Review of international/continental wetland resources

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1 Introduction

This component of the Global Review of Wetland Resources and Priorities for Wetland Inventory (GRoWI) reviews international and continental wetland inventories and other global wetland sources, in order to address the project aims. It covers all regions of the world, based on the seven regional categories used by the Ramsar Wetlands Convention – Africa, Eastern Europe, Western Europe, North America, Neotropics, Asia and Oceania.

This international/continental scale review contributes to quantification of the global wetland resource by compiling and reporting on existing wetland areal estimates and studies of wetland loss and degradation. It identifies knowledge gaps and makes recommendations as to priority areas for future wetland inventory effort, and preferred format for inventories in future.

2 Information sources

A broad range of inventories and other global wetland information sources were reviewed in this component of the GRoWI project, including global atlases for particular wetland types, regional inventories, journal and conference papers, books and web pages. Information sources were identified through literature searches, personal communication with relevant agencies and experts, and requests for assistance via wetland-related electronic mail forums.

Forty-five sources have been assessed and entered into a database (Microsoft Access 97). Others that were assessed and considered to contain too little relevant information were not included in the database, but all relevant information has been extracted and used in this written report, eg OECD (1996). References have been compiled in a bibliography. Some sources have proved difficult to locate or obtain, and new sources are being identified continually, so more could be assessed in future. Other sources such as continental or global scale maps or remotely sensed imagery have not been assessed; Sahagian and Melack (1996) have identified these as a source of inventory information that requires assessment.

2.1 Wetland coverage

As the sources reviewed have a broad-scale approach to wetlands, all were collations of information from a range of other regional, national and sub-national sources. They cover a wide range of wetland types, based on the definition of wetlands determined for the Ramsar Convention, namely ‘areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres’. Coral reefs and seagrasses have been included in this review.

Sources reviewed relate to the following wetland types: wetlands in general (26); coastal and marine wetlands (11) including 7 sources relating to mangroves and/or coral reefs; peatlands and mires (3); artificial wetlands and artificial beaches (3); and others (2) which relate to important bird areas and protected areas respectively.

2.2 Details of inventory sources

2.2.1 Perspective

Thirty of the sources reviewed gave a global or supra-regional perspective, providing information on wetland inventory and/or wetland loss. The remainder of sources gave a continental (in the case of Australia) or regional perspective, covering wetlands in general or specific wetland types in Africa (3), Neotropics (1), North America (1), Oceania (6) and Asia (4).

2.2.2 Age

The sources reviewed were published in 1980–85 (7), 1985–90 (12), 1990–95 (13) and 1995–98 (13). It can be expected that wetland area and/or wetland loss data from the earlier sources is now out of date, so the most recent data, eg post-1990, has been reported if available.

2.2.3 Format

Of the 45 sources reviewed, just two were electronic databases accessed via the World Wide Web (WWW), all others being paper publications. The majority of sources were reports or publications by non-government organisations (NGOs) (18) and books (12). The remainder were conference presentations or proceedings (7), journal articles (4) and government reports or publications (3).

The majority of sources reviewed (25) were non site-based inventories, reviews or overviews of wetland information. Sixteen sources were site-based inventories, and four were non site-based but included detailed descriptions of one or more wetland sites as case studies. Fourteen sources in total were true wetland directories or inventories.

2.2.4 Language

All sources reviewed had been published in English. It is possible that some supra-regional or continental sources have been published in languages other than English and have therefore been missed by this review, but it is believed that they are few. One such example is the South American Wetlands Assessment published recently in Spanish (I Davidson pers comm 1998), a copy of which has not been obtained in time for inclusion in this report. It appears the majority of large-scale reviews and inventories are published in one or more languages including English, ensuring a wide international distribution and readership.

2.2.5 Data storage

The method of data storage was mostly on paper only (13) or unspecified by the author/s (15). Nine sources stored data in electronic form, either on digital maps, database or WWW. Two sources stored data in a Geographic Information System.

2.2.6 Data method

The method of data collection was often poorly specified, if at all, but the vast majority of sources reviewed were collations (41), while just three were collations of information supplemented with remote sensing and/or ground survey (Gopal et al 1982, Frayer 1991, Spalding et al 1997), and one reference was entirely based on ground survey and remote sensing data (H Kirkman unpubl).

2.2.7 Implementing agency

Over half (24) of the inventories and reviews assessed were conducted by international NGOs. Others were carried out by academic agencies (8), national government agencies (4), and consulting agencies (1). The remaining eight sources were specified as ‘other’ or ‘unknown’, most being compilations of material from many contributors (and hence agencies) from around the world.

2.2.8 Funding sponsor

Funding sponsors varied, including international NGOs (12), national NGOs (2), national government agencies (9), and private companies (3). Six sources received joint sponsorship from combinations of international and national NGOs, international and national government agencies, and academic or private agencies. The funding sponsor was unspecified in 13 of the sources assessed.

3 Extent and distribution of wetlands

Sources reviewed provide data on extent and distribution of wetlands at various scales, from global estimates to the areal extent of particular wetland types at specific sites. There is considerable inconsistency in the information obtained for review, with data unavailable for some sites or countries due to a lack of adequate inventory or maps. Estimates obtained have been tabulated, including global wetland area (table 1), regional wetland areas (table 2) and national wetland areas (table 3).

Dugan (1993) provides a global estimate of 4 million km^2 (400 million ha) for peatlands (table 1), and presents some general wetland areas for Indonesia, Canada, Alaska, Mexico and the Caribbean (tables 2 & 3). Of particular note is the total of 1.4 million km^2 (140 million ha) of wetlands in western Canada and Alaska, which is said to equal one quarter of the world's total wetland area. Unfortunately, the method for this calculation is unclear and original data are not provided, but this statement implies that the world's wetland area is an estimated 5.6 million km^2 (560 million ha). Dugan (1993) uses the Ramsar definition of wetlands, and refers to non-marine wetlands only. Separate methane-emission studies have calculated the global extent of natural freshwater wetlands as 530 million ha (Matthews & Fung 1987), and 570 million ha (Aselmann & Crutzen 1989) respectively. The global distribution of wetlands has been mapped by NASA (1999), using data from Matthews and Fung (1987).

As part of an overview of wetland inventory, ecology and management, Whigham et al (1993) provide wetland area estimates for parts of Africa, the Mediterranean region, northern Australia, Papua New Guinea, South Asia, Canada, Greenland, United States of America, Mexico and tropical South America. This series was intended to supplement earlier regional inventories and directories, with global coverage and emphasis upon countries and wetlands of particular significance. Regional and national estimates from Whigham et al (1993) are included in tables 2 and 3 (listed as Britton & Crivelli 1993, Denny 1993, Glooschenko et al 1993, Olmsted 1993, Wilen & Tiner 1993).

Wetland directories for Asia (Scott 1989), Africa (Hughes & Hughes 1992), Middle East (Scott 1995), Neotropics (Scott & Carbonell 1986) and Oceania (Scott 1993a) provide areas and descriptions for individual wetland sites, with some data by wetland type at a national or continental scale.

Wetlands on the Ramsar Convention Bureau List of Wetlands of International Importance are generally well-inventoried, but note reservations on the completeness of this dataset identified by Pedretti (1997). The Ramsar Information Sheet is a standardised document for recording data on Ramsar wetland sites, and provides a general description of the wetland site, but was not designed to detect changes in ecological character and is at present unsuited to perform such a function. For the Ramsar Information Sheet (and hence the Ramsar Database) to be more useful for inventory and monitoring of Ramsar sites, it would need re-designing (Pedretti 1997). Ramsar site details are stored in the Ramsar Database and published regularly (Jones 1993a,b,c, WCMC 1990, Frazier 1996). As of 30 January 1999, Ramsar-listed wetlands total 965 sites covering 70 471 806 ha (D Peck pers comm 1999) (table 1). It is likely that future changes in format and publication method, eg WWW, will increase accessibility and improve the effectiveness of these directories as a source of wetland data and as a tool for wetland management.

Aside from wetland-specific directories, publications such as Grimmett and Jones (1989) and IUCN (1994) are useful sources of area data and inventory information for some wetland habitats, although their main emphasis is other than wetlands. Grimmett and Jones (1989) detail important bird areas in Europe, which includes wetland habitats such as rivers, lakes, islands and coastal wetlands. The recent South American Wetlands Assessment (published in Spanish only, a copy of which was not obtained in time for inclusion in this review) also assessed wetlands largely on the basis of their importance to birds. As a result not all wetlands of importance are included, and as such it is crucial to take the objectives of this and similar inventories into consideration when using the data (L Naranjo pers comm 1998).

IUCN (1994) provides site descriptions of protected areas throughout the world, including some area estimates for inland and marine wetlands, eg Sundarbans National Park in India, Egypt's Ras Mohammed National Park, Victoria Falls National Monument in Zimbabwe and Haleji Lake Wildlife Sanctuary in Pakistan.

3.1 Freshwater wetlands

The global extent of natural freshwater wetlands is calculated by Matthews and Fung (1987) as 530 million ha, and by Aselmann and Crutzen (1989) as 570 million ha, forming the basis of their methane-emission studies (table 1). These figures are similar, especially when it is considered that they were each calculated using different methods, and are approximately double earlier global wetland area estimates (Lieth 1975, Whittaker & Likens 1975, Ajtay et al 1979). The huge discrepancy with earlier estimates is due to the fact that the two recent studies used a broader definition of methane-producing wetlands, including seasonal and permanent freshwater ecosystems, either peat-forming or not (Aselmann & Crutzen 1989), and small ponded wetlands (Matthews & Fung 1987). Saltwater wetlands are excluded as their methane production is usually insignificant (Aselmann & Crutzen 1989), and so other sources must be examined in order to determine the true global extent of wetlands under the broad Ramsar definition.

Estimates of total extent of freshwater wetlands also vary on a regional basis, partly due to the difficulty of defining the extent of permanent and seasonal wetlands, eg swamps and floodplains. Denny (1985) reports that Africa has a total of 345 000 km^2 (34.5 million ha) of freshwater wetlands, while Aselmann and Crutzen (1989) estimate that permanent and seasonal wetlands in Africa combined total 356 000 km^2 (35.6 million ha). Nevertheless, these figures indicate that approximately 1% of Africa's surface area is freshwater wetland.

South America has an estimated total of 1.52 million km^2 (152 million ha) of freshwater wetlands (Aselmann & Crutzen 1989). The same authors also estimate that Europe has 6700 km^2 (670 000 ha) of various freshwater wetland types, noting that much of the original wetland area has been lost to development.

