6 Bibliography of monitoring

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This is a bibliography of publications and documents related to monitoring wetlands. Some of the references presented here discuss the use of the different indicators under particular circumstances, others describe the specific methods and techniques that can be used for measuring particular indicators, and a number of them present case studies of the application of these techniques for monitoring wetlands. The abundance of such publications makes it impossible to provide a comprehensive list. However, this bibliography indicates where descriptions of a large number of techniques can be found.

The bibliography has evolved from a preliminary bibliography on monitoring compiled by Aura Penloup for the MedWet sub-project on Inventory and Monitoring and published separately as an internal MedWet document (Penloup 1995). A selection of entries from this preliminary bibliography have been included along with references from further bibliographic research and publications recommended by authors of this guide.

The references are grouped under main headings. It has not been possible to follow the format of previous chapters of allocating publications by "type of ecological change". This is because the bibliography contains publications which deal with a range of subjects and categories, from techniques to indicators, which do not fit easily into the headings used previously; and because a number are relevant to more than one type of ecological change. The user of this guide is advised to begin with the most appropriate heading (e.g. for impact of grazing *look first under* 6.6 Plants and Vegetation*). Under each heading, references are arranged alphabetically. This will assist the user to locate references such as those given in chapter 5 without too much searching, even if they do not appear under the anticipated heading.*

Specific references are accompanied by brief descriptions. This supplementary detail is to assist users of the manual to identify sources and scope of information. The selection may appear somewhat arbitrary. However, those articles chosen were seen as being particularly useful by personnel involved in this programme over the last two years. In the case of references that are difficult to find (e.g. because they are unpublished or out of print), information is provided of a library or other source where the document may be available.

6.1 General

The following references provide a general overview and discussion about wetlands and/or monitoring. They do not necessarily describe any specific techniques.

Clarke, R. (ed.). 1986. *The handbook of ecological monitoring*. A GMS/UNEP publication. Clarendon Press, Oxford. 298 pp.

Goldsmith, F.B. (ed.). 1991. *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. 575 pp.

Goldsmith, F.B. 1993. Monitoring for Conservation. In: F.B. Goldsmith and A. Warren (eds.). *Conservation in Progress*. John Wiley and Sons, Chichester, UK. pp 241–253.

Finlayson, C.M. 1994. Monitoring ecological change in wetlands. In: G. Aubrecht, G. Dick and C. Prentice (eds.). *Monitoring of ecological change in wetlands of Middle Europe*. Stapfia 31, Linz, Austria and IWRB Publication 30, IWRB, Slimbridge, UK. pp 163–180.

Hellawell, J.M. 1986. *Biological Indicators of Freshwater Pollution and Environmental Management*. Elsevier Applied Science Publishers, London, UK. 546 pp.

Hook, D.D. *et al.* 1988. *The Ecology and Management of Wetlands*, vols. 1 and 2. Croom Helm, London, UK, and Timber Press, Portland, Oregon, USA. 592 pp and 394 pp.

Krebs, C.J. 1972. *Ecology: The Experimental Analysis of Distribution and Abundance*. Harper & Row, New York, USA.

Maher, W.A., P.W. Cullen and R.H. Norris. 1994. Framework for designing sampling programmes. *Environmental Monitoring and Assessment* 30: 139–162.

Maltby, E. 1986. *Waterlogged Wealth*. Earthscan. London, UK. 200 pp.

Margalef, R. 1983. *Limnología*. Ediciones Omega, Barcelona, Spain. 1010 pp.

Margalef, R. 1986. *Ecología*. Ediciones Omega, Barcelona, Spain. 951 pp.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. Second edition. Van Nostrand Reinhold, New York, USA. 722 pp.

Spellerberg, I.F. 1991. *Monitoring Ecological Change*. Cambridge University Press, Cambridge, UK. 334 pp.

6.2 Multidisciplinary

The references which cover different types of techniques are grouped here in order to avoid repetition. Some of them are a compilation of chapters or proceedings of conferences, workshops, etc. Some of the references mentioned in section 6.1, should also be consulted, e.g. Hellawell 1986, Spellerberg 1991, Clarke 1991.

Aubrecht, G., G. Dick and C. Prentice (eds.). 1994. *Monitoring of Ecological Change in Wetlands of Middle Europe*. Stapfia 31, Linz, Austria and IWRB Publication 30, IWRB, Slimbridge, UK. 224 pp. [Proceedings of an International Workshop, Linz, Austria, 26–30 October 1993].
Includes: monitoring lakes and ponds; monitoring mires/peatlands; monitoring rivers and floodplains.
Address: Wetlands International, Slimbridge, Glos, GL2 7BX, UK.

Baker, J.M. and W.J. Wolff (eds.). 1987. *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. 449 pp.
Includes: planning biological surveys; remote sensing; salt marshes; flora and macrofauna of intertidal sediments; macrofauna of subtidal sediments using remote sampling; meiofauna; intertidal rock; subtidal rock and shallow sediments using diving; bacterial and fungi; plankton; fish; birds; identification references for most groups; safety guidance.

Chalmers, N. and P. Parker. 1985. *The OU Project Guide. Fieldwork and Statistics for Ecological Projects*. Field Studies Council Pub., Oxford, UK. 106 pp.
Includes: planning ecological projects; basic ideas about statistics; fieldwork techniques: abundance distribution of non-mobile organisms (sampling, subjective methods, quadrats, transects, yield); abundance distribution of mobile organisms (mark-release-recapture, removal sampling, direct and indirect estimates); techniques for catching mobile organisms (invertebrates and free-floating plants in water, invertebrates in the air and on vegetation,

invertebrates in soil or leaf litter); measuring environmental factors (temperature, wind, rainfall, relative humidity, light, pH, salinity, water flow, oxygen levels in water, soil factors, biotic indices); statistical techniques; suppliers of field equipment.

Address: Field Studies, Nettlecombe Court, Williton, Taunton, Somerset TA4 4HT, UK, or The Richmond Publishing Company, Orchard Road, Richmond, Surrey, UK.

Environmental Protection Agency. 1992. *Monitoring guidance for the National Estuary Program*. Final. EPA 842-B-92-004, United States Environmental Protection Agency (US EPA). 245 pp.

Includes: guidance for the design, implementation (sampling, equipment, methods, data analysis, data interpretation, statistical considerations) and evaluation of monitoring programmes for the US National Estuary Program; physical characteristics and chemistry in the water column; sediment grain size and chemistry; plankton (biomass, productivity, community structure/function); aquatic vegetation; benthic infauna and fish community structure; fish and shellfish pathobiology; bioaccumulation; bacterial and viral pathogens; biological indices. Provides a large bibliography about all these aspects.

Address: Office of Water; Office of Wetlands, Oceans and Watersheds; US Environmental Protection Agency, 401 M. Street, S.W., Washington, D.C. 20460, USA.

Leibowitz, N.C., L. Squires and J.P. Baker. 1991. *Research Plan for Monitoring Wetland Ecosystems*. EPA/600/3-91/010, United States Environmental Protection Agency (US EPA) and Environmental Monitoring and Assessment Program (EMAP). 157 pp.

Includes: a method for quantitative assessment of the current status and long-term trends in wetland condition on regional and national scales: EMAP-wetlands design; monitoring network design; indicators of wetland condition; field sampling design; analysis; logistics approach; quality assurance; information management; coordination; expected outputs; future research and timeliness.

Address: Environmental Research Laboratory, US Environmental Protection Agency, 200 SW 35th Street, Corvallis, Oregon 97333, USA.

Madgwick, J. and R. Serafin. 1993. *Assessing and monitoring changes in wetland parks and protected areas*. Leading Edge Press & Publishing, North Yorkshire for Broads Authority, Norfolk, UK; Heritage Resource Centre, Waterloo, Canada; and University of East Anglia, Norwich, UK. 123 pp. [Proceedings of Wetland Workshop held in the Broads, 9–13 October 1992].

Includes: case studies of management, restoration, monitoring, and assessment in protected wetlands.

Address: Broads Authority, Thomas Harvey House, 18 Colegate, Norwich, Norfolk, NR3 1BQ, UK.

Moser, M., R.C. Prentice and J. van Vessem (eds.). 1993. *Waterfowl and Wetland Conservation in the 1990s – A Global Perspective*. IWRB Special Publication 26, IWRB, Slimbridge, UK. 248 pp. [Proceedings of an IWRB Symposium, St Petersburg Beach, Florida, USA, 12–19 November 1992].

Includes: waterbirds as bioindicators; Biotest techniques; use of satellite imagery.

Address: Wetlands International, Slimbridge, Glos., GL2 7BX, UK.

6.3 Hydrology

Brassington, R. 1988. *Field Hydrology*. Open University Press, Milton Keynes, UK.

Custodio, E. and M.R. Llamas. 1983. *Hidrología Subterránea* (2 volumes). Editorial Omega, Barcelona, Spain. 2359 pp.

Dunne, T. and L.B. Leopold. 1978. *Water in Environmental Planning*. Freeman, San Francisco, USA.

Includes: the principles underlying the role of water in environmental planning; simple field observations and calculations that can be used to avoid costly errors in planning and executing environmental projects; description and discussion of processes and methods in hydrology, geomorphology and river quality.

Gilman, K. 1994. *Hydrology and Wetland Conservation*. Wiley, Chichester, UK.

Includes: aspects of wetland hydrology important for water management and for evaluation of threats; a range of techniques for measuring hydrological parameters are described: from simple field techniques (such as groundwater level measurement) to water budget quantification using computer-controlled lysimeter.

Kusler, J. and G. Brooks. 1988. *Wetland Hydrology*. Assoc. of State Wetland Managers, Berne, New York, USA.

Includes: book designed to help wetland managers (regulators, planners, researchers, waterfowl managers) understand wetland hydrology, its relationship to various wetland functions, the impact of various activities on hydrology, and approaches for reducing or compensating for those impacts.

Maltby, E., D.V. Hogan and G.A. Oliver. 1995. Wetland soil hydrology and ecosystem functioning. In: J.M.R. Hughes and A.L. Heathwaite (eds.). *Hydrology and hydrochemistry of British wetlands*. John Wiley and Sons. pp 325–262.

Newson, M. 1994. *Hydrology and the River Environment*. Clarendon Press, Oxford, UK.
Includes: description of basic system of water circulation and patterns of runoff, and major ways in which human presence and activities alter processes and patterns; presents a number of methodical frameworks exploring both problem-solving by data collection, analysis, predictions and the use of non-digital values such as attitudes, preferences, policies and laws.

Shaw, E.M. 1983. *Hydrology in Practice*. Van Nostrand Reinhold, Wokingham, UK.
Includes: hydrological processes, with emphasis on methods of measurement; analytical techniques; references to other standard texts and original publications on specialized subjects.

Ward, R.C. 1975. *Principles of Hydrology*. Second edition. MacGraw-Hill, London, UK.

Wilson, E.M. 1974. *Engineering Hydrology*. The MacMillan Press Ltd., London, UK.

6.4 Water quality

Allen, S.E. (ed.). 1974. *Chemical Analysis of Ecological Materials*. Blackwell Scientific Publications, Oxford, UK.

Allen, S.E., H.M. Grimshaw and A.P. Rowland. 1986. Chemical Analysis. In: P.D. Moore and S.B. Chapman (eds.). *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. pp 285–344.
Includes: detailed description of methods for chemical analysis; Soil analysis: collection, transport, storage, moisture determination, sieving and grinding, pH, extractable fraction, analysis of cations and nutrient non-metals; Analysis of plant materials: collection, transport, storage, preparation for analysis, dry ashing, acid digestion; Analysis of waters: collection, storage, preliminary treatment, conductivity, pH, alkalinity, Al, Ca, C, Cl, Cu, Fe, Mg, Mn, N, P, K, Si, Na, S, Zn; Instrumental procedures: colorimetry, flame spectroscopy.

APHA. 1989. American Public Health Association, American Water Works Association and Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater*. 17th edition. American Public Health Association, Washington, D.C., USA.

Baker, C.J. and E. Maltby. 1995. Nitrate removal by river marginal wetlands: factors affecting the provision of a suitable denitrification environment. In: J.M.R. Hughes and A.L. Heathwaite (eds.). *Hydrology and hydrochemistry of British wetlands*. John Wiley and Sons. pp 291–313.

Brooking, D.G. 1988. *Eh-pH diagrams for geochemistry*. Springer-Verlag, Berlin, Germany. 176 pp.

CEMAGREF-IARE. 1994. *Recherche d'indicateurs de niveaux trophiques dans les lagunes méditerranéennes: Analysis bibliographique*. Agence de l'Eau Rhône-Méditerranée-Corse, Lyon, France. 116 pp.
Includes: bibliography covering many different methods for the regular survey of lacustrine waters. Methods included are: nutrients in water and sediment; redox potential; phytoplankton: biomass, production, systematic classification; macrophytes: presence/absence, biomass, systematic classification; benthic macrofauna: species richness, biomass, concise indices, ratio of filtering/detritivorous organisms and Mollusca/Polychaeta; the cost of each method is indicated in an appendix.
Address: CEMAGREF, Domaine de Lavalette - BP 5095/36, rue J. F. Breton, 34033 Montpellier, Cedex 1, France.

Chovanec, A. 1994. Water quality monitoring in Austria. In: G. Aubrecht, G. Dick and C. Prentice (eds.). *Monitoring of Ecological Change in Wetlands of Middle Europe*. Stapfia 31, Linz, Austria and IWRB Publication 30, IWRB, Slimbridge, UK. pp 137–150.
Includes: country-wide water quality monitoring system for running waters in Austria: design of the monitoring network, choice of variables, aspects of sampling, data management, and results of the first investigation period.

Empain, A. 1976. Estimation de la pollution par les métaux lourds dans la Somme par l'analyse des bryophytes aquatiques. *Bulletin Français de la Pisciculture*: 48: 138–142.

Environmental Protection Agency. 1985. *Methods for measuring the acute toxicity of effluents to freshwater and marine organisms*. Third edition. EPA/600/4-85/013, Environmental Monitoring and Support Laboratory, United States Environmental Protection Agency, Cincinnati, Ohio, USA.

FAC (Eidg. Forschungsanstalt für Agrikulturchemie und Umwelthygiene). 1989. *Methoden für Bodenuntersuchungen*. Schriftenreihe FAC, Nr. 5. Liebefeld-Bern, Switzerland.
Includes: detailed description of methods for soil monitoring and investigation in Switzerland: sample collection and transport, storage, physical and chemical analysis, determination methods; soil structure and density, alkalinity, organic matter, cation analysis, redox potential, pH, nutrient and heavy metals concentrations.
Address: Institute für Umweltschutz und Landschaft (IUL): Schwarzenburg Str. 155. CH-3097. Liebefeld-Bern, Switzerland.

Farrington, J.W., E.D. Goldberg, R.W. Risebrough, J.H. Martin and V.T. Bowen. 1983. U.S. "Mussel Watch" 1976–1978: An overview of the trace-metals, DDE, PCB, hydrocarbon, and artificial radionucleide data. *Environmental Science Technology* 17: 490–496.

Ferraro, S.P., H. Lee, R.J. Ozretich and D.T. Specht. 1990. Predicting bioaccumulation potential: A test of fugacity-based model. *Arch. Environ. Contam. Toxicol.* 19: 386–394.

Gasparini, R. 1983. Water quality and the discharge of cooling waters into rivers, lakes and coastal waters. In: S.H. Kenkins and P. Schjodtz Hansen (eds.). Cooling water discharges from coal-fired power plants: water pollution problems. *Water Science and Technology* 15.

Goldberg, E.D. 1975. The mussel watch – A first step in global marine monitoring. *Marine Pollution Bulletin* 6 (7): 111.

Goldberg, D.E., V.T. Bowen, G.H. Farrington, J.H. Martin, P.L. Parker, R.W. Risebrough, W. Robertson, E. Schneider and E. Gamble. 1978. The mussel watch. *Environmental Conservation* 5: 101–125.

Golterman, H.L., R.S. Clymo and M.A.N. Ohnstad. 1978. *Methods for Physical and Chemical Analysis of Fresh Water*. Blackwell Scientific Publications, Oxford, UK.

Guitart, R., J. To-Figueras, R. Mateo, A. Bertolero, S. Cerradello and A. Martínez-Vilalta. 1994. Lead Poisoning in Waterfowl from the Ebro Delta, Spain: Calculation of Lead Exposure Thresholds for Mallards. *Arch. Environm. Contam. Toxicol.* 27: 289–293.

Gupta, S.K. and H. Häni. 1989. *Methodik zur Bestimmung bilogisch relevanter Schwermetallkonzentrationen im Boden und Überprüfung der Auswirkungen auf Testpflanzen sowie Mikroorganismen in belasteten Gebieten. Schlussbericht des COST-Projektes 681*. Schriftenreihe FAC (Eidg. Forschungsanstalt für Agrikulturchemie und Umwelthygiene), Nr. 2. Liebefeld-Bern, Switzerland. 54 pp.
Includes: detailed description of methods for the analysis of heavy metal concentration in soils, plants and microorganisms in Switzerland: sample collection and transport, storage, chemical analysis.
Address: Institute für Umweltschutz und Landschaft (IUL): Schwarzenburg Str. 155. CH-3097. Liebefeld-Bern, Switzerland.

Heath, A. 1987. *Water Pollution and Fish Physiology*. CRC Press, Boca Raton, Florida, USA.

Hellawell, J.M. 1986. *Biological Indicators of Freshwater Pollution and Environmental Management*. Elsevier Applied Science Publishers, London, UK. 546 pp.
Includes: biological indicators; environmental stress; effects of physical disturbances; effects of toxic materials; field assessments of environmental quality; biological surveillance in environmental management; biotic indices.

Kabata-Pendias, A. and H. Pendias. 1984. *Trace elements in soils and plants*. CRC - Press, Boca Raton, Florida, USA. 315 pp.

Lyman, W.J., W.F. Reehl and D.H. Rosenblatt. 1982. *Handbook of chemical property estimation methods. Environmental behaviour of organic compounds*. McGraw-Hill, New York, USA.

Mackereth, F.J.H., J. Heron and J.F. Talling. 1978. *Water analysis: some revised methods for limnologists*. Scientific Publications of the Freshwater Biological Association 36, UK. 118 pp.

Maher, W.A. and R.H. Norris. 1990. Water Quality Assessment Programmes in Australia: deciding what to measure, and how and where to use bioindicators. *Environmental Monitoring and Assessment* 14: 115–130.

Malins, D.C. and A. Jensen. 1988. *Aquatic Toxicology*. Elsevier Science Publisher, Amsterdam, The Netherlands.

McCarthy, J.F. and L.R. Shugart (eds.). 1990. *Biomarkers of Environmental Contamination*. CRC Press, Boca Raton, Florida, USA.

McLean, R.O. and A.K, Jones. 1975. Studies of tolerance of heavy metals in the flora of the rivers Ystwyth and Clarach. *Freshwater Biology* 5: 431–444.

Merian, E. (ed.) 1989. *Metals and their compounds in the environment – Occurrence, analysis and biological relevance*. VCH Verlagsgesellschaft. Weinheim, Germany.

Includes: describes relationship between metals and the environment: origin, cycles, presence in different compartments: soil, water, air, waste, plants, animals, etc., tolerance values, toxicity values; describes in detail 25 metals: characteristics and methods of analysis; origin, emissions, ingestion, accumulation, absorption, effects on plants, animals and humans.

Montalbano, F. and T.C. Hines. 1978. An improved X-ray technique for investigating ingestion of lead by waterfowl. *Southeastern Assoc. Fish & Wildl. Agencies Ann. Conf. Proc.* 32: 364–368.

Mudge, G.P. 1984. Densities and settlement rates of spent shotgun pellets in British wetland soils. *Environmental Pollution* Ser B 8: 299–318.

Ormerod, S.J. and S.J. Tyler. 1993a. Birds as indicators of changes in water quality. In: R.W. Furness and J.D.D. Greenwood (eds.). *Birds as monitors of environmental change*. Chapman & Hall, London, UK. pp 179–216.

Includes: birds as indicators of pollution in freshwater systems; accumulation of PCBs and organochlorines in bird eggs; birds as ecological indicators of surface water acidification.

Ormerod, S.J. and S.J. Tyler. 1993b. Further studies of the organochlorine content of Dipper *Cinclus cinclus* eggs: local differences between Welsh catchments. *Bird Study* 40: 97'106.

Includes: this paper examines and interprets differences between the organochlorine content of eggs from adjacent sub-catchments of rivers in Wales. It provides information particularly on individual polychlorinated biphenyls (PCBs). It concludes that Dipper eggs can aid in the detection of local patterns in the contamination of rivers by some persistent organochlorines.

Pain, D.J. 1989. Haematological parameters as predictors of blood lead and indicators of lead poisoning in the Black Duck (*Anas rubripes*). *Environmental Pollution* 60: 67–81.

Pain, D.J. 1991. Lead shot densities and settlement rates in Camargue marshes, France. *Biological Conservation* 57: 273–286.

Peakall, D.B. and H. Boyd. 1987. *Birds as bio-indicators of environmental conditions*. Chairmen's introduction, ICBP Technical Publication 6: 113–118.

Rosenkranz, D., G. Bachmann, G. Einzele and E.M. Harress (eds.). 1988. *Bodenschutz. Ergänzbares Handbuch de Massnahmen und Empfehlungen für Schutz, Pflege und Sanierung von Böden, Landschaft und Grundwasser*. Herich Schmidt Verlag GmbH, Berlin, Germany.

Includes: prevention measures and recommendations for the protection, preservation and restoration of soils, groundwater and landscape; gives intervention and target values for parameters included in the "Netherlands list (Niederländische Liste)": metals, inorganic compounds, aromatic compounds, PAHs, PCBs, pesticides.

Sigg, L. 1985. Metal Transfer Mechanisms in lakes: the role of settling particles. In: W. Stumm (ed.) *Chemical Processes in Lakes*. Wiley Interscience, New York, USA.

Smith, K.A. (ed.). 1983. *Soil Analysis – Instrumental Techniques and Related Procedures*. Dekker, Basel, Switzerland.

Spellerberg, I.F. 1991. Freshwater Biological Monitoring. In: I.F. Spellerberg. *Monitoring Ecological Change*. Cambridge University Press, Cambridge, UK. pp 215–237.

Includes: biological and chemical monitoring; water quality; monitoring effects of refinery aqueous effluents; classification of rivers and lakes.

Wedepohl, R.E., D.R. Knauer, G.B. Wolbert, H. Olem, P.J. Garrison and K. Kepford. 1990. *Monitoring Lake and Reservoir Restoration*. EPA 440/ 4-90-007, prepared by the North American Lake Management Society for the US Environmental Protection Agency (Technical supplement to the lake and reservoir restoration guidance manual), Washington, D.C., USA. 140 pp.

Includes: guidance for the design and implementation of monitoring programmes of lake restoration and protection projects; In-lake monitoring: sample collection, handling and preservation; water chemistry, chlorophyll a, transparency, flow measurements, etc. Provides outlines of monitoring programmes for specific lake restoration techniques, such as dilution/flushing, artificial circulation, food web manipulation, dredging, water level drawdown, mechanical/chemical control of nuisance plants, etc.; Watershed monitoring: watershed inventories, limited stream monitoring, comprehensive watershed monitoring; long-term monitoring.

Address: Clean Lakes Programme (WH-583); US Environmental Protection Agency; 401 M. Street, S.W., Washington, D.C. 20460, USA.

Yasuno, M. and B.A. Whitton. 1986. Biological monitoring for aquatic pollution. In: J. Salinki (ed.). *Biological monitoring of the environment: bioindicators. A manual of methods*. IUBS Monographs Series, 1. IRL Press Limited, Oxford, UK, pp 57–66.

Includes: synthesis of methods of biological monitoring useful for aquatic pollution.

Address: International Union of Biological Sciences; 51, bd de Montmorency; 75016 Paris, France.

6.5 Biological Indicators

Keddy, P.A. 1991. Biological monitoring and ecological prediction: from nature reserve management to national state of the environment indicators. In: F.B. Goldsmith (ed.). *Monitoring for Conservation and Ecology*. Chapman & Hall, London, UK. pp 249–267.

Includes: choosing the state variable to measure; biological monitoring at national scale; prediction, monitoring and decision-making.

Keddy, P.A. H.T. Lee and I.C. Wisheu. 1992. Choosing indicators of ecosystem integrity: Wetlands as a model system. In: S. Woodley, J. Kay and G. Francis (eds.). *Ecological integrity and the management of ecosystems*. Ste Lucie Press. pp 61–79.

Roeck, U., M. Trémolières, A. Exinger and R. Carbiener. 1991. Les mousses aquatiques, bioindicateurs du niveau de pollution chimique. Utilisation des mousses aquatiques dans une étude sur le transfert du mercure en tant que descripteur du fonctionnement hydrologique (échanges cours d'eau - nappe) en plaine d'Alsace. *Hydroécologie appliquée* 3 (2): 241–256.

Includes: spectrophotometric technique applied to the use of mosses as bioindicators of chemical pollution (Hg) in rivers.

Salinki, J., D. Jeffrey and G.M. Hughes (eds.). 1986. *Biological monitoring of the environment. A manual of methods*. IUBS Monographs 1, IRL Press Limited, Oxford, UK. 73 pp.

Includes: discussion about different groups of bioindicators (microbial, plants, animals, cell biological methods) for monitoring the state of the environment.

Address: International Union of Biological Sciences; 51, bd de Montmorency; 75016 Paris, France.

Spellerberg, I.F. 1991. Biological Indicators. In: I.F. Spellerberg. *Monitoring Ecological Change*. Cambridge University Press, Cambridge, UK. pp 93–111.

Includes: plant and animal indicators; detectors and exploiters; accumulators; status of biological indicators in monitoring programmes.

Zakharov, V.M. 1993. Biotest as an integrated technique to monitor the degradation and recovery of wetlands and the status of waterfowl populations. In: M. Moser, R.C. Prentice and J. van Vessem (eds.). *Waterfowl and Wetland Conservation in the 1990s – A Global Perspective*. IWRB Special Publication 26, IWRB, Slimbridge, UK. pp 43–47.

Includes: presentation of the Biotest methodology.

Zakharov, V.M. and G.M. Clarke (eds.). 1993. *Biotest: a new integrated biological approach for assessing the condition of natural environments*. Moscow Affiliate of the International Biotest Foundation, Moscow, Russia. 59 pp.

