AN INTEGRATED FRAMEWORK FOR WETLAND HEALTH MONITORING IN DRYLAND NAMIBIA

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Abstract

Wetlands usually take the brunt of poor land management practices, and those in dry-land countries are under particularly serious pressures from environmental degradation, including biodiversity loss. Wetland management strategies need to be carefully integrated with land use planning and management at catchment- and landscape-levels. Namibia is developing an integrated framework for wetland (including river) health monitoring and analysis based on this premise, as part of its national biodiversity strategy and action plan (NBSAP), *Biodiversity and development in Namibia.* Key elements of this framework are: State of the environment reporting (SOER) based on catchment-wide biophysical and socio-economic: Use of existing long-term datasets and the emerging permanent sites of the Environmental: Observatories Network of Namibia (EONN): Applicability to a wide variety of arid and semi-arid freshwater and coastal wetlands: Community and specialist monitoring in selected wetland conservancies and other permanent sites; and a focus on indices of biological integrity (IBI). Existing long-term wetland datasets include bird numbers and richness, freshwater fish richness, hydrological flow data, invertebrate richness and standard indices of water quality. The pressure-state-response orientation of SOER in Namibia will be particularly applicable to the context of our wetlands, which although forming less than 5% of the country's surface, are of immense importance for biodiversity and human livelihoods, and are seriously vulnerable to degradation from local and broad scale pressures.

BACKGROUND

Namibia and its wetlands under pressure

Few countries face as serious long-term threats to their wetlands as Namibia. It is often noted that Namibia is sub-Saharan Africa's driest country, and only 4-5% of our 824 000 km^2 landscape is classed as wetlands, many of which are ephemeral (Simmons *et al*., 1991; Hines and Kolberg, 1996; Kolberg *et al*., 1996). Wetlands are certainly Namibia's rarest, and most pressurised ecosystem (Hines and Kolberg, 1996), and most occur outside protected areas (Curtis *et al*., 1998; Barnard *et al*., 1998).

Namibia's only perennial rivers lie along its national boundaries, and most of the rainfall is received in the upper catchments in neighbouring Angola, Zambia, Botswana, Lesotho and South Africa (Bethune, 1998).

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Legally, Namibia does not even share rights to the Orange (Gariep) River with South Africa, as the pre-Independence national boundary was drawn at the northern bank (G. Schneider, 2001, pers. comm.).

On top of this, Namibia's sparse human population is growing rapidly, often faster than any other SADC nation (NPC, 1995), and the government is under economic and policy pressure to reach extremely ambitious targets for national food self-sufficiency, crop and livestock production, and industrial development (Republic of Namibia, 2002).

At the same time, Africa is believed to be the continent most vulnerable to climate change, due to its aridity, poverty, low adaptive human capacity, heavily reliance on natural resources and rain-fed agriculture, vulnerability to increased human disease, and risk of desertification (IPCC, 2001: 234). Namibia is arguably one of the most seriously vulnerable African countries, where vulnerability is defined by projected weather, greenhouse gas concentrations, biophysical and economic indicators (IPCC, 2001: 5-6; CSIR, 2002: 73). Wetland-rich parts of Namibia are predicted to suffer more than dry areas from reductions in annual runoff, along with adjacent parts of Angola, Zambia, Zimbabwe and northern Botswana (IPCC, 2001: 229; CSIR, 2002: xii, 36-38).

Severe climate change, rapid human population growth, and national development targets for industrialisation, agricultural production, and equitable access to water and other natural resources, all pose enormous challenges for water security, and therefore wetland conservation and sustainable use in this young country.

Namibian wetlands in the future

The future of Namibian wetlands does not look good, despite a number of innovative and biodiversity-friendly policy and management instruments (below). It is essential that direct activities (such as the implementation of a well-focused monitoring framework), as well as indirect activities (such as promotion of community-based wetlands management, education and awareness, family planning, and environmentally sustainable land tenure reform) are implemented in order to safeguard wetlands into the distant future.