3.1.1 Extent and distribution of peatlands

There is an estimated 4 million km^2 (400 million ha) peatlands worldwide (Dugan 1993) (table 1). Taylor (1983) provides national peat areas and percentage of land surface area, although some of these estimates of peat area are considerably lower than more recent estimates (table 4). The current estimate for total area of undeveloped tropical peatland is 30–49 million ha, approximately 10% of the global peatland resource (Maltby et al 1996). Well over half is located in Southeast Asia, principally in Indonesia. Rieley et al (1996) provide summary statistics for the regional distribution of tropical peatlands (table 5). There is no agreement on the extent of the tropical peatland resource, due to differences in the definition of peat and peat soils, and the survey techniques employed. Rieley et al (1996) states that

Indonesia has the largest area of tropical peatlands, with the highest estimate of 27 million ha placing Indonesia fourth in the world league table of peatland by area, behind the former USSR, Canada and the United States of America.

Freshwater boreal wetlands cover an estimated 600 000 km^2 (60 million ha) of Alaska, and over 20% of central Canada. The wetlands are predominantly peatlands, but include a wide range of wetland types, including delta marshes, floodplain swamps and moist and wet tundra (Dugan 1993). Aselmann and Crutzen (1989) estimate the total area of mires in Alaska as 250–400 000 km^2 (25–40 million ha), mostly fens and bogs.

Zoltai and Pollett (1983) give the approximate area of wetlands in Canada as 1.7 million km^2 (170 million ha), defined as 'areas where wet soils are prevalent, having a water table near or above the mineral soil for most of the thawed season, supporting a hydrophilic vegetation, and pools of open water less than 2 metres deep'. Aselmann and Crutzen (1989) estimate that Canada's wetlands cover a total of 1.27 million km^2 (127 million ha), 95% of which are bogs and fens. Estimates provided by Cox (1993) concur, giving Canada's total wetland area as 127 199 000 ha, of which greater than 111 million ha is peatland.

Dugan (1993) provides areal extent of peatlands in many countries, notably Canada (70% of wetlands in eastern Canada are peatlands) and northern Europe (Sweden and Norway contain 60 000 km^2 (6 million ha) of bogs and fens). One-sixth of Sweden's land area is covered by peat, even if thin, including 20 000 km^2 (2 million ha) of wooded wetlands and over 50 000 km^2 (5 million ha) of open mire, mostly treeless (Sjörs 1983). Finland used to have over 100 000 km^2 (10 million ha) of mires, 30% of the country's land area, but 55 000 km^2 (5.5 million ha) has been lost to development (Ruuhijärvi 1983). Taylor (1983) provides peat areas for Great Britain and Ireland, specifically England (361 690 ha), Scotland (821 381 ha), Wales (158 770 ha) and Ireland (1 342 450 ha), totalling 26 842.91 km^2 (2 684 291 ha).

Peatlands in the former Soviet Union cover 830 000 km^2 (83 million ha), including 39 million ha (50% land area) in western Siberia. The total peat resources in this region are huge, estimated at 66% of the world's peat deposits (Botch & Masing 1983). Aselmann and Crutzen (1989) give a total wetland area of 1 500 000 km^2 (150 million ha) for the former Soviet Union, of which 1 450 000 km^2 (145 million ha) are bogs and fens.

China has an estimated 31 000–34 800 km^2 (3.1–3.48 million ha) of virgin peatlands, the majority located in the extreme north-east of the country (Aselmann & Crutzen 1989).

Legoe (1981) estimates Australia's peatland resource as 0.04% of the continent's land surface area, totalling 3072.92 km^2 (307 292 ha), although no areas are given for individual peatland sites in Australia. Yet Taylor (1983) estimates Australia's peat area at just 150 km^2 (15 000 ha), 0.002% of the land surface area. The difference may be due to the respective definitions of peatland, which were not detailed by either source.

Peat resources in South America and Africa are relatively poor. In Brazil, peatlands cover 1000 km^2 (100 000 ha), 0.01% of total land area (Junk 1983). African peatlands are very small areas and mostly low grade peat (Thompson & Hamilton 1983). Peat reserves in Central and East Africa are an estimated 430 ha (Denny 1985).

3.1.2 Extent and distribution of swamps

Swamps are often difficult to separate from other wetland types, and may include peatlands, bogs, flooded forest, etc. In this review all areas of wetland described as 'swamp' in their respective reference source have been reported, but with no attempt to choose a particular definition of the wetland type, or to separate the variety of definitions and information available.

Aselmann and Crutzen (1989) calculated the global area of bogs (1.9 million km^2), fens (1.5 million km^2), swamps (1.1 million km^2) and floodplains (800 000 km^2). They calculated the global area of truly permanent swamps, marshes and floodplains as 300 000 km^2 (30 million ha).

Africa has an estimated total of 345 000 km^2 (34.5 million ha) of wetlands (1% land surface area), including a number of very large swamp systems (Denny 1985). The Upper Nile Swamp covers 92 000 km^2 (9.2 million ha) including floodplain, of which 40 000 km^2 (4 million ha) is permanent swamp. Lake Bangweulu has 6000 km^2 (600 000 ha) of swamp and 6000 km^2 (600 000 ha) of floodplain. The swamps and islands of the Okavango Delta cover 16 000 km^2 (1.6 million ha). In Uganda there is a network of swamps over 11 800 km^2 (1.18 million ha), 6% of the total land surface area. Zambia has wetlands over 20% of its land surface to the total of 750 000 km^2 (75 million ha), including dambos (35 000 km^2), pans, swamp flats (Gopal et al 1982). Three percent of Zambia's land surface area is covered with swamps, totalling 24 000 km^2 (2.4 million ha) (Denny 1985).

Thompson and Hamilton (1983) provide areas for seven of Africa's largest swamps, which total over 60 000 km^2 (6 million ha) of permanent swamp and greater than 400 000 km^2 (40 million ha) of seasonally inundated swamps. They report a 1973 estimate of 340 000 km^2 (34 million ha) of tropical swamps in Africa, noting that this estimate is perhaps underestimated by up to 30%. They consider an estimate of the same date of 85 000 km^2 (8.5 million ha) for headwater swamps in Africa to be accurate. Further areal data for swamps, floodplains and shallow waterbodies of Africa are provided in Whigham et al (1993) and summarised in table 2.

South America is another region with vast areas of swamp, for example the Amazon River and its tributaries which Junk (1983) estimates has a catchment area of 7 million km^2 (700 million ha). It is estimated that there are 300 000 km^2 (30 million ha) of floodplains along the Amazon River and its tributaries, with an extra 1 million km^2 (100 million ha) of small river and stream floodplains in the Amazon Basin, much of it rainforest (Aselmann & Crutzen 1989). The small river floodplains in the Amazon basin contribute in a large part to the global area of 700 000 km^2 (70 million ha) of wetlands with no defined inundation period or unknown seasonality identified by Aselmann and Crutzen (1989).

It is estimated that the former Soviet Union has a total wetland area of 1.5 million km^2 (150 million ha), of which 65 000 km^2 (6.5 million ha) are swamps and marshes (Aselmann & Crutzen 1989).

Britton and Crivelli (1993) provide minimal estimated areas for Mediterranean wetlands including freshwater marsh, forested wetland and non-tidal salt marsh (table 3). However, they note that problems arise when inventorying wetlands in the Mediterranean region, eg difficulties in distinguishing non-tidal salt marsh from the larger wetland units in which it occurs (such as saline coastal lagoons and athalassic salt lakes), and the greatly reduced and fragmented distribution of freshwater marshes and forested wetlands.

Scott (1995) provides information on the extent and distribution of wetlands in the Middle East, including the Mesopotamian Marshes, a vast network of marshes covering 15 000 km^2 (1.5 million ha) in the middle and lower basin of the Tigris and Euphrates Rivers in Iraq. Until recently at least, these were considered the most extensive wetland ecosystems in the Middle East.

3.1.3 Extent and distribution of lakes and lagoons

Lakes contribute little to the global area of wetlands when compared with other wetland habitats such as peatlands. Aselmann and Crutzen (1989) calculate that the global area of lakes (12 million ha) and marshes (27 million ha) combined equal only 9% of the total wetland area.

Gopal and Wetzel (1995) contain information on the area of lakes, lagoons, reservoirs and other wetland types in developing countries. For example, Bangladesh has 36 663 km^2 (3 666 300 ha) of aquatic habitats, including rivers (217 135 ha), tributaries (262 600 ha), beels and haors (114 793 ha), oxbow lakes (5488 ha), seasonal floodplains (2 832 792 ha), and Kaptan Lake (68 800 ha).

Whigham et al (1993) contains some area estimates for African lakes and reservoirs. Taub (1984) presents information and areal data on lakes, reservoirs, rice fields, swamps and floodplains in many countries around the world.

Little information was available on salt lakes in continental and international inventories reviewed, although Gopal and Wetzel (1995) provide data on endorrheic depressions with a permanent salt layer which cover more than 6000 km^2 (600 000 ha) of Tunisia. Williams (1984) provides some information on saline lakes in Australia, but no figures for total area. Also in Taub (1984), are reports on the saline lakes of Canada (Hammer 1984) and Argentine, where the largest saline lagoon is Mar Chiquita at 1850 km^2 (185 000 ha) (Bonetto & Persia 1984). Whigham et al (1993) provide some information on the Kanem Lakes, including many small salt lakes 200 m^2 – 2 km^2 in area, in the northeast region of Lake Chad basin.

Williams (1998) describes the geographical distribution of salt lakes in Europe, North and South America, Africa, Asia, and the Australian continent, with brief mention of salt lakes in Antarctica and the Arctic region. Case studies are presented which provide areal estimates for the Caspian and Aral Seas (429 140 km^2 and 68 000 km^2 respectively) in Central Asia, Qinghai Hu (4437 km^2) in China, the Dead Sea (940 km^2) of Israel and Jordan, Australia’s Lake Corangamite (251.6 km^2), Mono Lake (158–223 km^2) in the United States of America, and Mar Chiquita (1960–5770 km^2) in northern Argentina.

3.2 Coastal and marine wetlands

As the definition of wetlands adopted for this review includes coastal and marine wetlands such as coral reefs, seagrasses and mangroves, there has been considerable emphasis upon locating inventories that could provide areal estimates for these wetland habitats. As ‘exclusively marine systems’, coral reefs and seagrasses have been excluded from key regional wetland directories such as Scott (1989), Scott (1993a), Scott and Carbonell (1986) and Scott and Poole (1989). A literature search and requests for information through relevant channels was successful in obtaining information sources relating to coral reefs (Wells et al 1988, WCMC 1998, WRI 1998) and mangroves (Ellison 1994, 1996, Saenger et al 1983, Spalding et al 1997, WCMC 1998).