Includes: description of the Biotest methodology (morphological, genetic, physiological, biochemical, immunological tests); application of Biotest (anthropogenic agents, changes in habitat, background monitoring, integrated problem solving); description of the approaches.

Address: Moscow Affiliate of the International Biotest Foundation, Institute of Developmental Biology, Russian Academy of Sciences, 26 Vavilov St., Moscow, 117808, Russia.

6.6 Plants and Vegetation

Bhadresa, R. 1986. Faecal Analysis and Exclosure Studies. In: P.D. Moore and S.B. Chapman (eds.). *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. pp 61–71.
Includes: faecal analysis: collection, analysis, identification and quantification of fragments; feeding trials; exclosure studies: siting and design.

Braun-Blanquet, J. 1932. *Plant sociology: The Study of Plant Communities*. (English language reprint 1966). MacGraw-Hill, New York, USA.

Crawley, M.J. 1983. *Herbivory: The dynamics of plant-animal interactions*. Studies in Ecology vol. 10, Blackwell Scientific Publications, Oxford, UK. 437 pp.

Dalby, D.H. 1987. Salt marshes. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 38–80.
Includes: planning the survey; markers and reference points; trampling effects; preparation of base maps; vegetation mapping; measures of plant abundance; marking individual specimens; transect studies; indicator species.

Duncan, P. 1992. *Horses and Grasses. The Nutritional Ecology of Equids and their Impact on the Camargue*. Ecological Studies 87, Springer-Verlag, New York, USA. 287 pp.

Evans, D.G. 1977. The interpretation and analysis of subjective body condition scores. *Anim. Prod.* 26 (2): 119–126.

Goldsmith, F.B., C.M. Harrison and A.J. Morton. 1986. Description and Analysis of the Vegetation. In: P.D. Moore and S.B. Chapman (eds.). *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. pp 437–524.
Includes: dynamics of vegetation; description of vegetation; sampling methods; indices of diversity; analysis of vegetation; analysis of vegetation patterns, vegetation mapping; vegetational and environmental gradients.

Goldsmith, F.B. 1991. Vegetation Monitoring. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 77–86.
Includes: vegetation sampling; location of samples; measures of abundance; quadrats; sampling patterns; mapping schemes.

Greig-Smith, P. (ed.). 1983. *Quantitative Plant Ecology*. Third edition. Blackwell Scientific Publications, Oxford, UK. 256 pp.
Includes: description of methods for study and statistical analysis of plant data: sampling, correlation, ordination.

Hutchings, M.J. 1991. Monitoring plant populations: census as an aid to conservation. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 61–76.
Includes: methods for monitoring plant populations; monitoring rare plant populations (e.g. orchids).

Kennedy, K.A. and P.A. Addison. 1987. Some considerations for the use of visual estimates of plant cover in biomonitoring. *Journal of Ecology* 75: 151–157.

Kershaw, K.A. and J.H.H. Looney. 1985. *Quantitative Plant Ecology*. Arnold, London, UK.

Moore, P.D. and S.B. Chapman (eds.). 1986. *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. 589 pp.
Includes: production and nutrient budgets; faecal analysis and exclosure studies; water relations and stress; mineral nutrition; site description and soils; chemical analysis of soils, waters; data analysis; plant population biology; description and analysis of vegetation; site history.

Wells, T.C.E. and J.H. Willems (eds.). 1991. *Population Ecology of Terrestrial Orchids*. S.P.B. Academic Publishing, The Hague, Netherlands.

Wolff, W.J. 1987. Flora and macrofauna of intertidal sediments. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 81–105.
Includes: qualitative and quantitative surveys; position fixing; transport; measurement of environmental factors.

6.7 Invertebrates

Hartley, J.P. and B. Dicks. 1987. Macrofauna of subtidal sediments using remote sampling. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 106–130.

Includes: methods for studying abundance and distribution of benthic organisms in soft coastal and estuarine sediments; sampling strategies; sampling equipment; correlative measurement.

Pollard, E. 1991. Monitoring butterfly numbers. In: F.B. Goldsmith (ed.). *Monitoring in conservation and ecology*. Chapman & Hall, London, UK. pp 87–111.
Includes: butterfly monitoring scheme; case study; limitations and potential of butterfly monitoring.

Pollard, E. and T.J. Yates. 1993. *Monitoring butterflies for ecology and conservation*. Chapman & Hall, London, UK. 274 pp.
Includes: methods of monitoring, validation of the method; local distribution; fluctuation in numbers; colonization and extinction; effects of weather; migration; flight-periods; rare butterflies; site studies; population ecology; climatic warming.

Riddiford, N.J. and K. Bowey. 1992. S'Albufera butterfly and dragonfly transect methodology. In: N.J. Riddiford and F. Perring (eds.). *Monitoring for Environmental Change. The Earthwatch Europe S'Albufera Project, A summary report of the third season's work 1991*. Earthwatch Europe, Oxford, UK. pp 54–59.
Includes: description of a technique for butterfly and dragonfly survey, using transects.
Address: Earthwatch Europe, Belsyre Court, 57 Woodstock Road, Oxford OX2 6HU, UK.

Southwood, T.R.E. 1978. *Ecological Methods, with particular reference to study of insect populations*. Second edition. Methuen & Co Ltd, London, UK. 391 pp.
Includes: animal population studies and sampling in air, plants, vertebrate hosts, freshwater habitats, soil and litter; marking techniques; population estimates by relative methods; estimates based on products and effects; estimation of natality, mortality and dispersal; age-specific life-tables; predictive population models; modelling; diversity and habitat description; energy budgets.

Tett, P.B. 1987. Plankton. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 280–343.
Includes: hydrography; general description of plankton; sampling methods; microscopical analysis; microplankton biomass; data analysis and presentation; measurement of chlorophyll.

6.8 Fish

Arrignon, J. 1970. *Aménagement piscicole des eaux intérieures*. SEDETEC, S.A. Eds., Paris, France. 643 pp.

Bagenal, T.B. 1978. *Methods for Assessment of Fish Populations in Fresh Waters*. Third edition. IBP Handbook 3, Blackwell, Oxford, UK.

Brander, K. 1975. *Guidelines for Collection and Compilation of Fishery Statistics*. FAO Fisheries Technical Paper 148, FAO Fisheries Department, Rome, Italy.

Gerkin, S.D. 1978. *Ecology of Freshwater Fish Production*. Halstead Press, New York, USA.

Hyslop, E.J. 1980. Stomach contents analysis – a review of methods and their application. *J. Fish. Biol.* 17: 411–429.

Lam Hoai, T. and G. Lasserre. 1984. Méthodes d'évaluation des ressources des lagunes côtières. In: J.M. Kapetsky and G. Lasserre (eds.) *Aménagement des pêches dans les lagunes côtieres*. Studies and Reviews, General Fisheries Council for the Mediterranean (GFCM), 61(1): 143–159.

Potts, G.W. and P.J. Reay. 1987. Fish. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 342–373.
Includes: observation techniques: aerial observation, underwater observation and photography, acoustic surveys; capture techniques: traps, nets, mark-recapture methods, egg and larval surveys; sample analysis: diet and age determination; data processing; use of fisheries statistics.

6.9 Amphibia/Reptiles

Beebee, T.J.C. 1996. *Ecology and Conservation of Amphibians*. Chapman & Hall, London, UK. 214 pp.

Davies, D.E. (ed.). 1982. *CRC Handbook of census methods for terrestrial vertebrates*. CRC Press, Boca Raton, Florida, USA. 397 pp.

Heyer, R., M.A. Donnelly, R.W. McDiarmid, L-A.C. Hayeck and M.S. Foster (eds.). 1994.

Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington, USA and London, UK. 364 pp.
Includes: standard techniques for inventory and monitoring (transects, quadrat, patch sampling, trapping, etc.); study of amphibian biodiversity; estimation of population size; statistical analysis; analysis of biodiversity data; handling live amphibians. Techniques for marking amphibians; recording frog calls; preparing scientific specimens; collecting tissue for analysis; list of vendors; table of random numbers.

6.10 Birds

Baillie, S.R. 1991. Monitoring terrestrial breeding bird populations. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 112–132.

Bell, D.V. and M. Owen. 1990. Shooting disturbance – a review. In: G.V.T. Matthews (ed.) *Managing Waterfowl Populations*. IWRB Special Publication 12, Slimbridge, UK. pp 159–171 [Proceedings of an IWRB Symposium, Astrakhan, USSR, 2–5 October 1989].
Includes: disturbance effects on behaviour and distribution; methods of assessing effects and impacts; methods of alleviating disturbance.
Address: Wetlands International, Slimbridge, Glos, GL2 7BX, UK.

Bibby, C.J., N.D. Burgess and D.A. Hill. 1992. *Bird Census Techniques*. Academic Press, Harcourt Brace Jovanich, Publishers, London, UK. 257 pp.
Includes: census errors; territory mapping methods; line transects, point counts, catching and marking; counting individual species; counting colonial nesting and flocking birds; distribution studies; description and measurement of bird habitat.

Furness, R.W. and J.J.D. Greenwood (eds.). 1993. *Birds as monitors of environmental change*. Chapman & Hall, London, UK. 356 pp.
Includes: use of birds as monitors of: radionucleides and other pollutants; water quality; changes in marine prey stocks.

Kushlan, J.A. 1993b. Waterbirds as bioindicators of wetland change: are they a valuable tool? In: M. Moser, R.C. Prentice and J van Vessem (eds.). *Waterfowl and Wetland Conservation in the 1990's – A Global Perspective*. IWRB Special Publication 26, Slimbridge, UK. pp 48–55.

Landry, P. 1990. Bag statistics: a review of methods and problems. In: G.V.T. Matthews (ed.) *Managing Waterfowl Populations*. IWRB Special Publication 12, Slimbridge, UK. pp 105–112 [Proceedings of an IWRB Symposium, Astrakhan, USSR, 2–5 October 1989].
Includes: techniques used for the collection of game bag statistics; problems with techniques and sources of error: questionnaire design, recall bias, response bias, non-response bias, biological interpretation; summary of methods of data collection used in Europe; analysis of responses.
Address: Wetlands International, Slimbridge, Glos, GL2 7BX, UK.

Madsen, J. 1994. Impacts of disturbance on migratory waterfowl. *Ibis* 137: S67-S74.

Mountford, M.D. 1982. Estimation of population fluctuations with application to the Common Bird Census. *Applied Statistics* 31 (2): 135–143.

Norton-Griffiths, M. 1978. *Counting animals*. 2nd ed. Handbooks in African Wildlife Ecology 1, African Wildlife Leadership Foundation, Nairobi, Kenya. 139 pp.

Prater, A.J. and C.S. Lloyd. 1987. Birds. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 374–403.
Includes: number and distribution of non-breeding coastal birds; number of breeding seabirds; beached-birds surveys; list of organisations responsible for coordinating bird surveys.

Roberts, K.A. 1991. Field monitoring: confessions of an addict. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 179–211.
Includes: field monitoring in theory; monitoring motives and philosophy; practical problems of monitoring (observation, identification, timing, sampling, interference); use of old surveys; integrated monitoring; birds and reserve management.

Rose, P. (ed.). 1990. *Manual for International Waterfowl Census Coordinators*. Office National de la Chasse, France and IWRB, Slimbridge, UK. 30 pp.
Includes: structure of IWC network; sites and site lists; organising a counting team; collecting and checking data; storage, analysis of count data; common problems. [Also published in French].

Address: Wetlands International, Slimbridge, Glos., GL2 7BX, UK.

Rose, P. 1995. *Western Palearctic and South-West Asia Waterfowl Census 1994*. IWRB Publication 35, Slimbridge, UK. 119 pp.
Includes: coverage and results of the 1994 International Waterfowl Census (IWC) in the Western Palearctic and South-West Asia; overview of status and trends (1967–1993) of 53 populations of *Anatidae* and Coot *Fulica atra*.

Rose, P. and D. Scott. 1994. *Waterfowl Population Estimates*. IWRB Publication 29, Slimbridge, UK. 102 pp.
Includes: identification of 1824 distinct biogeographic populations of waterfowl from 833 species worldwide; gives numerical estimates for populations of 632 species of waterfowl; provides information on population trends.

Smit, C. and G.J.M. Visser. 1993. Effects of disturbance on shorebirds: a summary of existing knowledge from the Dutch Wadden See and Delta area. In: Davidson, N. and P. Rothwell. Disturbance to Waterfowl in Estuaries. *WSG Bull.* 68 (Special issue): 6–19.

Spellerberg, I.F. 1991 Monitoring Bird Populations. In: I.F. Spellerberg. *Monitoring ecological change*. Cambridge University Press, Cambridge, UK. pp 197–214.
Includes: sampling, recording and interpretation; bird census and surveillance; data collection, analysis and interpretation.

Underhill, L.G. and R.P. Prys-Jones. 1994. Index numbers for waterbird populations. 1: review and methodology. *J. Appl. Ecology* 31: 463–480.

6.11 Mammals

Davies, D.E. (ed.). 1982. *CRC Handbook of census methods for terrestrial vertebrates*. CRC Press, Boca Raton, Florida, USA. 397 pp.

Strachan, R. 1995. A Short-term Investigation into the Ecology of the Small Mammals at s'Albufera. *Butlletí del Parc Natural de s'Albufera de Mallorca* 2: 49–69.
Includes: use of Longworth trap for catching small mammals (*Mus* sp., *Apodemus sylvaticus*); population estimates and structure; relative densities; spatial distribution and vertical stratification.

6.12 Biotic indices

Crawford, J. 1991. The calculation of index numbers from wildlife monitoring data. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 225–248.
Includes: index numbers and their properties; wildlife index numbers in practice. problems peculiar to analysis of biological data.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Croom Helm, London, UK.
Includes: wide range of diversity indices with many worked examples.

Moore, P.D. and S.B. Chapman (eds.). 1986. *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. 589 pp.
Includes: indices of diversity for description and analysis of vegetation.

Southwood, T.R.E. (ed.). 1978. *Ecological Methods, with particular reference to study of insect populations*. Second edition. Methuen & Co Ltd, London, UK. 391 pp.
Includes: alpha and beta diversity; species packing; habitats.

Spellerberg, I.F. 1991. *Monitoring ecological change*. Cambridge University Press, Cambridge, UK. 334 pp.
Includes: diversity indices; similarity, environmental and biotic indices; biological variables, processes and ecosystems.

6.13 Mapping and Remote Sensing

Anonymous. 1992. *Application of Satellite Data for Mapping and Monitoring Wetlands*. Federal Geographic Data Committee (FGDC), Wetlands Subcommittee Technical report 1, US Fish and Wildlife Service, Washington, D.C., USA. 32 pp + 4 appendices.
Includes: discussion about the advantages and limitations of different satellite data (SPOT, Landsat) for mapping and monitoring wetland habitats: spectral resolution, spatial resolution, costs; link to a Geographic Information System (GIS).
Address: FGDC Wetlands Subcommittee, US Fish and Wildlife Service, 1849 C Street, N.W., ARLSQ 400 Washington, D.C., 20240, USA.

Barrett, E.C. and L.F. Curtis. 1982. *Introduction to Environmental Remote Sensing*. Chapman & Hall, London, UK.

Barrett, E.C. and K.A. Brown (eds.). 1989. *Remote Sensing for Operational Applications*. Technical Contents of the 15th Annual Conference of the Remote Sensing Society, University of Bristol, 13–15 September 1989, Bristol, UK.

Budd, J.T.C. 1991. Remote sensing techniques for monitoring land-cover. In: F.B. Goldsmith (ed.). *Monitoring for conservation and ecology*. Chapman & Hall, London, UK. pp 33–59.
Includes: introduction to remote sensing; satellite and aerial sensors; ground survey; advantages of each technique.

Christensen, E.J., J.R. Jensen, E.W. Ramsey and H.F. Mackey. 1988. Aircraft MSS data registration and vegetation classification for wetland change detection. *Int. J. Rem. Sens.* 9: 23–28.

Cluis, D. 1992. *Des nouvelles technologies pour une gestion integrée à l'échelle du bassin versant*. Association Québecoise des techniques de l'eau, Assises annuelles, 8–10 avril 1992, Montréal, Canada.

Costa, L.T., J.C. Farinha, N. Hecker and P. Tomàs Vives (eds.). 1996 (in press). *Mediterranean Wetland Inventory. A Reference Manual*. MedWet publication, ICN, Lisbon, Portugal & Wetlands International, Slimbridge, UK.
Includes: method for wetland inventory; catchment, site and wetland identification; wetland habitats; data recording; data storage (MedWet Database); mapping wetlands; use of the inventory.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. US Fish and Wildlife Service, Washington, D.C., USA. 131 pp.
Includes: description of the classification of wetlands and deepwaters used for the United States National Wetland Inventory.

Curran, P.J. 1985. *Principles of Remote Sensing*. Longmans, Harlow, UK.

Dahl, T.E. 1993. Monitoring Wetland Change: The U.S. Wetlands Status and Trends Study. In: M. Moser, R.C. Prentice and J. van Vessem (eds.). *Waterfowl and Wetland Conservation in the 1990s – A Global Perspective*. IWRB Special Publication 26, IWRB, Slimbridge, UK. pp 170–174.
Includes: presentation of the US Wetlands Status and Trends Study.

Dahl, T.E. and C.E. Johnson. 1991. *Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's*. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA. 28 pp.
Includes: survey procedures; results of the analysis; trends in wetland resources by wetland systems; glossary of classification terminology.
Address: U.S. Government Printing Office. Superintendent of documents, Mail Stop: SSOP, Washington, D.C. 20402-9328, USA.

Dalby, D.H. and W.J. Wolff. 1987. Remote Sensing. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 27–37.
Includes: introduction to remote sensing techniques for estuaries; aerial photography; photogrammetry; photointerpretation; digital systems, satellite imagery; digital processing of analogue imagery.

Devillers, P. and J. Devillers-Terschuren. 1993. *A Classification of Palearctic Habitats and Preliminary List of Priority Habitats in Council of Europe Member States*. A report to the Council of Europe, Convention on the Conservation of European Wildlife and Natural Habitats. Strasbourg, France. 286 pp. (unpublished report)
Includes: CORINE biotopes typology; a global system of habitat classification; draft classification of Palearctic habitats; priority habitats.
Address: Council of Europe, BP 431 R6, 67000 Strasbourg Cedex, France.

Drury, S.A. 1990. *A Guide to Remote Sensing: Interpreting Images of the Earth*. Oxford University Press, Oxford, UK.

European Communities Commission. 1991. *CORINE biotopes manual – A method to identify and describe consistently sites of major importance for nature conservation. Volume 1: Methodology; Volume 2: Data specifications – Part 1; Volume 3: Data specifications – Part 2*. Office for Official Publications of the European Communities, Luxembourg. 270 + 126 + 300 pp.
Includes: detailed description of the methodology used for the CORINE biotopes project; applications.

Farinha, J.C., L.T. Costa, G.C. Zalidis, A. Mantzavelas, E. Fitoka, N. Hecker and P. Tomàs Vives (eds.). 1996 (in press). *Mediterranean Wetland Inventory. Habitat Description System*. MedWet publication, ICN, Lisbon, Portugal & Wetlands International, Slimbridge, UK.
Includes: adaptation to the Mediterranean region of the habitat system used for the US National Wetland Inventory; based on descriptors, e.g. cover, water regime, salinity, etc.

Frayer, W.E., T.J. Monahan, D.C. Bowden and F.A. Graybill. 1983a. *Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's*. Colorado State University, Fort Collins, USA. 31 pp.

Frayer, W.E., T.J. Monahan, D.C. Bowden and F.A. Graybill. 1983b. *Procedure for using existing statistical wetland data to determine sample sites needed to produce wetland acreage estimates for selected geographic areas*. Colorado State University, Fort Collins, USA. 8 pp + appendix.

Fuller, R.M. 1983. *Ecological Mapping from Ground, Air and Space*. Institute of Terrestrial Ecology (ITE), Cambridge, UK.

Gray, J.S. and T.H. Pearson. 1982. Objective selection of sensitive species indicative of pollution-induced change in benthic communities. I. Comparative methodology. *Marine Ecology Progress Series* 9: 111–119.

Holmes, M.G. 1992. Monitoring vegetation in the future: radar. *Botanical Journal of the Linnean Society* 108: 93–109.

Lillesand, T.M. and R.W. Kiefer. 1979. *Remote Sensing and Image Interpretation*. Wiley, Chichester, UK. 612 pp.

Mather, P.M. (ed.). 1993. *Geographic Information Handling – Research and applications*. John Wiley & Sons, Chichester, UK. 343 pp.
Includes: introduction to GIS; environmental modelling using GIS; environmental applications of GIS: urban areas, land cover and use, hydrological models, stream-channel network, catchment; planning applications of GIS: mapping natural hazards; development in rural areas; data supply and conflict; intelligent, interactive and analysis-based GIS.

Moreira, J.M. and J. Ojeda. 1992. *Andalucía, una visión inédita desde el espacio*. Agencia de Medio Ambiente, Consejería de Cultura y Medio Ambiente, Junta de Andalucía, Sevilla, Spain. 213 pp.
Includes: physical basis of remote sensing; satellite sensors; satellite imagery analysis; application of remote sensing for mapping agriculture areas, wetlands, coastal zone, protected areas, marine dynamics and pollution, vegetation and land uses.

Nakayama, M. 1993. Monitoring Asian wetlands and lake basins using remote sensing technologies. In: M. Moser, R.C. Prentice and J. van Vessem (eds.). *Waterfowl and Wetland Conservation in the 1990s – A Global Perspective*. IWRB Special Publication 26, IWRB, Slimbridge, UK. pp 39–42.
Includes: use of satellite imagery for wetland monitoring; monitoring changes in vegetation and water quality.

National Rivers Authority. 1992. *River Corridor Surveys*. Conservation Technical Handbook 1. National Rivers Authority (NRA), Bristol, UK. 34 pp.
Includes: technique for a standard ecological survey of river corridors; mapping; cross-section; guidelines for survey supervisors; health and safety; access.
Address: National Rivers Authority, Newcastle Upon Tyne X, NE85 4ET, UK.

Remillard, M.M. and R.A. Welch. 1992. GIS technologies for aquatic macrophyte studies: I. Database development and changes in the aquatic environment. *Landscape Ecology* 7 (3): 151–162.

Spellerberg, I.F. 1991.Monitoring Land Use and Landscape. In: I.F. Spellerberg. *Monitoring Ecological Change*. Cambridge University Press, Cambridge, UK. pp 253–271.
Includes: organisation and land use data; collecting, storing and analysing data; land classes and classification; land use and land cover monitoring programmes.

Townshend, J.R.G. (ed.). 1981. *Terrain Analysis and Remote Sensing*. George Allen & Unwin, London, UK.

Yates, M.G., A.R. Jones, J.D. Goss-Custard and S. McGrorty. 1993. Satellite imagery to monitor ecological change in estuarine systems: example of the Wash, England. In: M. Moser, R.C. Prentice and J. van Vessem (eds.). *Waterfowl and Wetland Conservation in the 1990s – A Global Perspective*. IWRB Special Publication 26, IWRB, Slimbridge, UK. pp 56–60.

Includes: satellite image processing methods: Maximum Likelihood (ML) Classification, Multiple Regression (MR) Analysis and Mixture Modelling (MM) used to map intertidal surface sediments.

Zalidis, G.C., A. Mantzavelas and E. Fitoka. 1996 (in press). *Mediterranean Wetland Inventory. Photointerpretation and Cartographic Conventions*. MedWet publication, ICN, Lisbon, Portugal & Wetlands International, Slimbridge, UK.
Includes: mapping Mediterranean wetland habitats; wetland identification criteria; photointerpretation; field work; cartographic conventions.

6.14 Other

Adamus, P. and L. Stockwell. 1983. *A Method for Wetland Functional Assessment. Vols. I and II.* Reports FHWA-IP-82-23 and 24, US Department of Transportation, Federal Highway Administration, Washington, USA. 181 and 134 pp.

Adamus, P., L. Stockwell, E.J. Clairain Jr., M.E. Morrow, L.P. Rozas and R.D. Smith. 1987. *Wetland Evaluation Technique (WET). Vol. I: Literature Review and Evaluation Rationale*. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, USA.

Adamus, P., E.J. Clairain Jr., R.D. Smith and R.E. Young. 1987. *Wetland Evaluation Technique (WET). Vol. II. Technical Report Y-87*. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, USA.

Athanasiou, C. 1993. *WWF Project GR0020 – Red Alert System (RAS). Progress Reports n° 7, 8, 9 and 11*. Greek Biotope/Wetland Centre (EKBY) and WWF. Thessaloniki, Greece.
Includes: these reports describe the aims and actions of the Red Alert System (RAS). This scheme was launched in Greece in 1990 to monitor threats in important wetland areas, in order to take action to avert these threats. The RAS takes into account the natural biological values of the sites, as well as the needs of local people.
Address: Greek Biotope/Wetland Centre (EKBY), 14th Km Thessaloniki-Mihaniona, 57001 - Thermi, Macedonia, Greece.

Baker, J.M. and W.J. Wolff. 1987. Safety (compiled from Institute of Biology and Natural Environment Research Council Safety Guidance Notes). In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 424–439.
Includes: General procedures: potential dangers, clothing and field-equipment, international distress signals, first-aid; Special procedures: intertidal flats and salt marshes, rocky shore and cliffs, small boats and research vessels, diving, electric fishing.

Begon, M. 1979. *Investigating Animal Abundance: Capture-Recapture for Biologists*. Edward Arnold, London, UK.

Bishop, D.N. 1983. *Statistics for biology*. Longman, Harlow, UK. 232 pp.

Blower, J.G., L.M. Cook and J.A. Bishop. 1981. *Estimating the Size of Animal Populations*. George, Allen & Unwin, London, UK.

Calvo, B. and R.W. Furness. 1992. A review of the use and the effects of marks and devices on birds. *Ringing & Migration* 13: 129–151.

Cochran, W.G. 1977. *Sampling techniques*. Third edition. John Wiley & Sons, Chichester, UK. 428 pp.

Cooley, W.W. and P.R. Lohnes. 1971. *Multivariate Data Analysis*. John Wiley & Sons, Chichester, UK. 364 pp.

De Groot, R.S. 1992. *Functions of Nature. Evaluation in environmental planning, management and decision making*. Wolters-Noordhoff, Amsterdam, Holland.

