local needs, resources and opportunity. However, they have all had an emphasis on local participation and many have encouraged interaction and collaboration with scientists and scientific institutions. In unison with the development of more participatory approaches towards wetland management there has been increased involvement of scientists with the general community and across sectoral bounds, resulting in greater exchange of information and knowledge about wetlands.

This has occurred in northern Australia with many individuals and organisations playing a role. In line with this general direction we have developed a number of specific activities designed to increase interaction between wetland scientists and managers and the general community. These have covered general awareness raising within the broader community, specific training of technical experts with input from both scientists and the broader community, and the provision of specific advice on technical issues at local, national and international fora.

The lessons derived from our efforts with members of the wider community interested in wetland management have contributed to many projects including the development of international guidelines for involving local communities and indigenous people in wetland management, community-based monitoring exercises, and specific training programs. Based on these experiences a paradigm for involving local people in a coastal wetland monitoring program was produced (Finlayson & Eliot 2001). An overview of these activities is given below.

At the outset it is emphasised that these efforts were team-based with input from many people, both professional scientists and managers as well as landowners and users. The team effort was seen as a key to both involving members of local communities and increasing interaction between professional scientists and the wider community. It is also noted that these efforts were at times accompanied by many difficulties including those due to the reluctance of some sectors or individuals to participate fully or with equity. Based on information reported from elsewhere (eg see papers in Carbonell et al 2001) it seems that these experiences may not be uncommon.

Community-based monitoring projects

As a component of general outreach activities a number of specific community-based monitoring projects were initiated. Two were undertaken within Kakadu National park: i) monitoring of bird species in the vicinity of an urban lake in the settlement of Jabiru, and ii) monitoring of waterbirds and vegetation in Yellow Water lagoon, a popular tourist and recreational fishing destination. A further project was undertaken at wetlands on a cattle station adjacent to Kakadu National Park.

These projects had dual goals. Foremost was the development of increased awareness by local people of wetlands and their species. This was done through involving local people in the monitoring activities. Within Jabiru this included the involvement of volunteers in regular systematic bird surveys around Jabiru lake. Tour guides were similarly involved at Yellow Water lagoon. While at Carmor station members of the leasees family were involved. Secondly, general data on seasonal changes in the wetlands were collected.

Those involved in these projects were given training in techniques to collect data from specific sites and were at all times supported by qualified scientists and technicians. The results were immediately passed on to the local people through discussion of the data and the major changes that were observed. This led quickly to increased awareness about wetlands and in the case of the tour guides the information was immediately transferred to visitors. Data were collected at regular intervals for 1–2 years and are currently being reviewed and used in formal and informal presentations.

Wetland training

Three formal training courses have been undertaken in collaboration with staff from the Northern Territory University, Darwin. Specifically this included taking responsibility for formal courses on wetland management within a Master of Tropical Environmental Management (www.ntu.edu.au/faculties/science/sbes/pgrad/tropenvman.htm). The courses lasted for 1–2 weeks and were held yearly from 1997–99. They covered general technical subjects such as wetland management and monitoring and included formal lectures, discussions and field work. In addition to input from experienced wetland scientists a concerted effort was made to invite local wetland managers and practitioners to present lectures and engage in discussion with course participants. In July 2000, a further course was presented as a component of the Asia Pacific Wetland Managers Training Program run by NTU and funded by Environment Australia (http://www.ntu.edu.au/ctwm/training.html). This included students specifically invited from a number of countries in Asia and covered similar materials as presented in the Masters courses.

In all courses the participants were presented with current scientific knowledge, such as that on wetland monitoring and assessment being developed through the Ramsar Wetlands Conventions technical panel, introduced to scientific techniques that were either under development or being applied in practical situations, eg aquatic ecotoxicological and stream monitoring techniques, as well as being able to discuss wetland management with on-the-ground managers and owners. Feedback from participants included appreciation at being exposed to real life research and management situations by practitioners rather than the more distant or theoretical treatments that many had experienced on other occasions.

The resource material for such courses came mainly from local studies (eg Bayliss et al 1997, Storrs & Finlayson 1997) and from a collation of papers from local wetland users, owners and managers (Finlayson 1995). Eventually further information on wetland management issues was collated from many local projects and experiences and presented as a compendium for students and managers alike (Finlayson & Spiers 1999a). The emphasis in these courses was on practical issues as opposed to theoretical analyses or textbook recitals.