Bird and Schwartz (1985) have mapped the world’s coastline, approximately 1 million km long, noting coastal features of mostly geomorphological interest. This source is potentially of use in monitoring coastal changes on a global scale. Couper (1983) and Elder and Pernetta (1996) provide an overview of the world’s marine wetlands as part of an atlas of the oceans.

3.2.1 Extent and distribution of coral reefs

Of the marine wetlands, coral reefs in particular are receiving much-needed attention, and considerable effort is being directed towards enhanced inventory and monitoring for coral reefs at a global scale (A Alling pers comm 1998). Electronic inventories and bibliographic databases for reefs and mangroves such those developed by the World Conservation Monitoring Centre (WCMC 1998), World Resources Institute (WRI 1998), and the International Center for Living Aquatic Resources Management (ICLARM 1998) are highly accessible on the WWW. They provide maps, area estimates and key information, where available, for coral reefs and mangroves around the world. These sources, if regularly updated, are a good indicator of information gaps and priority areas for future research.

Sheppard and Wells (1988) note that the exact areal extent of coral reefs in the world is difficult to estimate, but quote an estimate from 1978 of 600 000 km^2 (60 million ha) of reefs to a depth of 30 metres. Some 60% of this area is in the Indian Ocean region – 30% in the Indian Ocean, Red Sea and Gulf, and 30% in the Asiatic Mediterranean. WCMC (1998) gives the global area of coral reefs as 300 000–600 000 km^2 (30–60 million ha), while noting that its reef area estimates are derived from a wide range of sources at various levels of scale and quality (table 1).

As part of an overview of coastal zone wetlands in Oceania, Ellison (1996) provides areal data for the largest coral reef systems in the Oceania region, notably Australia's 350 000 km^2 (35 million ha) Great Barrier Reef, New Caledonia's barrier reef which encloses a 16 000 km^2 (1.6 million ha) lagoon, and 40 000 km^2 (4 million ha) of coral reefs in Papua New Guinea.

The Planetary Coral Reef Foundation conducts inventory and other research upon coral reefs around the world, and is developing a satellite to monitor coral reefs at a global scale. The satellite will use spatial and spectral resolutions and wavelengths specific to coral reefs, enabling monitoring at species level, for which neither Landsat nor SPOT imagery is suitable (A Alling pers comm 1998).

3.2.2 Extent and distribution of seagrasses

Comprehensive area and distribution information for seagrasses appears to be lacking. There are apparently huge gaps in knowledge of seagrasses in the South Pacific, Southern Asia, South America and some parts of Africa (L McKenzie pers comm 1998). Attempts to remedy this are underway, but will take some time to complete. Well-researched areas include England, North America and the Netherlands (L McKenzie pers comm 1998).

The only regional seagrass project to come to the attention of this review to date is a proposed inventory of marine habitats, including seagrass beds, in the East Asian Seas region, to be conducted as part of the United Nations Environment Programme. This is in response to a deficiency in inventory data for marine and coastal habitats in this region (H Kirkman pers comm 1998). It involves the coordination of mapping activities in 10 countries in East Asia, the data to be incorporated into a Geographic Information System. The techniques proposed for this inventory rely on pattern recognition and field work, not an extensive algorithm program, and hence it is not an expensive or highly technical task (H Kirkman pers comm 1998).

On a continental scale, mapping of underwater features is underway in Australia, with the aim of mapping the entire coastline of the continent. To date, underwater features such as seagrass beds have been mapped along the south-western and south-eastern coastlines using Landsat TM imagery and ground-truthing (H Kirkman unpubl). In 1997, a National Seagrass Workshop provided recommendations for the establishment of a national approach to monitoring seagrass in Australia (Jacoby 1998). Following from this, a review is currently underway to report on the status of research and knowledge, distribution, monitoring and assessment of seagrasses in that country (A Butler pers comm 1998). The results of the seagrasses review are expected to become available in early 1999.

It should be possible to estimate, albeit roughly, the areal extent of seagrasses by collating existing national inventories, but it appears few, if any, continental or global estimates are available (to date none have come to the attention of this review). However, the World Conservation Monitoring Centre is seeking funding for a project to compile a seagrass dataset, to be added to existing Geographic Information System coverage of mangroves and coral reefs (R Luxmoore pers comm 1998).

3.2.3 Extent and distribution of mangroves

Global

The *World Mangrove Atlas* (Spalding et al 1997) represents the first attempt to prepare a global map of mangrove forests and provides a global overview of mangrove distribution. It contains areal estimates and other data, where available, for 114 countries, and case studies of particular sites. Spalding et al (1997) note that differences in definition, age, scale and accuracy of different national sources mean there are likely to be considerable margins of error in estimates of global mangrove area provided in the Atlas. They also recommend extreme caution in the use of global composite statistics as a baseline for monitoring changes in global mangrove area. Although serious inconsistencies exist in the data (J Ellison pers comm 1998), it nevertheless provides a basis for further research at a regional or national scale, and can assist in determination of priority areas for future mangrove inventory. Data from Spalding et al (1997) has been incorporated into the *Coral Reefs and Mangroves of the World* dataset on the World Conservation Monitoring Centre internet site (WCMC 1998), which ensures the information is accessible and enables it to be updated as knowledge gaps are addressed.

Spalding et al (1997) estimate the global area of mangroves as some 181 000 km^2 (18.1 million ha) (table 1). Approximately 43% of the world's mangroves are located in just four countries – Indonesia (42 550 km^2), Brazil (13 400 km^2), Australia (11 500 km^2) and Nigeria (10 515 km^2). Each has between 25% and 50% of the mangroves in their respective regions, hence Spalding et al (1997) predict that political and management decisions in these countries will have a significant effect on the global status of mangrove ecosystems in the future.

Regional

Mangrove areas for the regions of South and Southeast Asia, Australasia, The Americas, West Africa, and East Africa and the Middle East are presented in table 6 (adapted from Spalding et al 1997). The region of South and Southeast Asia is particularly significant, containing 41.5% of the world's mangroves. In this region Indonesia alone has 23% of the global mangrove forest area (Spalding et al 1997), and should therefore be considered of high priority for inventory efforts and monitoring of mangrove habitat loss.

In listing mangrove areas for individual countries, Spalding et al (1997) provide, where possible, both an estimate from map sources and an 'alternative estimate' from recent reliable sources. Assessment of area data provided highlights the inconsistent approach to mangrove inventory throughout the world to date, and reveals knowledge gaps that can be regarded as potential priority areas for future mangrove inventory effort (table 7). Spalding et al (1997) provide map-based area estimates for most countries, with the exception of Singapore, Solomon Islands, Western Samoa, Togo, Qatar and United Arab Emirates, for all of which no map data was available. No alternative mangrove inventory sources were available for China, Taiwan, Hong Kong, Aruba, Netherlands Antilles, Netherlands Antilles (windward group), British Virgin Islands, Dominica, Guadeloupe (including St Martin and St Barthelemy), Martinique, United States of America (Florida only), Comoros, Mayotte, Seychelles, Djibouti, Egypt, Eritrea, Somalia, Sudan and Yemen. An alternative estimate was provided for mangrove area in Sri Lanka, but the inventory source used for this estimate did not cover the entire country and was somewhat less than the map-based estimate (63 km^2 as opposed to 89 km^2). No information was available at all for British Indian Ocean Territory, Maldives, Sao Tome and Principe.

Other countries also have information gaps, shown by discrepancies (sometimes quite large) between their map and alternative areal estimates, indicating a need for further inventory to clarify the actual extent of mangrove habitat. In most of the 114 countries covered by the Atlas there is an urgent need for more accurate mapping of mangrove areas at higher levels of resolution (Spalding et al 1997).

Saenger et al (1983) gave area data for 65 countries, and noted that vast areas of mangrove forest had been and were continuing to be destroyed. This in itself poses a challenge for assessing mangrove areas, as inventories may date quite rapidly. Ellison (1994) expressed similar concern, noting that knowledge about the mangroves of the Pacific region is poor and, despite their traditional use by islanders, mangroves are rarely a valued resource. Mangrove forest inventory and mapping has been carried out in countries with larger mangrove areas, namely Papua New Guinea, Solomon Islands, Fiji, New Caledonia, Vanuatu, Western Samoa and the Federated States of Micronesia. However, reduction in mangrove area due to commercial logging and other human impacts means that some of these inventories are now out-dated. Ellison (1994) stresses the need for urgent action to promote mangrove conservation in the Pacific islands, the establishment of more mangrove protected areas, and development of a regional monitoring program of ecosystem health, which could be linked to monitoring for climate change and sea level rise impact.

3.2.4 Extent and distribution of salt marshes

The salt marshes of the Wadden Sea, though only a modest remainder of the extensive salt and brackish marshes, peatlands and lakes which covered the area some 2000 years ago, are still the largest contiguous area of salt marsh in Europe. The Wadden Sea is Europe’s largest intertidal wetland, with tidal flats, sandbanks, salt marshes and islands covering 8000 km^2 (800 000 ha). However, in 50 years up to 1987, 33% of their area was lost to embankments (Dugan 1993).

Some of the most extensive salt marshes in north America lie along the 800 km shoreline of the Alaskan Yukon–Kuskokwim Delta, one of the largest deltas in the world. Seaward of the marshes are sand and mud flats that cover some 530 km^2 (53 000 ha) (Dugan 1993). In Canada, British Colombia’s largest salt marsh complex is just 27 km^2 (2700 ha), the rest of the coastline dominated by fjords, with brackish and freshwater marshes. The most intensive arctic and subarctic salt marsh development is found on the Ontario shores of Hudson and James Bay. Salt and brackish marshes cover an estimated 85–90% of the 1100 km shoreline (Glooschenko 1982). In some areas of Canada, such as New Brunswick and the Saint Lawrence Estuary, salt marshes have been mapped as part of detailed wetland inventories (G Chmura pers comm 1999). The wetlands of Saint Lawrence Estuary have been mapped using remote sensing at 7 metres resolution, producing 43 coloured 1:20 000 maps of freshwater and saline wetlands, algal and eelgrass beds (Centre Saint-Laurent 1996).

Salt marshes have been mapped extensively in Europe (G Chmura pers comm 1999). Dijkema (1987) provides areas of salt marsh by marsh type for this region, and estimates that there are at least 2300 km^2 (230 000 ha) of coastal salt marshes in Europe, with insufficient data for Svalbard, Iceland, northwest Spain and Turkey.

No estimate for the global extent of salt marshes was discovered by this review, and it appears that there are large information gaps for this particular wetland habitat throughout the world.