By the year 2020, Namibia (like most other southern African countries) will experience absolute water scarcity, defined by the United Nations as < 1000 m^3 of available water per capita per year (CSIR, 2002: 37) -- even in the absence of climate change. As a hyper-arid to sub-humid country, Namibia currently has a net water deficit (mean annual rainfall minus potential evaporation) of –4000 mm in the southeast to –1600 mm in the northeast (CSIR, 2002: 36). Moderate climate change scenarios, involving a 15% increase in evaporation and no change in rainfall patterns, are anticipated to put 'severe' additional stress on the water sector. Severe climate change scenarios, involving a 30% increase in evaporation and 30% decrease in rainfall, would have an extremely serious impact on the water sector, wetlands, and all aspects of human development that depend on them (CSIR, 2002: 37). Current dry-month water scarcity in the most populous areas of Namibia (SAf-MA, 2002: 7) will almost inevitably lead to increasing disruption by 2020, as ecologically, economically and politically feasible water supply options start to become exhausted by regional demand.

Future scenarios pertaining to the world's ecosystems tend to differentiate between a "high road" of order, planning and cooperation between people in sound resource management, and a "low road" or "fortress world" where chaos and unequal access to resources rule the day (Sunter *et al*., 1989; Raskin *et al*., 2002; SAf-MA, 2002). These scenario options apply directly to Namibian wetland ecosystems as to any other. A sound planning framework (including a basis for ecological monitoring, data analysis and management) and incentives for cooperation and good management are essential to keep wetlands from being irrevocably degraded or lost.

Threats to Namibian wetlands

Major, direct pressures on Namibia's fragile wetlands include the following (Simmons *et al*., 1991; Hines and Kolberg, 1996; Bethune, 1998):

- water abstraction from perennial rivers, aquifers and ephemeral wetlands;
- water pollution by livestock and people;
- local over-harvesting and unselective harvesting of wetland resources;
- wetland and aquifer pollution through substances used in industry, agriculture and disease control;
- river flow regulation, excessive impoundment and regular draw-down from impoundments;
- coastal and marine industrial development, including harbour activity and oil exploration.

All large state dams in Namibia are built on ephemeral rivers, and Namibia is one of the few countries in the world to impound ephemeral rivers in this way. These state dams provide the bulk water supply for urban development and extremely inefficient irrigated agriculture (Bethune 1998: 65). In addition, most major ephemeral rivers have been extensively impounded, often illegally, by freehold farmers for private agricultural and domestic purposes.

These direct pressures on wetlands result from a number of indirect "drivers," such as human population growth, land tenure systems, limited national and local economic options (e.g., the use of DDT for malaria control), inequitable access to natural resources; and lack of valuation of wetlands as productive and supportive ecosystems. The planned monitoring framework outlined in this paper (below) is designed to address both the direct pressures on, and indirect drivers of, wetland degradation and loss.

The wetlands policy framework

In Namibia, the policy and institutional framework for wetland management can be described as adequate to very good. This paper cannot treat this subject in any detail, but simply lists the key elements.

Namibia's Constitution is among the most progressive in the world, explicitly protecting biological diversity, sustainable use of natural resources, and essential ecological processes, and enshrining principles of sustainable national development. This, Namibia's supreme policy document, has been highly influential in directing national policies, strategies and action plans, legislation, and national development plans.

International conventions provide an important political stimulus and platform for financing. Namibia is a Party to the Ramsar Convention on Wetlands of International Importance, Convention on Biological Diversity (CBD), Convention to Combat Desertification (CCD), United Nations Framework Convention on Climate Change (UNFCCC). It has not signed nor ratified the Convention on Migratory Species (CMS, also called the Bonn Convention), but it monitors and implements its main provisions through national programmes supporting the CBD and Ramsar Convention.

The **Wetlands Working Group of Namibia (WWG)**, of which the authors of this paper are members, is a working group under the National Biodiversity Task Force supporting integrated implementation of the CBD and Ramsar Convention. The WWG also acts as the Ramsar national committee.

Namibia has a rough-draft **national wetlands policy**, to be revised with national participation in 2003. This draft is based on successful principles of several other national policies, and will aim for effective harmonisation within the SADC region. Currently, Botswana is the only other SADC country developing a national wetlands policy, although at least six countries have national water policies, and four have water acts (IUCN-ROSA, 2002:10), including Namibia. However, Namibia's **water policy and act**, while excellent in many respects, pay insufficient attention to water as an environment, rather than simply a human commodity.