Study tours and specific training events

In addition to the formal training course mentioned above a number of informal training courses were held. These included visitors from Tasek Bera, Malaysia, and the Mekong Delta, Viet Nam. The subject material was similar to that presented in the training course with the main difference being that the participants were given a greater opportunity to develop a program of specific interest to themselves. These tours have resulted in ongoing contact and communication and the development of joint project activities (eg *Vulnerability assessment of major wetlands in the Asia-Pacific region to climate change and sea level rise* — van Dam et al 1999b; and the Asian Wetland Inventory — Finlayson et al 2002).

Specific training and interaction has also occurred with local aboriginal communities. This has involved employment and training of individuals either in specific sampling projects, eg fish sampling of lowland billabongs, or more general field station duties. Input has also been given to special workshops and meetings, such as those on wise use of wetlands by Aboriginal people (Centre for Indigenous Natural and Cultural Resource Management 1997, Whitehead et al 1999) as well as many informal meetings and discussions about wetland management issues. Specific interaction has also been encouraged with technical staff from other institutions and countries (eg Czech Republic, Ghana, Papua New Guinea, The Netherlands, Switzerland and the United Kingdom) and visits by community groups or their representatives. The latter has been extended to occasional hosting of specialist environmentally-oriented tour groups and linked with celebration of World Wetlands Day on 2 February (in celebration of the formulation of the text of the Wetlands Convention in Ramsar, Iran, 1971). Regular effort is also given towards presentations and displays at local fetes, open days and other local celebratory or awareness raising events hosted by other organisations. Many of these have included wider representation of the research activities undertaken at ***eriss***.

Hosting and/or participation in such events has occurred through both structured and opportunistic processes as appropriate. This dual approach has had many advantages and has enabled scientific staff to develop specific interests and impart knowledge as well as respond to informal situations and both contribute to and learn from different forms of interaction. In this manner there has been a greater sharing of knowledge and mutual learning than may otherwise have occurred if formal scientific conferences and the like were the only focus.

Local community wetland management

At the invitation of landholders and interested agencies assistance and advice on wetland management issues has been provided through a number of formal processes and activities. The nature of these activities has varied and in part reflects the nature of the differing juridictional structures in the region. Finlayson et al (1998) have compared in brief the arrangements within Kakadu National Park and adjacent land and noted that the involvement of local people in wetland management raises a number of challenges:

- Community consultation takes time and potentially causes delays and challenges established authority lines.
- It can be difficult to establish the representativeness of views being promulgated.

- A common understanding of fundamental issues may be elusive.
- Local interests may conflict with broader interests.

They also note that 'governmental resources allocated for wetland management are not evenly disributed between particular issues and across locations'.

Within the Alligator Rivers Region, which includes Kakadu National Park, several approaches have been adopted towards assisting local communities with wetland management. One approach has involved catalysing interest from multiple stakeholders in a coastal monitoring program. Finlayson and Eliot (1999) have described the basis of this program and proposed a coastal monitoring node to facilitate ongoing assessment of the coast, in particular the wetlands, to the effects of short-term changes in climate and other environmental factors that occur within planning horizons of approximately 100 years. Eliot et al (2000) outline the major components of the program under the following headings:

- Introduction to the coastal monitoring program
- Data collection and information management
- Collation of baseline information: regional processes
- Collation of baseline information: the coastal plain
- Application and accountability

As consultation with multile stakeholders was a major component of the program Finlayson and Eliot (2001) also described the manner in which this was undertaken (see below).