3.2.5 Extent and distribution of coastal lagoons

No continental or international inventory of coastal lagoons was located for this review. However, Britton and Crivelli (1993) provide minimal estimated areas of Mediterranean wetlands including freshwater, saltwater, seasonal and saline coastal lagoons (summarised in table 3). John et al (1993) present some information on three large coastal lagoons in western Africa which, although they are interconnected with canals, each have a different hydrological regime.

3.3 Artificial wetlands

Reservoirs, dams, irrigation culverts and canals, fish farms, aquaculture ponds and rice fields are among the types of artificial wetlands contributing to the global wetland area, often providing habitat for flora and fauna as well as benefits to humankind.

Aselmann and Crutzen (1989) calculate the global area of rice paddies as 1.3 million km^2 (130 million ha), of which almost 90% is cultivated in Asia (table 1). It is likely this figure is now outdated. Matthews et al (1991), cited in NASA (1999), provide a map of rice harvest areas worldwide.

Gopal and Wetzel (1995) provide data on areas of reservoirs (858 311 ha in Ghana, >80 000 ha in Malaysia), dams (>92 145 ha in Malaysia), fish farms and ponds (223.02 ha in Ghana, 334 019.4 ha in Pakistan) and irrigation culverts (400 000 ha in Tunisia).

Michael (1987) provides areal estimates for fish farms and ponds, rice fields and other aquaculture sites around the world, but it is likely this information is now out of date and requires checking against national and regional sources.

4 Rate and extent of wetland loss and degradation

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

Inextricably linked with the rate and extent of wetland loss and degradation worldwide is the issue of water allocation and distribution, which has become extremely important in recent times and is only to become more so in the future. Many rivers around the world have been heavily regulated by the construction of dams to satisfy the increasing demand for irrigation and hydropower. Impacts on the rivers and associated natural waterbodies, swamps and marshes include increased salinisation, diminishing underground water reserves, declining biodiversity and impoverishment of fish stocks due to impeded migration and degraded habitat (Bolen 1982, Gopal & Wetzel 1995, Liu 1984). Ironically, countries are now facing problems with siltation of reservoirs. Taub (1984) reports that water demand in Japan resulted in many large artificial lakes on almost all river systems, but that a decrease in water volume of 70–80% occurred due to silting over 20–30 years.

Growing populations and increased development is also resulting in more domestic and industrial pollutants being discharged into wetlands. Yet there has been little research on pollutants and their effects, especially on fisheries, in many developing countries (Gopal & Wetzel 1995).

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

Moser et al (1996) note that data provided by Ramsar Contracting Parties indicated that 84% of Ramsar-listed wetlands had undergone or were threatened by ecological change. Similar figures arose when major threats to wetlands were analysed for Asia (Scott & Poole 1989) and the Neotropics (Scott & Carbonell 1986). Threats were recorded at 85% of the 734 wetland sites for which information was available in Asia, and for 81% of 620 wetlands in the Neotropics. Hunting, pollution, drainage for agriculture, and settlements and urbanisation were all within the top five major threat categories in each region (Moser et al 1996).

Scott (1993b) recommended that considerable thought should be given as to how existing and new wetland inventories can be used as a basis for monitoring wetland loss, particularly by updating and standardising them. Outside Europe and North America, there is very little information available or attempt made to calculate wetland loss on a systematic basis. Even in Europe, the majority of wetland loss data are from western Europe. Few published quantitative studies are available for Africa, South America, small South Pacific islands and much of Asia (Moser et al 1996).

The information currently available for these regions is largely descriptive, with some areal estimates and other details provided. For example, wetland loss and degradation in developing countries such as Ghana, Tunisia, Sri Lanka, Bangladesh, Pakistan, Papua New Guinea and Malaysia is described in Gopal and Wetzel (1995). Scott (1995) provides some wetland loss data and causes of wetland degradation in the Middle East. Denny (1985) provides an overview of African swamps and shallow waterbodies, with some data on the extent of swamp drainage, and lakes degraded by aquatic weed infestations. Wetland-related volumes of the *Ecosystems of the World* series (Chapman 1977, Gore 1983, Taub 1984, Michael 1987, Cushing et al 1995) contain some wetland loss and degradation data on a national or regional basis. These sources and others reviewed recognise the urgent need for improvement of this knowledge base.

4.1 North America

In the United States of America some 54% of wetlands that once existed (originally >890 000 km^2) have been lost, with 80% of this loss due to drainage for agriculture. In some states the proportion lost is even higher (Dugan 1993), the nation's historical attitude towards wetlands exacerbated by active encouragement of the conversion and destruction of wetlands by the United States federal government for over 200 years. Hofstetter (1983) reports that the President's address on Environment to the United States Congress in 1977 stated that over 40% of 48.6 million ha of wetlands inventoried in the 1950s had been lost, and that wetland area was being lost at the rate of 121 500 ha per year.

Although attitudes towards wetlands are changing, wetlands continue to be degraded and destroyed. Frayer (1991) outlines the status and trends of wetlands and deepwater habitats in the conterminous United States in the 1970s and 1980s. Average annual net losses have occurred for palustrine wetlands (283 500 acres, or 114 777 ha), palustrine vegetated (371 600 acres, or 150 445 ha) and palustrine forested (378 200 acres, or 153 117 ha), with a net loss of 3.4 million acres (1 376 518 ha) since the 1970s. Some of this loss is due to urban development, but the main reason was conversion to agriculture. Losses and gains have occurred for palustrine scrub/shrub wetlands, but deepwater habitats have increased in area in the United States, largely due to the formation of lakes and reservoirs (Frayer 1991). States with statistically significant wetland losses since the 1970s are identified, and Frayer (1991) warns that the importance of change in wetlands is not necessarily reflected by area alone. Some smaller wetlands, particularly along the coast, are extremely important habitats for plant and animal life. Newly created wetlands, such as lakes and reservoirs, must be studied further to determine their importance to fish and wildlife populations. Also, widespread degradation of wetlands may have consequences as serious as the loss of individual wetlands.

Of relevance to both Canada and the United States is concern over threats to the Great Lakes, which include sewage pollution, overfishing, water quality deterioration, destruction of breeding sites and depleting of fish stocks (Robertson & Scavia 1984).

In western Canada and Alaska, the freshwater wetlands have been subjected to little pressure from development to date. Some 800 km^2 (80 000 ha) of freshwater wetlands have been lost in Alaska since colonial times, approximately 0.1% of the original area (Dugan 1993). In eastern Canada 70% of wetlands are forested peatlands. Sustainable forestry practices in the region mean that the peatlands have experienced little development pressure until now, but recent proposals for major expansion of hydroelectric facilities are threatening diverse wetland and upland habitats, particularly coastal and estuarine wetlands (Dugan 1993). Zoltai and Pollett (1983) noted that utilisation of wetlands was rapidly expanding in Canada in the 1980s.

There are few details regarding wetland loss in Mexico, but Moser et al (1996) reports losses of approximately 35% of original wetland area. Neither the source data nor the original wetland estimate are provided.

4.2 Neotropics

There is a lack of reliable and quantitative data over large areas and over many years for the Neotropics, leading to difficulties in assessing the extent of wetland loss. However, the Neotropical directory revealed that over 80% of wetland sites in this region are under some threat from human activities, half of these under moderate to serious threat (Scott & Carbonell 1986).

Moser et al (1996) report that wetlands in the insular Caribbean show serious degradation due to long history of wetland reclamation and alteration, uncontrolled resource exploitation and neglect. A survey of 220 coastal wetlands, predominantly mangroves, in the eastern Caribbean between 1989 and 1991 revealed that every site visited on the 16 islands was degraded, with over 50% showing serious damage (Bacon 1993).

Wetlands in South America have remained relatively intact until recent decades, but small-scale studies have revealed the alarming rate at which wetlands are now disappearing in some parts of this region. Colombia's Cauca River Valley system lost 88% of its mapped wetlands between the 1950s and 1980s due to land reclamation, drainage, river regulation and pollution. Also in Colombia, changes in the hydrological cycle killed 80% of mangrove forests in the Magdalena River delta between 1970 and 1987 (Moser et al 1996). In Venezuela's Orinoco Delta, mangrove clearfelling operations have been approved in a 495 200 ha area.

One or two other sources of information on the Neotropics are known to exist but unfortunately copies have not been located in time for inclusion in this report. The data set is nevertheless scarce for this region.

4.3 Africa

Like South America, there is an extreme lack of published quantitative studies on wetland loss in Africa (Moser et al 1996). Dugan (1993) reports on the causes of wetland loss in Africa, and on the progress in protection and more sustainable use of wetlands in some areas, but no estimates are given. In west and central Africa there has been substantial loss and degradation of natural ecosystems due to population increase and other pressures over the last 80 years (Dugan 1993).

In Ghana, Gopal and Wetzel (1995) note that there has been poor documentation and research of contamination by domestic and municipal wastes, agrochemical pollution of rivers and groundwater, and effects of land degradation on water resources. Major waterbodies receiving such pollutants include the Volta, Birim, Densu, Ofin and Ankobra rivers, and Korle Lagoon. River waters and sediments in mining areas contain high concentrations of cyanide and arsenic.

In Tunisia, an overall loss of 15% of wetland area is reported, and an 84% loss of wetlands in the Medjerdah catchment (Moser et al 1996). Dams have been built on the three major oueds (rivers) flowing into Lake Ichkeul, causing progressive salinisation and decline in vegetation. Marshes surrounding the lake are dwindling due to drainage for agriculture. Other regions in Tunisia have been considerably altered due to agriculture, including the hills areas, where jessours (terrace-like dams) cover 400 000 ha (Gopal & Wetzel 1995).

In southern Africa, wetland loss figures are available for Natal, provided by Taylor et al (1995) in a review of wetland inventories in the region. In parts of the Tugela Basin over 90% of the wetland resources have been lost, and in the Mfolozi catchment 58% of the original wetland area has been lost (Taylor et al 1995, Moser et al 1996).

Denny (1985) provides some information on African wetlands which have been degraded by aquatic weeds. Lake Chad, for example, fluctuates in size from 600 000 ha to 2.5 million ha, but has been severely impacted by aquatic weeds, which cover 200 000 ha and interfere with transport and fishing on the lake. It is possible for such degraded wetlands to recover to some extent, and Denny (1985) gives the example of Lake Kariba, which was infested with 75 000 ha of the aquatic weed *Salvinia molesta* in the 1960s. Biological control measures were successful and the weed infestation decreased, stabilising at approximately 7700 ha.