Namibia's participatively developed **national biodiversity strategy and action plan, NBSAP**, includes the **national wetlands action plan** authored by the WWG (Republic of Namibia, 2002: 60-63, 109-111). To support better integrated resource management, the NBSAP also includes strategic aims on integrated land and water management (catchment management), environmental change monitoring and analysis, including climate change; sustainable land management; policy integration; capacity building; and related issues. An integrated framework for wetland monitoring and analysis was proposed in Strategic Aim 5.1 of the NBSAP, supported by other Strategic Aims in Chapter 3 on environmental change monitoring, state of the environment reporting (SOER), and the flow of information between the scientific and policy arenas.

Finally, the Ramsar Secretariat has published a preliminary **national wetlands inventory** (Kolberg, 2002), and the Wetlands Working Group has initiated the design and establishment of a **national wetlands database**, housed in the Department of Water Affairs, DWA (a core institutional member of the WWG). This will be fully compatible with other databases of the National Biodiversity Programme, State of the Environment Reporting (SOER) Programme and DWA, and ultimately accessible via the Environmental Information Systems Unit's web portal and metadatabase (http://www.dea.met.gov.na/soer). Public awareness of wetlands and water has been well served by the National Water Awareness Campaign, through publication of popular and semi-popular books for policymakers and learners (e.g. Pallett, 1997; Tarr, 2002).

Regionally, Namibia aims to contribute substantially to initiatives such as the Adaptation Framework for Climate Change, Water and Wetlands (IUCN-ROSA, 2003), the programme "Assessment of Impacts and Adaptation to Climate Change in Multiple Regions and Sectors (AIACC)," and ongoing SADC water management initiatives to reduce resource conflict and regional water scarcity (e.g. SADC, 2000). It is essential that water conservation efforts are a strong feature of strategies to protect southern African wetlands, as many arid countries including Namibia still use water wastefully, especially in the irrigated agriculture, industry and upper-income household sectors (Pallett, 1997). Water supply leakage is a major cause of loss in some areas.

COMPONENTS OF AN INTEGRATED MONITORING AND ANALYTICAL FRAMEWORK

Goal, principles, and scope of the framework

This paper proposes a national framework for wetland monitoring. The overall goal of this monitoring is to provide adequate, policy-relevant data on wetland health and status from a representative network of sites in Namibia, to support effective planning and conservation of wetland ecosystems into the future.

Namibia, like many African nations, is conducting its environmental and water planning without adequate data. This is a dangerous situation for any country, but especially so for arid countries at high risk of desertification and water scarcity. A modest and well-focused wetland ecosystem monitoring framework, leading into sound data analysis, management, and translation into the arena of environmental planning and policy, is essential (Table 1). However, Namibia has extremely limited financial and technical resources, including the time of monitoring personnel. It is therefore a priority to design a modest, adequate and cost-effective framework.

Table 1. Seven principles of the proposed Namibian national wetlands monitoring framework

Principle	Comment
1. Arid nations most need sound ecosystem planning and management	1. Arid nations often have the least resources to do so
2. Ecosystem planning and management need adequate data	2. "Adequate" is a balance between good scientific (spatial / temporal) design, cost-effectiveness and capacity
3. Wetlands are integral parts of landscapes	3. Integrated management and monitoring need land use/ catchment indicators to study impact of broad scale pressures
4. Natural variation is extremely high in arid environments	4. Careful long-term ecological research (LTER) design is needed to distinguish trends from natural variation in SOER. Permanent monitoring sites linked to the Environmental Observatories Network of Namibia (EONN) will be used.
5. Perennial, ephemeral and tidal wetlands require different monitoring methods and design under a single framework	5. Sound management of ephemeral wetlands needs greater precaution, and longer-term datasets than perennial wetlands
6. Wetland health is rooted in ecosystem structure/function	6. The index of biological integrity (IBI) incorporates diversity, trophic structure, abundance and is sensitive to ecological function and stressors, e.g. water pollutants
7. Wetland monitoring must involve specialists and users	7. Community-based and traditional scientific monitoring must be combined. Community Basin Management Committees and their test sites should play a key role

Just as wetland management strategies need to be carefully integrated with land use planning and catchment management, wetland monitoring, too, needs to take into account land use practices in the broader landscape. This framework is thus an integrated one which treats wetlands and catchments in their landscape context.

