Resolution VII.10

"People and Wetlands: The Vital Link"
7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971), San José, Costa Rica, 10-18 May 1999

Wetland Risk Assessment Framework

Contents:

Introduction

1. The Convention on Wetlands (Ramsar, Iran, 1971) has developed this conceptual framework for wetland risk assessment to assist its Contracting Parties with predicting and assessing change in ecological character of the sites included in the List of Wetlands of International Importance and other wetlands. This Framework provides guidance on how to go about predicting and assessing change in the ecological character of wetlands and promotes, in particular, the usefulness of early warning systems. The *Wetland Risk Assessment Framework* is presented as an integral component of the management planning processes for wetlands.

2. The Ramsar Convention's processes for assessing and maintaining the ecological character of wetlands comprise many elements and are central to the Convention's concept of wise use and to the obligations of Contracting Parties under the treaty. These elements include:

   a. the Criteria for Identifying Wetlands of International Importance (Resolution VII.11);
   b. the Montreux Record of Ramsar sites where changes in ecological character have occurred, are occurring, or are likely to occur (Resolution 5.4); and
   c. the Working Definitions, Guidelines for Describing and Maintaining the Ecological Character of Listed Sites, and Guidelines for Operation of the Montreux Record (Resolution VI.1).

3. Resolution VI.1, adopted at the 6th Conference of the Contracting Parties to the Convention in 1996, also presented a framework for designing an effective wetland monitoring programme and called for the development of appropriate early warning systems for detecting adverse change and for assessment of the working definitions of "ecological character" and "change in ecological character". In the triennium that

followed, these working definitions were reviewed and amended as shown in Resolution VII.10 which also adopts this *Wetland Risk Assessment Framework*.

Types of change in ecological character

4. The causes of adverse change in the ecological character of a wetland can be grouped in five broad categories:

   a. changes to the water regime;
   b. water pollution;
   c. physical modification;
   d. exploitation of biological products; and
   e. introduction of exotic species.

5. The relative importance of these causes varies regionally, nationally and even from site to site. In addition, the above causes of change are often inter-linked, and it can be difficult to separate the effects of each of them. A simpler way to view change in ecological character is by the **type of change** as opposed to the **cause of change**. In accordance with the definition of change in ecological character (refer to paragraph 11 of Resolution VII.10 adopting this Framework), the type of change can be considered under three general headings – **biological, chemical and physical**.

6. In outlining an appropriate framework and methods for the prediction of change in ecological character of wetlands, site managers are primarily concerned with **types of change**. Specifically, they are concerned with adverse change caused by human activity.

Wetland Risk Assessment

7. To ensure the appropriate application of early warning indicators, it is essential that the processes of selecting, assessing, analysing and basing decisions on indicator responses be contained within a structured but flexible form of assessment framework. In the context of the Ramsar Convention, a modified ecological risk assessment framework, termed **wetland risk assessment**, is encouraged. The framework aims to outline how Wetland Risk Assessment can act as the 'vehicle' for driving the process of predicting and assessing change in ecological character, with a particular emphasis on the application of early warning techniques.

8. A basic model for wetland risk assessment, modified from a generalised ecological risk assessment paradigm, is shown in Figure 1. It outlines six steps that are described in the following paragraphs.

9. **Step 1 - Identification of the problem.** This is the process of identifying the nature of the problem and developing a plan for the remainder of the risk assessment based on this information. It defines the objectives and scope of, and provides the foundation for, the risk assessment. In the case of a chemical impact, it would include obtaining and integrating information on the characteristics (for example, properties, known toxicity) and source of the chemical, what is likely to be affected, and how is it likely to be affected, and importantly, what is to be protected.