4.4 Middle East

Scott (1995) notes that large-scale wetland degradation is occurring in the Middle East for various reasons including deforestation, overgrazing, reclamation, water diversion for irrigation, increased salinity, expanded urban and coastal development, overfishing, oil and other pollution, and war damage. In this region of scarce water resources, drainage, pollution and reclamation for industrial and urban development has put wetlands under particularly severe pressure. Flood control schemes, irrigation, and diversion of water for domestic and industrial consumption has resulted in significant loss and degradation of wetlands in the region. As in other regions, the fact that rivers such as the Jordan, Tigris and Euphrates flow independently of national borders means that proposed irrigation schemes in countries upstream can greatly impact upon water quality and scarce water supplies of the river and other remaining wetlands downstream. Almost all of the original freshwater wetlands in Syria, Lebanon and Israel were drained for agriculture in the early 1900s (Dugan 1993).

Drainage of marshes continues, one such example being the systematic drainage of the Al Huweizah marshes in a 30 000 km^2 (3 million ha) area of southern Iraq. Water diversion through dykes and a drainage canal has decreased the area of marshes by 50% since 1972 (INC 1998). Over a seven-year period (1985–1992), the area of permanent lakes and marshes, and seasonal and temporary marshes in Lower Mesopotamia had been reduced by over 25%, from 1.94 million ha to 1.44 million ha. To date, much of the Haur Al Hammar marshes and the greater part of the Central Marshes have been drained, with disastrous ecological, social and human consequences for the region (Scott 1995).

Few countries in the Middle East have made any serious attempt to conserve dwindling wetland resources (Dugan 1993). Yet water demand in the region has also led to the formation of a large number of artificial wetlands, including water storage reservoirs, sewage treatment ponds and artificial lagoons for containment of urban and industrial waste water. These artificial wetlands have become important habitats for wildlife, including migratory birds (Dugan 1993, al Wetaid & Faizi 1993).

4.5 Asia

Unlike Africa and South America, Asia has experienced wetland loss for thousands of years, with vast wetland areas drained for agriculture or settlement, or converted into rice fields (Moser et al 1996). In some areas, destruction of natural wetlands has been total, eg Vietnam’s Red River delta floodplains originally covered 1.75 million ha, but are now non-existent. Much of the 40 million ha of rice fields in the central plains of India, and the 1.9 million ha of paddies in the central plains of Thailand must have been developed at the expense of natural wetlands (Moser et al 1996). Wetlands continue to be degraded or destroyed in Asia; in their overview of the Asian wetland directory, Scott and Poole (1989) report threats at 85% of the 734 sites in the directory for which information was available.

Of particular importance in this region is Indonesia, which contains 42 550 km^2 (4 255 000 ha) of mangrove habitat, 23% of the world’s total mangrove area (Spalding et al 1997). This review has not obtained a quantitative estimate of mangrove loss in Indonesia to date, but Scott (1993b) reports the loss of 11.8 million ha of Indonesia’s original 37.6 million ha (31%) of wetlands by 1981–82. Spalding et al (1997) detail mangrove losses in Malaysia, the Philippines, Thailand and Vietnam totaling 7445 km^2 (744 500 ha), over 4% of the current global total. It is considered that the 1% loss of mangrove habitat each year in Malaysia is a conservative estimate of mangrove loss in the Asia Pacific region (Spalding et al 1997, Ong 1995).

Indonesia also contains a significant proportion of the global tropical peatland resource, which totals 30–49 million ha and over half of which is located in southeast Asia (Maltby et al 1996). The highest estimate of tropical peatland loss is 27 million ha (Radjagukguk 1992). Maltby et al (1996) detail losses of pristine peat swamps in Indonesia (531 000 ha) and

Peninsular Malaysia (500 000 ha), due to drainage for agriculture and forest clearance. Peatland inventories for Malaysia and Thailand are already outdated and inaccurate due to recent, rapid decreases in the peatland area following forest removal, drainage and utilisation for land settlement and conversion to agriculture (Maltby et al 1996).

Many rivers in Asia are threatened by water impoundment and diversion, deforestation, industrial and domestic pollution. Almost all rivers in Japan have been impounded to create large reservoirs, and the agricultural use of large amounts of fertiliser is believed to be causing eutrophication and pollution of the waterways (Mori et al 1984).

In Malaysia, a total of 42 rivers are biologically dead due to domestic, agricultural and industrial wastes. Loss of fisheries has occurred in some of these rivers. The total reservoir area in Malaysia is 80 000 ha, and may escalate to 206 000 ha by the year 2000 as demand increases for irrigation and hydropower dams (Gopal & Wetzel 1995).

In Pakistan, the Layari, Malir, Soan and Kabul rivers are highly polluted due to unregulated flow of sewage and industrial effluents. Aquatic weed infestations affect 182 118 ha of wetlands in Pakistan, adversely affecting fish production (Gopal & Wetzel 1995).

Gopal et al (1982) note that rapid wetland reclamation and destruction of mangrove area is occurring in India, but no figures were provided.

In Sri Lanka most lentic waterbodies show increased eutrophication due to organic pollution. Wetland degradation is occurring due to river impoundment and diversion, water pollution, deforestation, gem and sand mining (Gopal & Wetzel 1995).

Bangladesh has 3 666 300 ha of wetlands, 90% of which are dependent on flow from three major rivers now threatened by diversion of water in India from the Ganga-Padma River. Rivers in Bangladesh are contaminated with industrial discharge, and increased monoculture of rice has resulted in greatly increased fertiliser and pesticide use. These chemicals are flushed into the rivers by monsoonal rains (Gopal & Wetzel 1995).

This review has not located any overall estimate of wetland loss in Asia. More quantitative data is required. Many wetlands of the region are poorly known, particularly in Bangladesh, China, Bhutan, Burma, Cambodia, Laos, Mongolia and the Democratic People's Republic of Korea (Scott & Poole 1989). Judging by the current rate of mangrove and peatland losses, more information is urgently required for all wetland types in order to determine the status of wetlands and total wetland loss in the region.

4.6 Oceania

4.6.1 Australia

No overall wetland loss figures were obtained by this review for the continent of Australia, although 50% loss of original area is often used as a general estimate (B Churchill pers comm 1998). Loss estimates for the state of Victoria (26.8%) and the southeastern part of South Australia (89%) show that in some areas loss of inland freshwater wetlands in particular has been considerable (Moser et al 1996). By 1970, 60% of the most valuable waterfowl habitat on the coastal lowlands of New South Wales had been destroyed or degraded, most of the wetlands drained for flood mitigation. Similar losses occurred on the Swan Coastal Plain of Western Australia. In Tasmania, the buttongrass mires have suffered the majority of human impacts on wetlands, adversely affected by grazing and burning over many years. More recent impacts have included the construction of roads, dams and canals, and flooding of vast areas. Peatlands in the Eastern Highlands of the Australia's mainland are also being degraded by burning, grazing and drainage (Campbell 1983). The wetlands of northern Australia have not been subject in the past to the same population and development pressures as those in southern Australia, but are now under increasing threat due to changes in the water regime, pollution, invasive species and physical alteration (Finlayson et al 1999).

One of Australia’s largest and most important rivers, the Murray River, has been degraded by the construction of over 280 large dams, numerous small dams, weirs and locks, withdrawal of water, channelling of the stream and other flood mitigation activities.

The proposed national wetland inventory for Australia should provide data useful for estimating rate and extent of wetland loss in the future, although it is unlikely to include marine wetlands.

4.6.2 New Zealand

In New Zealand it is estimated that 90% of the original wetland area has been lost (Moser et al 1996), with wetlands now covering just 2% (5323.42 km^2 or 532 342 ha) of the country’s total land area (266 171 km^2) (Dugan 1993, NZ Govt 1998). Loss has been due to drainage, gold mining, flood control, land clearance, agricultural development, kauri-gum digging and flax milling (Dugan 1993).

4.6.3 Papua New Guinea

The wetlands of Papua New Guinea are poorly known (Scott & Poole 1989) and research is needed into logging impacts (Gopal & Wetzel 1995). Mining impacts are monitored in the Ok Tedi and Fly River, and research has shown that the 120 ha Waigani Lake has been degraded by sewage effluents from Port Moresby(Gopal & Wetzel 1995).

4.6.4 Pacific Islands

Moser et al (1996) reports that little published quantitative information is available for wetland loss in south Pacific island nations, despite the wetland inventory by Scott (1993a). Ellison (1994) provides estimates of mangrove loss in New Caledonia (380 ha), Fiji (2457 ha or 6%), Western Samoa (1.8 ha) and American Samoa (~50 ha), and threatened mangrove areas in Guam and Northern Mariana Islands. Significant areas of mangroves have been lost or degraded in Tonga, Vanuatu and Papua New Guinea, but areal extent is unknown. There is an urgent need for management and conservation of mangroves in the Pacific islands, as they are increasingly threatened by coastal development and exploitation. In Tonga, for instance, many mangrove areas have been lost to reclamation at Popua and Sopu, and all other significant areas are now allocated for clearance (Ellison 1994).

4.7 Europe

Rates of wetland loss are less well documented in Europe than in the United States, but the conversion of natural ecosystems such as wetlands is believed to be greater due to Europe’s high population density and longer history of economic development (Dugan 1993). Jones and Hughes (1993) provided an overview on the extent of wetland loss in Europe, the first attempt to collate information at a Pan-European level, but little information has been published since. Loss studies of particular wetland types, eg peatlands and lowland wet grasslands, provide some recent data, but the diversity of methodologies used to measure wetland loss, and the lack of coordination between studies in different countries or for different wetland types prohibits any regional overview (Moser et al 1996).

The considerable wetland losses in Europe are demonstrated by the example of Finland, which originally had 10.4 million ha of mires (30% of its land area), but has lost

5.5 million ha, largely due to forest drainage. Ruuhijärvi (1983) expected that the amount of mire lost in Finland would total 7 million ha by the mid-1990s.

European wetlands have been lost largely due to drainage and conversion to agriculture and grazing land, and urban and industrial development. Exploitation of wetlands, often leading to wetland degradation, includes water storage, fisheries and aquaculture, hunting, harvesting of wetland vegetation, tourism and water sports. Urban and industrial development has greatly contributed to wetland loss in recent years, while creating the added pressure of greater water demand to supply the increasing population (Dugan 1993).

4.7.1 Northern Europe

In northern Europe, peatlands are an important resource in the rural economy. Reindeer herds graze on peatlands, and wild fruits are harvested, some on a commercial basis. Yet while such traditional and largely sustainable practices continue, destructive use of peat is adding to the pressure from agriculture and forestry which has resulted in the drainage of extensive areas over the centuries. Interest in the energy potential of peat has increased in Europe, such that 400 new sites have been accepted for commercial exploitation in Sweden. Finland's annual peat fuel production is 4 million tonnes, as well as 300 000 tonnes of horticultural peat (Dugan 1993). Loss rates for peatlands in excess of 50% have been reported for 11 European countries (Immirzi et al 1992).