Overall, a complete wetlands monitoring framework must provide for

- data collection,
- data analysis and synthesis,
- data management, including accessibility, storage, updating, metadata basing and archiving,
- popularisation of analytical results into the planning, policy and awareness arenas.

The third and fourth issues (data management and popularisation) have been well discussed in other papers, including the environmental indicator development and data management processes of the Environmental Monitoring and Indicators Network of Namibia, EMIN (EMIN, 2002; http://www.dea.met.gov.na/data), the draft information access policy of the National Biodiversity Programme, adopted by the Environmental Observatories Network of Namibia, EONN (http://www.drfn.org.na/eonn), and the National Biodiversity Strategy and Action Plan (Republic of Namibia, 2002a; http://www.dea.met.gov.na/data). These two issues are therefore not treated in depth in this paper, and readers are referred to those sources for further information. The discussion below focuses instead on the scope and design of data collection, and the institutional requirements for data collection, management, analysis and synthesis.

The scope and design of data collection

The scope of wetlands to be reflected in this monitoring framework is large, as Namibia has a wide variety of wetland ecosystem types. These range from large and distinctive perennial rivers to varied ephemeral rivers or *omiramba*, lakes, pans, sinkholes and caves, marshes, geothermal or halophytic seeps and springs, estuaries and others (categorised by Bethune, 1998: 61, with species richness and endemism provisionally summarised by Curtis *et al*., 1998: 450). Although not all individual wetlands can be sensibly monitored with existing human and financial resources, it is important to select ecologically representative and potentially pressurised examples of each category for some level of monitoring, and not simply focus on perennial rivers and impoundments which have been the source of bulk water supply. The Wetlands Working Group of the National Biodiversity Task Force is engaged in detailed prioritisation of wetlands in 2002, as part of the implementation of the wetlands action plan in the NBSAP. Along with the development of the Environmental Observatories Network of Namibia, EONN (administered by the EONN steering committee of the National Biodiversity Task Force), a joint identification of wetlands at which permanent monitoring sites exist or can be established will take place in 2003.

Good design of monitoring programmes is not a trivial issue in an arid and highly variable country such as ours. The Wetlands Working Group is now seeking resources to adapt, test and implement existing detailed but simple methods (e.g. Karr, 1981; Hay *et al*., 1996; Taylor and Palmer, 2002), using a variety of Namibian wetlands, ephemeral, coastal and perennial. These methods must be carefully adapted or re-designed to take adequate account of spatial and temporal variability in Namibian wetland ecosystems.

This adaptation and testing process will be done starting in 2003-04, if financing is available, partly through the planned River Health Project (RHP), which will form a major component of this framework. Components of this framework are already implemented, including a number of long-term monitoring programmes (Table 2).

Table 2. Relevant wetland monitoring datasets and activities currently ongoing or planned in Namibia