10. **Step 2 - Identification of the adverse effects.** This step evaluates the likely extent of adverse change or impact on the wetland. Such data should preferably be derived from field studies, as field data are more appropriate for assessments of multiple impacts, such as occur on many wetlands. Depending on the extent of adverse change and available resources, such studies can range from quantitative field experiments to qualitative observational studies. For chemical impacts, on-site ecotoxicological bioassays constitute appropriate approaches, whereas for changes caused by weeds or feral animals, on-site observation and mapping may be all that is required.

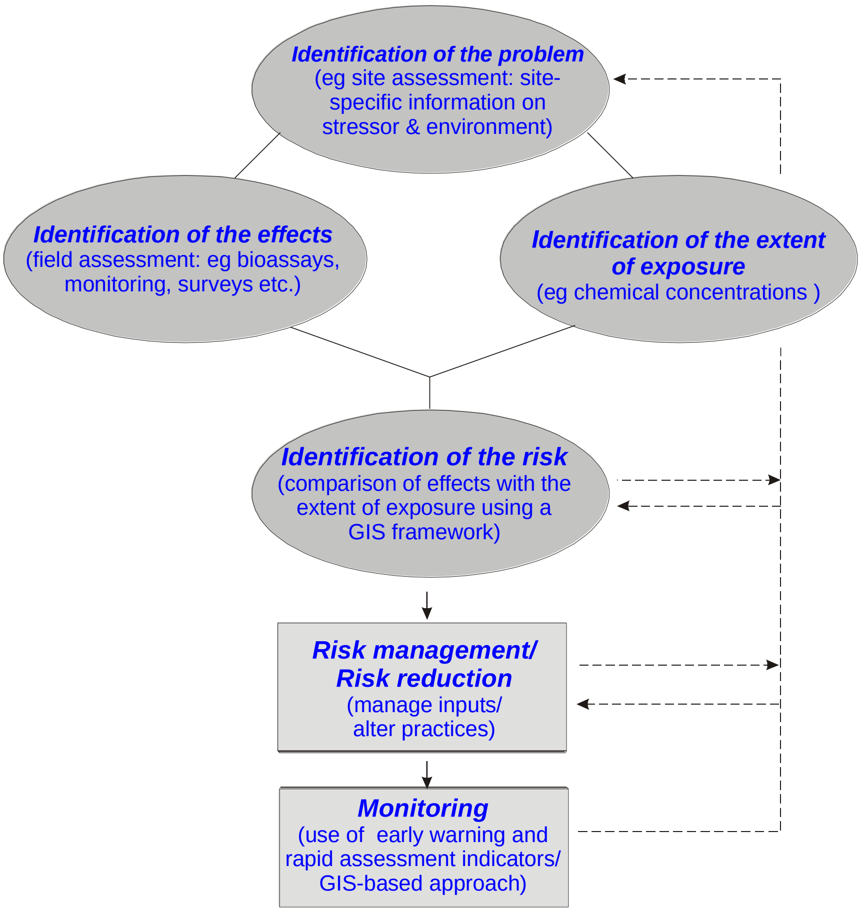

Figure 1: Suggested model of wetland risk assessment

11. **Step 3 - Identification of the extent of the problem.** This step estimates the likely extent of the problem on the wetland of concern by using information gathered about its behaviour and extent of occurrence elsewhere. In the case of a chemical impact, this includes information on processes such as transport, dilution, partitioning, persistence, degradation, and transformation, in addition to general chemical properties and data on rates of chemical input into the environment. In the case of an invasive weed, it might include detailed information on its entry into an ecosystem, rate of spread and habitat preferences. While field surveys most likely represent the ideal approach, use of historical records, simulation modeling, and field and/or laboratory experimental studies all represent alternative or complementary methods of characterising the extent of the problem.

12. **Step 4 - Identification of the risk.** This involves integration of the results from the assessment of the likely effects with those from the assessment of the likely extent of the problem, in order to estimate the likely level of adverse ecological change on the wetland. A range of techniques exist for estimating risks, often depending on the type and quality of the likely effects and their extent. A potentially useful technique for characterising risks in wetlands is via a GIS-based framework, whereby the results of the various assessments are overlaid onto a map of the region of interest in order to link effects to impact. In addition to estimating risks, such an approach would also serve to focus future assessments and/or monitoring on identified problem areas.