Wetland management issues have also addressed and assistance and advice provided at the behest of local people and/or the park service in response to their needs for further scientific data (Wellings 1995, Lindner 1995, 1999). This resulted in specific investigations, such as the extent of hydrocarbon pollution in Yellow Water lagoon (van Dam et al 1999) and at Gunlom waterfall from chemicals used by visitors for personal protection from the sun and insects (Rippon et al 1994). On both ocassions adverse results were not found, but it was stressed that further and more detailed investigations could be warranted. A further analysis involved investigating the effect of herbicides used to spray the floating weed *Salvinia molesta* (Finlayson et al 1994a). Again, data and recommendations were provided to the park managers. Involvement in weed management built on a longer term involvement with weed issues in Kakadu (Cowie et al 1988, Finlayson et al 1994b), including provision of an analysis of the spread of paragrass (*Brachiaria mutica*) within the Magela Creek wetlands from being sparsely distributed in the mid 1980s (Finlayson et al 1989) increasing to 920 ha coverage in 1996 (Knerr 1998).

To the west of Kakadu local landholders had formed a land care group that became known as the Mary River Landcare group. Expert opinion on issues as diverse as climate change and wetlands (Bayliss et al 1997), weed management and saline intrusion was provided during regular meetings of this group. Formal input to the development of a Total Catchment Management Plan for the Mary River was made through involvement in the landcare group. The concept of wise use was also raised in a paper (Finlayson 1996a) presented at a workshop to address land use options for the wetlands in the lower Mary (Jonauskas 1996). This paper raised the spectre that whilst wise use was an attractive concept (akin to sustainable development) it may be elusive unless supported by ongoing commitment and assessment of options and outcomes.

A major effort was also undertaken in the Blythe-Liverpool wetlands in Arnhem Land to the east of Kakadu. After being approached by representatives of local landholders and after further consultation a series of wetland and river surveys were conducted (Finlayson et al 1997). These included working with local Aboriginal people to sample fish, macro-invertebrates and vegetation at a number of locations (Pidgeon & Boyden 1997, Thurtell 1997). The results were reported and on ocassions formal training was provided to members of the community involved. Through the formally established Top End Indigenous People's Wetland Program (Storrs 1999a,b) a review of information sources that could be useful for developing a management plan for the Blythe-Liverpool wetlands was undertaken (Thurtell et al 1999). This review drew heavily on information available from published sources and from dialogue with local people. It was also accompanied by a brief commentary on the Ramsar Wetlands Convention and its key principles of wise use and involvement of local communities and indigenous people in wetland management. The latter were developed by a cooperative effort based on case studies drawn from around the world, including the Blythe-Liverpool wetlands (Hunziker et al 1999). Representatives from the local community were interested in further information on the Ramsar Convention. This was achieved through direct contact with representatives of the Convention and its subsidiary scientific and technical panel and other interested parties. This dialogue has continued (eg Finlayson 1999a) with a view to enabling local people to determine their own interest and possible direct participation in this international Convention.

Problems for wetland managers of the future were also addressed (Finlayson et al 1997, Finlayson & Pidgeon 1999). In particular it was stressed that indigenous wetland managers and owners in northern Australia may need to address: allocation of environmental flows; development of acid sulphate soils; adaptation to climate change and sea level rise; control and management of feral animals and weeds; and responses to proposals to construct tidal power barrages. In raising awareness of these issues Finlayson & Pidgeon (1999) noted the following 'We would like our scientific expertise to assist them [people] in making wise choices and to prevent the potential disasters that could befall the valued wetlands of northern Australia.' This statement is as true today as it was when the talk that formed the basis of the paper by Finlayson and Pidgeon (1999) was presented in 1998 at a workshop on the Wise Use of Wetlands in Northern Australia (Whitehead et al 1999).

Involving local communities in an assessment and monitoring program

In developing a coastal wetland assessment and monitoring program for the Alligator Rivers Region (see Eliot et al 1999a) a paradigm for involving local communities in assessment and monitoring activites was developed (Finlayson & Eliot 2001). The paradigm revolves around formal consultation involving interested and relevant community groups and governmental agencies coupled with scientific rigour and feedback to participants. It includes the following steps:

- Establishment and empowerment of an expert assessment and monitoring centre – based on discussion with key stakeholders and recognition of all technical competencies.

- Consultation with and empowerment of key stakeholders, including the local community – identification of key stakeholders and their individual roles at the start of the process and supported by formal and informal meeting processes to both develop awareness and seek advice and assistance where practicable.