Activity or dataset[1]	Lead institution / curating institution	Design elements[2] ps	tb	fd	asn
Water sector activities					
Hydrological monitoring	Department of Water Affairs (DWA)	●	x	●	x
Water quality and pollution control	DWA	●	?	●	x
Rural borehole monitoring: depth, chemistry	DWA; Rural Waterpoint Committees	●	x	●	x
Khoichab Basin monitoring	NamWater; DWA; Ministry of Environment	●	●	●	●
Environmental health activities					
State of the Environment Reporting (SOER)	Directorate of Environmental Affairs (DEA)	x	●	●	x
Env'l Observatories Network (EONN)**	EONN of National Biodiversity Task Force	●	●	●	?
River Health Project**	DWA; Namibia Nature Foundation (NNF)	●	●	●	?
National wetlands inventory & database**	Wetlands Working Group (WWG); DWA	●	●	●	?
Ramsar site management planning	National Ramsar Secretariat; WWG	●	●	●	x
Long-term quarterly wetland bird	Ministry of Environment	●	●	●	●
monitoring	Ministry of Fisheries and Marine Resources	●	●	●	●
Long-term perennial river fish monitoring	DWA	●	●	x	x
Long-term water ecology monitoring	DWA	●	●	●	x
Ecological flow requirements modelling**					
Rural resource management activities	Conservancy associations; Min. of Environmt	●	●	●	x
Conservancies - communal and freehold	NNF	●	●	●	●
Every River Has Its People Project II**	Desert Research Foundation of Namibia	x	●	●	x
Ephemeral Rivers Project*	Desert Research Foundation of Namibia	●	●	●	x
Hoanib River Catchment Project *	Desert Research Foundation of Namibia	●	●	●	x
ELAK (Kuiseb River Catchment Project)	Namibia Water Resources Mgmt Review	●	●	●	x
Basin Management Committee test sites	ICZM Committee/ Regional Councils	x	x	x	x
Integrated Coastal Zone Mgmt Programme*	ICZM Committee/ Regional Councils	●	●	?	?
Namib Coast Biodiv. Mgmt (NACOMA)**					
Background datasets	Surveyor-Gen'l; DEA Reg'l Env'l Profiles	●	x	x	x
Time-series aerial & remote sensing images	DWA (Ugab R, Karstveld); Forest Inventory	●	●	●	x
Time-series fixed-point photographs	DEA Env Economics Unit & WILD Project	x	●	●	?
Economic & livelihoods data	DEA Regional Environmental Profiles	●	●	●	x
Regional environmental profile datasets**	Ministry of Lands, Resettlement, Rehabilit'n	●	x	?	x
Regional Land Use Plans**					
Regional programmes	IUCN Regional Office for Southern Africa	?	●	●	?
Zambezi Basin Wetlands Conserv'n RUP*	IUCN ROSA	●	?	?	?
Adaptive Framework for Climate Change,					
Water and Wetlands**	Southern African Development Community	?	?	?	?
SADC Shared Watercourses Protocol	Okacom, Zacplan, Kunene JPTC committees	?	?	?	?
Transboundary basin management					

[1] Categories in this column are subjective as many projects serve multiple purposes. [2] ● = yes; x = no;? = uncertain or still to be determined. ps = permanent monitoring sites or spatially referenced datasets; tb = includes taxon-based indicators; fd = formal monitoring design or method; asn = adequate spatial network (as perceived by authors). * project completed **project not yet fully funded or developed

Indicator-based monitoring and analysis

Existing long-term wetland datasets from Namibia include bird numbers and richness, freshwater fish richness, hydrological flow data, invertebrate richness and standard indices of water quality, as well as a variety of short-term socio-economic data on rural livelihoods and use of wetland resources (Table 2).

This National Integrated Wetland Monitoring Framework will feed data directly into the State of the Environment Reporting (SOER) process, by which the Minister of Environment and Tourism will publish and present to Parliament information on a regular, probably biannual, basis (Nakanuku *et al*., 2001; Noongo *et al*., 2002). SOER indicators have been provisionally identified, refined, scored and elaborated by a participatory and consultative process of the Environmental Monitoring and Indicators Network (EMIN), coordinated by the SOER Programme staff of Namibia's Environmental Information Systems Unit (Nakanuku *et al*., 2001; Noongo *et al*., 2002). Biodiversity indicators in particular have been developed in close collaboration with the National Biodiversity Programme, including members of its terrestrial and wetland ecosystems working groups.

Indicator criteria

Monitoring is an expensive process. It needs to be carefully focused, with clearly defined criteria for indicators, to achieve its purposes and avoid wasted years of costly effort. Monitoring staff need basic training in both the goals and the minutae of the programme, and results must be regularly translated into popular recommendations, so that politicians, donors, resource users and other decision makers all support the monitoring effort.

For wetland monitoring data to be effective in terms of detecting and describing environmental change in space and time, the chosen indicators need to meet certain criteria. Nakanuku (2003, MSc thesis in prep. University of the Witwatersrand) has summarised questionnaire responses from Namibian specialists on the best criteria for selection of terrestrial biodiversity indicators, distilling a list of perhaps 12 core criteria. However, most of these can be further 'boiled' to about five – simple, cheap, sensitive, repeatable, and maximally informative.