Lakes and watercourses are also coming under pressure in Scandinavia, with use of water resources becoming increasingly less sustainable. In Sweden, 75% of all suitable lakes and rivers have been regulated as part of hydroelectric developments, the result being irreversible ecological change (Dugan 1993). Several mires of high scientific value were destroyed during construction of hydroelectric reservoirs, and mires continue to be threatened by drainage for afforestation and large-scale extraction of fuel for town heating systems (Sjörs 1983).

Acid rain is contributing to the degradation of wetlands, with 40% of lakes in Norway and a significant proportion of lakes in Sweden and Finland showing serious acidification (Dugan 1993).

4.7.2 Western and Central Europe

In western and central Europe, the vast majority of natural wetlands were destroyed to make way for extensive industrialisation and agriculture (Dugan 1993). Overall wetland losses exceeding 50% of original area have occurred in the Netherlands, Germany, Spain, Greece, Italy, France and parts of Portugal. In the United Kingdom, 40% of wet grasslands, 23% of estuaries and 50% of saltmarshes have been drained since Roman times (Moser et al 1996). In the Mediterranean Basin and eastern Europe, many wetlands remained intact until the 1800s and 1900s, when most were drained for agriculture and to eradicate malaria. Deltas on the north shore of the Mediterranean support complex mosaics of wetland habitats, but riverine floodplain systems have been greatly altered, reduced to a few small isolated remnants. This destruction of the forest, dyking, grazing, agriculture and logging has also greatly reduced the riverine forest habitat, now present in just a few isolated stands.

4.7.3 Eastern Europe

In eastern Europe, change in the political environment has seen wetlands pass from state into private jurisdiction, resulting in their destruction to make way for agriculture (S Svazas pers comm 1998). Aselmann and Crutzen (1989) note that in Poland, over 95% of the estimated original mire area of 15 000 km^2 (1.5 million ha) has been exploited.

5 Wetland benefits and values

Over half (30) of the sources assessed provided information in some form or another on the values and benefits of wetlands. Of the 16 site-specific directories and inventories, only half (8) provided information on the values and benefits of particular wetland sites. These contain information, where available, on human utilisation and values and benefits to flora and fauna as part of each site description (eg Grimmett & Jones 1989, Hughes & Hughes 1992, Scott 1989, 1995). In other sources, values and benefits were summarised in a particular chapter (Dugan 1993, Saenger et al 1983, Ellison 1994), in country summaries (Scott 1993a, Spalding et al 1997, WCMC 1990), or interspersed throughout the text (Patten 1990).

Dugan (1993) and Patten (1990) detail the values and benefits of all wetlands to global ecology, flora, fauna, and humans. Scott (1993a) describes the values and benefits of wetlands in the Oceania region in summaries for each country, noting some unique aspects due to the extreme isolation of some Pacific islands, and the strong cultural attachment to mangrove wetlands in particular. The special significance of arid zone wetlands to people, flora and fauna is detailed by al Wetaid and Faizi (1993) and Scott (1995).

The values and benefits of mangroves, including coastal protection, flood reduction, sediment accumulation, nursery function for fish and crustaceans, and a vast number of human uses, are detailed in Saenger et al (1983), Spalding et al (1997) and Ellison (1994, 1996).

Legoe (1981) and Maltby et al (1996) describe the values and benefits of peatlands and peatland swamp forests, including their regulating effect on entry of water into drainage systems, nutrient reservoir, diverse human uses of the peat and plant resources, and an important role in biogeochemical cycles.

Grimmett and Jones (1989) provide descriptions of important wetland sites in Europe, on the basis of their value as breeding or feeding habitat for birds. Protected areas are valued by humans for various reasons, such as conservation of biodiversity, tourism and fishing (Grimmett & Jones 1989, IUCN 1994).

Schwartz and Bird (1990) approach the benefits of wetlands from a development perspective, noting the value of artificial beaches and coastal wetlands in protecting human values and uses, such as infrastructure, tourism and housing. Dugan (1993) also mentions the benefits of artificial wetlands, detailing the importance of salines to migratory bird populations in countries such as Portugal. Michael (1987) provides information on the productivity of rice paddies, fish farms and ponds around the world and oyster racks in coastal Japan.

6 Land tenure and management structures

Of the 16 site-based sources assessed in this review, at least 85% commonly or always covered issues related to land tenure (14), jurisdiction (15), conservation status (16) and proposed conservation measures (14), indicating a good coverage of these issues in past inventory projects. From these inventories and other sources, it is apparent that many wetland sites in Africa, Oceania, Asia and the Neotropics are unprotected or protection measures are ineffective.

Scott (1993b) recommends that all countries that have not yet done so conduct national wetland inventories, including all sites of national importance and perhaps local importance in the inventory. This would better enable quantification of the wetland resource at global, regional and national scale, and ultimately provide information for improved management and protection of wetlands.

Scott and Poole (1989) note that many wetland types and systems characteristic of southern and eastern Asia are under-represented in existing networks of protected areas, and that even legal protection is no guarantee that a wetland type will not remain under threat. While a significant proportion of Asia's wetlands of international importance have some form of legal protection, the enforcement of these protected areas leaves much to be desired, and over one third of them are still considered under moderate to severe threat.

Ellison (1996) reports a similar problem in the Oceania region, where more inventory, mapping and basic ecological research is needed. Despite some progress in implementing conservation legislation in Pacific countries, it is rarely enforced and wetlands continue to be degraded by increasing population pressures. Ellison (1996) lists urgent needs for mangrove conservation in the Pacific islands. Scott (1993a) believes the lack of effective wetland policies or legislation, if any at all, in countries of the Oceania region is due to difficulties in accommodating or overcoming traditional attitudes towards wetlands, their communal and private use, and government acquisition or regulation.

Spalding et al (1997) provides information on protection of mangrove habitat globally, noting that most countries with very large areas of mangroves have a significant number of protected areas, eg Australia (180), Indonesia (64) and Brazil (63). However some countries such as Nigeria contain very large areas of mangroves, but none within legally gazetted areas.

7 Extent and adequacy of updating programs

Of all the broad-scale inventories and directories assessed in this review, few have reported an updating process. Some inventories have been 'updated' as a more recent inventory or directory has been published, providing new or updated information (Wells et al 1988, WCMC 1998, WRI 1998). However, none apart from the Ramsar Convention Bureau's directories of Wetlands of International Importance (Jones 1993a,b,c) appear to be part of a program of regular updating; in this case summarising the more detailed information contained in the Ramsar Database and providing it to Contracting Parties on a regular basis. Some sources may have a plan or program for updating, but if so they are in the minority, and have not made this component of the inventory clear in their reporting. The overall result is a poorly updated knowledge base of wetland inventory worldwide, making it difficult to compare between studies and determine the overall extent of wetlands and wetland loss.

This situation of inadequate updating is perhaps understandable, given the overall cost and logistical effort of conducting and publishing (in hard copy) supra-regional, continental or international inventories on a regular basis. However, the recent development of 'user-friendly' database packages and increased availability and use of electronic systems such as GIS and the WWW is expanding the options available for scientific data storage and accessibility. It is possible to store wetland inventory information in an electronic database or GIS, link it to a web page, and make it accessible from anywhere in the world via the WWW. There are some promising new developments in this direction in wetland inventory, WCMC (1998) and WRI (1998) being two such examples. Hardcopy publications are certainly still useful, but more efficient and creative use of the WWW will improve the accessibility of inventory information and ease and efficiency of updating.

8 Standardising of inventory approaches

Gopal et al (1982) noted the serious lack of knowledge worldwide about wetland resources, their ecology and use, making important recommendations including that 'standardisation of methodology is required in all areas of wetland ecosystems, more particularly … wetland survey and inventorisation'. It was recognised that, as a first step for identifying the needs for conservation and management, national inventories of wetlands were required.

Now, almost twenty years later, it is evident that we still do not have adequate standardisation of inventory and enough completed national wetland inventories to be able to determine with confidence the status of wetlands worldwide. Of greatest concern, perhaps, is the recognition that, while this woeful situation continues, many wetlands are fast disappearing due to increased development and demands on water and other resources. We do not yet know what wetlands we have and how important they are, and if we do not strive now for improvement in our wetland inventory and assessment, it may soon be too late.

What must be done to remedy this situation? A few points to consider:

- **Reporting:** Careful attention should be paid to the comprehensiveness of reporting. Inventories too often lack basic information such as the objective or purpose of the inventory, the wetland definition and classification systems used, the method/s of data collection, source data for statistics of wetland area or wetland loss, name and affiliation of the compiler for individual site data, a program for updating the inventory, etc. Comprehensive reporting avoids confusion and ambiguity.
- **Standardised approach:** Standardisation of inventory approach is necessary. Development of a standardised framework for wetland inventory will help individual countries to prepare national wetland inventories in a process and format compatible with their objectives, and yet also compatible with the inventory of neighbouring countries. This would greatly improve the capacity for comprehensive wetland inventory on a regional, and ultimately global, scale.
- **Standardised framework:** A standardised framework may incorporate key data elements to be collected for a national inventory, while still allowing each country's implementing agency flexibility to determine the objectives of the inventory and the form its inventory will take, according to variables such as the climate, wetland type and classification, resources and management objectives.
- **Electronic data storage:** Use of electronic data storage systems such as databases and GIS, linked to the WWW will enhance the availability of data and related information (eg bibliographies) for particular countries and wetland sites. It will also allow for regular, cost-effective updating of inventory information.
- **Standardised database:** Development of a standardised or generic wetland inventory database, perhaps developed and distributed alongside the standardised framework for wetland inventory, may be extremely useful for countries with limited resources or expertise in wetland inventory.
- **Accessibility:** Wetland inventory metadata should be added to a globally accessible metadatabase such as the Biodiversity Conservation Information System (BCIS), to ensure details and contacts are available for others to access the inventory and its source data in the future. This will further enhance global accessibility of information and the capacity for determining inventory gaps and priorities.

Note that two models, the Mediterranean Wetland Inventory (Costa et al 1996), and the National Inventory of Wetlands conducted by the United States Fish and Wildlife Service using the classification system of Cowardin et al (1979), have been successfully adapted for use in other countries and could provide a basis for a standardised framework and/or generic wetland inventory database.

9 Priority areas for wetland inventory

9.1 Priority regions

The global wetland inventory resource is, on the whole, a woefully inadequate dataset. All regions of the world – Africa, Asia, Oceania, Neotropics, North America, Western and Eastern Europe – have information gaps and priority areas for wetland inventory. Some of these information gaps are already urgent, and will become increasingly so as wetland loss continues.