Fowler, J. and L. Cohen. 1995. *Statistics for Ornithologists*. Second edition. BTO guide 22, British Trust for Ornithology, Tring, UK.
Includes: techniques and examples designed to be user-friendly for ornithologists, but applicable to a range of biological disciplines and groups.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold Co., New York, USA.

Goldsmith, F.B. 1983. Ecological Effects of Visitors and the Restoration of Damaged Areas. In: A. Warren and F.B. Goldsmith (eds.). *Conservation in Perspective*. Wiley & sons, Chichester, UK. pp 201–214.

Goldsmith, F.B., R.J.C. Munton and A. Warren. 1970. The Impact of Recreation on the Ecology and Amenity of Semi-natural Areas: Methods of Investigation used in the Isles of Scilly. *Biological Journal of the Linnean Society* 2: 287–306.

GEMS-UNEP. 1993. *An introduction to HEM & HEMDisk*. Global Environmental Monitoring System – United Nations Environment Programme. Oberschleissheim, Germany. 26 pp + 1 disk.

Includes: description of the "Harmonization of Environmental Measurement Information System" (HEMIS) established by UNEP as part of the Global Environmental Monitoring System (GEMS); HEMIS is a computer-based system to facilitate the transfer of information about who is doing what, how, where, and why in environmental measurement; the system aims to promote harmonization of environmental information in several ways: encouraging cooperation, promoting standardized and harmonized nomenclature, assembling information on commonly used classification systems, identifying existing data sources, thus reducing duplication of monitoring efforts. A meta-database is included in a diskette, providing information on: institutions, monitoring programmes, methods and models, classification systems, databases, reference materials, key individuals.

Green, R.H. 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. John Wiley & Sons, New York, USA. 257 pp.

Green, R.H. 1980. Multivariate approaches in Ecology: the assessment of ecologic similarity. *Ann. Rev. Ecol. Syst.* 11: 1–14.

Green, R.H. 1984. Statistical and non-statistical considerations for environmental monitoring studies. *Environmental Monitoring and Assessment* 4: 293–301.

Harper, D.G.C. 1994. Some comments on the repeatability of measurements. *Ringing & Migration* 15: 84–90.

Hewett, C.N. 1986. *Methods of Environmental Data Analysis*. Chapman & Hall, London, UK. 309 pp.

Maltby, E., D.V. Hogan, C.P. Immirzi, J.H. Tellam and M.J. van der Peijl. 1994. Building a new approach to the investigation and assessment of wetland ecosystem functioning. In: W.J. Mitsch (ed.). *Global Wetlands – Old World and New*. Elsevier Sciences B.V., Amsterdam, The Netherlands. pp 637–658.

Maltby, E., R. Hughes and C. Newbold. 1988. *The Dynamics and Functions of Coastal Wetlands of the Mediterranean Type*. A report for DGXI contract 6611/ZH/10. 52 pp. (unpublished report)

Address: Royal Holloway College Institute for Environmental Research, Royal Holloway College, University of London, Egham, Surrey TW20 0EX, UK.

Morgan, B.J.T. and P.M. North (eds.). 1985. *Statistics in Ornithology*. Springer-Verlag, Berlin, Germany.

Nichols, D. 1983. *Safety in biological fieldwork-guidance notes for codes of practice*. Second edition. Institute of Biology, London, UK.

Penloup, A. 1995. *Techniques for Monitoring Mediterranean Wetlands: A Preliminary Bibliography*. MedWet sub-project on Inventory & Monitoring, IWRB & Tour du Valat, Camargue, France. 111 pp.

Includes: a review of 176 references related to monitoring wetlands, 109 of them described in a concise form; glossary of terms.

Address: Wetlands International, Slimbridge, Glos., GL2 7BX, UK.

Prince, S.D. 1986. Data Analysis. In: P.D. Moore and S.B. Chapman (eds.). *Methods in Plant Ecology*. Blackwell Scientific Publications, Oxford, UK. pp 345–375.

Includes: sampling; purpose of an investigation; types of measurements; number of variables; mathematical and statistical models; computer and data analysis.

Sockal, R.R. and F.J. Rohlf. 1981. *Biometry: The Principle and Practice of Statistics in Biological Research*. Second edition. W.H. Freeman & Co., San Francisco, USA. 859 pp.

Wolff, W.J. 1987. Identification. In: J.M. Baker and W.J. Wolff (eds.). *Biological Surveys of Estuaries and Coasts*. Cambridge University Press, Cambridge, UK. pp 404–421.

Includes: guidelines for identification of coastal and estuarine species: Bacteria, Fungi, Algae, Lichens, Plants, Invertebrates, Fish, Birds, Mammals; problems for the identification of organisms from estuaries and coastal waters; literature to be used.

7 Case studies

This chapter presents the results of five case studies, in which the methodological framework for designing monitoring programmes has been followed in order to test its application to real situations. These pilot studies, which were carried out in 1995 and 1996 at five internationally important wetland sites, have generated valuable feedback and practical input to the guide. The five pilot sites are:

- *Sado Estuary Nature Reserve, Portugal*
- *S'Albufera de Mallorca Natural Park, Balearic Islands, Spain*
- *Lake Kerkini, Greece*
- *Étang de l'Or, Languedoc-Roussillon, France*
- *Aiguamolls de l'Empordà Natural Park, Catalonia, Spain*

Monitoring programmes have been designed for these Mediterranean wetlands following the process described in this guide. This was done by the manager(s) of the sites or by scientists working in close collaboration with them, in order to ensure that the objectives and needs of the management were taken into consideration, and that the monitoring programmes could easily be integrated into the management. Indeed, in most of the pilot sites, the monitoring programmes defined were launched in 1996 or were to start soon after, as part of the site management.

Future phases of MedWet should see this process being applied on a Mediterranean-wide scale as the focus moves to the implementation of the methodologies proposed during the current first phase. Certainly, many Mediterranean wetlands would benefit from programmes for monitoring ecological change and implementation would be an appropriate practical response to the resolution on the importance of monitoring changes in the ecological character of wetlands adopted by the Conference of the Contracting Parties to the Ramsar Convention at their sixth meeting in Brisbane, Australia, in March 1996.

Ramsar Wetland Types

In the case studies, the authors have used the typology adopted by the Ramsar Convention to describe their wetlands. The codes are based upon the '*Classification of Wetland Type*' approved by Rec. C.4.7 (Rev.) of the Conference of the Contracting Parties (Montreux, 1990). The categories listed are intended to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site. This framework should not be considered as an attempt at a comprehensive wetland classification (Frazier 1995).

Frazier, S. 1995. *The Ramsar Database System. Interim Documentation*. 7 March 1995. IWRB and Ramsar Bureau. 16 pp. (unpublished document)

RAMSAR WETLAND TYPES AND THE CODES USED FOR THE RAMSAR DATABASE (March 1995) [1]

A Permanent **shallow marine waters** less than six metres deep at low tide; includes sea bays and straits.
B Marine **subtidal aquatic beds**; includes kelp beds, sea-grass beds, tropical marine meadows.
C **Coral reefs.**
D **Rocky marine shores**; includes rocky offshore islands, sea cliffs.
E **Sand, shingle** or **pebble shores**; includes sand bars, spits and sandy islets; includes dune systems.
F **Estuarine waters**; permanent water of estuaries and estuarine systems of deltas.
G **Intertidal mud, sand** or **salt flats.**
H **Salt marshes**; includes salt meadows, saltings, raised salt marshes.
I **Intertidal forested wetlands**; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests.
J **Coastal brackish/saline lagoons**; brackish to saline lagoons with at least one relatively narrow connection to the sea.
K **Coastal freshwater lagoons**; includes freshwater delta lagoons.
L Permanent **inland deltas**.
M **Permanent rivers/streams/creeks**; includes waterfalls.
N **Seasonal/intermittent/irregular rivers/streams/creeks**.
O **Permanent freshwater lakes** (over 8 ha); includes large oxbow lakes.
P **Seasonal/intermittent freshwater lakes** (over 8 ha); includes floodplain lakes.
Q **Permanent saline/brackish/alkaline lakes**.
R **Seasonal/intermittent saline/brackish/alkaline lakes**.*
Sp **Permanent saline/brackish/alkaline marshes/pools**.
Ss **Seasonal/intermittent saline/brackish/alkaline marshes/ pools**.*
Tp **Permanent freshwater marshes/pools**; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season.
Ts **Seasonal/intermittent freshwater marshes/pools** on inorganic soil; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.*
U Non-forested **peatlands**; includes shrub or open bogs, swamps, fens.
Va **Alpine wetlands**; includes alpine meadows, temporary waters from snow melt.
Vt **Tundra wetlands**; includes tundra pools, temporary waters from snow melt.
W **Shrub-dominated wetlands**; Shrub swamps, shrub-dominated freshwater marsh, shrub carr, alder thicket; on inorganic soils.*
Xf **Freshwater, tree-dominated wetlands**; includes freshwater swamp forest, wooded swamps; on inorganic soils.*
Xp **Forested peatlands**; peatswamp forest.*
Y **Freshwater springs; oases**.
Z **Geothermal wetlands**.

Man-made wetlands

1 **Aquaculture** (e.g. fish/shrimp) **ponds**
2 **Ponds**; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3 **Irrigated land**; includes irrigation channels and rice fields.
4 **Seasonally flooded agricultural land**. #
5 **Salt exploitation sites**; salt pans, salines, etc.
6 **Water storage areas**; reservoirs/barrages/dams/impoundments; (generally over 8 ha).
7 **Excavations**; gravel/brick/clay pits; borrow pits, mining pools.
8 **Wastewater treatment areas**; sewage farms, settling ponds, oxidation basins, etc.
9 **Canals and** drainage **channels**, ditches.

0 No information

NOTES:

1 At the Sixth Conference of the Contracting Parties, Brisbane, March 1996, a new type was added to the Ramsar wetland classification: **Subterranean karst and cave hydrological systems**. At the moment of publication this new type has not been assigned a definitive code.
* As appropriate, includes: **Floodplain wetlands**, such as seasonally inundated grassland (including natural wet meadows), shrublands, woodlands or forest.
\# To include intensively managed or grazed wet meadow or pasture.

7.1 Sado Estuary, Portugal

Rui Rufino, M. Helena Costa,
Carmen Rosado and António Bruxelas

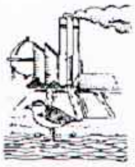

Plate 7.1.1 Intertidal areas and estuarine waters in the Sado estuary. (Rui Rufino)

7.1.1 Description of the site

Location, size, physiography

The Sado estuary, 38°27'N 08°43'W, is located on the west coast of Portugal 45 km south of Lisbon (Figure 7.1.1) and occupies an area of approximately 24,000 ha. The estuary has a wide central area and two main arms: one oriented almost north-south (Canal da Marateca) and the other, larger, oriented ESE-WNW and formed by the Sado river (Canal do Sado). The southwest side of the estuary is separated from the sea by a well developed dune system. The central area of the estuary has an average depth of 10 m and that part of the Sado river included in the estuary has an average depth of 5 m. The tidal range varies from 1 m to 3.5 m. The catchment area of the Sado river extends over 7,600 km^2 (Cabeçadas *et al.* 1994).

Wetland types occurring at the site

Within the estuary occur a variety of natural wetland types. Using the Ramsar classification they are: sand bars, islets and dune system (Ramsar type E), estuarine waters (F), mud and sand inter-tidal flats (G) and salt marshes (H). Artificial wetland types are also represented: by aquaculture (1), rice fields (3), salt pans (5), wastewater treatment areas (8) and canals (9).

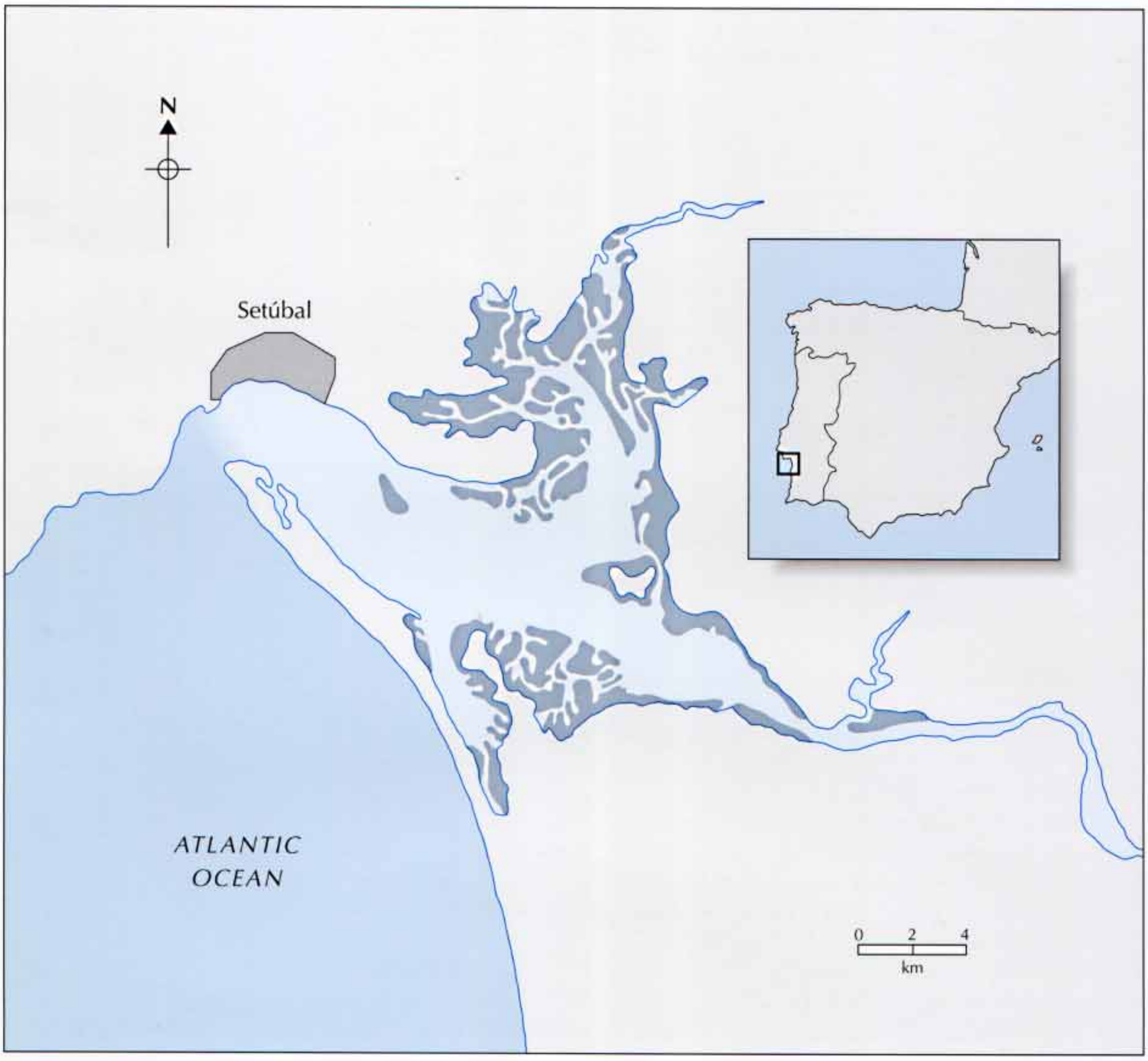

Figure 7.1.1 Sado estuary, Portugal.

Main values of the wetland

A series of wetland functions, products and attributes can be identified for the Sado estuary:

Functions: shoreline stabilisation and erosion control, sediment and toxic material retention, nutrient retention, biomass export, storm protection, micro-climate stabilisation, recreation and tourism.

Products: wildlife resources, fisheries, forage resources, agricultural resources.

Attributes: biological diversity, uniqueness to culture/heritage.

Land use and main threats

The Sado estuary is intensively used by man and plays an important role in the local and national economy. Close to the mouth on the north side lies Setúbal, a medium sized city, with over 100,000 inhabitants, where an important industrial concentration has developed during the last 30 years. This concentration includes a large shipyard, a pulp mill and a fuel power plant. In other areas around the estuary intensive farming, mostly rice fields, is the main feature together with traditional salt pans and increasingly intensive fish farms. Within the estuary, relatively intensive fisheries are conducted for fish, molluscs and bait.

All these activities have an impact upon the estuary's wildlife but the main threats to the quality and sustainability of this area are pollution (organic and chemical) resulting from untreated wastewater discharges from Setúbal, industrial waste and wastewater, rice field discharges and the leaking of residues into the Sado river from an iron and copper mine located upstream. This, and increasing pressure from fish farming is leading to the abandonment and destruction of salt pans, and their replacement by aquaculture settlements which now occupy about 30% of the former area of salt pans, thus reducing habitat availability for several breeding, migrant or wintering waterbird species.

Ownership, legal status and management body

The open water areas, tidal flats and salt marshes are the property of the Portuguese State whereas all the surrounding land, including the rice fields and salt pans, is privately owned. The vast majority of the estuary, excluding the outer areas and the city of Setúbal and its port, and a considerable part of its surrounding area were classified as a Nature Reserve (D.L. n° 430/80 of October 10). Most of the Nature Reserve was designated by the Portuguese Government as a Special Protection Area under the EC Birds Directive, 79/409/EEC. A land use plan for this protected area is not yet implemented but should be effective shortly. The Nature Reserve is the managing authority for the whole area but a series of other governmental agencies have jurisdiction over the area for harbour administration, fisheries, wastewater discharges, agricultural practices and urban planning.

7.1.2 Existing monitoring and surveillance programmes

Wintering waterbirds

1. All species – annual surveys in January since 1978, carried out by the Centro de Estudos de Migrações e Protecção das Aves (CEMPA/ICN) as part of the national winter wader and waterfowl counts. Resources: 4–5 CEMPA staff and 1–2 Nature Reserve staff for two days.

2. Waterfowl – monthly surveys, October to March, carried out since 1992/93 by CEMPA/ICN as part of a specific national monitoring programme for wintering waterfowl. Resources: 2 CEMPA staff and one Nature Reserve staff member for 1–2 days per month, October to March.

Both programmes aim to record population changes and evaluate the effects of different management practices.

Analysis of the numerical data obtained from the census is quite simple and deals only with total numbers of birds counted. Trend analysis at the national scale is being implemented.

National reports include the Sado estuary and are published every year by CEMPA/ICN (Rufino 1988, 1990, 1992; Rufino & Costa 1993).

Monitoring the status of salt pans and their breeding bird populations

This is carried out by CEMPA/ICN. It was begun in 1991 and will continue until 1998. Afterwards a simple monitoring system should be maintained.

The aim of this programme is to:

1. Monitor the physical status of the salt pans and the changes to which they are subject.

2. Monitor the breeding waterbird community, with special attention to black-winged stilt *Himantopus himantopus* and little tern *Sterna albifrons*, in terms of numbers, distribution and productivity.

Resources: two CEMPA staff members making 2–4 visits to the estuary per month.

Trend analysis is performed of changes in the status of salt pans and of breeding bird populations. This programme also aims to identify trends in habitat use in order to permit management decisions.

Part of the data collected has been analysed already and presented at consecutive Wader Study Group Conferences, in 1994 and 1995, but has not been published yet. Another part of the data is currently being published as a CEMPA/ICN report (Neves & Rufino 1995).

Plate 7.1.2 Salt pans are important breeding habitats for birds. (Renato Neves)

Monitoring of PSP and DSP toxins in edible bivalves

Monitoring of these shellfish toxins is carried out by the Portuguese Marine Research Institute, IPIMAR. The objective is to control the quality of bivalves captured in the estuary in order to avoid the commercialisation of animals not fit for human consumption.

Water Quality (INAG)

River water is sampled regularly at a series of locations. A range of parameters are measured, both chemical and organic. This procedure works as an alert system.

Other baseline studies and short-term programmes

Phytoplankton and Primary production (Cabeçadas 1993)

A three year project to measure chlorophyll a and cell density together with suspended matter and particulate carbon in a series of sampling stations from the centre to the upper reaches of the estuary. Sampling was carried out monthly at five different stations, from the centre of the estuary to the Sado river during 1986, 1987 and part of 1988.

Heavy metals and Organic contaminants in salt pans (Pimentel & Costa in prep.)

This project was set up to evaluate and monitor the contamination of heavy metals in salt pans. The project uses birds as indicators, measuring contaminant levels in eggs and feathers. Measurements are also taken to establish contaminant levels in the salt pan ecosystem components: sediment, water, macro-invertebrates and salt.

Heavy metals analysed include copper (Cu), lead (Pb), zinc (Zn), cadmium (Cd) and mercury (Hg). The organic contaminants include polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and organochlorated pesticides.

Sampling follows temporal and spatial gradients. Four sites, covering different parts of the estuary, were selected for monthly sampling after initial baseline sampling over a wider range of salt pans within the estuary. The salt was collected in a

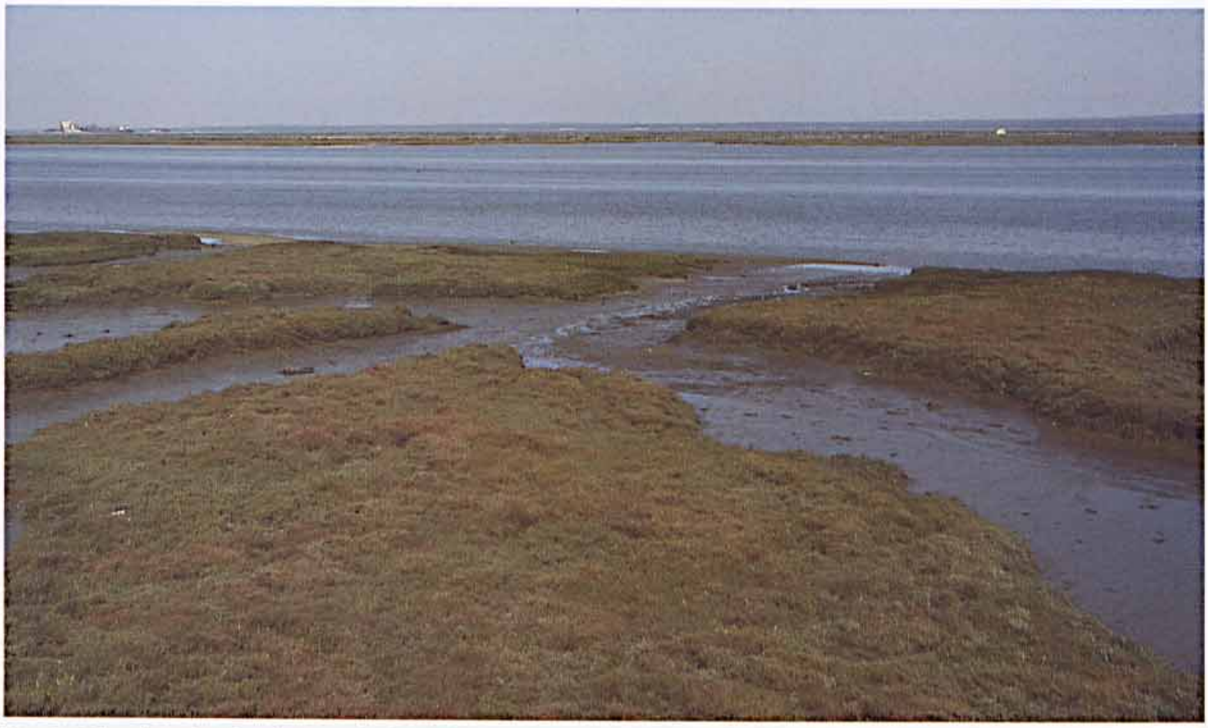

Plate 7.1.3 The salt marsh in the Sado estuary has been reclaimed in the past for salines, which are now transformed into aquaculture. (Rui Rufino)

limited number of salt pans at the end of 1995 season.

This project was conducted during 1994 and 1995.

Nutrients (Cabeçadas *et al.* 1994)

The objectives of this short-term programme were: a) identification of nutrient sources, assessment of their weight and definition of distribution patterns; b) identification of primary production processes.

The parameters measured were phosphorus (P), nitrogen (N), silicon (Si) and organic matter. Sampling was carried out at different times of the year.

The project had a duration of three years.

7.1.3 Monitoring programme proposed for the Sado estuary

The Sado estuary was never the subject of a comprehensive monitoring programme. There is, however, a considerable amount of baseline information as a result of the surveys conducted during the last 20 years and few specific monitoring programmes are currently under way. Most of the existing data were gathered independently and a cause-effect analysis of all the parameters measured was never attempted.

The managing authorities make their decisions based on information collected unevenly and no monitoring programme has yet been set up to provide basic information and guidance.

This pilot study was developed by bringing together the skills of a group of people working at ICN and at the New University of Lisbon (Universidade Nova de Lisboa, Dept. de Ambiente), and using the available information. The result is a monitoring programme which covers a wide variety of parameters, biological, chemical and physical, but centred on waterbirds with particular regard to their populations and the factors affecting their habitats and food resources.

The way pollution, over-fishing and habitat loss affects the bird populations is not yet well understood but it is know that features like hunting and bait digging reduce habitat availability. This pilot study was designed to

TABLE 7.1.1 ***Summary of key points of the monitoring programme for the Sado Estuary.***

General problem/issue	Industrial and tourist development in the areas surrounding the estuary. Aquaculture development and salt industry decline.
Specific problem/issue	Loss of habitat for waterbirds. Increasing contamination of wader and waterfowl food resources.
Objective	Monitor the rate of habitat change, contamination, traditional fisheries, dredging, wintering waterbird populations, and breeding waterbird population levels and reproductive success.
Hypothesis	Available habitat will not decline significantly (beyond 10% of pilot study mean) and shall not lead to a reduction in bird numbers and their breeding performance. Contamination and depletion of resources will not assume very large proportions, as defined for each study.
Methods and variables	Water flow (using the information collected by INAG). Salinity in the upper reaches of the estuary. Mapping methods will be used to monitor rates of habitat change, using aerial photography and topographic maps (1:25,000 IGC). Contaminants in the water, sediment, macro-invertebrates and bird eggs and feathers. Indirect assessment of contamination using invertebrate assemblages (Warwick 1981). Wintering and breeding bird census to construct population indices (Underhill & Prys-Jones 1994). Breeding success, in terms of annual production of young, for black-winged stilt and little tern. Fishing effort will be measured, using declared landings and counting the number of bait diggers in selected sampling sites at regular intervals. Dredging will be measured using the declared landings.
Feasibility/Cost effectiveness	Equipment from the UNL (New University of Lisbon). Permanent staff from ICN, graduating students and permanent staff from UNL. Maintenance of equipment as part of normal UNL routine.
Sampling	Sampling for macro and meiofauna at seven different stations, with ten or five replicates, covering three different sediment types. Systematic sampling of all available *pullus* feathers for black-winged stilt and little tern. Random sampling of bird eggs for the commonest species and of those available for the other species. Water, sediment and indicator macro-invertebrate species, from intertidal areas and from salt pans.
Sample analysis	Various, pertaining to subject.
Reporting	Statistically analysed data will be reported to the managers of the Nature Reserve, in order to set policies and take management actions.

allow for habitat changes (in area and quality) to be monitored in parallel with bird populations and their reproductive success, providing information on changes in the wetland and the bird populations using it as well as the impact of changes on the birds.