- Identification of major processes and causes of ecological change – primarily a technical exercise but honed through discussion with and input from local residents etc.
- Collation and coordination of available data and information – involving rigid data management protocols to enhance access and store/file information.
- Identification of potential collaborators and partners – an ongoing and iterative process involving technical and lobby groups.
- Design and implementation of technical assessment and monitoring projects – a technical task based on the best available knowledge and advice from as many sources as feasibly possible.
- Audit and, if necessary, termination of assessment and monitoring projects – a review process that involves outside advice and participation.
- Implementation of management prescriptions based on results of the assessment monitoring projects — dependent on the establishment and maintenance of links with management agencies and officials.
- Provision of feedback to stakeholders, partners and community groups — an ongoing and iterative process whereby awareness and trust are established and maintained.
- Audit of management outcomes and readjustment of the monitoring program in the context of impacts arising from the management strategies adopted — a process to ensure that the best available information was being used for management purposes in an adaptive manner.

The relative merit of each step of the paradigm is dependent on local circumstances, such as the interest of the local community groups and their interaction with governmental officials. Whilst the emphasis on individual steps may vary it is extremely unlikely that any step will be completely bypassed without placing the entire process in jeopardy.

Formal advice and presentation of scientific information

The knowledge and experience developed from research activities undertaken in the tropical wetlands of northern Australia, particularly those within Kakadu National Park, have been used to provide guidance and assist wetland managers and policy makers elsewhere. The provision of advice to Australian national programs on the National River Health Program (AUSRIVAS component) (Environment Australia), and the Revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (a publication of the National Water Quality Management Strategy) (for ANZECC and ARMCANZ and coordinated by Environment Australia) has been described elsewhere in this volume ('AUSRIVAS operator sample processing errors: Implications for model sensitivity', Humphrey; 'An overview of the new water quality guidelines for Australian and New Zealand aquatic ecosystems', Humphrey & McAlpine).

Other activities have included input into the Porgera Environmental Advisory Komiti in Papua New Guinea, a mining project that appointed an independent committee to assess its environmental management (Placer Dome Asia Pacific 2000). Independent scientific advice has also been proved on the water reform processes in NSW specifically through the Macquarie-Cudgegong River Management Committee in New South Wales (Finlayson 2001). These activities have seen the direct transferrance of knowledge and expertise to wetland managers and owners and a greater understanding by scientists of the issues involved in community-based environmental committees.

Scientific knowledge developed in the region has also been used to support the efforts of the Australian Society for Limnology to outline key issues for inland waters in Australia and present a list of major challenges facing aquatic and wetland ecosystems (www.asl.org.au/asl_poldoc_challenges.htm). The list includes: provision of surface and groundwater for environmental benefits; prevention of pollution and contamination of aquatic habitats; prevention and reduction of salinisation of wetlands; prevention of further drainage and infilling of wetlands; management of grazing in wetlands; restoration and protection of riparian vegetation; prevention and control of invasive species; mitigation of climate change and sea level rise; and development of rigorous inventory, assessment and monitoring protocols.

Support was also given to the alliance of the Australian Society for Limnology, Wetland Care Australia and WWF-Australia that formed the Australian Wetland Forum to produce A Strategy to Stop and Reverse the Loss and Degradation of Australian Wetlands (www.asl.org.au/asl_wetlandforum.htm). This outlined strataegies and actions that should be taken to achieve the goal of stopping and reversing the loss and degradation of Australian wetlands. The strategy was divided into four components: telling stories about wetlands; implementing policies and initiatives; providing mechanisms to involve all sectors; and a view of the next steps.

Scientific knowledge has also been used to develop national and international protocols for wetland inventory (Finlayson 1999b, Finlayson et al 1999), risk assessment (van Dam et al 1999a) and monitoring (Finlayson 1996b,c). Contributions have also been made to the Intergovernmental Panel on Climate Change third assessment report (Gitay et al 2001, Pittock & Wratt et al 2001). Such efforts continue and have seen the involvement of international wetland scientists in the program of work being conducted in northern Australia. This adds a further dimension to the expertise and knowledge available for managing wetlands in northern Australia and complements the efforts being made to involve local people and other stakeholders and to share knowledge and experience. Technical issues covered have included the reasons for the loss and degradration of Australian wetlands (Finlayson & Rea 1999) and the status of wetland inventory in Australia (Finlayson & Spiers 1999b) and globally (Finlayson & van der Valk 1995, Finlayson & Spiers 1999c).