All data, socio-economic or biophysical, need to be sensitive to small changes, repeatable, simple to collect without complex apparatus or training, and cost-effective. Biological indicators in addition need to be easily recognised, preferably without recourse to expert taxonomic identification unavailable within-country. We also argue that sampling indicator species from top, middle and bottom trophic levels is most useful for evaluating ecosystem integrity (e.g. Hay *et al*., 1996).

Two (avian) examples of time-series wetland indicator use

During a recent period of guerrilla activity in northeast Namibia, Angolan UNITA insurgents moved across the Kavango (Okavango) River from December 1999 to July 2002. Namibians resident along the river moved away from it, for fear of murder, kidnapping, and stock theft. Local observers noted an immediate change in the bird community: richness more than doubled and abundance of birds tripled within months (Table 3). Was this change due to reduced disturbance of fish eagles by people, or reduced pressure by local people on river fish? Sampling by C. Hay (unpublished data) before and after this spell of guerrilla activity indicate that large fish were absent from the river beforehand, and made an equally dramatic comeback during this period. It seems plausible that the return of fish eagles and other wetland bird species was thus due to improved fish availability, and not necessarily from changes in direct disturbance. Fish eagles, as easily recognised top predators, can act as a simple guide to the health of a river system.

Table 3. Fish Eagles (*Haliaeetus vocifer*) as potential indicators of (Okavango) River health in Namibia

	People present (n = 7 counts) (April 1990 - Dec 1999)	**People absent** (n = 5 counts) (Jan 2000 to July 2002)
Eagle density *(birds/10km of river)*	**0.00** eagles in 7 counts	**3.00** (range 1.67 - 5.00)
Mean species richness	**17** spp (range 11 – 39)	**37** spp (range 23 - 48)
Mean wetland bird abundance *(birds/ 10 km of river)*	**321** (range 135 - 560)	**940** (range 208 - 1545)

The second example concerns the use of national wetland bird counts. For 12 years, Namibian observers have been part of Wetlands International's pan-African wetland health monitoring programme. Namibia's Ministry of Environment and Tourism and volunteer observers monitor bird populations at up to 83 wetlands throughout Namibia every January and July, with top priority sites monitored quarterly (Jarvis *et al*., 2000). Can these results be used to monitor wetland health?

Birds have been widely debated as indicators of overall biodiversity, but certainly are useful as indicators of ecosystem health and productivity (Beintema and van Vessem, 1999). Fish eagles and kingfishers are good indicators of wetland health in some contexts. Both are top predators. They rapidly leave (or die) when wetlands are pressurised by direct human activity, over-fishing or pesticide pollution, and rapidly return when conditions improve (Table 3, and numerous case studies of piscivorous raptors in North America). They are year-round territorial residents. As top predators, they can be expected to give an overall picture of healthy fish populations. All six of Namibia's perennial border rivers have been monitored for bird population fluctuations. Table 4 gives overall results for wetland birds, and Table 5 gives densities of fish eagles per 10 km of river.

Table 4. Namibia's rivers compared: linear density of wetland birds (excluding passerines and kingfishers) and species richness from Namibia's six main perennial rivers[1]