Identification of problems

The area is subject to several forms of pollution, notably untreated wastewater from the surrounding urban areas, industrial effluents, thermal pollution from the power plant, pesticides and fertilisers washed from the rice fields, and leaking residues from the mine upstream. At the same time strong pressure is put upon the managers of the Nature Reserve to allow the development of a wide variety of activities which cause (or may cause) significant impacts upon the waterbird populations using the estuary. These are fish farming, tourism, port development and fisheries.

Identification of objectives

The management objective is to maintain or increase the waterbird populations using the Sado estuary, as they were one of the main reasons for designating the area as a Nature Reserve.

The aim of the programme is to monitor the rate of *habitat change*, levels of *contamination* in waterbird food resources, *traditional fisheries*, the rate of *dredging*, *wintering and breeding population* changes and the changes in *breeding success*. It is also expected to provide the authorities and the managers of the site with the necessary information upon which decisions concerning waterbird populations and wetland integrity and quality will be made.

Set up hypothesis, and selection of parameters and techniques

The approach will be made at two different levels: *changes in area* and *changes in the quality* of the wetland. To assess both types of change, a different set of parameters will be measured for each.

Changes in area

Variations in area will be monitored for the following habitats:

Inter-tidal areas (treated as three separate types: mud, sand and muddy-sand). A full survey will be made at the onset of the pilot study. A selection of transects will be used and change will be recorded annually in parallel with a survey of areas lost due to infill reclamation. Acceptable variation for a ten year period: 10% deviation from baseline.

Salt marshes. A full survey will be made at the onset of the pilot study. To measure change a selection of transects will be used where change will be recorded yearly. Acceptable variation for a ten year period: 10% deviation from baseline.

Salt pans (subdivided into three categories: active, partially active and inactive salt pans). A full survey already exists and will be updated annually using aerial photography and ground surveys. Limits will have to be set up for each category individually but for the whole group an acceptable variation of 10% from baseline is defined.

Aquaculture. A full survey already exists and will be updated yearly using aerial photography and ground surveys. Acceptable variation no more than 10% increase over area occupied during recent survey (this takes into account that about 35% of the existing salt pans has already been lost to fish farming or destroyed in the last 10 years).

Rice fields: A full survey will be made at the onset of the pilot study. Change will be recorded yearly using ground surveys. Acceptable variation: 30% deviation from baseline conditions (this change very much depends on water availability. The aim is to limit the permanent replacement of rice by other crops such as sunflower).

NB: all the acceptable variation limits were established for a ten year trend.

These changes will be measured through aerial photographic analysis of the whole estuarine area using the available coverage, which tends to be at 5–10 year intervals. Available photographic

TABLE 7.1.2 ***Simple monitoring programme for the Sado Estuary.***

General problem/issue	Industrial and tourist development in the areas surrounding the estuary. Aquaculture development and salt industry decline.
Specific problem/issue	Loss of habitat for waterbirds.
Objective	Monitor the rate of habitat change, traditional fisheries, dredging, wintering waterbird populations, and breeding waterbird population levels and reproductive success.
Hypothesis	Available habitat will not decline significantly (beyond 10% of pilot study mean) and will not lead to a reduction in bird numbers and their breeding performance.
Methods and variables	Mapping methods will be used to monitor rates of habitat change, using aerial photography and topographic maps (1:25,000 IGC). Wintering and breeding bird census to construct population indices (Underhill & Prys-Jones 1994). Breeding success, in terms of annual production of young, for black-winged stilt and little tern. Fishing effort will be measured by recording the declared landings and counting the number of bait diggers in selected sampling sites at regular intervals. Dredging will be measured using the declared landings.
Feasibility/Cost effectiveness	Permanent staff from ICN.
Sampling	Various, pertaining to subject.
Sample analysis	Various, pertaining to subject.
Reporting	Statistically analysed data will be reported to the managers of the Nature Reserve, in order to set policies and take management actions.

Plate 7.1.4 Enlargement of the Setúbal harbour is threatening the intertidal areas and salt marshes of the Sado estuary. (Rui Rufino)

resources include: a 1990 set in infrared false colour at 1:15,000; a 1994 set in black and white (panchromatic) at 1:15,000 and a 1995 set in infrared false colour at 1:40,000. To obtain baseline estimates for the three different estuarine sediment types, satellite imagery will be preferred. The areas selected for transect follow-up will be mapped using information from satellite imagery and aerial photography.

Analysis will consider the trends. In identifying trends, factors affecting the area of each habitat type temporarily, e.g. climate features such as droughts and floods, will be taken into account.

The results are expected to be used by conservation and land use managers to set up policies in order to arrest further degradation. The identification of trends will also provide baseline information for interpretation of the changes in avian and other biological communities.

Changes in the quality of the wetland

The monitoring programme is centred on the waterbird populations and the factors affecting their habitats and food resources. Therefore, it is concerned with parameters that can be measured: the population changes of both breeding and wintering birds; the reproductive success of birds breeding in the estuary; the factors affecting their reproductive success, directly or indirectly; the factors affecting food availability, both in terms of actual reduction of stocks and reduction of access to the stocks; and the factors affecting the system as a whole and thus, indirectly, the birds, their habitats and food resources. Measurements will be made directly or through indicators, such as bird feathers and eggs.

To obtain this information, the following parameters have been selected:

a) Wintering and breeding waterbird populations

Regular mid-winter census of waterbirds (waders and ducks) will be carried out at high tide roosts for the whole estuary. Identification of refuge areas will be mapped on 1:25,000 IGC National Grid maps. Both census and mapping will be done annually, in January.

The breeding populations of black-winged stilt *Himantopus himantopus*, little tern *Sterna albifrons* and little egret *Egretta garzetta* will be censused

Plate 7.1.5 Salt marshes in the Sado estuary. (Rui Rufino)

and mapped every year. Census methods and timing will be determined according to species. Breeding population estimates for black-winged stilt and little tern will be based upon a census of adults present in late May/early June. For little egret, a census of occupied nests at the nearest colony (Murta dam) will be conducted in May. The distribution of breeding birds will be mapped on 1:15,000 aerial photographs.

An estimate of black-winged stilt breeding success will be made every year. This estimate will combine the results of a census made at the end of July, when virtually all young birds are on the wing, with a late June census of territorial birds.

Both breeding and wintering population numbers will be analysed by means of a population index (e.g. Underhill & Prys-Jones 1994) in order to identify trends. The acceptable variation of these is set at 20% deviation from the 1991–1996 average if the changes can be attributed to factors affecting the estuary. This is not always the case, especially for migratory species whose populations may be affected by factors away from the estuary, such as on their breeding or wintering grounds.

Changes in bird distribution will also be analysed in relation to habitat use and availability in order to identify trends.

Population and distribution change indices are expected to provide guidance to managers implementing management and protection measures.

b) Factors which may affect reproductive success

Water levels are a key factor in the breeding success of a number of waterbirds. Levels need to be relatively stable: too high and nests are liable to flooding; too low and nest contents are vulnerable to ground predators, particularly mammals. Water levels at potential breeding sites will be estimated for that part of the estuary used by breeding birds, namely the salt pans, the rice fields and the reservoir where the little egret breeds.

Water levels will be measured by late May in all salt pan compartments and at the Murta dam. These measurements will provide information on the amount of habitat available as waterbird breeding sites and will identify trends in breeding habitat availability.

The acceptable variation will be set at 20% (deviation from baseline conditions which will be defined as the average of measurements taken in the last two years and in terms of area of salt pans with adequate water level) but temporary climatic factors will be taken into account when estimating the rate of change.

Contaminants in the eggs and prey of waterbirds, notably heavy metals and organic compounds, can affect breeding success if they exceed certain limits. Therefore, measurements will be taken for Cu, Pb, Zn, Cd, and Hg as well as for PAHs, PCBs and organochlorated pesticides.

Sampling of eggs is designed to cover spatial variations within the estuary as well as temporal variations through the breeding season. For the heavy metals, data will be analysed using atomic absorption spectrophotometry/flame graphite oven with a previous acid digestion. The organic contaminants will be subject to a qualitative and semi-quantitative analysis of the dominant groups by means of high precision and resolution chromatography (HPLC-DA and HRGC-MS).

c) Food availability for waders and factors affecting it

Macrofauna are the prime food resource for waders present in the estuary during the winter, or during migratory periods. Breeding waders use the salt pans almost exclusively. Here, food availability is heavily dependent on water levels. The focus will be on measuring changes in abundance of a selection of species which form the bulk of the prey taken by wintering waders; the polychaetes *Diopatra neapolitana*, *Marphysa sanguinea* and *Hediste diversicolor*, the bivalves *Scrobicularia plana* and *Cardidae* species and the *Peracaridae* crustaceans.

Sampling has been designed to cover three substrate types (mud, sand and muddy-sand) with a total of 7 sampling sites. At each site 10 replicates will be made. A PVC core with 121 mm internal diameter will be used to collect substrate down to a depth of 30 cm. The sample material will be sieved through a 1 mm mesh and the animals preserved in formalin.

The target species will be separated in the laboratory and counted according to size class. These data will be stored in a database and subjected to trend analysis.

Meiofauna are ingested by some wader species and can also provide information on levels of contamination of the ecosystem. Therefore, this group of animals will be sampled to monitor food availability for wintering waders and contamination levels in the substrate.

Sampling locations will be the same as for macrofauna but with only five replicates per site. The material will first be sieved through a 1 mm mesh, then through a 63 m mesh to isolate the meiofauna. These will be decanted and flocculated with Ludox™ and washed in freshwater. The most significant groups in abundance will be counted and separated.

Analysis of the data will be done to calculate an index for Nematode/Copepod rates (Warwick 1981), density estimations for the most significant groups, assessment of the relative abundance of these groups, diversity and evenness indices and the building of K-dominance curves.

Fishing and bait digging affect stocks of macro and meiofauna and cause disturbance to birds. The declared landings of the commercial fish species will be monitored, as well as of cockles and *Scrobicularia plana*. The declared landings do not include all captures but are thought to be correlated with total catches. For *Marphysa sanguinea* and *Diopatra neapolitana*, measurements will also be made to obtain an estimate of "effort". These measurements will be based on counts of diggers on the flats, the time they spend digging and the average amount caught by individual diggers.

As an indirect measure of food made available for birds through aquaculture, information will be collected on the proportion of each target species used by the producers and on aquaculture exploitation cycles.

Hunting disturbance: although prohibited over most of the estuary, some hunting takes place illegally within its southern part. This hunting disturbance is known to displace birds from their feeding grounds and can be measured. An estimation of the total number of hunter-days will result from regular visits to the areas where illegal hunting is known to occur.

d) Factors affecting the whole system

Salinity will be measured at the upper reaches of the estuary in order to monitor changes in the salinity distribution pattern of the estuary.

To complement that information, rainfall figures will be obtained for the Sado river catchment area using data collected by the National Meteorological network.

Pollution is a factor which affects the birds and their food resources. This will be measured in two different ways:

a) directly: by means of water, sediment and prey analysis, both in the estuary and in the salt pans, to detect the presence of pollutants in the sediment and in the waterbody.

b) indirectly: by monitoring the quality of the sediment through the use of meiofauna and macrofauna community structures as indicators of pollution rates in the substrate. Sampling for Chironomid larvae will be conducted using the salt pans as control areas.

Levels of pollutants in bird eggs will also provide information on contamination, especially in salt pans, and will be supplemented by contaminant analysis of feathers from non-fledged birds of a wide range of breeding species.

Measurements will be taken for levels of Cu, Pb, Zn, Cd and Hg as well as for PAHs, PCBs and organochlorated pesticides. For the heavy metals, data will be analysed using atomic absorption spectrophotometry/flame graphite oven with a previous acid digestion. The organic contaminants will be subjected to a qualitative and semi-quantitative analysis of the dominant groups by means of high precision and resolution chromatography (HPLC-DA and HRGC-MS).

It was not possible to find bibliographic baseline data concerning maximum and minimum levels for contaminants (heavy metals and organic micro-pollutants) in bird feathers and eggs. This type of information is only available for specific organs and species in determined physiological conditions. The information that will be collected can only be discussed in relative terms, taking into account concentrations in the environment and published data for the same species in different areas. Therefore, at present it is not possible to establish limits of acceptance for these parameters.

The use of chemicals for agriculture in the surrounding areas will be monitored by direct enquires both to farmers and the stores where these chemicals are purchased. Standard information will also be collected both of the way they are used and their intensity of use. We will have to rely on the information supplied by the farmers.

Dredging affects the sediment structure directly, by removing and disturbing the sediment, and indirectly, by interfering with water circulation patterns. The amount of sand landed at Setúbal and the level of commercial dredging effort inside the estuary will be monitored.

7.1.4 Problems

Generally speaking the fieldwork should not encounter too many problems, provided the necessary requirements are met. However, problems are expected in a few instances, namely:

a) *Breeding success of black-winged stilt* is not easy to measure. The offspring of this species are nidifugous and difficult to detect. The species is highly territorial and breeds in loose colonies which makes detection of young even more difficult. Recently fledged birds can easily move away from their breeding grounds. Therefore, though an estimate which is likely to be related to the actual production will be used, this still needs to be tested.

b) *Fishing for bivalves and bait digging* activities are not fully controlled by the Fisheries authorities. Therefore, there are no statistics for the actual catches. Indirect techniques will have to be developed to assess this. A combination of enquiries, landing evaluations and information available from the sanitary control plant which receives bivalves from this estuary is likely to be included.

c) *Dredging* impact will also be difficult to assess fully. Although data are available for the amount of sand landed, its origin is not reported. The landing figures will be used in conjunction with official data regarding the concessions granted.

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7.2 S'Albufera de Mallorca, Spain

Nick Riddiford and Joan Mayol Serra

Plate 7.2.1 Aerial view of former rice fields now reverting to reed bed. (Gabriel Perelló)

7.2.1 Description of the site

Location, size, physiography

S'Albufera de Mallorca, 39°47'N 3°6'E, is a 1,700 ha coastal wetland in northeast Mallorca, Spain (Figure 7.2.1). The area is flat and just above sea level. The boundaries comprise the sea, tourist urbanisation and agricultural land. An inland band of stabilised dunes partially interrupts the wetland. S'Albufera is part of Sa Pobla Plain, a 30–40 m thick layer of quaternary sediments. It has a typical Mediterranean climate, though somewhat milder and with a slightly higher rainfall than the surrounding area.

Wetland types occurring at the site

The Ramsar wetland types comprise: non-forested alkaline fen (Ramsar wetland type U), permanent freshwater marshes/pools (Tp), salt marsh (H), coastal brackish and saline lagoons (J), coastal freshwater lagoons (K), permanent saline, brackish and alkaline marshes and pools (Sp), seasonal saline, brackish and alkaline marshes and pools (Ss), and freshwater springs (Y). One permanent narrow connection and two one-way connections controlled by sluices connect part of the marsh with Alcudia Bay in which three further Ramsar wetland types are represented: permanent shallow marine waters less than six metres deep (A); marine subtidal aquatic beds, of the sea grass *Posidonia oceanica* (B); sand shores, comprising 1.5 km of a 10 km shell sand

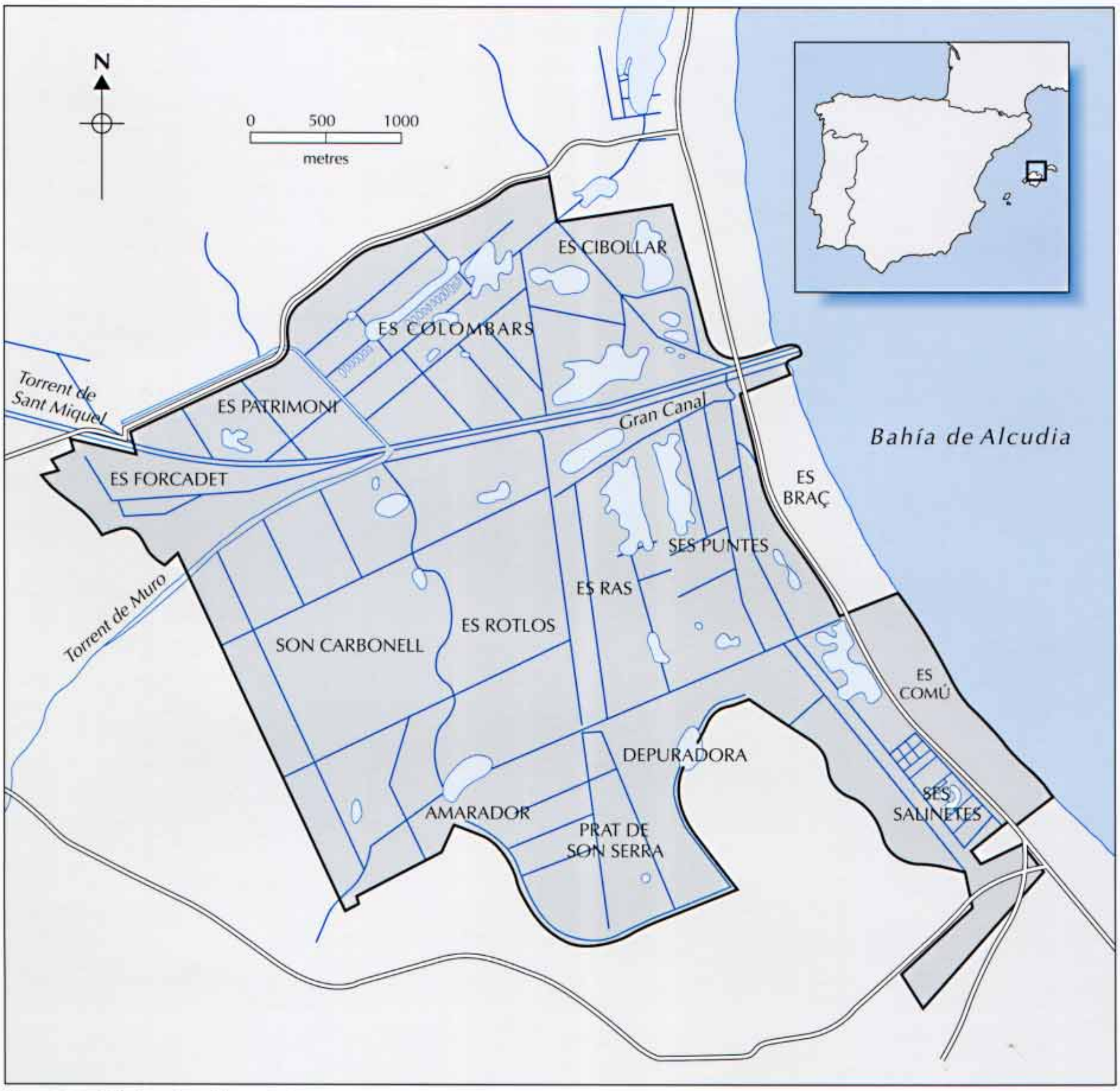


Figure 7.2.1 S'Albufera de Mallorca, Spain.

beach, backed by a 0.5 km wide band of coastal dune which began to form about 10,000 years ago (E). A rocky marine shore habitat (D) is simulated by stone block banks to the canalised connection between marsh and sea. See also Table 7.2.1.

Main values of the wetland

Products include a traditional eel fishery; forage resources, now confined to grazing for environmental purposes; and agricultural resources, by retaining a high water table of benefit to cultivations immediately inland and by the action of plants and positive human management to improve and/or maintain water quality. The most important product is wildlife resources, which led to designation as a Natural Park in 1988. This designation recognised the biological richness of the site and its importance to conservation, including conservation education, and to "green tourism".

The biological attributes are numerous, and occur at regional, national and international levels: they include breeding populations of a number of internationally or nationally rare vertebrate species; rare and newly discovered invertebrates; and endemic and nationally rare plant species. At a regional level, S'Albufera augments the rich biological diversity of Mallorca by providing

TABLE 7.2.1 *Categories and extent of CORINE biotopes in S'Albufera de Mallorca.*

CATEGORY	CORINE Code	Area (%)
Fen-sedge (*Cladium mariscus*) beds	53.31	49
Flooded *Phragmites* beds	53.111	24
Dry *Phragmites* beds	53.112	10
Giant *Phragmites* beds	53.113	4
Mediterranean tall rush salt marshes	15.51	1
Mediterranean salt scrubs	15.61	1
Mediterranean halo-psammophile meadows	15.53	0.5
Open water communities:		(10.5)
Chara carpets	22.441	5
Small *Potamogeton* communities	22.422	2.5
Ruppia communities of brackish and salt waters	23.211	2.5
Eutrophic waters	22.13	0.5

habitats and species not or hardly replicated elsewhere on the island. The site has an international reputation and attracts large numbers of wildlife enthusiasts from throughout Europe.

S'Albufera has a well documented history from Roman times, when the wetland was much larger. The site has a major place in the folklore and cultural identity of the human population surrounding it, and is appreciated for its roles as a buffer against saltwater intrusion (essential for the farming community) and in its contribution to wildlife tourism which, amongst other attributes, has afforded the region an environmental "quality label" and lengthened the tourist season into the spring and autumn.

Land use and main threats

Land use is restricted to activities compatible with nature conservation. These comprise a small, regulated eel fishery, licensed angling, conservation orientated grazing by livestock, regulated visitor access and scientific research. Previous activities included paper production from reed bed plants, salt production, hunting and rice growing. The last two still occur in wet areas outside the Park. Elsewhere, urbanisation has led to the disappearance of wetland, though two lagoons remain to the north and a water purification plant has been established at the park's southern border.

The declaration of a natural park has removed the threat of development within the designated area. One serious threat is the impact on water quality of nutrient runoff from agricultural land and inputs of phosphates from the extensive tourist urbanisation on the coastal strip. Other tourist impacts include erosion damage to the seaward edge of the protected coastal dunes, litter within those dunes, and an ever-present fire risk. Competition for water supply is an issue, which has extended recently to extractions from the S'Albufera aquifer to provision for human populations elsewhere on the island. The level of pollution from a coal fired power station, situated immediately north of the Park, is unknown.

Ownership, legal status and management body

A total of 1,708.75 ha, including nearly all the current wetland, became the Parc Natural de S'Albufera by Balearic government decree in 1988. Ownership is shared by the Balearic Government, the Spanish Ministry of Agriculture, Fisheries and Food (MAPA), and the Municipality of Muro. There are still private landowners in a small proportion of the Park. The site was declared a Special Protection Area under the EC Birds Directive in September 1987. The Park is administered by the Department of Agriculture and Fisheries of the Balearic Government, and functions under guidelines set out in a Plan for Use and Management, drawn up by the Park directorate and approved by the Park Board (*Junta Rectora*). The *Junta* acts as an advisory body and comprises representatives of governmental and non-governmental bodies with an interest in the site. A small proportion of the wetland, as it now exists, lies outside the protected zone.

Other relevant aspects

Urbanisation is prohibited on the Park's west and southwest borders, otherwise there is no strict buffer zone. The Park is constrained to balance conservation management with some local needs and requirements (e.g. to avoid flooding of adjacent agricultural land).

7.2.2 Existing monitoring programmes

Two principal bodies are involved in monitoring: the Park directorate and Project S'Albufera. The University of the Balearic Islands (UIB) assists with some monitoring, and other Universities and scientists from various countries have undertaken research studies.

Plate 7.2.2 The proximity of intensive agriculture at the west of s'Albufera leads to nitrate entry into the wetland. (Gabriel Perelló Coll)

Monitoring measures by the Park directorate are specified in its management plan. The park has achieved more comprehensive monitoring than its structure and funding would have allowed by cooperating with an international agency, Earthwatch Europe, to instigate a scientific research programme with monitoring as a major theme – supported by a multidisciplinary scientific team, Earthwatch Europe's Project S'Albufera.

Project S'Albufera

Project S'Albufera comprises an independent team of scientists affiliated to Earthwatch Europe, a charitable organisation which provides funds and volunteers for scientific field studies. However, the scheme is a cooperative venture and incorporates monitoring studies undertaken by the project, the Park directorate and the UIB.

Objectives of the monitoring

The Project defined five objectives, two of which are related to monitoring. The first comprised the collection of baseline information (to assemble full and detailed ecological data to reach an understanding of composition, functioning and dynamics of the ecosystems; to assemble Public Use data, including visitor use and impact of visitor numbers). The second was to provide standardised comparative data for evidence of environmental change, to be re-recorded at intervals of time, to provide a model for other monitoring stations. The other objectives were: to afford material for application in further research and reserve management at S'Albufera and in general conservation practice; to provide resources for comprehensive interpretive programmes and dissemination in all appropriate forms; to serve as a focus for education of residents and visitors of all age-groups and levels and to help in creating environmental awareness and commitment. The Project employs a combination of inventory, monitoring and applied research to achieve its objectives.