13. **Step 5 - Risk management and reduction.** This is the final decision-making process and uses the information obtained from the assessment processes described above, and it attempts to minimize the risks without compromising other societal, community or environmental values. In the context of the Ramsar Convention, risk management must also consider the concept of *wise use* and the potential effects of management decisions on this. The result of the risk assessment is not the only factor that risk management considers; it also takes into account political, social, economic, and engineering/ technical factors, and the respective benefits and limitations of each risk-reducing action. It is a multidisciplinary task requiring communication between site managers and experts in relevant disciplines.

14. **Step 6 - Monitoring.** Monitoring is the last step in the risk assessment process and should be undertaken to verify the effectiveness of the risk management decisions. It should incorporate components that function as a reliable early warning system, detecting the failure or poor performance of risk management decisions prior to serious environmental harm occurring. The risk assessment will be of little value if effective monitoring is not undertaken. The choice of endpoints to measure in the monitoring process is critical. Further, a GIS-based approach will most likely be a useful technique for wetland risk assessment, as it incorporates a spatial dimension that is useful for monitoring adverse impacts on wetlands.

Early warning indicators

15. The underlying concept of early warning indicators is that effects can be detected, which are in fact, precursors to, or indicate the onset of, actual environmental impacts. While such 'early warning' may not necessarily provide firm evidence of larger scale environmental degradation, it provides an opportunity to determine whether intervention or further investigation is warranted. As such, early warning indicators can be defined as *"the measurable biological, physical or chemical responses to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest*".

16. Of the five major types of change in ecological character described in paragraph 4 above, chemical change has received by far the most attention in terms of its environmental impacts and their prediction. As a result, the vast majority of early warning techniques have been developed to assess the impacts of chemicals on aquatic ecosystems. It is recommended that further assessments be carried out to identify appropriate indicators for the other major types of change in ecological character. Examples of early warning indicators included in this Framework mostly represent biological and physico-chemical assessment approaches to predict or forewarn of important chemical changes (that is, pollution) on wetlands.

17. The choice of indicators follows a hierarchy of other decisions required by managers in setting up monitoring programs to assess ecosystem health. Thus, after identifying the issue of concern or potential concern and determining the environmental values to be protected, managers should then be concerned with identifying **assessment objectives** for protection of the wetland. As an example, the following can be used:

    a. **Early detection of acute and chronic changes,** providing pre-emptive information so that ecologically important impacts are avoided.
    b. **Assessing the ecological importance of impact** through measurement of biodiversity, conservation status and/or population, community or ecosystem-level responses.

18. To determine effects upon the ecosystem as a whole – or the ecological importance of effects that are observed – measurement of ecosystem 'surrogates' is usually required. Typically these surrogates are communities or assemblages of organisms, or habitat or keystone-species indicators where these have been closely linked to ecosystem-level effects. Information on the ecological importance of adverse effects is best met in programs that have regional or national coverage and that encompass a full disturbance gradient, that is, covering a range of sites that have not been degraded to those that have been severely degraded. Rapid assessment methods can provide this context.

19. In selecting an indicator it is important to be mindful of the definition of the ecological character of a wetland (refer to paragraph 11 of Resolution VII.10 adopting this Framework) and its emphasis on the **biological, chemical and physical** components of the ecosystem. Therefore, it may be useful to select early warning indicators according to which of the above three components is/are considered more susceptible to change. The three components are intricately linked. Although these interactions exist, the *Wetland Risk Assessment Framework* provides a process to assist in identifying the most appropriate indicators to assess or predict change.