The National Centre for Tropical Wetland Research

The communication, consultation and training aspects of the wetland research program undertaken have been formally included in the working process of the National Centre for Tropical Wetland Research (***nctwr***). The ***nctwr*** is a formal alliance between four research and/or training institutions: James Cook Univeristy, Northern Territory University, the University of Western Australia and the Environmental Research Institute of the Supervising Scientist. It is governed by a formal agreement that establishes the aim to 'promote the wise use of tropical wetlands' through research and training programs with an emphasis on efective consultation with stakeholders. Training directions encompass formal and academic programs (with formal accreditation) as well as informal and field-based training, with specific short courses for researchers, managers, owners and users of tropical wetlands. The research directions include: assessing existing and potential threats to wetlands; devleoping procedures and standards for monitoring wetlands; developing procedures and standards to sustainably use and restore wetlands; investigating physical, chemical and biological processes in wetlands; and describing the values and benefits derived from wetlands.

The ***nctwr*** incorporates a formally constituted board with representatives from each partner and an independent chair. It also incorporates a broad stakeholder group known as the Advisory Committee. Membership of this committee currently includes national/international non-governmental organisations, federal and provincial governmental agencies, industry representatives and community based organisations. Membership is regularly reassessed based on the need for advice on wetland research and training priorities. The committee is specifically asked to provide advice and input and to support project based activities undertaken by staff from the partner organisations and other collaborators.

The development of the ***nctwr*** is seen as one outcome of many past collaborative efforts involving scientists and wetland managers in northern Australia. It is also seen as a vehicle for promoting further collaboration and for maximising efforts to support wetland conservation and management of tropical wetlands.

References

Bayliss B, Brennan K, Eliot I, Finlayson CM, Hall R, House T, Pidgeon R, Walden D & Waterman P 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia*. Supervising Scientist Report 123, Supervising Scientist, Canberra.

Carbonell M, Nathai-Gyan N & Finlayson CM (eds) 2001. *Science and local communities: Strengthening partnerships for effective wetland management*. Ducks Unlimited Inc., USA.

Centre for Indigenous Natural and Cultural Resource Management 1997. *Research and management in the Arafura Swamp region, central Arnhem Land*. Workshop Proceedings, 24–25 November 1997, Northern Territory University, Darwin.

Cowie ID, Finlayson CM & Bailey BJ 1988. *Alien plants in the Alligator Rivers Region, Northern Territory, Australia*. Technical Memorandum 23, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Eliot I, Saynor M, Eliot M & Finlayson CM 2000. *Assessment and monitoring of coastal change in the Alligator Rivers Region, northern Australia*. Supervising Scientist Report 157, Supervising Scientist, Darwin.

Finlayson CM (ed) 1995. *Wetland research in the wet-dry tropics of Australia*. Workshop, Jabiru NT 22–24 March 1995, Supervising Scientist Report 101, Supervising Scientist, Canberra.

Finlayson CM 1996a. Wise use of wetlands — can we do it? In *Making multiple land use work: Proceedings of the Wetland Workshop*, ed P Jonauskas, 6–7 December 1994 Darwin, Department of Lands, Planning and Environment, Technical Report 1996/3.

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, United Kingdom and ICN, Lisbon, 25–34.

Finlayson CM 1999a. The Ramsar Convention and local community involvement in wetland management. In *Wise use of wetlands in northern Australia: indigenous use*. Workshop, Batchelor, NT, 29 September to 1 October 1998, eds P Whitehead, M Storrs, M McKaige, R Kennett & M Douglas, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 57-59.

Finlayson CM 1999b. Protocols for an Australian national wetland inventory. In *Techniques for enhanced wetland inventory and monitoring*, eds CM Finlayson & AG Spiers, Supervising Scientist Report 147, Supervising Scientist, Canberra, 119–145.

Finlayson CM (collator) 2001. Views from divergent stakeholders on the Macquarie-Cudgegong River Management Committee. Ecological Management and Restoration 2, 87–98.