River	Length surveyed (km)	Number of birds (survey date)	Linear density birds/10 km	Species richness	Observers
Lower Orange[a]	50	130 (Dec 96)	26	16	R. Simmons
	10	34 (Apr 97)	34	10	R. Simmons
	160	705 (Jul 91)	44	20	Allan & Jenkins,1993
	64	248 (Mar 00)	39 □ **= 36 ± 8**	18	A. Hester, S. Edelstein
Cunene	5	14 (Apr 93)	28	8	D. Ward
	6	18 (Apr 94)	30	8	D. Ward
	22	136 (Nov 97)	63	26	R. Simmons
	3.6 (SerraC)	36 (Nov 00)	100	11	R. Simmons
	11.3 (2 from mth)	269 (Nov 00)	238 □ **=91.8 ± 5**	8	R. Simmons
Kwando	5	19 (Jul 91)	38	9	J. Tagg
	5	28 (Jan 92)	56	10	J. Tagg
	5	144 (Jan 95)	288	31	M. Holstenson
	5	178 (Apr 96)	356	30	M. Lifasi
	5	104 (Feb 97)	208	22	M. Holstenson
	5	193 (Jan 98)	386 **= 310 ± 79**[b]	27	W. Oeder
Kavango[b]	2	71 (Apr 90)	355	11	R. Simmons
	2	27 (Jul 92)	135	10	P. Lane
	2	112 (Jan 93)	560	23	P. Lane
	2	62 (Jan 95)	310	17	P. Lane, M. Paxton
	2	43 (May 95)	215	10	P. Lane, M. Paxton
	2	103 (Apr 96)	515	11	P. Lane, M. Paxton
	51	811 (Dec 96)	159	39	D. Allan
	12	249 (Aug 00)	208 □ **= 307**	23	M. Paxton, L. Sheehan
	6?	420 (Jan 01)	700	20	M. Paxton, L. Sheehan
	6	927 (Jul 01)	1545	48	M. Paxton, L. Sheehan
	6?	700 (Jan 02)	1167	48	M. Paxton, L. Sheehan
	6?	647 (Apr 02)	1078	44	M. Paxton, L. Sheehan
Zambezi	10	221 (Jan 98)	221	22	E. Taylor
	10	429 (Feb 99)	429	32	V. Sparg, D. Sparg
	35	1690 (Jul 98)	488	34	L. Scheepers
	10	251 (Apr 00)	251 □ **=347±131**	20	R. Sparg, V. Sparg
	5-10	677 (Jul 00)	677	36	V. Sparg
	5	469 (Apr 01)	938	25	V. Sparg
	5	434 (May 02)	868	36	V. Sparg
Chobe	23	2091 (Aug 98)	925	38	R. Simmons *et al.*[c]
	40-55	1743 (Dry)[d]	378	36	Herremans, 1999
	40-55	399 (Wet)[e]	86	27	Herremans, 1999
	8	3303 (Sept 99)	4129	43	M. Paxton
	10	5220 (June 00)	5220 □ **= 1652**	40	M. Paxton, L. Sheehan
	??	1224 (Feb 02)		40	M. Paxton, L. Sheehan

*Linear density in bold is given as mean ± 1 S.D. The first two rivers cross the Namib Desert for over 300 km, traversing rocky gorges and sandy plains. The remaining rivers are tropical in origin, traversing higher rainfall areas through flat woodland savannas. Note the ten-fold higher densities of the tropical vs. desert rivers.

a. Middle sections only - the lower reaches within 20 km of the mouth support higher densities.

b. The first counts (1991 and 1992) are not included in this average because they may have been pesticide influenced.

c. Includes M. Paxton, A. Jarvis, T. Robertson, D. and K. Sharpe.

d Mean of 6 counts in the dry season (June-August 1993-1994)

e Mean of 3 counts in the wet season (December-March 1993 –1994)

Table 5. Fish Eagle densities from Namibia's six main perennial rivers[1]