20. The ecological relevance of an early warning indicator should be considered. However, the concepts of early warning and ecological relevance can conflict. The types of biological responses that can be measured, and their relationship to ecological relevance and early warning capability, is generalised in Figure 2. As an example, biomarker responses can offer exceptional early warning of potential adverse effects, but there exists very little evidence that observed responses result, or culminate in adverse effects at an individual level, let alone the population, community or ecosystem level. Therefore, they cannot be considered ecologically relevant. If the primary assessment objective is that of early detection, then it is likely that it will be at the expense of ecological relevance, while the opposite would probably apply if knowledge of the ecological significance of effects was considered.

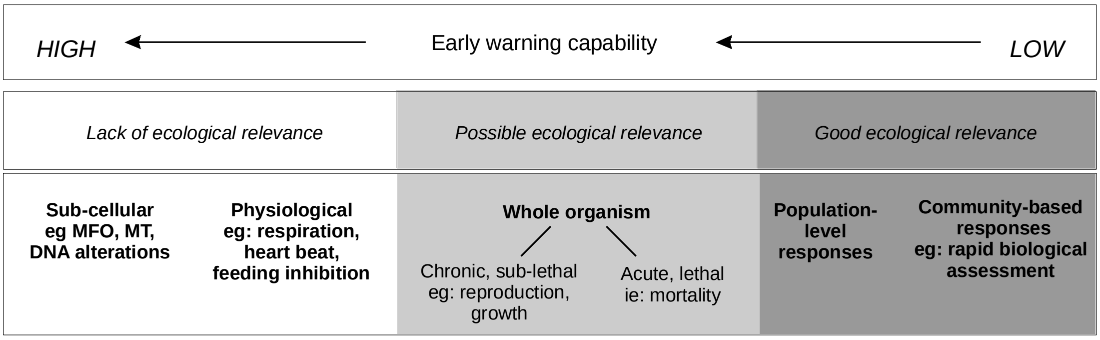

Figure 2: Relationship of ecological relevance and early warning capability to measurable biological responses

Ideal attributes of early warning indicators

21. To have potential as an early warning indicator, a particular response should be:

a. **anticipatory**: it should occur at levels of organisation, either biological or physical, that provide an indication of degradation, or some form of adverse effect, before serious environmental harm has occurred;
b. **sensitive**: in detecting potential significant impacts prior to them occurring, an early warning indicator should be sensitive to low levels, or early stages of the problem;
c. **diagnostic**: it should be sufficiently specific to a problem to increase confidence in identifying the cause of an effect;
d. **broadly applicable**: it should predict potential impacts from a broad range of problems;
e. **correlated to actual environmental effects/ecological relevance**: an understanding that continued exposure to the problem, and hence continued manifestation of the response, would usually or often lead to significant environmental (ecosystem-level) adverse effects;
f. **timely and cost-effective**: it should provide information quickly enough to initiate effective management action prior to significant environmental impacts occurring, and be inexpensive to measure while providing the maximum amount of information per unit effort;
g. **regionally or nationally relevant**: it should be relevant to the ecosystem being assessed;
h. **socially relevant**: it should be of obvious value to, and observable by stakeholders, or predictive of a measure that is socially relevant;
i. **easy to measure**: it should be able to be measured using a standard procedure with known reliability and low measurement error;
j. **constant in space and time**: it should be capable of detecting small change and of clearly distinguishing that a response is caused by some anthropogenic source, not by natural factors as part of the natural background (that is, high signal to noise ratio);
k. **nondestructive**: measurement of the indicator should be nondestructive to the ecosystem being assessed.

22. The importance of the above attributes cannot be over-emphasized, since any assessment of actual or potential change in ecological character will only be as effective as the

indicators chosen to assess it. However, an early warning indicator possessing all the ideal attributes cannot exist, as in many cases some of them will conflict, or will simply not be achievable.

Examples of early warning indicators

23. A number of early warning indicators have been developed for the assessment of wetland ecosystems. These are placed into three broad categories:

    a. rapid response toxicity tests;
    b. field early warning tests; and
    c. rapid assessments.