Finlayson CM & Eliot I 1999. Coastal management in the Alligator Rivers Region. In *A Compendium of information for managing and monitoring wetlands in tropical Australia,* eds CM Finlayson & AG Spiers, Supervising Scientist Report 148, Supervising Scientist, Canberra.

Finlayson CM & Eliot I 2001. Ecological assessment and monitoring of coastal wetlands in Australia's wet-dry tropics: A paradigm for elsewhere? *Coastal Management* 29, 105–115.

Finlayson CM & Pidgeon R 1999. Problems for wetland managers of the future. In *Wise use of wetlands in northern Australia: indigenous use*. Workshop, Batchelor, NT, 29 September to 1 October 1998, eds P Whitehead, M Storrs, M McKaige, R Kennett & M Douglas, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 37–39.

Finlayson CM & Rea N (eds) 1999. *Reasons for the loss and degradation of Australian wetlands*. Special Issue of Wetland Ecology and Management 7, Kluwer Academic Publishers, The Netherlands.

Finlayson CM & Spiers AG (eds) 1999a. *A compendium of information for managing and monitoring wetlands in tropical Australia*. Supervising Scientist Report 148, Supervising Scientist, Canberra.

Finlayson CM & Spiers AG (eds) 1999b. *Techniques for enhanced wetland inventory and monitoring*. Supervising Scientist Report 147, Supervising Scientist, Canberra.

Finlayson CM & Spiers AG (eds) 1999c. *Global review of wetland resources and priorities for wetland inventory*. Supervising Scientist Report 144, Supervising Scientist, Canberra. (also available on CD)

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.

Finlayson CM, Bailey BJ & Cowie ID 1989. *Macrophyte vegetation of the Magela Creek flood plain, Alligator Rivers Region, Northern Territory*. Research report 5, Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Finlayson CM, Klessa DA & Rippon GD 1994a. Possible ecological effects arising from the use of herbicides to control *Salvinia molesta* in Kakadu National Park. Unpublished report to ANCA, Canberra.

Finlayson CM, Hall RN & Bayliss BL 1997. *Regional review of wetland management issues: Wet-dry tropics of northern Australia*. LWRRDC Occasional Paper 03/97, Canberra.

Finlayson CM, Pidgeon RC & Thurtell L 1997a. Wetland research in the Blyth-Liverpool wetlands, Maningrida and central Arnhem Land. In *Research and Management in the Arafura Swamp region, Central Arnhem Land,* Workshop Proceedings, 24–25 November 1997, Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 44–45.

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, Julien MH, Russell-Smith J & Storrs M 1994b. Summary of a Workshop on *Salvinia molesta* in Kakadu National Park, Northern Territory, Australia. *Plant Protection Quarterly* 9, 114–116.

Finlayson CM, Yibarbuk D, Thurtell L, Storrs MJ & Cooke P 1999. *Local community management of the Blyth-Liverpool wetlands, Arnhem Land, Northern Territory, Australia*. Supervising Scientist Report 137, Supervising Scientist, Canberra.

Finlayson CM, Thurtell L, Storrs MJ, Applegate R, Barrow P & Wellings P 1998. Local communities and wetland management in the Australian wet-dry tropics. In *Wetlands in a dry land: Understanding for management*, ed WD Williams, Environment Australia, Canberra, 299–311.

Gitay H, Brown S, Easterling W, Jallow B et al 2001. Chapter 5. Ecosystems and their goods and services. In *Climate change 2001: Impacts, adaptations, and vulnerability*, Contribution of Working Group II to the Third Assessment Report of the International Panel on Climate Change, eds McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, IPCC/Cambridge University Publication Press, 235–342.

Hunziker D, Oviedo G, de Sherbinin A & Argumendo A (organisers) 1999. Workshop on indigenous peoples and local communities participation in wetlands management. In *Report of the 13th Global Biodiversity Forum 1999*, San Jose, Costa Rica, IUCN-The World Conservation Union, Gland, Switzerland & Cambridge, UK. 37–43.

Jonauskas P (ed) 1996. *Proceedings wetlands workshop: Making multiple land use work*. Department of Lands, Planning and the Environment, Palmerston NT.