Parameters measured and techniques used

In the six years of the project, over 80 monitoring, surveillance and applied research studies have been undertaken using a variety of

Plate 7.2.3 Dredging has been used in s'Albufera to restore natural flow rates. (Gabriel Perelló)

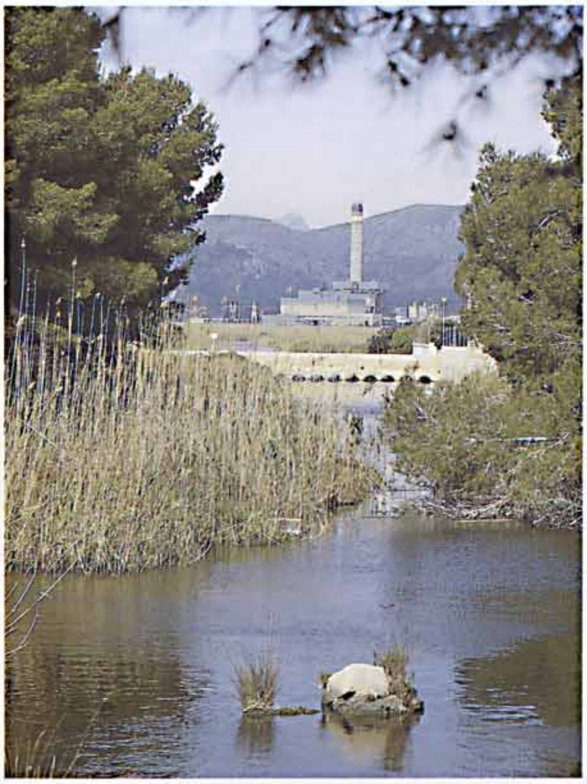


Plate 7.2.4 Pumping of marine water for cooling the nearby power station has caused leakage of saline water into the marshes of s'Albufera. (Pere Tomàs Vives)

parameters and techniques. For the purpose of this pilot study, the parameters and techniques to be used are those which apply to the key issues of wetland monitoring. These are included in the proposed monitoring programme presented in Tables 7.2.3–7.2.6.

Resources available: staff, equipment, cost

Project S'Albufera comprises teams of scientists and volunteers. Monitoring tasks are also carried out by Park staff. The Principal Investigator, Nick Riddiford, is in charge of Project planning and administration. Some equipment costs are met by Earthwatch Europe. Other equipment needs have been met from major grants or from loans from the UIB. Project funding comes from Earthwatch Europe and the American arm, Earthwatch (Boston), and is mainly drawn from contributions made by participating volunteers. Annual estimates of costs are made for each area of expenditure. The 1996 budget is presented as an example (see Table 7.2.2). Project S'Albufera is an example of what can be done with good resources. Cheap, simple studies with few parameters are equally valid.

TABLE 7.2.2 ***Project S'Albufera budget for 1996; an example of the costs for a monitoring programme using volunteers.***

Fieldwork dates
- Team 1: Thursday 11th April to Thursday 25th April
- Team 2: Sunday 28th April to Sunday 12th May
- Team 3: Saturday 26th October to Saturday 9th November

	Minimum	Maximum
Research Team		
Principal Investigators[1]	1	2
Scientific staff[1]	1	4
Earthwatch volunteers[1]	4	8
Invited local volunteers[1]	1	2
Total team size (Number of teams: 3)	7	16
Total Earthwatch volunteers for project	12	24
Field Expenses[2]		
Food	2220	4440
Accommodation	700	1400
Equipment/Tools	100	500
Staff salaries	0	0
Transportation for staff to research site	2250	4230
Research team transport in field	1575	1940
Other expenses		
freight	120	150
administration & contingencies	300	500
Total Budget[3]	£7265	£13160

Notes:
[1] Number per fieldwork team. [2] All budget estimates in UK£.
[3] Does not include costs for Park staff or University of the Balearics time and equipment.

Methods for data analysis and interpretation

Although the means and process of data analysis and interpretation were fully considered at the planning stage, it is the responsibility of each scientist to achieve his/her own analysis and interpretation. However, the multidisciplinary nature and expertise of team members assists with ensuring that acceptable methods are used.

Use of the results

The results have been used in a number of ways, which are addressed later in this chapter. Results have been published in a number of journals and reports (see References).

7.2.3 Monitoring programme of S'Albufera de Mallorca

The S'Albufera de Mallorca pilot study is based on a site protected since 1988 and with a well developed and wide ranging scientific programme initiated in 1989. Monitoring was identified from the start as a requisite for understanding the ecosystem development and change as well as providing an essential tool in assessing the effect and effectiveness of management. It was also identified that the monitoring programme should respond to the needs of the Park. The site is administered and managed by a team of nine full-time employees assisted by a series of long-term and short-term volunteers. The monitoring programme is undertaken by members of the Park staff and visiting scientists and volunteers, the last mainly through Earthwatch Europe's Project S'Albufera. Responsibility for this pilot study has been taken by Nick Riddiford, Principal Investigator of Project S'Albufera, and Joan Mayol Serra, Wildlife Officer for the Balearic Islands and Director of the Parc Natural de S'Albufera. Project S'Albufera scientists and Park staff, particularly public use coordinator Gabriel Perelló, chief warden Francesc Lillo and ornithologist Pere Vicens, made contributions and comments.

The pilot study comprised the design of a monitoring programme for S'Albufera based on the MedWet methodology as if Project S'Albufera was to be launched in 1996, but drawing heavily on experiences gained since 1989. It was clear at the start that no hypotheses could be established before baseline data had been obtained, and this takes time. The Project experience has been that a great deal of preparatory work is required before enough knowledge is in place for a monitoring programme to be launched.

Identification of problems (present and potential)

In planning the study, evaluation of features, issues and threats pertaining to the site was a key first step followed by their prioritisation for a monitoring programme Three main problems or issues have been identified, all related to human activities: they comprise alterations to the hydrology; physical/ biological alterations affecting the ecosystem; and the impact of tourist and agricultural developments and activities adjacent to the Park. Positive and negative aspects of public use within the Park is also an issue. More information is needed for other potential problems: the impact of climate change on sea levels, and the potential for pollution from the Es Murterar power station adjacent to the Park.

Identification of objectives

The following priority objectives have been identified.

i) *Alterations to the hydrology*. Monitor water extraction amounts and evaluate in relation to water levels in the Park; monitor conductivity of water for salinity; reinstate natural flow through sluices, natural revegetation of drains and creation of non-rectilinear channels, then monitor effects by measuring flow rates.

ii) *Physical/biological alterations*. Monitor changes in salinity; monitor aquatic invertebrate communities as indicators of water quality; monitor the levels of disturbance to waterbirds through illegal human activities.

iii) *Tourist and agricultural developments and impacts*. Reduce negative impacts by tourists through regular surveillance; monitor level of beach-head erosion; monitor water quality to assess nitrate load and phosphate discharges into Park.

iv) *Climate change*. Monitor meteorological trends and changes in sea levels which may disrupt or alter the ecosystem.

TABLE 7.2.3 Summary of key points of a monitoring programme for s'Albufera de Mallorca: Monitoring of alterations to the water regime

General problem/issue	a) Water is being taken from the aquifer for agricultural and urban uses, in and beyond the catchment area. b) The digging of a network of drains in the nineteenth century has accelerated the outflow of water and has brought about a compartmentalisation of flows.
Specific problem/issue	ai) Over-abstraction may lead to desiccation of parts of the marsh. aii) Abstraction of water lowers water table and leads to increased salinisation. b) Water is lost too quickly from the marsh into the sea or to pumping stations and has damaged the character of the marsh by increased speed and canalised movement of water.
Objective	ai) Monitor water levels to evaluate the effects of water abstraction. aii) Monitor water quality for salinity; monitor aquatic invertebrate communities as indicators of water quality. b) Reinstate natural flow by sluices, natural revegetation of drains and create non-rectilinear channels, then monitor effects by measuring flow rates.
Hypothesis	ai) Mean water levels should not fall below the lowest mean water level recorded in the last five years. aii) *For salinity*: conductivity at any one site and season should not exceed the mean levels for conductivity during the 1980s baseline study at the same site and season. aii) *For aquatic invertebrate indicators*: to be formulated based on presence/absence of key salinity tolerant or intolerant indicator species or assemblages once these have been identified. b) Water flow should be significantly reduced.
Methods & variables	ai) Record water levels from a series of stageboards. aii) *For salinity*: on-site measurements of conductivity (and pH, oxygen content and temperature of water). aii) *For aquatic invertebrate indicators*: standardised sweep-net sampling and counting of aquatic invertebrate fauna at water quality sites; results compared with water quality data. b) Measurements of water flow, using flow meter; keep record of when sluices opened and closed; record water levels from stageboards.
Feasibility/ cost effectiveness	ai) Simple technique requiring two staff-days per month. aii) *For salinity*: feasible because of donation of portable electronic meters measuring the above parameters; requires four staff-days per month (also feasible at lower cost using simple conductivity meters). aii) *For aquatic invertebrate indicators*: cheap for equipment but labour intensive. Only feasible because the Project has ample volunteer labour, and water quality data are available from the water quality monitoring programme. b) Requires purchase of flow meter; staff time.
Pilot study	ai) Five years' data to provide a baseline from which to form hypothesis (was done prior to start of water abstraction away from the catchment). Methodology tested at beginning of baseline study. aii) *For salinity*: equipment and procedures were tested under field conditions in 1994. Calibration of equipment was done by University (UIB) technicians. Staff trained in use and maintenance of equipment.. aii) *For aquatic invertebrate indicators*: requires initial specialist expertise to establish a baseline reference and identification keys; species may require identification to species level. b) Test feasibility of collecting data, particularly in relation to current staff time availability.
Sampling	ai) Done twice a month at regularly spaced intervals from stageboards positioned strategically throughout the Park. aii) *For salinity*: staff trained during pilot study. Sampling done at sample sites selected as strategic (junctions of canals, points of water input into the Park, etc.) and, for comparative reasons, at the same locations as chosen for doctoral study into water quality and macrophytes in the 1980s (Martínez 1988). Samples collected at 15 day intervals. aii) *For aquatic invertebrate indicators*: collections at each site at comparable seasons annually; macro-invertebrates identified, counted and released at the site of origin; some specimens of each species retained as reference and for specialist confirmation of identifications. Training of staff and development of straightforward replicable sampling techniques. b) At 15 day intervals.
Sample analysis	ai) Data stored on Park computer. Statistical analysis done by staff and members of the UIB Limnology Department. aii) *For salinity*: as ai). aii) *For aquatic invertebrate indicators*: for each sample site and survey a water quality score is determined and an average score per taxon (ASPT) calculated. Chemical data analysed using Analysis of Variance (ANOVA) and biological/chemical data comparison using Principal Components Analysis (PCA). b) Data stored at Park. Analysis done by Park staff.
Reporting	ai) Data statistically analysed and reported annually in the Park's annual report with conclusions and recommendations for management action and further monitoring. aii) *For salinity*: as ai). aii) *For aquatic invertebrate indicators*: data statistically analysed and reported annually in the Project's annual report and/or the S'Albufera Bulletin series, with conclusions and recommendations for management action and further monitoring. b) Data statistically analysed and reported annually in the Park's annual report with conclusions and recommendations for management action and further monitoring. Park handling of data allows immediate re-evaluation and management action if hypothesis is not being achieved.

TABLE 7.2.4 *Summary of key points of a monitoring programme for s'Albufera de Mallorca: Monitoring for water quality.*

General problem/issue	a) Water quality in the upper part of the Park is threatened by nitrate runoff from intensive agricultural land immediately west of the Park. b) Water quality in the south of the Park is threatened by organic material and phosphates discharged from tourist developments.
Specific problem/issue	a) Nitrate concentrations threaten eutrophication of water in the Park. b) Though a water purification plant exists south of the Park and treated water from it is discharged away from the aquifer, illegal untreated discharges may still occur.
Objective	a) Monitor water quality to assess nitrate loads entering Park. b) Monitor water quality to assess phosphate discharges into Park.
Hypothesis	a) Nitrogen concentrations at Park sample sites should not exceed 40 µg/l for any sample and mean nitrogen concentrations should not exceed half that level. b) Phosphate levels at Park sample sites should not exceed 4 µg/l for any sample.
Methods & variables	Collect water samples from sites used for water quality monitoring.
Feasibility/ cost effectiveness	Expensive. Requires laboratory analysis and chemists' time and expertise. Only possible by cooperation with UIB (Depts. of Limnology, Vegetal Physiology, Analytical Chemistry).
Pilot study	Regular collections from key sample sites throughout the year to establish a baseline.
Sampling	Acceptable intervals for sampling determined by pilot study. Collection of samples possible by Park staff after training but direct transfer of samples to laboratory essential. Collection by UIB scientists and field assistants preferred.
Sample analysis	Data stored on Park computer. Statistical analysis done by staff and members of UIB Departments.
Reporting	Data statistically analysed and reported annually in the Park's annual report with conclusions and recommendations for management action and further monitoring (which may include revision of hypotheses to meet a requirement for lower mean levels than currently stated).

Much more precise individual objectives have had to be developed for individual monitoring studies addressing these issues. Analysis of studies already undertaken indicate that clear objectives have in most cases been identified and described (e.g. Water level recording in the Gran Canal: objective – to evaluate whether fluctuations in the water levels over a period of time can be used to assess any changes in sea level which might affect S'Albufera).

Set up the hypothesis

The MedWet monitoring methodology calls for precise hypotheses to be developed. Many of the studies are based on hypotheses, but these may be too general (e.g. Aquatic Invertebrate study: hypothesis – invertebrate species assemblages will change with changes in water quality). Project scientists have been asked to reconsider their objectives and to construct hypotheses which more precisely address the issue.

It is very difficult to know which hypothesis should be applied without considerable baseline knowledge. It is now possible to construct a number of precise hypotheses based on knowledge of S'Albufera Park and its natural environment. This may not be the case for other less well studied sites. The Mediterranean environment is known for naturally occurring large seasonal and longer-term fluctuations and a suite of data collected over a period of years may be necessary before a meaningful hypothesis can be formulated.

Selection of parameters, and establishment of a baseline

These issues were addressed during the Project's original planning stage. In order to record ecological change, an understanding was needed of the ecosystem. The first requirement was to set up a baseline from which to work. Some information was already available, particularly for water quality and freshwater biology from the work of Martínez (1988) on aquatic macrophytes, while aspects of hydrology, geology and history along with inventories of various taxa, mainly incomplete, had been published by Barceló and Mayol (1980). To extend these baselines, Project S'Albufera embarked on research in priority areas concurrently with establishing more comprehensive inventories. University College London's Ecology and Conservation Unit assisted in the first two years, to give the project an initial impetus. Baseline data were collected under the following priority area headings: hydrology, ecosystem dynamics and functioning, geophysical information, meteorology, history and the historical archive, vegetation, fauna (birds, mammals, reptiles, amphibians, fish, invertebrates), human impact, and management. The inventories were reinforced by permanent reference material, beginning with the establishment of an herbarium. This was later extended to a specimen collection for various invertebrate groups. Both were augmented by photographs. Photographs were also used to record human artefacts still present in the Park, in conjunction with mapping. The reference collections are seen as a vital resource for the field research. Three years were allocated to establish the baseline, with gaps being filled thereafter – and to this day as new information is gathered or becomes available.

Once a baseline had been established the following priority steps were identified and introduced:

1. multidisciplinary study of processes affecting or dependent on: i) the *Phragmites-Cladium* dominated wetland ecosystem, ii) the hydrological system, iii) the dune systems, iv) the whole catchment of the Park and adjoining coastal waters;
2. the impact of management and related studies;
3. environmental and socio-economic studies;
4. data-processing and the database potential and methodology, including in the light of its wider applicability;
5. long-term monitoring aimed at assessing environmental change;
6. extension of baseline information.

TABLE 7.2.5 *Summary of key points of a monitoring programme for s'Albufera de Mallorca: Monitoring negative impacts of human activities.*

General problem/issue	a) Disturbance to wildlife is caused by illegal human activities. b) Large tourist complexes adjacent to the Park create impact on and disturbance to the Park vegetation and wildlife.
Specific problem/issue	a) Illegal fishing and hunting still occurs, though at much lower levels. b) Tourists using the beach and dune systems for recreation create negative impacts through beach-head dune erosion, litter and accidental or intentional damage such as fires.
Objective	a) Monitor the levels of disturbance to wildlife through illegal human activities. b) Reduce negative impacts by tourists through regular surveillance; monitor level of beach-head dune erosion.
Hypothesis	a) Levels of illegal fishing and hunting should not exceed and continue to decline from levels recorded in 1993–95; numbers of waterbirds should not fall below mean counts established during pilot study. b) Surveillance, publicity and signs will reduce levels of litter and prevent fires; beach-head dune erosion will cease.
Methods & variables	a) Control activities through permits and/or surveillance; record number and locations of incidents; count waterbirds using Park, by location. b) Regular staff patrols to control general disturbance; count numbers using the beach and dune systems and record their activities. Record dates and extent of "events" such as fires. Monitor beach-head erosion using photographic monitoring from fixed points.
Feasibility/ cost effectiveness	a) Cost mainly staff time, comprising 3 full-time guards and one ornithologist. b) Main costs are staff time and materials. In summer, staff costs are at least one person daily. Beach-head erosion requires photo equipment and materials, photographic processing.
Pilot study	a) Check previous records for trends. Ensure methodology for waterbird counts clearly defined. Establish what frequency of night-time patrols effective as deterrent. b) Test feasibility of collecting data. Calculate minimum photographic requirements. Locate and accurately describe fixed points for photography. Make archive search for historic record of beach and dune systems, particularly beach-head profile and form.
Sampling	a) Control of activities through daily duties of guards, at least one night-time patrol per week. Waterbird counts monthly. Will be planned to coincide with national/international surveys. b) Photographic monitoring annually at same season initially to establish types and rates of erosion; may be reduced to longer intervals thereafter.
Sample analysis	a) Data stored at Park. Analysis done by Park staff. b) Data stored at Park and with Project scientists. Analysis done by Park staff and Project scientists.
Reporting	a) Data statistically analysed and reported annually in the Park's annual report with conclusions and recommendations for management action and further monitoring. Park handling of data allows immediate re-evaluation and management action if disturbance levels rise. b) Data analysed and reported annually in the Project's annual report and/or the S'Albufera Bulletin series, with conclusions and recommendations for management action and further monitoring.

TABLE 7.2.6 Summary of key points of a monitoring programme for s'Albufera de Mallorca: Monitoring for climate change.

General problem/issue	Climate change may lead to large physical alterations to the wetland, leading to ecological change.
Specific problem/issue	A relatively small sea level rise would lead to invasion by the sea changing the wetland from mainly freshwater to saline lagoon and salt marsh; long-term meteorological changes may disrupt or alter the seasonal variations and climate conditions to which the ecosystem is adapted.
Objective	Monitor climate changes which may disrupt or alter the ecosystem.
Hypothesis	Mean sea levels should not exceed current mean sea levels by more than 0.5 m. Meteorological trends should fall within the levels of variation recorded for the area over the previous 25 year period.
Methods & variables	Collect regular sea level data from the seaward part of the Gran Canal. Collect on-site data daily for sun, precipitation, minimum and maximum temperature, wind speed and direction. Augment these with data from the Instituto Español de Oceanografía, Palma (for Balearic sea level measurements) and Instituto Nacional de Meteorología, (for a fuller suite of meteorological data from Sa Canova – nearest station to S'Albufera).
Feasibility/cost effectiveness	On-site data requires staff time, one hour per day for meteorological data, one hour per week for sea levels. Collection of other data requires cooperation with the Institutes of Oceanography and Meteorology.
Pilot study	Consultation with Institutes to ensure that adequate data are being collected; and that access to that data will be allowed. Staff training in collection of data.
Sampling	On-site by staff. Other data by institutes. Institute information passed to Park monthly (Meteorological) and annually (sea levels). Park data made available to Institute of Meteorology each month.
Sample analysis	Off-site analysis done by Institutes. On-site data stored at Park and analysed by Park staff.
Reporting	Data statistically analysed and reported annually in the Park's annual report with conclusions and recommendations for management action and further monitoring.

These priorities were identified from information gathered prior to the declaration of the Park, heavily augmented by the first three years' work of Project S'Albufera. Parameters were selected during the baseline data collection period and tested during the pilot study stage. A range of parameters was identified before any fieldwork was carried out; in reality, however, these were modified and in some cases rejected in favour of more useful or sensitive ones during the original baseline and pilot study test periods. Research subjects chosen were those considered most likely to demonstrate ecological change. The hydrological studies were assessed as of utmost importance not just because of the influence of water on the entire ecosystem but also because the marsh's position at, and marginally above, mean sea level makes it extremely vulnerable to sea level changes, particularly rises. Problems of identifying the causes of ecological change are compounded at S'Albufera by local and regional influences and activities. The hydrological study and studies related to hydrology (e.g. freshwater biology) obtained data on water quality, both to assess spatial and temporal variations in salinity and as a first step towards identifying intrusion within the Park of pollutants from nearby farmland and tourist complexes. Data sought in areas of Park management were designed to assist with formulating good management practice and to act as a measure of the impact of management in halting, reversing or promoting change.

Selection of techniques and design of sampling methods

Wherever possible, standard techniques and methodologies have been used. If these had to be adapted, testing ensured that the revised methodology would not introduce new, unwelcome sources of error. Wherever possible, random sampling techniques were used. However, in reality, choices have often had to be made of "best" or "most representative" sample sites. Access, and continuity of access, were other factors influencing the techniques chosen. Once sample sites had been selected, a key issue was to ensure that these sites, or in some cases their boundaries, were clearly described to ensure relocation. Precise written descriptions of the site, including annotated maps, coordinate positions and a visual reference using fixed photography are essential adjuncts to the written methodology and are usually sufficient to allow relocation of the site. The use of metal markers also allows relocation using metal detectors, if the descriptive information fails.

Selection of sampling sites

The number and location of sampling sites took into consideration the following criteria: sufficient sites to provide valid results; the choice of representative locations; and access. Selection was often influenced by work previously done (e. g. selection of sample sites used by Martínez for his doctoral study of aquatic macrophytes and water quality in the 1980s), but only when these were considered representative and sufficient to provide the information required.

Sampling frequency

Other factors which also had to be taken into account included sampling frequency in relation to time of year, fieldworker availability and the ability of fieldworkers to accurately collect the required information. These factors inevitably reduce the number of monitoring studies which can reasonably be undertaken (e.g. there is no point undertaking a study which requires year-round information when fieldworkers are only available in spring and autumn). Collecting data from sufficient sample sites to provide statistically valid and usable information is a real problem for a monitoring programme which relies heavily on volunteers available for only short periods. There is often a risk that, with limitations on time and work force, sample sizes are too low and variation too large to detect ecological change.

Collecting the data

Considerable thought was given to the collection of information and samples. A clear, but concise written methodology should be produced, particularly when using volunteers. To collect information, uncomplicated data sheets should be prepared before embarking on the study. Implementing the methodology in the field should be done initially by the scientist responsible for the study alongside the volunteers. For some studies, full scientist involvement is required throughout. Otherwise, volunteers should be tested first to ensure that the information collected will be of an acceptable level and quality. The scientist should always check the data sheets carefully for errors or incorrect application of methodology as soon as possible after the data has been collected (normally the same day). All these factors can be assessed by rigorous field testing. Conducting a pilot study frequently reveals flaws and unsuitable methodology or techniques which can be amended or improved before the main study starts.

Handling samples for analysis

Where the samples comprise biota or physical materials, considerable pre-planning has proved necessary. This includes ensuring that all the required handling materials (collecting containers, chemicals, etc.) are at hand – which may require ordering several months in advance. Preparation time should also include ensuring that the collectors know the methods of collection, collect in a replicable manner and label the samples clearly and correctly. Thought also needs to be given to the safe transport of samples or, in the case of samples which change or degrade quickly, of having the relevant equipment for immediate on-site testing. Agreements may also be necessary with scientists and/or laboratories to process the samples, notifying them when the samples are due to arrive, and ensuring that transport is available to deliver them. When immediate delivery is not possible, storage must be arranged (which may require on-site deep freeze facilities or a large amount of cool or dark storage space). There is little point collecting samples if the required facilities are not available.

Safeguarding the data

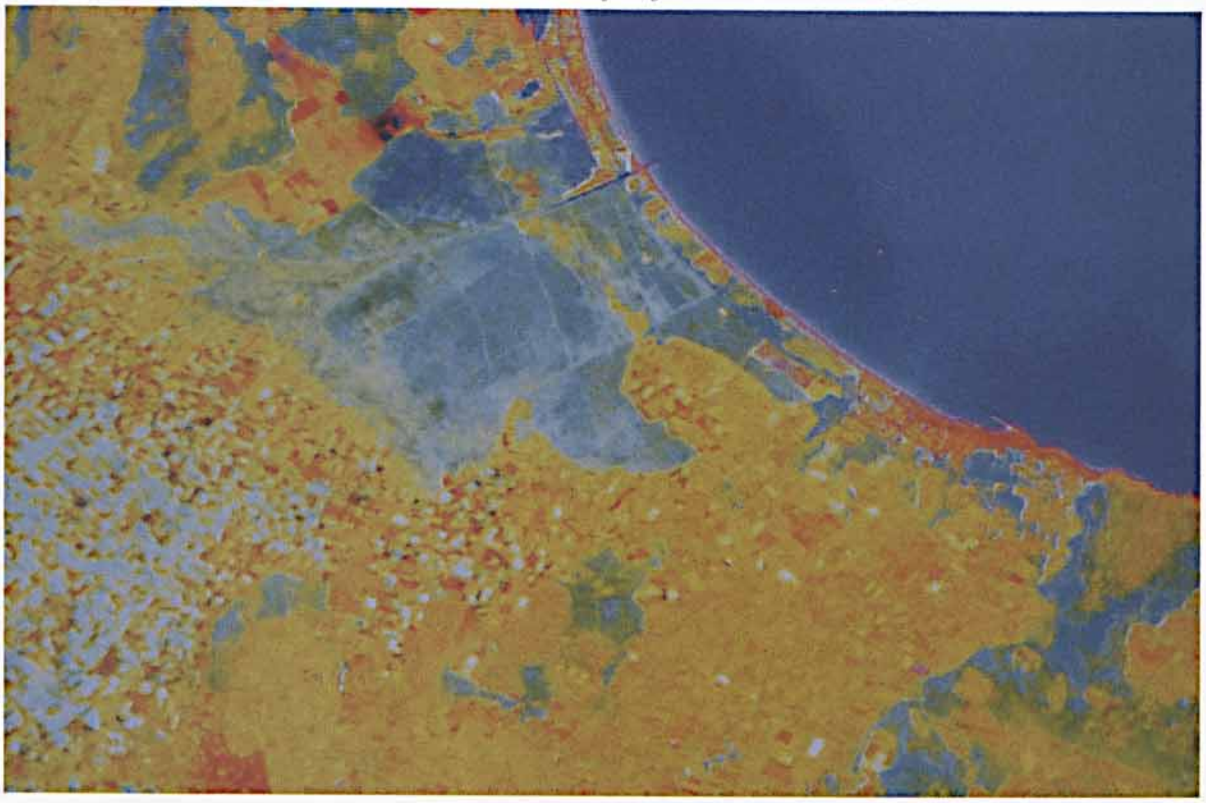
Data and information should be checked and filed in an archive which is clearly labelled and cross-referenced for easy relocation of the data. Field data may require transferring to master sheets, but on no account should the original data or the master be left lying around – information can easily be lost, particularly when more than one person is working in the facility or office. Temporary files can be established for unworked data, but these should also be clearly labelled and a list of the contents displayed and cross-referenced. Ideally, a computer database should be established and new data entered as soon as they are collected. Irrespective of access to a computer, the original data (and any worked data, including results) should be kept as a reference. Where raw data have been entered on a master sheet, both sets of data should be kept to allow for checks on errors which analysis might later suggest (though stringent checks should still be made when copying sets of data from one location to another, i.e. to master sheet or computer). The Project S'Albufera main archive is kept at the Park (using an adapted form of the British Nature Conservancy Council's data management system, described in *Site management plans for nature conservation – a working guide*, NCC 1987). For security, an additional copy is lodged with Earthwatch Europe in Oxford, England. Individual scientists hold a third copy pertaining to their own particular study or studies. A number of data sets are also stored on Park, Project or individual scientists' computers.