24. A general description of these, including potential limitations, is outlined in Table 1. Each of the techniques may meet different objectives in water quality assessment programs. Although the majority of early warning indicators are of a biological nature, physico-chemical indicators do exist and often form the initial phase of assessing water quality.

Table 1: Role and possible limitations of types of early warning indicators

Type of response and role	Potential limitations
a. Rapid response toxicity tests Laboratory toxicity assessment of sensitive whole organism responses (for example, growth, reproduction) with rapid turn-around of results. They are predictive tests that potentially enable timely and flexible management actions (for example determining a safe dilution for discharge of effluents of changing composition) to be implemented.	Ecological relevance of measured sub-lethal responses (for example, growth, reproduction) has generally not been established.
b. Field early warning tests Field measurement of sensitive sub-lethal organism responses through monitoring or assessment. They can provide pre-emptive or preventative information so that substantial and ecologically important impacts are avoided.	Ecological relevance of measured responses (especially biochemical biomarkers) has generally not been established.
c. Rapid assessments Standardised, rapid and cost-effective monitoring of various forms can provide 'first-pass' assessment of the ecological condition of sites over large areas. Broad coverage has potential to identify 'hot spots' and hence pre-empt and prevent similar occurrences elsewhere.	Output is usually coarse and generally only detects relatively severe impacts.

Rapid response toxicity tests

25. These represent laboratory toxicity bioassays designed to provide rapid and sensitive responses to one or more chemicals. They provide an indication that there may be a risk of adverse effects occurring at higher levels of biological organization (for example, communities and ecosystems). Laboratory toxicity tests are of particular use for a chemical or chemicals yet to be released into the aquatic environment (for example, a new pesticide or a pre-release waste water). They provide a basis upon which to make decisions about safe concentrations or dilution/release rates, thereby eliminating, or at least minimizing, adverse impacts on the aquatic environment. However, there are major differences in the ecological relevance of responses that can be measured.

Early warning field tests

26. This group comprises a range of techniques that are grouped because they are used to measure responses or patterns in the field and thus provide a more realistic indication of effects in the environment. In contrast to laboratory rapid response toxicity tests, early warning field tests predict and/or assess the effects of existing chemicals. Some of the techniques can also be applied to biological and physical problems.

27. **Direct toxicity assessment.** This is the use of toxicity tests to assess and monitor the consequences of chemicals in aquatic ecosystems (for example, waste water releases, contamination of waterways with pesticides and other agricultural chemicals). *In situ* toxicity assessment of a waterbody receiving a pollutant input serves to monitor the

effectiveness of predictions based on the rapid response toxicity tests described above (paragraph 25). However, assuming the measured responses are sensitive, results can also provide early warning of potential impacts at higher levels of biological organization.

28. **Phytoplankton monitoring.** Due to their nutritional requirements, their position at the base of aquatic food webs, and their ability to respond rapidly and predictably to a broad range of pollutants, phytoplankton represent perhaps the most promising early warning indicators of change in ecological character of wetlands due to chemicals. In addition, their sensitivity to changes in nutrient levels makes them ideal indicators for assessing eutrophication. They can be used in the types of toxicity bioassays described above, for rapid response toxicity tests and direct toxicity assessment. Such methods are rapid, inexpensive and sensitive, and can be carried out in the laboratory or in the field, using either laboratory cultured algae or natural phytoplankton assemblages. For example, algal fractionation bioassays (AFB) assess the effects of pollutants on the functional parameters (for example, C^{14} uptake, biomass) within various size fractions of a natural assemblage of algae. Structural indicators, such as species composition and size assemblage shifts have also been found to be particularly sensitive.