Knerr NJA 1998. Grassland community dynamics of a freshwater tropical floodplain: Invasion of *Brachiaria mutica* (Para grass) on the Magela Floodplain, Kakadu National Park. Internal report 275, Supervising Scientist, Canberra. Unpublished report.

Lindner G 1995. Wetland management issues in Kakadu National Park In *Wetland research in the wet-dry tropics of Australia.* Workshop Jabiru, NT, 22–24 March 1995, ed CM Finlayson, Supervising Scientist Report 101, Supervising Scientist, Canberra, 23–31.

Lindner G 1999. Contemporary indigenous utilisation and management of wetland resources in Kakadu National Park, monsoonal northern Australia. In *Wise use of wetlands in northern Australia: indigenous use*. Workshop, Batchelor, NT, 29 September to 1 October 1998, eds P Whitehead, M Storrs, M McKaige, R Kennett & M Douglas, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 27–36.

Pidgeon RWJ & Boyden J 1997. Report on preliminary survey of freshwater fish in the Djelk wetlands, November 1996. Internal report 265, Supervising Scientist, Canberra. Unpublished paper.

Pittock B & Wratt D et al 2001. Chapter 12. Australia and New Zealand. In *Climate change 2001: Impacts, adaptations, and vulnerability*, Contribution of Working Group II to the Third Assessment Report of the International Panel on Climate Change, eds McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, Cambridge University Publication Press, 591–640.

Placer Dome Asia Pacific 2000. Porgera Mine 1999: *Sustainability report. Caring for the future*. Placer Dome Asia Pacific, Papua New Guinea.

Rippon GD, Hunt SM & Camilleri C 1994. Water quality monitoring at Gunlom. Unpublished report to ANCA, Canberra.

Storrs MJ 1999a. The Northern Land Council's Caring for Country Unit and the Top End Indigenous People's Wetlands Program. In *Wise use of wetlands in northern Australia: indigenous use*, Workshop, Batchelor, NT, 29 September to 1 October 1998, eds P Whitehead, M Storrs, M McKaige, R Kennett & M Douglas, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 51–52.

Storrs MJ 1999b. Community wetland management: the Northern Land Council's Top End Indigenous People's Wetlands Program. In *A compendium of information for managing and monitoring wetlands in tropical Australia*, eds CM Finlayson & AG Spiers, Supervising Scientist Report 148, Supervising Scientist, Canberra, 271–278.

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

Szabo S 1999. Indigenous Protected Areas. In *Wise use of wetlands in northern Australia: indigenous use*. Workshop, Batchelor, NT, 29 September to 1 October 1998, eds P Whitehead, M Storrs, M McKaige, R Kennett & M Douglas, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin, 55–56.

Thurtell L 1997. Macroinvertebrates of the Djelk wetlands. Internal report 234, Supervising Scientist, Canberra. Unpublished paper.

Thurtell L, Finlayson CM, Yibarbuk D & Storrs MJ (collators) 1999. *The Blyth/Liverpool wetlands, Arnhem Land, northern Australia: Information for management planning*. Supervising Scientist Report 146, Supervising Scientist, Canberra.

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

van Dam RA, Finlayson CM & Watkins D (eds) 1999b. *Vulnerability assessment of major wetlands in the Asia-Pacific region to climate change and sea level rise*. Supervising Scientist Report 149, Supervising Scientist, Canberra.

van Dam RA, Camilleri C & Turley CJ 1999. Preliminary assessment of petroleum hydrocarbons in water and sediment at Yellow Water, Kakadu National Park. *Australasian Journal of Ecotoxicology* 4(1), 61–68.

Wellings P 1995. Wetlands on Kakadu National Park — the management setting. In *Wetland research in the wet-dry tropics of Australia.* Workshop Jabiru, NT, 22–24 March 1995, ed CM Finlayson, Supervising Scientist Report 101, Supervising Scientist, Camberra, 15–22.

Whitehead P, Storrs M, McKaige M, Kennett R & Douglas M (eds) 1999. *Wise use of wetlands in Northern Australia: Indigenous use*. Proceedings of a workshop, 29–30 September & 1 October 1998, Batchelor College, Northern Territory, Centre for Tropical Wetlands Management & Centre for Indigenous Natural and Cultural Resource Management, Northern Territory University, Darwin.