Analysis and interpretation of data

The key to monitoring at S'Albufera has been the use of volunteers, including volunteer scientists. Although many scientists have been willing to spend some of their holiday time participating in the fieldwork, most of them are very busy and have difficulty finding the time to complete the analysis and interpretation of the data collected. Nevertheless, the Project has a good record of reporting back and most scientists manage to achieve at least a summary of results for publication in the Project's annual report. Many of the visiting scientists are already specialists in their particular line of study and bring to the Project a high level of expertise and previous experience in methodology, statistical analysis and interpretation of results. Many of them stress that they can give preliminary results, but that natural fluctuations and perhaps natural cycles overlie any interpretation of ecological change – so that in a number of cases a long-term programme of study and data collection is required to filter out these fluctuations and cycles.

The process of data analysis and interpretation begins at the planning stage for each study. Key factors which determine the studies undertaken and methodologies used are the availability of specialist scientists, time in relation to season and length of fieldwork period and the extent to which the methodology is volunteer-friendly. Pilot studies are normally done to assess suitability of methodologies within those limitations. Nevertheless, importance is placed on the scientific validity of information collected both in terms of accuracy and statistical viability. Some studies can be done more effectively by volunteers than others (e.g. distribution mapping). Selection of study sites, which often requires a random approach, and the number of samples required to show a statistically valid trend are factors which are addressed at the planning stage. The Project is often confronted, after pilot study, with problems which can only be solved by much greater in-depth research and data collection. This has frequently been overcome by encouraging postgraduate students or scientific institutions (e.g. Aberdeen University's Centre for Remote Sensing and Mapping Science) to tackle the problem with a programme of intensive research which is beyond the expertise, equipment resource, timescale and/or seasonal availability of volunteer teams.

Plate 7.2.5 Remote sensing has been tested at s'Albufera as a tool for monitoring changes in wetland habitat and land use.



Reporting: Publications

Research at S'Albufera has generated a large number of publications. They include interim reports of individual studies, published in the annual *Monitoring for Environmental Change, the Earthwatch Europe Project S'Albufera Report*. Since 1994, results have also been published in the Park bulletin (*Butlletí del Parc Natural de S'Albufera de Mallorca*). A synthesis of baseline data, covering a range of subjects, has been produced recently as a S'Albufera monograph (Martínez & Mayol 1996) by a team of Park, Project and University scientists with the support of the Balearic Natural History Society. Details of published results relevant to this study are given in the reference list. The Project also produces regular reviews and planning documents, instigates peer review meetings, feeds results into the management planning process, provides illustrative and textual resource materials for education, encourages collaboration with and participation by other international organisations and strives to fulfil its objective of making data compatible with and available to conservation bodies. It should be noted that monitoring results often uncover further problems which need specialist investigation or research.

Use of the results

The S'Albufera monitoring programme has a clear vision of how the results will be used. They are:

Management

The Park has a well established management programme, clearly defined in the Park's Plan for Use and Management. This plan has recently been updated with the monitoring results incorporated and applied to the management programme for the period of the new plan, 1995–1999. Monitoring and surveillance are considered key aspects in relation to management planning, both in guiding and assessing the impact and effects of management practice. For instance, monitoring of visitors has already been used to improve planning and management of public use.

Public domain

This addresses two inter-related issues. The first concerns public perception of the Park and its importance for conservation, for preserving and enhancing the natural and cultural heritage and for promoting economically beneficial environmental

Plate 7.2.6 Water flow is controlled with sluices at the main inputs and outputs to and from the wetland. (Gabriel Perelló Coll)

tourism. The second concerns informing the political decision makers. The scientific element may have a greater impact and be more likely to provoke political action to safeguard the site's ecological values, but a positive perception of those values, particularly locally, may also contribute through public pressure on the decision making bodies.

Interpretation

The results obtained through the monitoring programme are already being incorporated into interpretation materials – which currently include educational materials (including a CD ROM for schools), booklets, leaflets, posters, permanent displays, audio-visual presentations, and guided interpretive visits for schoolchildren and, increasingly, other groups.

Guidance for other schemes

It has always been an aim of the S'Albufera monitoring scheme to make results, and experiences gained in obtaining those results, available to other schemes or organisations tackling similar problems and issues.

Final considerations: some practical aspects

Planning an integrated programme

When Project S'Albufera was launched, the original planning was done from Britain. Early contact was made, however, with the Park authorities and a site visit organised. This confirmed an overwhelming acceptance, enthusiasm and welcome by the Park authorities for such a programme of monitoring, involving a large number of scientists and volunteers external to the Park and unknown to the Park directorate and staff. Other positive factors were the existence of a permanent Park staff which, though restricted by a heavy workload of other duties, was available to fill some of the monitoring gaps that Project S'Albufera was unable to achieve. The Park was also within an hour's driving distance from a University with science departments, a number of which had undertaken research at the Park and/or were willing to do more.

This will not be the case at all Mediterranean wetlands. Access may prove much less straightforward, particularly if the site is not under public, protected ownership and the system of international teams, organised by and involving nationals from other countries, is not possible. Even at S'Albufera, language barriers were at first a problem – particularly for scientists needing local knowledge and expertise to assist the planning of their studies. This problem was overcome by the ability of key members to converse in shared languages (English and French) and the willingness of some participating scientists to reach a reasonable level of spoken Spanish. Another very important aspect was the involvement of local volunteers. These were usually keen young environmentalists from UIB, but also some from mainland Spain. Local/national involvement is essential for any programme which plans to use the S'Albufera model of international participation.

Using volunteers

Programmes considering the use of international volunteer assistance should also take into account that Mallorca is a holiday destination serviced by inexpensive flights from many parts of Europe. Thus volunteer scientists, many of whom pay their own travel, are attracted to come. Travel expense to less cheaply accessible sites may, however, be offset by better funding to defray costs than Mallorca can currently attract. The input that a team of enthusiastic volunteers, led by experienced scientists, can make to a monitoring programme is considerable but presents restrictions on the types of information which can be collected, both in terms of techniques which are suitable for collection by volunteers and in sampling methodology – which has to take into account that information can only be gathered during the relatively short periods when teams are in the field. Without funding and with other commitments, volunteer scientists may be unable to come at the best time for their study nor continue for the amount of years required to complete their study. This can be overcome by training assistants or keeping the methodology simple enough for others to replicate. Ideally, those carrying on the study should be local volunteers.

Funding

Funding is a major issue which needs to be addressed before embarking on any monitoring programme. Between 50% and 60% of funding for Earthwatch projects is drawn from the contributions made by participating volunteers. However, the multidisciplinary nature of Project S'Albufera makes far greater financial demands than is normally the case with Earthwatch projects. The shortfall was met by Earthwatch Europe during the first five years. Since then they have continued to seek extra funding, through sponsorship deals with companies and other organisations.

The project has been fortunate so far in obtaining the services of scientists, many of them leaders in their fields, without cost. Nevertheless, the project incurs expenses in bringing them to the site, accommodating and feeding them and in providing them with equipment. Equipment is one of the greatest initial costs in a project of this type. A substantial grant to Earthwatch Europe from the World Wide Fund for Nature (WWF) in 1991 was a major factor in meeting this need. It also allowed us to pay the travel expenses and accommodation of leading scientists needed to undertaken specific studies within the Park. A cooperation agreement signed between Earthwatch Europe and UIB in 1990 also gave benefits in allowing for the loan of equipment to the project and other University assistance. Currently, project costs range from £7,000 to £15,000 per annum, though a hidden extra administrative cost is absorbed by the supporting body, Earthwatch. Other costs, including on-site accommodation, logistic support and staff participation in monitoring, are hidden extras borne by the Park.

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7.3 Lake Kerkini, Greece

Antonis Mantzavelas and Tasos Dimalexis

Plate 7.3.1 Strymon river entering Lake Kerkini, including the riparian forest. (Pere Tomàs Vives)

7.3.1 Description of the site

Location, size, physiography

Lake Kerkini, 41°13'N 23°8'E, lies in the northwestern part of the Prefecture of Serres, northern Greece (Figure 7.3.1). The lake is partly artificial and was created on the site of the former natural Lake Kerkinitis, after the construction of a dam across the Strymon river in 1932. This project was carried out primarily for flood control, and secondarily for mosquito control. Later it served irrigation purposes. Further construction in 1982 increased the reservoir storage capacity. The eastern and northwestern sides of the lake are dyked. Thus currently the lake covers 7,500 ha (Zalidis *et al.* 1995). The Kerkini catchment coincides with the River Strymon catchment and lies mainly in Bulgaria. The total catchment area of the Strymon upstream of Kerkini is 11,521 km^2, of which 10,775 km^2 lie in Bulgaria. Kerkini is a shallow lake with a maximum depth of 10 m, characterised by large fluctuations in water level (more than 5 m), caused by the current irrigation-oriented water management.

Wetland types occurring at the site

Following the Ramsar classification, Lake Kerkini is a reservoir which forms a mosaic of wetland types including: a permanent river (Ramsar type M), an

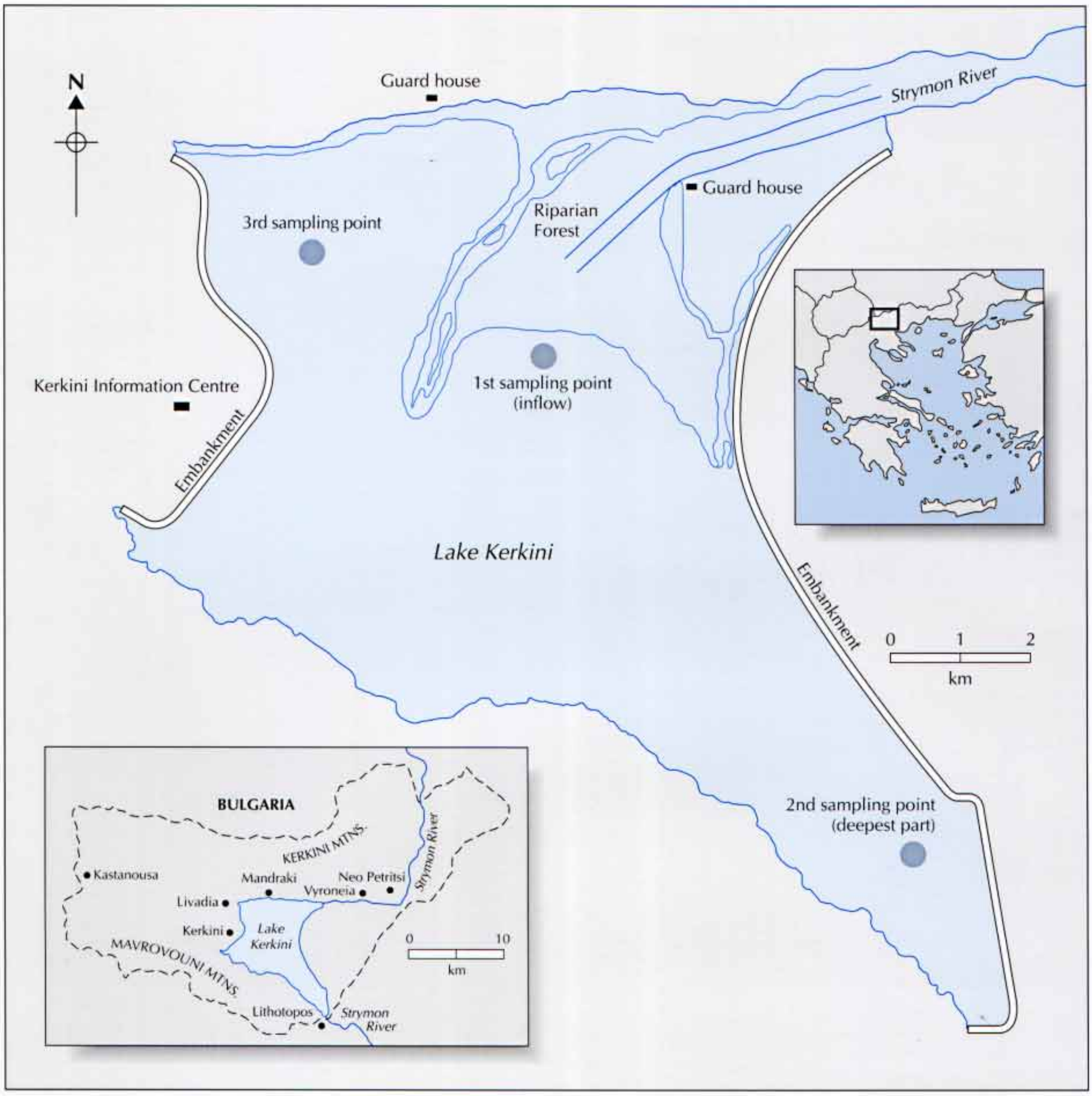

Figure 7.3.1 Lake Kerkini, Greece.

inland delta (L), a permanent freshwater lake (O) in the central and southern part, a seasonal freshwater lake (P) in the northern part, and seasonal freshwater marshes (Ts) in the northern and northeastern part.

Main values of the wetland

The main natural functions of Kerkini are: modification of flood events, trapping of sediment and food chain support. Significant current values are: flood control, irrigation water supply, biological diversity, fish production and forage production.

Land use and main threats

The wetland is used primarily for flood control and irrigation and secondarily for fishing and grazing. The main threats to the wetland are the development of further land reclamation projects, illegal fishing, hunting and logging, and transboundary chemical and transboundary pollution.

Ownership, legal status and management body

The wetland area is owned by the state. It is a Ramsar site. It is also designated as a Special Protection

Area under the EC Birds Directive, 79/409/EEC, and is a game reserve. Many state authorities are responsible for the management of the wetland. The Land Reclamation Directorate of the Prefecture of Serres is responsible for the water management, the Directorate of Agriculture is responsible for fisheries, livestock and arable farming and the Forest Service of Sidirokastron is responsible for hunting and the management of the riparian forest.

A body, based on a joint initiative between central government and the local authorities, is currently being established. It will be responsible for implementing environmental education programmes, informing visitors and supporting the wardening of the site.

7.3.2 Existing monitoring and surveillance programmes

The Greek Biotope/Wetland Centre (EKBY) developed a questionnaire to elicit a detailed description of any existing monitoring programme for the study area. The questionnaire was distributed to the civil services of the prefecture of Serres and to various individuals. Information was also collected by personal contacts. This procedure resulted in the following list of existing monitoring activities at Lake Kerkini and its catchment area:

Catchment Area and Strymon River Monitoring Schemes

I. Region of Central Macedonia

a) The Forest Service of Sidirokastron keeps records on wood cutting and hunting licences.

II. Prefecture of Serres

a) The Directorate of Agriculture keeps annual records of crop and animal farming (number of animals, areas of cultivated land, etc.).

b) The Directorate of Public Works keeps daily records of the discharge of the River Strymon, in order to estimate the flood risk.

c) The Directorate of Hygiene takes monthly water samples from the Strymon to determines quality parameters associated with human health.

d) The Directorate of Environment records pH, water temperature, transparency, conductivity, dissolved oxygen and river water level in the Strymon waters. The Directorate is planning to expand monitoring to include nutrient loads (nitrates and phosphates). The purpose of this monitoring is mainly to evaluate levels of transboundary pollution of the river from Bulgaria.

e) The Land Reclamation Directorate of Irrigation records from the Strymon every month: pH, dissolved oxygen, conductivity and the concentration of chlorine, sulphates, sodium and potassium in the water. The purpose of the project is to monitor the quality of the water used for irrigation.

Lake Monitoring Schemes

I. Region of Central Macedonia

a) The Forest Service of Sidirokastron keeps records of hunting licences.

II. Prefecture of Serres

a) The Directorate of Agriculture keeps monthly records of the fish yields for the four most important commercial fish species and for the total catch of the remaining species.

b) The Division of Public Works keeps daily records of the lake water level in order to apply the appropriate water regime for preventing flooding of the downstream areas.

III. Other Bodies

a) Monitoring of threats during 1992–1994, by EKBY.

b) Monitoring (every January) of the wintering waterfowl since 1982 as part of the wider project of midwinter waterfowl counts in Greece, organised by the Hellenic Ornithological Society in cooperation with Wetlands International (formerly IWRB).

c) Regular monitoring of the numbers of breeding pairs of wading birds for the last ten years, by individual researchers.

Plate 7.3.2 Aquatic bed with free floating vascular plants occur in areas of good water quality (Tasos Dimalexis)

d) Irregular monitoring of water quality parameters (pH, water temperature, concentration of nitrates, phosphates, etc.) and sedimentation, by individual researchers during the last decade.

It is clear that there is considerable overlap in the work of the above schemes. It should also be pointed out that few are carried out as effectively as the authorities responsible would wish because of insufficient funds and a shortage of suitably qualified personnel.

The body being established (see 7.3.1 above) will be based at the Kerkini Information Centre (KIC) and will hopefully be responsible for the implementation of local monitoring programmes. The personnel and the infrastructure of this new body will initially be as follows:

Personnel:

- Two scientists with sufficient training and field experience,
- Two wardens.

Infrastructure:
Information Centre, two houses for wardens, two observation towers, one 4×4 jeep, one motorboat, one personal computer, one photocopying machine, elementary laboratory and other equipment such as a freezer, a refrigerator, a water quality sampling kit, a camera, two telescopes, five pairs of binoculars, a video camera, a VHF base and three portable receivers.

7.3.3 Monitoring programme proposed for Lake Kerkini

The main benefits from the development of an integrated monitoring scheme at Lake Kerkini are expected to be:

- checking the efficiency of wise management measures,
- identifying the threats from unwise management of the wetland's resources and alerting the relevant authorities and the public.

After reviewing and evaluating the available information on the lake and its catchment area, a work plan was developed which includes the following:

- determination of the baseline,
- identification of problems (present and potential),
- identification of the items to be monitored,
- setting of hypotheses,
- design of an integrated monitoring scheme,
- feasibility, cost effectiveness of data collection,
- treatment of the data and interpretation of the results,
- use of the results.

Determination of the baseline

The review of the existing literature concerning Lake Kerkini, the River Strymon and its catchment area showed the following:

Water

There are sufficient data on water level and water balance (Directorate of Public Works/Prefecture of Serres) as well as on sedimentation (Psilovikos 1992, 1994). Water quality data are considered insufficient for both the Greek and Bulgarian parts of the catchment area. Nevertheless existing data on water quality (Directorate of Hygiene/Prefecture of Serres, Directorate of Environment/Prefecture of Serres; Papastergiadou 1990, Kilikidis 1989, Psilovikos 1994) can provide a baseline for future monitoring (see Annex 1).

ANNEX: *Baseline data*

a) **Water regime**:

Average minimum:	31.8 m above MSL
Average maximum:	36 m above MSL
Duration of maximum flooding (above 35 m):	65 days
Sedimentation:	1,000,000 m^3/year

b) **Vegetation**:

Area of riparian forest:	470.6 ha
Area of reed beds:	34.1 ha
Area of wet meadows:	29.2 ha
Area of aquatic bed vegetation:	411.2 ha

(for the condition of the riparian forest; from Crivelli *et al.* 1995)

c) **Wildlife**:

For average numbers of waterbirds (Crivelli *et al.* 1995)
For otters, population estimation; from Gourvelou 1993

d) **Human activities**:

For Fisheries, average fish yields; from Tatarakis 1995
For grazing pressure; from Gerakis 1990

TABLE 7.3.1 ***Summary of key points of a monitoring programme for Lake Kerkini.***

Problems/issues	a) Changes of wetland area. b) Changes in water regime and sedimentation. c) Unwise use of natural resources.
Objectives	a) Monitor the extent of threatened habitat types. b) Monitor lake water level, sedimentation, duration of flooding. c) Monitor grazing pressure and fisheries production.
Hypotheses	a) The area of threatened habitats will not decrease significantly from the current area. b) The lake water level will not exceed 36 m above MSL. Max. flooding will not exceed a period of 2 months. Sedimentation will not exceed the average of the last 10 years. c) Grazing pressure, and fishing will not exceed the average of the last ten years.
Methods & variables	a) Field verification every 5 years. b) Daily records of lake water level. Bathymetric surveys for sediment. Duration of flooding at specific plots. c) Population surveys of birds. d) Records of grazing animals and fish production.
Feasibility/cost effectiveness	Kerkini Information Centre will provide the personnel for sampling analysis and interpretation.
Sampling	a) Every 5 years. b) Daily records of lake water level. Monthly (bathymetric surveys, duration of flooding). c) Twice a month. d) Monthly.
Sample analysis	Comparison with the baseline.
Reporting	Annual reporting. A special Monitoring Office of the Prefecture of Serres should have as its function the coordination of the present monitoring activities carried out by the Prefecture's civil services.

Vegetation

Sufficient data on species composition. Vegetation studies and vegetation map available (Papastergiadou 1990, Pyrovetsi & Papastergiadou 1992, Crivelli *et al.* 1995, Psilovikos 1995, Zalidis *et al.* 1995). Sufficient baseline data.

Wildlife

Sufficient data on bird populations (Hellenic Ornithological Society 1983–95, Jerrentrup 1990, Crivelli *et al.* 1995, Naziridis unpublished, Dimalexis unpublished). Sufficient data on specific mammalian species, i.e. otter (MacDonald & Mason 1982, Gourvelou 1993). Insufficient data on other vertebrates and invertebrates.

Human activities

Insufficient data on grazing. Sufficient data on fish yields (Directorate of Agriculture/Prefecture of Serres), insufficient data on populations of non-commercial species.

Identification of problems (present and potential)

Based on the results of a previous project concerning monitoring of threats to Greek wetlands, carried out by EKBY (Kazantzidis *et al.* 1995) and derived from reference to various other reports, field visits and contacts, the key problems of the area are:

- changes of wetland area,
- changes in the water regime and sedimentation,
- unwise use of natural resources due to non-integrated management of the wetland and its surrounding area.

Identification of the items to be monitored

The following items meriting monitoring were identified:

- area of specific wetland habitats considered to be under severe threat of degradation or extinction, such as the riparian forest, wet

Plate 7.3.3 Temporarily flooded area of littoral zone of Lake Kerkini. (Tasos Dimalexis)

meadows, reed beds and aquatic bed vegetation,
- lake water level, duration of flooding, and sedimentation,
- grazing pressure and fisheries production.

Setting of hypotheses

Prior to elaborating the way in which the previous items will be monitored, limits have to be set beyond which the whole system may deteriorate. These limits are established as follows:

- The area of wetland habitats should not decrease significantly from the current area.
- The lake water level should not exceed the limit of 36 m above MSL which is the average maximum for the last 10 years. Maximum flooding should not exceed 2 months each year. Sedimentation rates should not exceed the average maximum of the last 10 years.
- The level of eutrophication and chemical pollution will not exceed the average of the last 10 years.
- Grazing pressure and fishing should not exceed the average of the last 10 years.

Design of an integrated monitoring scheme

The most appropriate monitoring scheme for the site may be outlined as follows:

Monitoring changes of wetland area

It should be carried out every 5 years using EKBY's digitised map and fieldwork (verification).

Monitoring changes in water regime

This should include daily records of lake water level (provided by the dam authorities), fortnightly records of the height and duration of flooding in selected plots of the riparian forest, and wet meadows during the growing period. Since siltation of the lake is a problem, bathymetric (bottom contour) and sediment depth surveys of the lake should be performed to determine the water depth with a depth recorder and the depth of the unconsolidated (loose) bottom sediments by

Plate 7.3.4 The area of riparian forest is being reduced due to the raise of water level in the lake.

probing with a steel rod at cross-sections throughout the lake.

Monitoring the status of the riparian forest

Field measurements of the condition of trees in the forest will be carried out once a year (during the low flooding period); percentage of dead trees in each of three sampling plots established at different positions in the forest (Figure 7.3.2). Tree densities, regeneration, height and duration of inundation.

Monitoring the status of wet meadows

Sampling will be carried out once every two weeks during the growth period to determine water level height and duration of water in wet meadows.

Monitoring waterbird populations

It will be carried out twice every winter (early in December and at the end of February); monthly monitoring during spring migration and breeding (March–June) and post-breeding period and autumn migration (July–November). Monitoring should include populations of waterfowl, wading birds, birds of prey and, during the breeding season, number of breeding pairs.

Monitoring grazing pressure

Use of the annual records kept by the Directorate of Agriculture/Prefecture of Serres combined with direct counts of the number of the animals present on the site. The Directorate should provide data on the grazing capacity.

Monitoring fisheries production

Monthly monitoring of fish production.

Feasibility, cost effectiveness of data collection

The implementation of the monitoring scheme above will require sufficient funding and efficient organisation. It is suggested that to begin with, the organisational structure will have to rely on two bodies: the Kerkini Information Centre and a Special Monitoring Office of the Prefecture of Serres. The second body must be created by the Prefecture of Serres and its function should be to coordinate the current monitoring activities carried out by the Prefecture's various civil services. The following is a possible division of the work load:

Kerkini Information Centre:

- provide boat and car for lake monitoring,
- assist in the other monitoring tasks, including waterbird, fish and vegetation surveys,
- provide (or collect from other public authorities) land use data for study,
- coordinate the data flow from the public authorities of the Prefecture of Serres,
- analyse and interpret monitoring data, prepare the final report.