29. **Biomarkers.** These can be defined as biochemical, physiological, or histological indicators of either exposure to, or effects of, particular chemicals at the sub-organismal or organismal level. The underlying concept is that changes to the biochemistry, physiology or histology of individual organisms often precede effects at the organismal and therefore, potentially, population, community and ecosystem level. Briefly, aquatic animals are collected from the site(s) of interest and a reference site, and the biomarkers assessed and compared. A modification of this is to place 'caged' micro-organisms in the environment of interest, and to measure biomarker responses following a pre-determined period of time. Biomarkers have been used to predict potential adverse effects of a number of pollutant types, including organic chemicals such as pesticides and petroleum hydrocarbons, heavy metals, and complex mixtures (for example, industrial effluents).

30. Three potentially useful types of biomarkers are mixed function oxidase, vitellogenin which is a biomarker of potential endocrine disruption, and bioaccumulation. Many biomarkers have been demonstrated to give early warning of potential adverse environmental effects of particular chemicals or complex effluents. They provide the most advanced form of biological early warning.

Rapid assessments

31. These are being increasingly used for water quality monitoring, having the appeal of enabling ecologically-relevant information to be gathered over wide geographical areas in a standardised fashion and at relatively low costs. The trade-off in these virtues is that rapid assessment methods are usually relatively 'coarse' and hence are not designed to detect subtle impacts. Desired or essential attributes of rapid assessment include:

   a. measured response is widely regarded as adequately reflecting the ecological condition or integrity of a site, catchment or region (that is, ecosystem surrogate);
   b. approaches to sampling and data analysis are highly standardised;
   c. response is measured rapidly, cheaply and with rapid turnaround of results;
   d. results are readily understood by non-specialists; and
   e. response has some diagnostic value.

32. A range of rapid assessment approaches is being developed. These include rapid biological assessment using invertebrates, monitoring of birdlife, and remote sensing. These all have particular applications and in many cases still require further development.

33. Physico-chemical monitoring has also been recognised as being a vital component of an integrated assessment program that utilises biological measures for assessing the condition of waterways. The monitoring of standard physico-chemical parameters can be of use in several ways. Firstly, it provides a record of the physico-chemical characteristics of the waterbody, which when continued over an extended period, provides a record of the variation in the characteristics over time. Secondly, many physico-chemical parameters have the ability to alter the toxicity of particular pollutants. The majority of standard physico-chemical water quality parameters are simple, inexpensive and quick to measure, and should be used to complement any ecotoxicological or biological monitoring study.

Responsiveness of early warning indicators

34. Acceptance of the need for early warning indicators in a monitoring program implies that information on early change is acted upon and an agreed management plan is in place. The initial stages of this management plan may entail a series of iterations amongst negotiating stakeholders about the type and size of the change that are deemed important, as well as the relative costs of inferring that there is an impact when in fact there is none, and of failing to detect a real impact. These are important statistical parameters that must be agreed, as they stipulate the confidence with which the results of the monitoring are accepted.

35. Inclusion of early warning indicators in a monitoring program implies a precautionary management approach, that is, intervention before real and important ecosystem-level changes have occurred. Intervention in response to changes in an early warning indicator, therefore, occurs at some conservative and generally arbitrary threshold or trigger value in the measured response.

36. The most powerful impact assessment programs will generally be those that include two types of indicator, namely those associated with early warning of change and those (regarded as) closely associated with ecosystem-level effects. The ‘ecosystem-level’-type indicator might include ecologically important populations (for example, keystone species) or habitat, or communities of organisms that serve as suitable ecosystem ‘surrogates’. Indicators used in rapid assessment would also normally serve this role. With both types of indicators measured in a monitoring program, information provided by ‘ecosystem-level’ indicators may then be used to assess the ecological importance of any change observed in an early detection indicator.

37. Just as for early warning indicators, thresholds of change and other statistical decision criteria for the ‘ecosystem-level’ indicators must also be negotiated and decided upon in advance. Specific decisions on thresholds of change are an issue that can only be dealt with effectively on a site-specific basis, whilst taking account of the ecological values and wise use of the site.