RIVER	Length surveyed-km	Fish Eagles counted	Linear density eagles/10 km	Observers
Lower Orange[a]	 5.01e+08	5 (Dec 96) 2 (Apr 97) 24 (Jul 91) 11 (Mar 00)	1.00 2.00 1.50 1.72 □ = **1.56**	R. Simmons R. Simmons Allan & Jenkins, 1993 S. Edelstein, A. Hester
Cunene	5 6 21.7 3.6 (serra	1 (Apr 93) 1 (Apr 94) 3 (Nov 97) 0 (Nov 00)	2.00 1.67 1.38 0.00 □ = **1.26**	D. Ward D. Ward R. Simmons R. Simmons
Kwando	 555555	1 (Jul 91) 1 (Jan 92) 3 (Jan 95) 4 (Apr 96) 4 (Feb 97) 1 (Jan 98)	2.00 2.00 6.00 8.00 8.00 2.00 □ = **6.00** [b]	J. Tagg J. Tagg M. Holstenson M. Lifasi M. Holstenson W. Oeder
Kavango	2 2 2 2 2 2 51 **12 [war]** **6 [war]** 6 6	0 (Apr 90) 0 (Jul 92) 0 (Jan 93) 0 (Jan 95) 0 (May 95) 0 (Apr 96) 0 (Nov 96) **2 (Aug 00)** **2 (July 01)** 3 (Jan 02) 2 (Apr 02)	0 0 0 0 0 0 0 **1.67** **3.34** **5.00** **3.34 □ = 1.25**	R. Simmons P. Lane P. Lane P. Lane P. Lane P. Lane D. Allan M. Paxton, L. Sheehan M. Paxton, L. Sheehan M. Paxton, L. Sheehan M. Paxton, L Sheehan
Zambezi	10 10 34.6 10 5 5 5	1 (Jan 98) 2 (Feb 99) 22 (Jul 98) 2 (Apr 00) 2 (Jul 00) 2 (Apr 01) 3 (May 02)	1.00 2.00 6.36 2.00 4.00 4.00 6.00 □ =**3.62**	E. Taylor V. Sparg, D. Sparg L. Scheepers R. Sparg, V. Sparg V. Sparg V. Sparg V. Sparg
Chobe	22.6 277 140 10 12	5 (Aug 98) Dry (93-94) Wet (93-94) 5 (Jun 00) 3 (Feb 02)	2.21 2.7 2.6 5.0 2.5 □ = **3.13**	R. Simmons *et al*.[d] Herremans, 1999 Herremans, 1999 M. Paxton, L. Sheehan M. Paxton, L. Sheehan

[1] The first two rivers both cross the Namib Desert for over 300 km, while the remaining four traverse higher rainfall areas through flat woodland savannas. Note the low abundance of Kavango River Fish Eagles and the change during war.
a. Middle sections only - the lower reaches within 20 km of the mouth support higher densities
b. Does not include the first two counts because they may have been pesticide influenced
c Includes M. Paxton, A. Jarvis, T. Robertson, D. and K. Sharpe.

Tables 4 and 5 show that (i) rivers crossing arid regions (Cunene and Orange/Gariep) show lower species richness and a ten-fold lower abundance than do tropical rivers (Table 4); (ii) fish eagles (Table 5) are similarly two- to four-fold less abundant in arid than in tropical regions. Bird species richness changes in these rivers form important time-series data on river health.

The next step in our Namibian process is a thorough review of the methodologies and statistical considerations of the sampling design of existing monitoring programmes. That paper will make specific recommendations to streamline or harmonise programmes, and identify spatial, temporal, and content gaps to be filled.

IMPLEMENTATION AND INSTITUTIONAL REQUIREMENTS

Database design and management

The National Wetlands Database, based on a MS-Access platform, is housed and maintained at the Water Environment Section of the Department of Water Affairs (DWA). It has been designed by database specialists of the Environmental Information Systems (EIS) Unit of the Directorate of Environmental Affairs with detailed inputs from the Wetlands Working Group, and is fully compatible with other biodiversity-related databases held by the EIS Unit, and maximally operationally compatible with hydrological and other databases of the Department of Water Affairs. Its chief products will be updated national and local wetlands inventories; inputs to the biannual State of the Environment Reports (SOER) and other national and international ecosystem analyses; wetland maps; checklists; management planning data for local and national users; and bibliographic updates, among others. Data will be analysed by the DWA in collaboration with the WWG and EIS Unit.

Monitoring teams

Countries like Namibia cannot afford to carry out environmental change monitoring using its very limited numbers of professional ecologists and socio-economists alone. It is likely that core government monitoring capacity may decrease further, rather than increase, and that project teams such as the Environmental Learning and Action in the Kuiseb (ELAK) and Basin Management Committee members (Table 2) may assume a more prominent role. However, we are concerned that the highly variable nature of Namibia's wetlands requires a long-term approach to monitoring, analysis and popularisation which will not be sustained by short-term donor-funded projects. For this reason, we propose that a flexible and mobile 'Biodiversity Inventory Team' of motivated young professionals and parataxonomists be established to support, and work under the direction of, specialists associated with the National Biodiversity Programme. This should obtain core funding from Namibia's Environmental Investment Fund for a ten-year period and recoup 40% or more of its costs from projects and contracts. It should act to support existing, constrained efforts within Government and NGOs, and train specialists of the next generation through productive mentorships.

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