Special Monitoring Office of the Prefecture of Serres:

- provide data on lake water level,
- provide data on Strymon discharge,
- provide data on fisheries, crops and livestock,
- provide data on the water quality of the Strymon waters.

Analysis of the data and interpretation of the results

The monitoring data have to be compared with the baseline (e.g. the average value of the last 10 years).

For this purpose, importance is placed on: a) the scientific reliability of information collected, b) the proper statistical procedures for the treatment of the data and c) the interpretation of the data.

Some of the scientific problems that the monitoring programme will need to solve are beyond the expertise, equipment, or timescale of the local personnel and/or the range of activities of the Information Centre and the Prefecture of Serres.

To overcome these problems it is necessary to encourage a close collaboration between the Information Centre and EKBY. Such a collaboration would be beneficial for the local working team both in terms of experience and skills.

Use of the results

The evaluation of the above mentioned data will give significant indications of the prevailing problems that the lake is presently facing, and consequently provide the framework for the development of well documented suggestions for managing the lake and its catchment area. It will also provide meaningful predictions of changes likely to occur in habitat quality in the study area.

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7.4 Étang de l'Or et Marais de Candillargues, France

Aura Penloup

Plate 7.4.1 Marshes at Le Petit Marais. (Nathalie Vazzoler)

7.4.1 Description of the site

Location, size, physiography

This site is situated in the south of France, 43°35'N 4°0'E, in the administrative region of Languedoc-Roussillon, Hérault Department, near Montpellier (Figure 7.4.1). It is part of the Languedoc lagoon complex. The main municipalities are Mauguio and la Grande Motte, and the adjacent ones are Candillargues, Lansargues, Marsillargues and Pérols. The lagoon occupies 3,167 ha and its surrounding marshes a further 2,068 ha. Its volume is 24 Hm^3. It is 22 km long and 3 km wide. The average depth is 0.80 m and the maximum depth 1.30 m. The average annual salinity is 14 g/l (Perdieu 1992).

Wetland types occurring at the site

The Étang de l'Or is a coastal brackish lagoon (Ramsar type J); the Marais de Candillargues (Candillargues marshes) are seasonal and permanent brackish and freshwater marshes (Ramsar wetland types Ss, Sp, Ts and Tp).

Main values of the wetland

The main functions and values of the Étang de l'Or and its shores are: nutrient retention, fisheries, biological diversity, recreation and tourism.

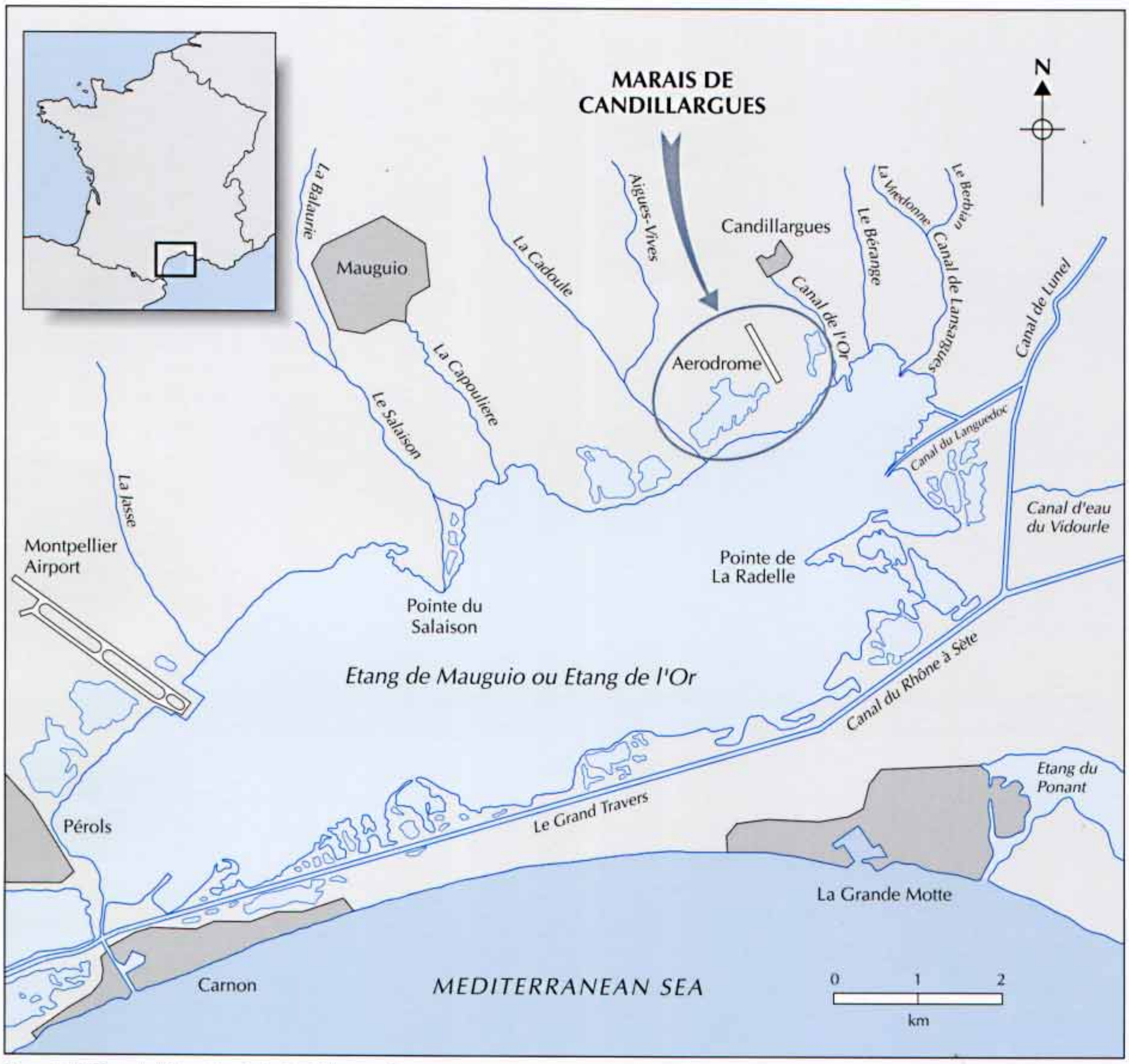

Figure 7.4.1 Étang de l'Or et Marais de Candillargues, France.

Land use and main threats

The lagoon is used for fisheries; the shores are used for grazing, agriculture and hunting. The main threat is pollution and eutrophication.

Ownership, legal status and management body

The main owners are the *Domaine Public Maritime*, with 3,100 ha (the entire lagoon), and the *Conservatoire du Littoral et des Rivages Lacustres*, with 733 ha of the shores.

The entire lagoon and its shores are designated as *Site Classé*, which affords strong protection against building projects; some of the marshes have an *Arrêté de Biotope*, and the entire area is subject to the *Loi littoral*.

The lagoon forms a single ZNIEFF (*Zone Naturelle d'Intérêt Ecologique, Faunistique et Floristique*), and a high proportion of the shores is covered by a further eight ZNIEFF. This designation does not confer protection status, but reflects the ecological importance of the site.

The management body is the *Syndicat Mixte de Gestion de l'Étang de l'Or* (SMGEO) which was created in 1991 and is formed by 13 municipalities. It is in charge of management of the lagoon and its shores. It is administered by local, regional and state administrations, professionals (fishermen), associations (hunting bodies) and scientists. The main objectives of the *Syndicat* are:

- pollution control of the catchment area;
- restoration and protection of the wetland area;
- management of the water entrances to the lagoon.

7.4.2 Monitoring programmes proposed for the Étang del'Or and the Candillargues Marshes

Monitoring the condition and extent of the reed bed and the landscape quality of the Candillargues marshes

Knowledge of the reed bed is needed before a monitoring programme can be initiated (see Table 7.4.1) and this requires preliminary investigation. This includes:

1. assessing the general condition of the reed bed;
2. identifying the possible causes of reduction in reed bed area, e.g. increased salinity, excessive or insufficient water levels during parts of the annual cycle, problems of water quality.
3. assessing the previous extent of reed bed area. This can be done in two ways:

a) using satellite imagery. Techniques of reed bed identification and area calculations are known (e.g. Sandoz 1996). The advantages of this technique are that reed bed area is calculated automatically and satellite imagery for the Étang de l'Or and its shores is already available for the last five years.

b) by photo-interpretation of black and white and/or infrared photographs (available from the National Geographic Institute).

TABLE 7.4.1 *Monitoring the condition and extent of the reed bed, and the landscape quality of the Candillargues marshes.*

General problem/issue	Decrease of the reed bed area.
Specific problem/issue	The present condition of the reed bed in terms of area and quality (density, height) is not quantified; a decrease in reed bed area has been noticed in some studies since the 1950s and especially in the last ten years, but no regular long-term survey has been launched.
Objective	To quantify the reduction in reed bed area. To quantify the occurrence of different habitats. To assess the general reed bed condition and its evolution over time.
Hypothesis	Null hypothesis: 1. The surface area of the reed bed will not decrease. 2. The structure of the reed bed will not change (height, density). 3. The species composition of the reed bed will not change.
Methods & variables	A series of 1 x 1 m quadrats along 150 m transects. An exclosure (25 x 25 m) will be built to protect vegetation from grazing; one-metre quadrats will be selected randomly within the exclosure and outside to assess the impact of grazing on the vegetation. Lists of flora, abundance classes for the principal plant species. Description of the reed bed: counts of stem density and height of the five tallest stems within 1 x 1 m quadrats along transect. Repeat photographic monitoring (four times a year at fixed points and locations) using markers to obtain qualitative measures of landscape evolution .
Feasibility/ cost effectiveness	Transects: three days/year. On-ground photographs: 800 FF; four days/year.
Pilot study	Transects:, abundance and description studies: no more than 1-2 months to test methodology, etc. Photographs: no pilot study needed, because it has already begun (1995); marker posts will be installed.
Sampling	Transects: three times/year: April, June and August. Photographs: four times/year, at each season.
Sample analysis	Statistical analysis of transect data: mean, variance (on EXCEL); comparison of transects to establish seasonal and annual variations; graphic representation.
Reporting	Annual reporting, including conclusions and recommendations for management action and further monitoring.

TABLE 7.4.2 *Monitoring the water level in the Candillargues marshes.*	
General problem/issue	Decrease in reed bed area.
Specific problem/issue	Inadequate management of the water levels has been identified as one of a number of potential factors contributing to reductions in reed bed area.
Objective	To ascertain the full annual cycle of water levels in the marshes, in order to identify the key periods of recharge and discharge for the ecosystem. From the end of the first year, to use the information as an early warning system and to guide management decisions towards maintaining or restoring the health of the reed bed.
Hypothesis	The water levels will not vary significantly (within 95% confidence limits) from the long-term average in relation to season (x ± y cm, established during baseline investigation and taking into account seasonal variations).
Methods & variables	Installation of stageboards for water level recording.
Feasibility/ cost effectiveness	Investment: 600 FF for three stageboards. It will require 24 half-days per year.
Pilot study	1–2 months to establish methods, etc.
Sampling	Twice monthly readings of water levels at three selected, fixed points (one per marsh). The stageboards should be installed in the deepest part of each marsh, but readable at distance from an accessible place.
Sample analysis	Mean, variance (on EXCEL); seasonal and annual variation; graphic representation. Statistical issues: the first year will be used to establish a reference baseline for the annual profile of water levels and to assess the impact of sluice-controlled water management. However, in testing the hypothesis, allowance will be made for exceptionally high or low water levels (occurring no more frequently than once every five years) attributable solely to the Mediterranean climate, which is characterised by strong perturbations; and provided its impact on the ecosystem is reversible.
Reporting	Annual reporting, including conclusions and recommendations for management action and further monitoring. If water level measurements indicate management incompatible with the well-being of the reed bed, recommendation will be made for actions to be applied to amend the hydraulic management.

TABLE 7.4.3 *Monitoring the water salinity in the Candillargues marshes.*	
General problem/issue	Decrease in reed bed area.
Specific problem/issue	Increased or excessive water salinity has been identified as one of a number of potential factors contributing to reductions in reed bed area. Saline intrusion may occur through damaged dykes, uncontrolled openings of the sluice and incorrect manipulation of the anti-salt barrage. At the culmination of this monitoring programme, recommendations for the management of water inputs and outputs are expected.
Objective	To ascertain the full annual cycle of water salinity in the marshes in order to identify the key periods of saline water intrusion. From the end of the first year, to use the information gathered as an early warning system and to guide management decisions towards maintaining or restoring the good health of the reed bed.
Hypothesis	Water salinity will not vary significantly (within 95% confidence limits) from the long-term average (x ± y cm, established during baseline investigation and taking into account seasonal variations).
Methods & variables	Conductivity measurements, using a conductivity meter. Conductivity scores will be converted to levels of salinity using existing tables.
Feasibility/ cost effectiveness	It will be done simultaneously with the water level monitoring and will take 24 half-days per year.
Pilot study	1–2 months to establish methodology, sampling techniques, etc.
Sampling	Measurements twice a month, at three selected, fixed points (one per marsh).
Sample analysis	Mean, variance (on EXCEL); comparison of transects in order to establish seasonal and annual variation; graphic representation. Statistical issues: the first year will be used to obtain the profile of a complete annual cycle. However, in testing the hypothesis, allowance will be made for exceptionally high or low water levels (occurring no more frequently than once every five years) attributable solely to the Mediterranean climate, which is characterised by strong perturbations; and provided its impact on the ecosystem is reversible.
Reporting	Annual reporting, including conclusions and recommendations for management action and further monitoring.

Plate 7.4.2 Marshes of Fauguière. (Nathalie Vazzoler)

Photographic techniques are better suited to this scale, but the calculation of area is not achieved automatically and the photographs are expensive.

The study entails a bibliographic review of maps of vegetation cover in order to understand how the reed bed has evolved (see Corre 1989, 1992; Delplanque 1992) and of Mosquito Control Service (EID) maps.

Monitoring the water level in the Candillargues marshes

Before a monitoring programme can be initiated, a preliminary investigation is required to assess the means and variance of water levels at different times of the year for the reed bed to function healthily. The reed bed is represented by three different hydraulic units: Cros-Martin, Fauguière, le Petit Marais. See Table 7.4.2.

Monitoring the water salinity in the Candillargues marshes

Before a monitoring programme can be initiated, a preliminary investigation is required to assess means and variance of water salinity in the reed bed in relation to the seasons. To analyse water salinity fluctuations, a series of measurements are required for different seasons over a number of past years (see management plan SMGEO/IARE/ Agence de l'Eau/MedWet 1995a and 1995b). The reed bed is represented by three different hydraulic units: Cros-Martin, Fauguière, le Petit Marais. See Table 7.4.3.

Monitoring the water and sediment quality in the Candillargues marshes

Knowledge of the reed bed is needed before a monitoring programme can be initiated and this requires a preliminary investigation (see Table 7.4.4). It should consist of a bibliographic study, analysis of P and N rates in the water and sediments (existing short-term studies done by IARE) and comparison of these values with analyses done in other Mediterranean marshes (see El-Habr 1987). Advice of experts should be sought regarding best choice of nutrients to monitor.

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TABLE 7.4.4 ***Monitoring the water and sediment quality in the Candillargues marshes.***

General problem/issue	The Étang de l'Or has high trophic levels linked to urban and agricultural discharge.
Specific problem/issue	Improvement of water treatment plants is planned or under way, and other management actions are planned. These are input of freshwater with low rates of nutrients (water from the Vidourle river), some agro-environmental legislation and restoration of the marshes' function as nutrient filters. It is not known how effective these measures will be. It is fundamental to assess the trophic level of the marshes, as they have a denitrification function for the whole lagoon. These shallow ecosystems have large, rapid interactions between water, plants and sediments (the water column is not stratified, unlike deeper waters). In consequence, it is essential to obtain measurements of nutrients in both water and sediments.
Objective	To ascertain the levels of: phosphates, nitrates, nitrites, ammonia and chlorophyll a in the water; total phosphorus and total nitrogen in the sediments.
Hypothesis	No significant annual variation of nutrient concentrations (95% confidence limits).
Methods & variables	In laboratory: sediment samples to detect rates of total phosphorus and total nitrogen. Water samples for orthophosphates, ammonia, nitrates, nitrites, chlorophyll *a*. *In situ*: rates of dissolved oxygen, water colour (green: presence of phytoplankton; brown: presence of sediments in suspension; colourless or yellowish: presence of colloids in suspension), transparency (with a Secchi disk), temperature, hour of measurement. Data storage on EXCEL.
Feasibility/cost effectiveness	Sampling: two half-days per month. Analysis cost: 10,000–20,000 FF per year for the chemical analysis (except chlorophyll *a*, which is very expensive).
Pilot study	1–2 months to test sampling procedures.
Sampling	Twice a month, in each hydraulic unit: Cros-Martin, Fauguière, le Petit Marais. In response to the objective, sampling will be done: 1) throughout the year, to establish the annual cycle and to identify the peaks and stable periods for each nutrient; 2) during a series of consecutive years, to assess the evolution of the trophic level, in order to amend and adapt management decisions in relation to polluted water sources and points of entry (a period of at least 10 years may be necessary to detect a tendency to eutrophication at the significant level).
Sample analysis	Sediment and water samples analysed by chemical analysis laboratories.
Reporting	Nitrates: annual mean, maximum mean, variance. Phosphates: annual mean, maximum mean, minimum mean, variance. Others nutrients and chlorophyll *a*: mean and variance. Graphic representation. Interpretation of the results of chemical analyses: by site manager with help from specialists. Annual reporting, including conclusions and recommendations for management action and further monitoring.

Plate 7.4.3 Marshes at Cros Martin. (Nathalie Vazzoler)

CEMAGREF. 1989a. *Suivi de la salinité et de l'état trophique de l'étang le l'Or*. Rapport de synthèse 1986–1988, SMLNR, l'Hérault, France. 25 pp.

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7.5 Aiguamolls de l'Empordà, Spain

Sergio Romero de Tejada

Plate 7.5.1 Aerial view of the coastal lagoons system at the Integral Reserve nº 2 Les Llaunes. (Jordi Sargatal)

7.5.1 Description of the site

Location, size, physiography

The Aiguamolls de l'Empordà, 42°13'N 3°5'E, is a 4,824 ha coastal wetland in northeast Catalonia, Spain (Figure 7.5.1). The area is flat and just above sea level. The boundaries comprise the sea, tourist urbanisation and agricultural land. Along the sea shore, a system of sand dunes is present.

Aiguamolls de l'Empordà is part of the Empordà Plain, with characteristic quaternary sediments as a result of the interaction of the river sediments and the dynamics of the sea. The evolution of this delta system is responsible for the existence of the wetland. It has a typical Mediterranean climate and experiences periods of strong NNE winds during the winter and spring.

Wetland types occurring at the site

The Ramsar wetland types comprise: sand, shingle or pebble shores (Ramsar wetland type E); salt marshes (H); coastal brackish/saline lagoons (J); coastal freshwater lagoons (K); permanent river, streams and creeks (M); seasonal streams or creeks (N); seasonal freshwater lakes (P); permanent saline/brackish lakes (Q); seasonal saline/brackish lakes (R); permanent saline/brackish marshes (Sp); seasonal saline/brackish marshes (Ss); permanent

Figure 7.5.1 Aiguamolls de l'Empordà, Spain

freshwater marshes and pools (Tp); seasonal freshwater marshes and pools (Ts).

Main values of the wetland

The main values of the site are the following:

Wildlife habitat: this is one of the most important functions and reflects the strategic position of the Park on one of the migration routes between North Europe and Africa.

Active recreation: the Park receives thousands of visitors throughout the year and one of its main roles is environmental education.

Wildlife resources: hunting and fishing.

Forage resources: a large part of the Park is characterised by flooded meadows which formerly sustained large numbers of cattle. Nowadays this practice has diminished due to intensive indoor

Plate 7.5.2 Limnographic stageboard for measuring water levels installed in 1993 next to the sluice that allows control of the water entering the Integral Reserve nº 2 Les Llaunes. (Sergio Romero)

cattle rearing but cattle are used in the Reserve as a management tool.

Agricultural resources: the majority of the old flooded meadows have been drained and have now been transformed into arable land, mainly for the cultivation of sunflowers and maize.

Biological diversity: This is one of the principal attributes of the Park. The diversity of species and the number of individuals per species have increased substantially since the area became protected.

Land use and main threats

In the Integral Reserve, land use is restricted to activities considered compatible with nature conservation. This includes grazing. In the Park, urbanisation and changes in land use are restricted and thus forestry cannot be modified for agriculture purposes.

The main threat is in the quality of water entering the wetland. The cultivated fields which surround it are heavily fertilised and large quantities of P and N contaminate the water.

Another threat is the area's high level of tourism which generates strong, anthropogenic pressure on the coastal zones, mainly affecting the dune systems lining the beach. These are already badly eroded.

One part of the Integral Reserve is in private hands and this causes serious management problems for that area, especially with regard to the maintenance of water levels.

TABLE 7.5.1 ***Monitoring the water levels in the marshes of Integral Reserve n° 2.***

General problem/issue	The increase in number and diversity of waterfowl in Integral Reserve n° 2 (les Llaunes) seems to be largely linked to management of the water level. This is the only place in the Park where the management of water input and output is possible (because of a sluice between a drainage canal and the marshes).
Specific problem/issue	Management of water levels can only be achieved through knowledge of the hydrology in Integral Reserve n° 2, in particular water level fluctuations throughout the year and whether each hydraulic unit (each marsh) is linked to the others.
Objective	To monitor the water level in each hydraulic unit (each marsh) of Integral Reserve n° 2: 1) to obtain a better understanding of the hydraulic functioning of the marshes (including whether links exist between units); 2) to select the most representative site to install an automatic limnograph.
Hypothesis	The difference in water levels will not vary significantly (within 95% confidence limits) between each marsh, during the year of the pilot study.
Methods & variables	During the first year, limnographic stageboards will be placed in each of six marshes considered to be distinct hydraulic units, to establish the best location to position a limnograph. In year one, collection of data will be weekly, followed in subsequent years by continuous recording using an automatic limnograph.
Feasibility/cost effectiveness	Investment:: making or buying a further six stageboards (one is already in place). Staff time: one half-day per week for recording water levels at the seven sites; 2–3 days per year for statistical analysis and interpretation of the results, in conjunction with specialist advice.
Pilot study	1) Statistical analysis (mean, variance) of data already available, comprising three years' records (1993–95) from the only current site; comparison with data for the whole of 1996 at the same site, to establish the temporal variation. 2) Survey of the water levels at 7 sites throughout one year, to obtain a full annual cycle; comparison of 1996 data at the 7 sites, to establish the spatial variation. The automatic limnograph will need to be installed in a deep but accessible place. If important differences emerge between marshes, these differences and the extent of linkage between each hydraulic unit will need to be assessed. If similar results are obtained from each stageboard (one per marsh), the records obtained from the single automatic limnograph will be sufficient to achieve the study's objectives. If not, some of the stageboards will need to be kept and recording continued from them.
Sampling	Once a week during "normal" conditions; more often if some exceptional event occurs (heavy rainfall, for example). Data storage in computer programmes EXCEL and SPSS.
Sample analysis	Not applicable.
Reporting	Statistical analysis on EXCEL and SPSS: monthly, seasonal and annual means and variance. Analysis of trends by comparison of periodic mean for each year, and by regression analysis. Graphic representation. Annual reporting, including conclusions and recommendations for management action and further monitoring.

TABLE 7.5.2 *Monitoring water quality in Integral Reserve n° 2.*

General problem/issue	The Reserve is bounded by agricultural land, which receives substantial quantities of fertilisers. Runoff of the excess occurs and this enters by way of a channel which brings freshwater into the Reserve. This is the only channel bringing water into these marshes, and is controlled by the Reserve managers.
Specific problem/issue	The nutrient loads entering Integral Reserve n° 2 and present in the marshes are unknown but could be excessive, leading to eutrophication of the ecosystem, as suggested in a recent thesis (Quintana i Pou 1995).
Objective	Conduct one year preliminary study to establish whether eutrophication of the marshes is occurring. If confirmed, monitor the rates of nutrients in the channel: 1) to establish the annual nutrient cycle; 2) to establish an early warning system for the following years. The study will quickly determine the most suitable periods for water input and those periods of high mean nutrient load when water input control is essential to prevent nutrient entry to the marshes.
Hypothesis	The amount of nutrients in the water of the channel will not exceed (within 95% confidence limits) the critical values $x \pm y$. The values of x and y will be established *a priori* for the first year in accordance with the bibliographic study and more precisely in the succeeding years, in relation to the results from the water quality pilot study for the channel and lagoons. The values x and y for the two principal nutrients (N and P) are expected to vary at different times of the year.
Methods & variables	Measure nutrient rates in the water of the channel and lagoon water: nitrates, nitrites, ammonia, orthophosphates, total N and P, chlorophyll a and organic matter. Measure total N and P, chlorophyll a and organic matter in the lagoon sediment.
Feasibility/cost effectiveness	Sampling costs met by the *"Servei de Control de Mosquits"* (Mosquito Control Service) and chemical analysis by the University of Girona.
Pilot study	There will be a one year pilot study in which the rates of the specified nutrients will be measured in the water and sediments of the channel and the lagoons. This will permit: a) determination of the annual profile for the rates of each nutrient, organic matter and chlorophyll a. b) identification of the favourable and unfavourable periods for opening the sluice connecting the channel to the marshes.
Sampling	Weekly sampling of water from the channel and in three areas of the marsh with different flooding frequency. Monthly sampling of water and sediment from the areas already mentioned and three other representative areas. Six marshes are considered to be one hydraulic unit and will be sampled monthly; the other three are considered as separate hydraulic units and will be sampled weekly.
Sample analysis	Chemical analyses in laboratory.
Reporting	All nutrients, chlorophyll a and organic matter measured: annual mean, maximum mean and variance. Temporal evolution. Statistical analysis on EXCEL and SPSS. Graphic representation. Annual reporting, including conclusions and recommendations for management action and further monitoring.

Ownership, legal status and management body

The Natural Park of Aiguamolls de l'Empordà encompasses 4,842 ha (Figure 2.5.1), of which 849 ha are in Integral Reserves. A total of 646 ha is publicly owned (by the Regional Government of the *Generalitat de Catalunya*).