Priority is given here to regions in which the wetlands are least known and perhaps 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. These priority regions are:

- Neotropics
- Asia
- Oceania
- Africa
- Eastern Europe

All these regions urgently require further wetland inventory and wetland loss studies, to determine the current extent of wetlands, and the rate and extent of loss. In order to make the task more manageable, priority should be given to encouraging countries which do not yet have a national wetland inventory to commit resources to this endeavour. The great importance and urgency of national wetland inventories cannot be overstressed. They provide the base information for effective monitoring, management, sustainable use and conservation of wetlands at all levels – local, national, regional and international.

9.2 Priority habitats

Attention must also be given to 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 include:

- **Seagrasses:** The majority of seagrass habitat in southern Asia, South Pacific, South America and some parts of Africa has not been mapped, and yet is under increasing threat from pollution, coastal development, destructive fishing practices, recreational use, etc. Mapping can be done by remote sensing techniques with ground-truthing (eg H Kirkman unpubl).
- **Coral reefs:** There is increasing awareness of the importance of coral reefs in maintaining biodiversity and various ecosystem functions, and global mapping and monitoring efforts are underway. Loss and degradation continues, however, and in no small part due to the development, deforestation and pollution of coastal and inland wetlands.

- **Salt marshes and coastal flats:** There appear to be few international and continental sources that include these habitats, and the information available is sketchy with few areal estimates and no true global 'picture'. Salt marshes and coastal flats are under increasing threat worldwide, particularly in Africa, Asia and Oceania due to increasing coastal development, eg land reclamation and aquaculture activities such as shrimp farming.
- **Mangroves:** Mangal habitat is better mapped than other coastal and marine wetlands, but serious inconsistencies exist. There is a need for more comprehensive inventory in order to be better able to determine mangrove loss. Mangroves are being degraded and destroyed at an alarming rate in many parts of Africa, south-east Asia and Oceania through deforestation, land reclamation, and development for aquaculture.
- **Arid-zone wetlands:** Poorly mapped but increasingly important in the light of escalating population pressures and water demand, most notably in Africa and the Middle East. The impact of dams and trans-boundary sharing of limited water resources are already crucial issues, and wetlands in arid regions must be better mapped and understood to enable more effective management of their use by people, livestock, industry and ecosystems.
- **Peatlands:** In comparison with other wetland habitats there is a relatively good global 'picture' of the extent and distribution of peat resources. However, peatlands are threatened by drainage for agriculture and afforestation in Europe, Asia and North America in particular, despite their importance as a global carbon sink and valuable economic resource. Tropical peatlands are poorly known, especially in south-east Asia.
- **Rivers and streams:** It is difficult to obtain areal estimates of rivers and streams (their length is often provided but rarely their width) and the extent of associated swamps, marshes, ox-bow lakes and lagoons. Yet rivers in all regions of the world are seriously threatened by industrial and domestic pollution, water diversion and regulation by dams. Their effective management is only possible with better understanding of the full extent of the resources they provide, their values and benefits.
- **Artificial wetlands:** These include reservoirs, dams, salines, paddies, and aquaculture ponds, and are increasing in number in all regions of the world, notably Asia, Africa and the Neotropics. Artificial wetlands can become habitat for wildlife, particularly migratory birds, but the values and benefits of these wetlands relative to natural wetlands are little understood. Improved inventory of artificial wetlands such as salines, paddies, fish and shrimp ponds is necessary in order to determine their extent and distribution for management purposes, while providing some data also as to extent of loss and modification of natural wetlands.

10 Priority processes

The work required to establish, update or extend wetland inventory seems monumental when viewed at a global scale, but is eminently achievable if a genuine will exists and a few key processes are targeted for improvement (Finlayson & van der Valk 1995, Finlayson 1996, Scott & Jones 1995).

There is a need to improve:

- **Communication:** Wetland inventory information is useful to people at all levels, local through to global, and should be made available to as wide an audience as possible. Advertise the existence of inventories through interpersonal communication, e-mail forums, conferences and seminars, and by providing the metadata to relevant web-accessible databases such as the Biodiversity Conservation Information System Meta-database (BCIS 1998), *ReefBase* (ICLARM 1998), etc. Encourage feedback and approach new ideas and inventory techniques with an open mind, while retaining the integrity of data and outcomes.

- **Cooperation:** Improve cooperation, financial and otherwise, between countries, agencies and individuals, with the common aim of increasing the wetland inventory resource for all wetland habitats, particularly those most threatened. Resources and effort are often 'wasted' on numerous pilot studies or overly-ambitious projects which have little reward ultimately in terms of inventory and improved management or conservation of wetlands, indicating a need for even more careful prioritisation when allocating resources, especially in the light of the current dismal global dataset for wetland inventory.

- **Definition of purpose:** The purpose of an inventory influences the type of data collected and the analysis and conclusions reported. If the purpose is poorly defined at the outset, the result is often an unfinished inventory that tried to achieve too much with too little, or an unwieldy dataset difficult to compare with other inventories, its reliability, purpose and relevance to other applications being unclear. It is therefore crucial to define the purpose of the inventory clearly at the beginning, set achievable and relevant outcomes, and ensure that limitations of the dataset or approach are recognised and reported. Similarly, it is crucial that the objectives and limitations of an inventory are taken into consideration when the data is used for other purposes.

- **Standardisation:** There is a need for a standardised framework and a generic database for wetland inventory, to assist countries and agencies with limited resources and inventory expertise in conducting inventory. This would also better enable comparisons between inventories, thus improving the global 'picture' of the wetland resource, priority habitats for management and conservation, and extent of wetland loss and degradation.

- **Reporting content:** Published wetland inventories often lack basic information, eg the means of data collection and storage, names and contact details for compilers, wetland definition and classifications used. Broad-scale overviews containing areal estimates for wetlands or wetland loss rarely include the source data or references, making it difficult to assess the age and reliability of the information. Reporting therefore needs to be improved, eg a standardised framework for wetland inventory could include recommendations for reporting.

- **Reporting format:** Wetland inventories are often published in hardcopy only, which can be large and unwieldy, and prohibitively expensive to update and reprint. It is advised that all future wetland inventories are stored and published electronically in addition to hardcopy, and the metadata, at least, made available on the WWW.

- **Data storage:** Data storage and handling issues must be addressed at the outset of an inventory project, and systems established for storage, maintenance and updating of the dataset. Electronic methods such as GIS and databases are preferred, as they simplify data updating, accessibility and dissemination issues.

11 Specific recommendations

- All countries that have not yet conducted a national wetland inventory should do so, preferably using an approach that is comparable with other large-scale wetland inventories already underway or complete, and in line with recommendations from the Ramsar Wetland Convention.

- All countries currently without wetland protection and sustainable use legislation should introduce it as soon as possible, and take the necessary steps to ensure its effectiveness, again in line with recommendations from the Ramsar Wetland Convention.
- Wetland inventory information for particular countries and regions should be used to determine priority wetland habitats for conservation and intensive management, and action taken on the recommendations of such assessments.
- Quantitative studies of wetland loss and degradation are urgently required for much of Asia, Africa, South America, and the Pacific Islands.
- Improve the approach and effectiveness of all aspects of wetland inventory through standardisation, eg a standardised framework and a generic wetland inventory database, designed to be as flexible as possible for use in all regions of the world and to accommodate various inventory objectives.
- All wetland inventories in future should be stored and published electronically in addition to hardcopy. This improves accessibility and allows regular updating of information. Ideally the metadata at least should be published on the WWW to make it easily accessible to as wide an audience as possible.

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Table 1 Global area estimates obtained from wetland inventory sources

Source	Region	Wetland type	Global area (ha)
Matthews & Fung (1987)	Asia, Oceania, Africa, Europe, Neotropics, North America	Forested bog	207 800 000
		Nonforested bog	89 700 000
		Forested swamp	108 700 000
		Nonforested swamp	100 700 000
		Alluvial formations	19 400 000
		Total natural wetlands (excl. irrigated rice fields)	530 000 000
Aselmann & Crutzen (1989)	Asia, Oceania, Africa, Europe, Neotropics, North America	Rice paddies	130 000 000
		Bogs	190 000 000
		Fens	150 000 000
		Swamps	110 000 000
		Floodplains	80 000 000
		Marshes	27 000 000
		Lakes	12 000 000
		Total natural freshwater wetlands	570 000 000
Dugan (1993)	Asia, Oceania, Africa, Europe, Neotropics, North America	Wetlands (assumedly freshwater only)	560 000 000
Frazier (1996)	Asia, Oceania, Africa, Europe, Neotropics, North America	Wetland sites on the Ramsar List of Wetlands of International Importance.	52 334 339 *
Spalding et al (1997)	Asia, Africa, Oceania, Neotropics, North America	Mangroves only	18 100 000
WCMC (1998)	Asia, Oceania, Africa, Neotropics, North America	Coral reefs only	30 000 000 – 60 000 000
Dugan (1993)	Asia, Oceania, Africa, Europe, Neotropics, North America	Peatlands only	400 000 000
Aselmann & Crutzen (1989)	Asia, Oceania, Africa, Europe, Neotropics, North America	Artificial wetlands – rice paddies only (no other global areas located for artificial wetland types)	130 000 000

* Update (30/1/99): Ramsar now lists 965 wetland sites of international importance, covering 70 471 806 ha.

Table 2 Regional wetland area estimates by wetland type
(Note: Approximate only, refer to GRoWI regional reports and original sources for further detail)

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

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

Table 3 National wetland area estimates by wetland type; summary of information presented in 'Extent and distribution of wetlands' and GRoWI database

(Note: Some estimates highly approximate, refer to original sources for more detail. Where estimates differ (eg mangroves), both are reported. Some mangrove areas are listed here; see Spalding et al (1997) for more detail. Peatland estimates listed in more detail in table 4.)