The site was declared a Special Protection Area (SPA) under the EC Birds Directive in 1988 and was included in the Ramsar List on 15 March 1993. The Park is administered by the *Servei de Parcs i Espais Naturals* within the Catalan Government's Department of Agriculture and Fisheries. The Park Board (*Junta de Protecció*), comprising representatives of governmental and non-governmental bodies with an interest in the site, acts as an advisory body.

7.5.2 Monitoring programmes proposed for the Aiguamolls de l'Empordà

Monitoring the water levels in the marshes of the Integral Reserve n° 2

Baseline information is required before the monitoring programme can begin, in order to establish the "ideal" water levels (i.e. which mimic a natural Mediterranean system) expected at different seasons (for example to identify the desired date of desiccation in summer). At the beginning, comparison of the data for the three previous years will allow assessment of how near we are to the "ideal". See Table 7.5.1.

Monitoring water quality in Integral Reserve n° 2

As a first step, a preliminary study is required to measure the trophic level of the marsh: in the waterbody (nitrates, nitrites, ammonium and orthophosphates; chlorophyll a) and in the sediments (total P and total N). The critical periods during which the marshes are very sensitive to the input of nutrients have to be identified. See Table 7.5.2.

The results from the preliminary study can then be compared with the rates of nutrients recorded in two relevant postgraduate studies. They are:

- a thesis documenting research done in some marshes of Integral Reserve n° 2, in the Natural Park of Aiguamolls de l'Empordà (Quintana i Pou 1995);
- a thesis documenting research done in other Mediterranean marshes (El-Habr 1987).

Advice from experts will then be necessary to establish the trophic level of these marshes in relation to other examples.

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Synthesis

Pere Tomàs Vives

The development of a monitoring programme involves a series of aspects which have been presented in the previous chapters and which must be considered from the start. A checklist of the key points that should always be considered when developing a monitoring programme is presented here, including some practical aspects that help ensure the success of the monitoring.

- Are the issues or problems clearly identified? The issues can be internal to the site, e.g. the effects of management; or external, e.g. the effects of upstream pollution.

- Is the objective of the monitoring clear? Is it attainable within a reasonable time period? The objectives of monitoring should not be confused with the objectives of the management, especially when monitoring aims to assess the success of management.

- Have you identified the hypothesis? Can you determine acceptable variation limits, so that the hypothesis can be tested on the basis of collected data?

- Do you have good baseline data to compare? Have you planned to examine any existing information available (e.g. published research, management, policy documents, maps, aerial photographs, local people, etc.)?

- Are other scientists and local experts invited to comment and/or participate in the monitoring? They often have great knowledge about the site and can provide very useful advice. Local universities and research centres may have undertaken research at the site and they may be able to provide field and laboratory equipment, or to participate in the monitoring.

- Which variables are you planning to measure? Do they provide information to test the hypothesis? Are they suitable for your type of wetland?

- When selecting the indicator variables, are you considering possible taxonomic problems? In some cases, the use of higher taxa is recommended (e.g. families or orders of invertebrates).

- Can the selected method detect change at the required level of detail and over the chosen time period? Is the method able to assess the significance of the change?

- Have you located the sampling points? Are they accessible? Random sampling is often recommended, although it is not always possible. Consideration should be given to physical difficulties of access to the sampling locality (e.g. soft substrate), transport to the sampling locality (e.g. boat for lakes or lagoons), land ownership, protection measures (e.g. access restricted during breeding season), etc.

- Are the sampling localities marked and easy to relocate by yourself or other people? The physiognomy of a wetland site may change over the years, due to natural and/or human-induced causes.

- How many samples are you planning to collect? A statistician would provide useful advice.

- Have you decided the frequency of sampling? Have you identified the best time of the year or the best season for sampling? It is essential that sampling takes place at the necessary frequency and at the right moment in order to obtain valid data. The best moment(s) for sampling depends on the indicators or variables selected.

- Do you need to establish control sites for comparison of data (e.g. grazing exclosures)? This has to be considered at an early stage, since it may increase the costs and efforts required.

- Have all the costs been estimated, in order to define whether or not they are within the budget available? If the costs are too high to ensure obtaining valid results from the monitoring, the hypothesis and/or the methods and variables should be reassessed.

- Are all the samples properly labelled? If changes to the protocols for sample collection and processing are needed, are they properly recorded? This is very important to allow comparisons of the results.

- Do you have the necessary equipment for collecting, storing and analysing the samples/ data? Some items – such as equipment, handling materials (e.g. special collecting containers), chemicals, etc. – may require ordering in advance. Certain samples need to be kept under special conditions (e.g. frozen, in darkness, etc.) during transport or storage until they are processed.

- Have you planned the quick storage and/or transport of the samples to be processed and analysed, in particular those samples which change or degrade quickly (e.g. biological tissues). If the processing is not sufficiently rapid, changes to the procedures may be necessary.

- Are the staff required available? Do the staff in charge of collecting and processing the samples need to be trained? It is crucial that staff in charge of sample collection and processing know the methods well, collect in a replicable manner, handle the samples correctly and label the samples clearly.

- Has the methodology been clearly documented in writing, in a concise form including detailed description of the procedures of sample collection and processing? This is very important in the case of changes in personnel, to allow new staff to repeat the procedures easily.

- Have you planned how to store your data and results? It is very important to file data and information in clearly labelled archives or database files as soon as they are collected. The original data should always be kept as a reference. Availability of adequate equipment (e.g. computers, software) has to be considered.

- Do you need to undertake statistical analysis? A statistician would provide useful advice about the most appropriate statistical tests.

- Are the means for interpreting the data and reporting the results readily available? How will the results be reported? The report should be concise and contain recommendations for management actions. It should also be used to assess the effectiveness of the monitoring.

- Are you including a pilot study in your monitoring, to test the methods and assess the above aspects? The pilot study is very important to check the sampling (number of samples, frequency, dimensions etc.) and processing procedures, and to test the field equipment and the means of analysing the data. This is also the moment to assess the training needs for staff involved. The pilot study is an essential step in order to save time and resources in the future.

- Has the pilot study revealed that you need to reassess the hypothesis, and/or the methods and variables? This is the time to make changes to the procedures that have been chosen, and to establish the final standard protocols.

- When will the monitoring stop? Have criteria for deciding this been defined? Once the objectives of monitoring have been met, management actions should be implemented and it must be decided whether monitoring should continue or terminate.

- Is the monitoring being carried out in the framework of a response system, such as management plan, rural planning or legislation? If so, who will be in charge of implementing the actions recommended as result of the monitoring? For the monitoring to be effective, it is essential that actions are taken in response to the monitoring results.

- Is the funding required for this monitoring secured in the long term? In case funding is not secured, it is advisable to keep it easy and simple.

Glossary

Nick Riddiford

This glossary contains a number of definitions relating to wetland and monitoring terminology but for those omitted, and a comprehensive set of Mediterranean wetland terms and definitions, please refer to MedWet Wetlands Glossary (Montemaggiori & Pratesi Urquhart in prep). The glossary also gives descriptions or titles for acronyms used in the text of this document.

Abiotic: those components of an ecosystem which are not living. Also a term used for physical & chemical influences upon organisms, e.g. humidity, temperature, pH and salinity. An abiotic environment is one which is devoid of life. (Goudie 1985)

Abstraction: the removal of water from the waterbody or aquifer, usually for human consumption or use.

Accretion rate: the rate of increase in the area of land as a result of sedimentation. (Goudie 1985)

Aerated: exposed to the chemical action of air. (Liebeck 1994)

Algal Bloom: dramatic increase in algal growth resulting from high levels of nutrients or pollutants (Finlayson & Moser 1991). The drastic increase in the population density of microorganisms (usually algae) in a waterbody resulting from the presence of all growth conditions (e.g. temperature, nutrients) at optimum levels (P.A. Gerakis *in verbis*). [Montemaggiori & Pratesi Urquhart in prep]

Alien species: a species introduced to a region or environment where it is not indigenous.

Anaerobic: lacking oxygen; anaerobic organisms need an environment without oxygen. Refers: a) to the life or to life processes that occur when there is no free oxygen. b) to the condition which is characterised by absence of free oxygen (P.A. Gerakis *in* verbis). [Montemaggiori & Pratesi Urquhart in prep]

ANOVA: Analysis of variance.

Anoxic: totally or largely deficient in oxygen. See Anaerobic.

Anthropogenic: man-made or caused by man.

Aquaculture: cultivation of natural faunal resources of water. (Anon 1986). Fish or seafood farming (Davis 1994). [Montemaggiori & Pratesi Urquhart in prep]

Aquatic plants: emergent plants, such as sedges, reeds and rushes, rooted in the sediment and protruding above the water surface. Free floating plants, such as waterlilies, rooted in the sediment with leaves floating on the water surface. Submerged plants such as *Najas*, growing below the water surface (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Aquifer: porous rock containing water (Pearce & Crivelli 1994). A permeable body of rock capable of yielding quantities of groundwater to wells and springs. A subsurface zone that yields economically important amounts of water to wells (Anon 1986). An underground layer of rock, sand or gravel which holds water and allows water to percolate through (Davis 1994). [Montemaggiori & Pratesi Urquhart in prep]

ASPT: Average Score Per Taxon.

Attributes: of a wetland include the following: biological diversity; and unique cultural and heritage features. These attributes may lead to certain uses or the derivation of particular products, but they may also have intrinsic, unquantifiable importance. (Ramsar 1996, Brisbane)

Autecological requirement: ecological requirements of an individual species (P. Grillas *in litt.*).

Baseline: collection of data or line used as an information base, reference base or starting-point.

Benthic organisms: living on or near the bottom substratum, sedentary or mobile. Organisms attached to or rooted in the substratum at the bottom of a waterbody. (Fitter & Manuel 1986)

Biodiversity: the diversity of life; the total range of living organisms in a locality or ecosystem.

Biogenic: the production or formation of substances as a result of the activities of living organisms. (Allaby 1985)

Biogeographical region: a region characterised by distinctive flora and fauna (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Bio-indicator: biological organisms used as indicators of the state of the ecosystem.

Bio-monitor: a living organism used for the periodic recording of different parameters of environmental quality.

Biotope: in a strict ecological sense it is the non-living structural part of an ecosystem e.g. climate, soil, water. In a wider sense it is the space in which the organisms of a biotic community live and reproduce. (Note: in both cases the biotope is described either by abiotic factors or geometrical parameters. Never by biotic factors. It is therefore an error to say for example "the reed bed is the biotope of leeches" – P.A. Gerakis *in verbis*). [Montemaggiori & Pratesi Urquhart in prep]

Bloom: coloured area on the surface of water caused by heavy planktonic growth. See Algal bloom. (Lapedes 1976)

Brackish: of water, having salinity values ranging from approximately 0.50 to 17.00 parts per thousand. Having less salt than sea water, but undrinkable (Anon 1986). Slightly salty (Davis 1994). [Montemaggiori & Pratesi Urquhart in prep]

Catchment: the area drained by a river and all its tributaries; also referred to as a drainage basin or, in North America, as watershed.

CEMPA: Centro de Estudos de Migrações e Protecção das Aves (Portugal).

Census: a complete enumeration of a whole population with respect to specific variables. Allaby (1988)

Change in ecological character: 'change in ecological character' of a wetland is the impairment or imbalance in any of those processes and functions which maintain the wetland and its products, attributes and values. (Ramsar 1996, Brisbane)

Channelization: the modification of river channels for the purposes of flood control, land drainage, navigation, and the reduction and prevention of erosion. Straightening the meanders in a river system to create more navigable waterways, or when accompanied by channel deepening to provide flood control.

Conductivity: the ability of an aqueous solution to conduct an electrical current. Pure water has a very low specific conductance, but the conductance will increase with an increasing concentration of charged ions in solution. (Goudie 1985)

CORINE: Coordination of Information on the Environment. Programme of the European Commission to create an information system on the state of the environment throughout the European Community (Hecker & Toms Vives 1995). Begun in 1985.

DDA: Direction Départmentale de l'Agriculture du Département des Bouches-du-Rhône (France).

Denitrification: the conversion of nitrate or nitrite to gaseous products, chiefly nitrogen, by certain types of bacteria. (Allaby 1985)

DHKD: Dogal Hayati Koruma Dernegi, Society for the Protection of Nature (Turkey).

DNA: deoxyribonucleic acid.

Drainage: removal of groundwater or surface water, or of water from structures, by gravity or pumping (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Drainage basin: an area in which surface runoff collects and from which it is carried by a drainage system, as a river and its tributaries. Also known as catchment area; drainage area; feeding ground; gathering ground; hydrographic basin (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Droppings: waste matter (faeces) from the bowels of animals and birds (Quirk 1987). In this guide **dropping accumulations** refers to droppings of grazing animals.

DSP: Diarrheic Shellfish Poisoning.

Dune slack: a depression or hollow, often wet, in an area of sand dunes.

Dyke: a wall or embankment of timber, stone, concrete, fascines, or other material, built as training works for a river, to confine the flow rigidly within definite limits over the length treated. [Montemaggiori & Pratesi Urquhart in prep]

Ecological character: structure and inter-relationships between the biological, chemical and physical components of the wetland. These derive from the interactions of individual processes, functions, attributes and values of the ecosystem(s). (Ramsar 1996, Brisbane)

Ecosystem: a community of organisms, interacting with one another, plus the environment in which they live and with which they also interact; e.g. a pond, a forest. A system consisting of producers, autotrophic organisms (mainly green plants); consumers, heterotrophic organisms (animals); and decomposers (saprophytes), heterotrophic organisms (chiefly bacteria and fungi) which break down dead organisms, absorbing nutrients for growth and releasing nutrients to the environment for use by producers; all of these activities being influenced by physical conditions of environment (Abercrombie *et al.* 1980; Montemaggiori & Pratesi Urquhart in prep).

EIB: European Investment Bank.

EID: Entente Interdépartementale de Démoustication, Mosquito Control Service (France).

EKBY: Greek Biotope/Wetland Centre (Greece). [English version of title]

Elvers: immature eels. (Liebeck 1994)

Endemic species: species that are unique to one region, i.e. they are found nowhere else in the world. [Montemaggiori & Pratesi Urquhart in prep]

Endorheic: pertaining to a drainage system with no surface outlet. (Ramos *et al.* 1995)

Environmental noise: conditions and elements of variation in the local environment which mask or confuse interpretation of wider environmental change.

Epiphytic: referring to plants or animals which grow on plants. The host plants are used only as a support, not as a source of nutrients (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Eutrophic: rich in nutrients and hence having excessive plant growth which kills animal life by deprivation of oxygen (Skinner & Zalewski 1995). See also Trophic status.

Eutrophication: nutrient (mainly nitrogen and phosphorous) enrichment of water – this may result in "blooms" of algae. Increase in nutrients required for the growth of organisms may come about by natural processes, or rapid enrichment may take place due to some cause such as an introduction of sewage effluent (Anon 1992). The biological changes which occur in lakes as a result of eutrophication can be separated into those which are the direct result of raised nutrient influx, such as the stimulation of algal growth, and those which are the indirect effect, such as changes in the fish community, as a result of reduced oxygen concentrations. The direct effects occur when organisms, usually planktonic algae, are released from nutrient-limited growth. Indirect biological effects are due to the release of a population from the state of limitation by an inadequate supply of all resources or may occur when an increase in production of any one species' population has effects upon the physico-chemical environment in which it lives. This will affect other species sharing that environment, but not directly competing for resources within it. [Montemaggiori & Pratesi Urquhart in prep]

Eutrophic lakes: "rich" lakes; those well provided with the basic nutrients required for plant and animal production. In some lakes this enrichment becomes harmful, and light penetration and oxygen production are insufficient to maintain productivity. Oxygen is then consumed at a rate equal to that at which it is produced (Anon 1992). [Montemaggiori & Pratesi Urquhart in prep]

Evapotranspiration: the diffusion of water vapour into the atmosphere from vegetated surfaces. The combined loss of water by evaporation and transpiration. (Goudie 1985)

Exotics: species alien to their introduced environment (and see Alien species above).

Flagship species: species which by reason of rarity, popularity or other high profile public interest act as "standard-bearers" for promoting protection of the environment.

Fry: young fish. (Liebeck 1994)

Functions: are activities or actions which occur naturally in wetlands as a product of the interactions between the ecosystem structure and processes. Functions include actions such as flood water control; nutrient, sediment and contaminant retention; food web support; shoreline stabilisation and erosion controls; storm protection; and stabilisation of local climatic conditions, particularly rainfall and temperature. (Ramsar 1996, Brisbane)

Gene flow: movement of genes within an interbreeding group that results from mating and gene exchange with immigrant individuals. Such an exchange of genes may occur in one direction or both. (Allaby 1985)

GIS: Geographic Information System.

Groundwater: water stored in an aquifer. Water that occurs in the permanently saturated zone beneath the water table. All subsurface water that participates in the hydrological cycle. (Goudie 1985)

Histopathological: pertaining to the study of the effects of disease on the microscopic structure of tissues. (Smith 1990)

Hydraulic: operated or effected by the action of water or other fluid of low viscosity (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Hydrogeology: the science dealing with the occurrence of surface and ground water, its utilisation, and its functions in modifying the earth, primarily by erosion and deposition (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Hydrology: the study of the cycle of water movement on, over and through the surface of the earth (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

ICN: Instituto da Conservação da Natureza (Portugal).

ICONA: Instituto Nacional para la Conservación de la Naturaleza (Spain), now Dirección General de Conservación de la Naturaleza.

IGC: Portuguese national grid maps.

Immunological: pertaining to scientific study of resistance to infection.

INAG: Instituto Nacional da Agua (Portugal).

Indigenous: existing and having originated naturally in a particular region or environment. (Lapedes 1976)

Infill: dumping of materials or sediment by humans into wetlands, generally for the purpose of land reclamation.

Influent: either a tributary stream or river, or a term applied to a stream which supplies water to the groundwater zone. (Goudie 1985)

Infra-cellular: below the cellular level.

Infra-specific: below the species level.

Inter-basin transfer: a method of water supply whereby the natural or regulated flow from one river system is transferred, usually by pumping to another river system. (Goudie 1985)

Ions: an isolated electron or positron or anatom or molecule which by loss or gain of one or more electrons has acquired a net electrical current. (Lapedes 1976)

IPIMAR: Portuguese Marine Research Institute. [English version of title]

Irradiance: intensity of radiation. The amount of light energy falling per unit area per unit time. (Lapedes 1976)

IWRB: International Waterfowl and Wetlands Research Bureau (now Wetlands International).

Karstic: typical of limestone region [Montemaggiori & Pratesi Urquhart in prep]. Karst regions are typified by the dominant erosion process of solution, the lack of surface water and the development of stream sinks (dolines), cave systems and resurgences or springs.

Lagoon: a body of water cut off from the open sea by sandbars or coral reefs [Montemaggiori & Pratesi Urquhart in prep].

Lake: an inland body of water, small to moderately large, with its surface water exposed to the atmosphere (Anon 1986). Large, natural inland waterbody, occasionally saline (Burgis & Symoens 1987). [Montemaggiori & Pratesi Urquhart in prep]

Macro-algae: literally "big algae". The term is used to differentiate these from small algae that have to be studied under the microscope (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Macrophytes: literally "big plants", used to describe waterplants other than microscopic algae (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Marine intrusion: influx of sea water into land or freshwater environments.

Marsh: a transitional land-water area, covered at least part of the time by estuarine or coastal waters, and characterised by aquatic and grasslike vegetation, especially without peatlike accumulation (Anon 1986). Marshes differ from swamps in that there is little or no standing water among the vegetation (Wetzel 1975). The sediments are water-saturated. The distinction between the terms marsh and the European "fen" is largely made on the basis of phytosociological differences, where floristic associations occur with species of groups of species exhibiting high fidelity. Some marshes and fens under poor nutrient conditions possess a well developed bryophyte layer, particularly of *Sphagnum* species. The moss vegetation can eventually dominate the system in the formation of bogs (Wetzel 1975, Burgis & Symoens 1987). [Montemaggiori & Pratesi Urquhart in prep]

Meiofauna: small invertebrates, but not minute. Ranging from 63 µm to 1 mm (R. Rufino *in litt.*).

Monitoring: monitoring is based on surveillance and is the systematic collection of data or information over time in order to ascertain the extent of compliance with a predetermined standard or position (Finlayson, chapter 3 of this guide).

Morphogenetic: characterised by a distinctive assemblage that coincides with climatic change. It is believed that the forms largely result from the action of a unique combination of processes controlled by climate. (Allaby 1985)

NCC: Nature Conservancy Council (UK).

Nitrophilous: living in nitrogenous soils. (Lapedes 1976)

Non-biogenic: not essential or negative to maintenance of life. Not produced by action of living organisms.

Non-biotic: not of or pertaining to life and living organisms. Not induced by actions of living organisms.

Organochlorines: synthetic chlorinated hydrocarbon based chemicals of high, persistent toxicity known largely for their agricultural application as pesticides.

OTU: Operational Taxonomic Unit.

Oxidation: a reaction in which oxygen combines with, or hydrogen is removed from, a substance. (Allaby 1985)

PAHs: Polycyclic Aromatic Hydrocarbons.

Pathogen: any micro-organism capable of causing disease. (Allaby 1985)

PCA: Principal Components Analysis.

PCBs: Polychlorinated biphenyls.

Peat: a dark-brown or black residuum produced by the partial decomposition and disintegration of mosses, sedges, trees and other plants that grow in marshes and other wet places (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Pelagic: of, or performed on, the open sea (Skinner & Zalewski 1995).

Periodicity: being periodic, with the tendency to recur at intervals; often relating to the seasons.

Periphyton: plants that grow attached to a solid, non-living substrate, such as rock or plastic (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

pH: a measure of acidity of water, in which pH 7 is neutral, values above 7 are alkaline and values below 7 acid (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Photosynthesis: a chemical process, which takes place in the cellular structures of green plants, blue-green algae, phytoplankton and certain other organisms, and which transforms received solar energy into chemically stored foodstuffs through the conversion of carbon dioxide and water into carbohydrates with the simultaneous release of oxygen.

Phytoplankton: planktonic plant life (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Pilot study: a preliminary study undertaken to test the feasibility of, and suitable methodology for, a further more detailed programme of work.

Poaching (of soils): disturbance of soft soil by animal hoofs to leave an uneven, pocked surface, often resulting in reduced or no vegetation cover.

Potable: non-saline, drinkable.

Pristine: in its original condition; undamaged, unspoilt.

Processes: are changes or reactions which occur naturally within wetland ecosystems. They may be physical, chemical or biological. (Ramsar 1996, Brisbane)

Products: products generated by wetlands include the following: wildlife resources; forest resources; forage resources; agricultural resources; and water supply. These products are generated by the interactions between the biological, chemical and physical components of a wetland. (Ramsar 1996, Brisbane)

Protocol: a schedule of procedure or set of rules.

Proximate factor: local or immediate factors impinging on the site.

PSP: Paralytic Shellfish Poisoning.

Quadrat: a sampling area, often 1 metre square, used in studying the composition of an area of vegetation. The area is usually defined by a frame, sometimes subdivided by fine wires, laid on the ground. (Allaby 1988)

Redox potential: scale indicating the reduction (addition of electrons) and oxidation (removal of electrons) for a given material. The position on the scale is expressed as an electric potential in millivolts, normally in the range 0–1300 or 0–1400mV. The pH of the sample must be known since this can alter the reading. (Allaby 1985)

Runoff: overland flow of water following rain or irrigation events (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

Salinisation: increase in the salt concentration. [Montemaggiori & Pratesi Urquhart in prep]

Sediment:: a mass of organic or inorganic solid fragmented material, or the solid fragment itself, that comes from weathering of rock and is carried by, suspended in, or dropped by air, water, or ice; or a mass that is accumulated by any other natural agent and that forms in layers on the earth's surface such as sand, gravel, silt, mud, fill or loess (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Sedimentation: the process of deposition of sediment.

Silt:: fine sediment deposited by water in channel, harbour, delta, etc. (Skinner & Zalewski 1995).

SMGEO: Syndicat Mixte de Gestion de l'Étang de l'Or (France).

SPA: Special Protection Area under the EC Birds Directive 79/409.

Stressor: a force acting to cause difficult circumstances for organisms leading to their physical distress.

STRP: Scientific and Technical Review Panel of the Ramsar Convention.

Surveillance: an extended programme of surveys, undertaken in order to provide a time series, to ascertain the variability and/or range of states or values which might be encountered over time, but without preconceptions of what these might be (Goldsmith 1991).

Survey: an exercise in which a set of qualitative or quantitative observations are made, usually by means of a standardised procedure and within a restricted period of time, but without any preconception of what the findings ought to be (Goldsmith 1991).

Toxic substance: the substance which through its physical and/or chemical action may cause damage to, or even the death of, an organism. [Montemaggiori & Pratesi Urquhart in prep]

Toxin: any of various poisonous substances produced by certain plant and animal cells, including bacterial toxins, phytotoxins and zootoxins (Anon 1986). [Montemaggiori & Pratesi Urquhart in prep]

Trophic level: nourishment or "feeding" level within a biological system. Position in the food chain. (Lapedes 1976)

Trophic status: trophic comes from the Greek word for feeding. There are generally three classes distinguished: 1) eutrophic (well-fed) means nutrient-rich and is usually associated with low oxygen levels. 2) mesotrophic (medium); 3) oligotrophic (little-fed), nutrient-poor except for oxygen. The trophic status for any one wetland is a condition determined by the surrounding catchment, landform and geology (Finlayson & Moser 1991). [Montemaggiori & Pratesi Urquhart in prep]

UIB: University of the Balearic Islands. [English version of title]

UNL: New University of Lisbon. [English version of title]

Vallicoltura: extensive aquaculture in natural marshes (G.E. Hollis in litt.). [derived from Valli: one of the most successful and durable systems of TRADITIONAL fishing used in the 10,000 lagoons of the Italian Adriatic, including the Po delta and the Venice lagoon. Though practised for many hundreds of years, the valli system comes close to many of the techniques of modern fish farming. (Pearce & Crivelli 1994)]

Values: are the perceived benefits to society, either direct or indirect, that result from wetland functions. These values include human welfare, environmental quality and wildlife support. (Ramsar 1996, Brisbane)

WWF: World Wide Fund for Nature.

ZNIEFF: Zone Naturelle d'Intérêt Écologique, Faunistique et Floristique (France).

Zooplankton: animals, many of them microscopically small, that float or swim very feebly in fresh and salt water. (Allaby 1988)

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Produced with financial support of the European Commission

Price UK£20