Country	Wetland type	Continental area (ha)	Source
Alaska	Freshwater boreal wetlands	60 000 000	Dugan (1993)
	Mires (fens and bogs)	25–40 000 000	Aselmann & Crutzen (1989)
Albania	Freshwater lakes	<35 000	Britton & Crivelli (1993)
Algeria	Coastal lagoons	3700	Britton & Crivelli (1993)
	Freshwater lakes	>2000	
	Reservoirs	3300	
	Athalassic salt lakes	358 900	
	Freshwater marshes	29 000	
	Forested wetlands	<100	
Australia	Peatlands	15 000	Taylor (1983)
		307 292	Aselmann & Crutzen (1989)
	Coral reefs	>35 000 000	Ellison (1996)
	Mangroves	1 150 000	Spalding et al (1997)
Bangladesh	All wetlands	3 666 300	Gopal & Wetzel (1995)
	Rivers	217 135	
	Tributaries	262 600	
	Beels and haors	114 793	
	Oxbow lakes	5488	
	Seasonal floodplains	2 832 792	
	Artificial ponds	163 492	
Brazil	Peatlands	100 000	Junk (1983)
	Mangroves	1 340 000	Spalding et al (1997)
Canada	Freshwater wetlands	170 000 000	Zoltai & Pollett (1983)
	Wetlands (bogs and fens)	127 000 000	Aselmann & Crutzen (1989)
	Total wetlands	127 199 000	Cox (1993)
	Peatlands	111 327 000	Cox (1993)
China	Undeveloped peatlands	3.1–3.48 000 000	Aselmann & Crutzen (1989)
Finland	Peatlands	5 000 000	Ruuhijärvi (1983)
France	Coastal lagoons	93 800	Britton & Crivelli (1993)
	Non-tidal salt marsh	20 800	
	Freshwater lakes	500	
	Reservoirs	3600	
	Freshwater marshes	20 300	
	Forested wetlands	<1000	

Table 3 Cont

Country	Wetland type	Continental area (ha)	Source
Ghana	Lagoons	>4 786 400	Gopal & Wetzel (1995)
	Reservoirs	858 311	
	Fish ponds	223.02	
Great Britain and Ireland	Peatlands	2 684 291	Taylor (1983)
Greece	Coastal lagoons	29 200	Britton & Crivelli (1993)
	Non-tidal salt marsh	9400	
	Freshwater lakes	164 100	
	Reservoirs	12 500	
	Freshwater marshes	5300	
	Forested wetlands	300	
India	Mangroves	355 000	Gopal et al (1982)
		537 900–670 000	Spalding et al (1997)
Indonesia	Swamp forests	>17 000 000	Dugan (1993)
	Peatlands	27 000 000	Rieley et al (1996)
	Mangroves	4 255 000	Spalding et al (1997)
Italy	Estuaries	200	Britton & Crivelli (1993)
	Coastal lagoons	11 500	
	Freshwater lakes	3000	
	Athalassic salt lakes	<100	
	Freshwater marshes	1500	
	Forested wetlands	>300	
Malaysia	Reservoirs	>80 000	Gopal & Wetzel (1995)
	Dams	>92 145	
Mexico	Inland wetlands	650 000	Dugan (1993)
	Coastal wetlands	1 250 000	Dugan (1993)
	All wetlands	3 318 500	Olmsted (1993)
Morocco	Estuaries	>1700	Britton & Crivelli (1993)
	Intertidal flats	>3100	
	Intertidal salt marsh	3400	
	Coastal lagoons	21 600	
	Freshwater lakes	1400	
	Reservoirs	>7500	
	Athalassic salt lakes	41 600	
	Freshwater marshes	200	
	Forested wetlands	<100	
Nigeria	Mangroves	1 051 500	Spalding et al (1997)

Table 3 Cont

Country	Wetland type	Continental area (ha)	Source
Pakistan	Inland waters	>7 800 000	Scott (1989)
	Delta marshes	300 000	Scott (1989)
	Mangroves	250–283 000	Scott (1989)
	Lakes and reservoirs	472 070	Gopal & Wetzel (1995)
	Fish farms and ponds	334 019.4	Gopal & Wetzel (1995)
Papua New Guinea	Coral reefs	4 000 000	Ellison (1996)
	Mangroves	162–200 000	Ellison (1994)
		411 600–539 900	Spalding et al (1997)
Portugal	Intertidal flats	65 500	Britton & Crivelli (1993)
	Coastal lagoons	14 000	
former Soviet Union	Freshwater wetlands	150 000 000	Aselmann & Crutzen (1989)
	Bogs and fens	145 000 000	Aselmann & Crutzen (1989)
	Peatlands	83 000 000	Botch & Masing (1983)
	Swamps and marshes	6 500 000	Aselmann & Crutzen (1989)
South Africa	Wetlands in Natal region	111 427	Breen et al (1993)
Spain	Intertidal flats	20 400	Britton & Crivelli (1993)
	Athalassic salt lakes	>5500	
	Freshwater marshes	>6500	
Sri Lanka	Artificial reservoirs and marshes	169 940	Gopal & Wetzel (1995)
Sweden	Wooded wetlands	2 000 000	Sjörs (1983)
	Open mire (mostly treeless)	>5 000 000	
Tunisia	Irrigation culverts	400 000	Gopal & Wetzel (1995)
	Endorrheic salt depressions	600 000	Gopal & Wetzel (1995)
	Sebkhas	>56 500	Gopal & Wetzel (1995)
	Intertidal flats	28 100	Britton & Crivelli (1993)
	Intertidal salt marsh	5900	Britton & Crivelli (1993)
	Coastal lagoons	65 900	Britton & Crivelli (1993)
	Freshwater lakes	11 200	Britton & Crivelli (1993)
	Athalassic salt lakes	752 500	Britton & Crivelli (1993)
	Freshwater marshes	5100	Britton & Crivelli (1993)
	Forested wetlands	<500	Britton & Crivelli (1993)
Uganda	Swamps	1 180 000	Gopal et al (1982)
United States of America	Reservoirs (>202 ha)	3 900 000	Taub (1984)
Zambia	All wetlands	75 000 000	Gopal et al (1982)
	Swamps	2 400 000	Denny (1985)

Table 4 Percentage of national area covered by peat in rank order (adapted from Taylor 1983), with additional data from other inventory sources

Country	**Peat area (ha)**	**% land surface**	**Data from other inventory sources**
Canada	129 500 000	18.4	Peatland estimates vary from 5.9–30 million ha (Zoltai & Pollett 1983). More recently, peatlands estimated at 111 327 000 ha (Cox 1993).
former U.S.S.R.	71 500 000[1]	6.7	Peatlands 83 000 000 ha incl. 39 000 000 ha in western Siberia (50% land surface) (Botch & Masing 1983).
Finland	10 000 000	33.5	5 000 000 ha lost to development; expected loss of 7 000 000 ha by mid-1990s (Ruuhijärvi 1983)
United States of America	7 510 000	3.3	60 000 000 ha freshwater boreal wetlands in Alaska, predominantly peatlands (Dugan 1993)
China	3 480 000	0.4	
Norway	3 000 000	9.4	
British Isles (incl. Ireland)	2 684 291	8.6	
Malaysia	2 360 000	7.2	500 000 ha peat swamps drained (Maltby et al 1996)
Republic of Ireland	1 175 590	17.2	
United Kingdom	1 508 701	6.3	
Poland	1 500 000	4.4	
Sweden	1 500 000	17.1	~16% land surface covered by peat, incl. 2 000 000 ha wooded wetlands, >5 000 000 ha open mire (Sjörs 1983)
Iceland	1 000 000	9.7	
Scotland	821 381	10.4	
Indonesia	700 000	13.7	Highest recent estimate is 27 000 000 ha, placing Indonesia fourth in the world (Rieley et al 1996). 531 000 ha peat swamps drained (Maltby et al 1996).
Germany (G.D.R.)	489 000	5.1	
Germany (G.F.R.)	489 000	4.4	
England	361 690	2.8	
Cuba	200 000	3.9	
Japan	200 000	0.5	
Northern Ireland	166 860	12.4	
New Zealand	166 000	0.6	
Wales	158 770[2]	7.7	
Hungary	100 000	1.1	
Country (cont'd)	Peat area (ha)	% land surface	Data from other inventory sources
The Netherlands	100 000	7.4	
Yugoslavia	100 000	0.4	
Uruguay	100 000	0.5	
Brazil	100 000	0.01	This estimate from Junk (1983)
Denmark	60 000	2.8	
Italy	60 000	0.4	
France	60 000	0.2	

Table 4 Cont

Country	Peat area (ha)	% land surface	Data from other inventory sources
Switzerland	55 000	1.3	
Argentina	45 000	0.016	
Czechoslovakia	33 000	0.2	
Austria	22 000	2.8	
Belgium	18 000	0.6	
Australia	15 000	0.002	Legoe (1981) estimates peatlands cover 0.04% land surface area (307 292 ha).
Romania	6 000	0.03	
Spain	6 000	0.012	
Israel	5 000	0.25	
Greece	5 000	0.04	
Bulgaria	1 000	0.001	

1 These are exploitable reserves and substantially underestimate peatland areas especially in the tundra and adjacent territories of northern Siberia.

2 This figure includes extensive areas of thin (<0.9m) hill peat

Table 5 Regional estimates of tropical peatland area, adapted from Rieley et al (1996)

Region	Area (ha) – mean	Area (ha) – range
Central America	2 438 000	2 276 000–2 599 000
South America	4 037 000	4 037 000
Africa	2 995 000	2 995 000
Asia (mainland and south)	2 351 000	1 351 000–3 351 000
Asia (southeast)	26 435 000	9 932 000–32 938 000
The Pacific	19 000	19 000
Total	**38 275 000**	**30 610 000–45 939 000**

Table 6 Regional estimates of mangrove area, adapted from Spalding et al (1997)

Region	Mangrove area (ha)
South and Southeast Asia	7 517 300 (41.5%)
Australasia	1 878 900 (10.4%)
The Americas	4 909 600 (27.1%)
West Africa	2 799 500 (15.5%)
East Africa and the Middle East	1 002 400 (5.5%)

Table 7 Gaps in mangrove inventory data in the World Mangrove Atlas (Spalding et al 1997)
(Note: 'Alternative' estimates are extracted from mangrove inventory sources other than maps)

Region	Mangrove inventory gaps
South and Southeast Asia	Map data available for all countries except Singapore. No alternative estimates available for China, Taiwan and Hong Kong. Sri Lanka's alternative estimate does not include the entire country and is therefore likely to be an underestimation.
Australasia	No map data available for Solomon Islands and Western Samoa. All countries have alternative estimates.
The Americas	Map data available for all countries. No alternative mangrove inventory sources for Aruba, Netherlands Antilles, British Virgin Islands, Dominica, Guadeloupe (including St Martin and St Barthelemy), Martinique, Netherlands Antilles (windward group) and United States of America (Florida only).
West Africa	No map data for Togo. No information at all on presence of mangroves in Sao Tome and Principe.
East Africa and the Middle East	No map data available for Qatar and United Arab Emirates. No alternative mangrove inventory sources for Comoros, Mayotte, Seychelles, Djibouti, Egypt, Eritrea, Somalia, Sudan, Yemen. No data at all for British Indian Ocean Territory and Maldives.