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ENVIRONMENTAL QUALITY STANDARDS TO PROTECT IDENTIFIED USES OF CONTROLLED WATERS - General ecosystem and special ecosystem

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ENVIRONMENTAL QUALITY STANDARDS TO PROTECT IDENTIFIED USES OF CONTROLLED WATERS - General Ecosystem and Special Ecosystem

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EXECUTIVE SUMMARY

The Water Quality Survey Group of the NRA has proposed use-related environmental quality objectives for controlled waters. This report considers the development of Environmental Quality Standards for the general ecosystem and special ecosystem uses. Biological assessment methods are reviewed that could be applied to measure the quality of waters identified for general ecosystem use and the suitability of methods as a basis for standards is considered. For rivers and canals, the use of invertebrate monitoring and RIVPACS is recommended as a basis for the derivation of standards. However, further testing of the RIVPACS model and application of BMWP scores is recommended. Also, the monitoring of other parts of the biological community should be considered and suitable techniques developed. A potentially useful technique for general habitat assessment, the Conservation Potential Index, has been developed in this project. For other categories of controlled surface waters further research is required to develop suitable methods, though approaches that enable natural variability in communities to be quantified such as the RIVPACS approach may be the most suitable.

A limited number of tentative chemical standards are proposed for ecologically relevant parameters for each category of controlled surface water. Standards for dissolved oxygen and ammonia are proposed. The development of standards for nutrients is recommended to be applied on a site-specific basis.

Selection criteria for the identification of waters for special ecosystem use are discussed. Sites with statutory designations, primarily Sites of Special Scientific Interest and Marine Nature Reserves, should be identified for this use due to their nature conservation importance. Additional criteria should also be considered.

KEY WORDS

Environmental Quality Objectives; EQSs; Biological Monitoring; Ecosystem; Conservation; Biological Standards; Chemical Standards

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1. INTRODUCTION

The Water Quality Survey Group (WQSG) of the NRA have proposed 14 use-related Environmental Quality Objectives (EQOs) to apply to controlled waters (WQSG 1990a). In an earlier report to the WQSG Smith *et al* (1991) reviewed the standards currently available and proposed some others for the 14 identified water uses. The report considered chemical standards available for all 14 uses and, in addition, the application of biological standards for the general ecosystem use. The chemical standards for all 14 uses were summarised in a further report to the WQSG (Smith and Gulson 1991). Following the production of the former report (Smith *et al* 1991) it was decided by the WQSG that standards for the general ecosystem use should be predominantly biological, and thus the bulk of available chemical standards considered in earlier reports are not repeated here.

This report considers the General Ecosystem and Special Ecosystem objectives separately. The concept of general ecosystem and special ecosystem as uses is novel in that the uses are not anthropocentric. The underlying philosophy of these uses is the protection and conservation of whole ecosystems. Though the intention is that compliance with these objectives is assessed primarily against biological criteria, consideration is also given to certain key ecologically relevant chemical criteria. The emphasis of the report, particularly with respect to the general ecosystem use has been on rivers and canals. This is currently the priority controlled water category for the NRA.

The objectives identified for the General Ecosystem and Special Ecosystem uses are essentially biological and as such the development of biological standards may provide the most appropriate approach to assess compliance with the objectives. Previously chemical water quality monitoring has been used as a surrogate for assessing biological quality. The development of chemical standards to protect whole ecosystems has tended to be based on toxicological data from experiments involving organisms assumed to be both sensitive and representative of the ecosystem, it being very difficult to readily study whole aquatic communities in the laboratory. The chemical water quality approach (i.e. to assess compliance with standards) assumes that the monitoring programmes adopted will provide an accurate measure of the range of water quality at a particular site. Experience has shown that chemical water quality monitoring programmes are often inadequate; episodic events usually pass undetected, the choice of determinands is necessarily limited, and the nature of communities may not necessarily be correlated with recorded water quality. The use of more direct ecological measurements, in addition to providing an indicator of composite water quality over a period of time, may also be sensitive to the impacts of habitat change, e.g. the effects of land drainage works. Such sensitivities to other factors make some biological assessment techniques less useful as water quality indicators *per se*, as they provide an indication of broader environmental quality which confounds a water quality assessment. Chemical water quality standards provide a means of protecting waters such that they may be capable of supporting high ecological interest. Biological techniques may measure that interest directly and detect degradation due to factors other than water quality.

The establishment of a biological monitoring programme will enable compliance with the proposed EC directive on the ecological quality of surface waters. The proposed directive (COM 1991) aims "to protect the aquatic environment of the surface waters of the

2. GENERAL ECOSYSTEM USE

2.1 Objective

The general ecosystem EQO is applicable to all surface waters (i.e. it is not applicable to groundwaters). The EQO for general ecosystem has been defined by the Water Quality Survey Group (WQSG 1990a) as:

Water type	EQO	Explanatory notes
For all Fresh Waters		Includes all aquatic flora and dependent organisms, excluding fish• which are covered by salmonid and cyprinid fishery uses
1a For Rivers (and Canals) of or near to, pristine conditions	Maintain water quality so as to protect all aquatic life and dependent non-aquatic organisms, such that the ecosystem is typical of a river with those physical characteristics and flow régime OR	
1b For Rivers where achievement of pristine conditions is impracticable	Maintain or improve water quality to such a condition that it can provide a fauna and flora capable of supporting relevant fish populations (see salmonid and cyprinid fishery objectives)	This more limited objective would apply where it was economically or practically not feasible to return a river to its natural state. The level of ecosystem to be achieved would be specified as part of the 'standards'
2 Lakes	Maintain water quality so as to protect all aquatic life and dependent non-aquatic organisms, such that the ecosystem is typical that the ecosystem is typical of a with those physical characteristics	Includes all aquatic flora and fauna and dependent organisms, excluding fish which are covered by salmonid and cyprinid fishery uses
3 For Estuaries		To include fish, shellfish and the protection of other aquatic life and dependent organisms

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2.2 Potential approaches to setting standards

Potentially the standards adopted to assess compliance with the general ecosystem use could be chemical, biological or a combination of both. This report considers a limited number of relevant chemical standards and a number of biological assessment techniques from which biological standards may be drawn.

2.2.1 Chemical standards

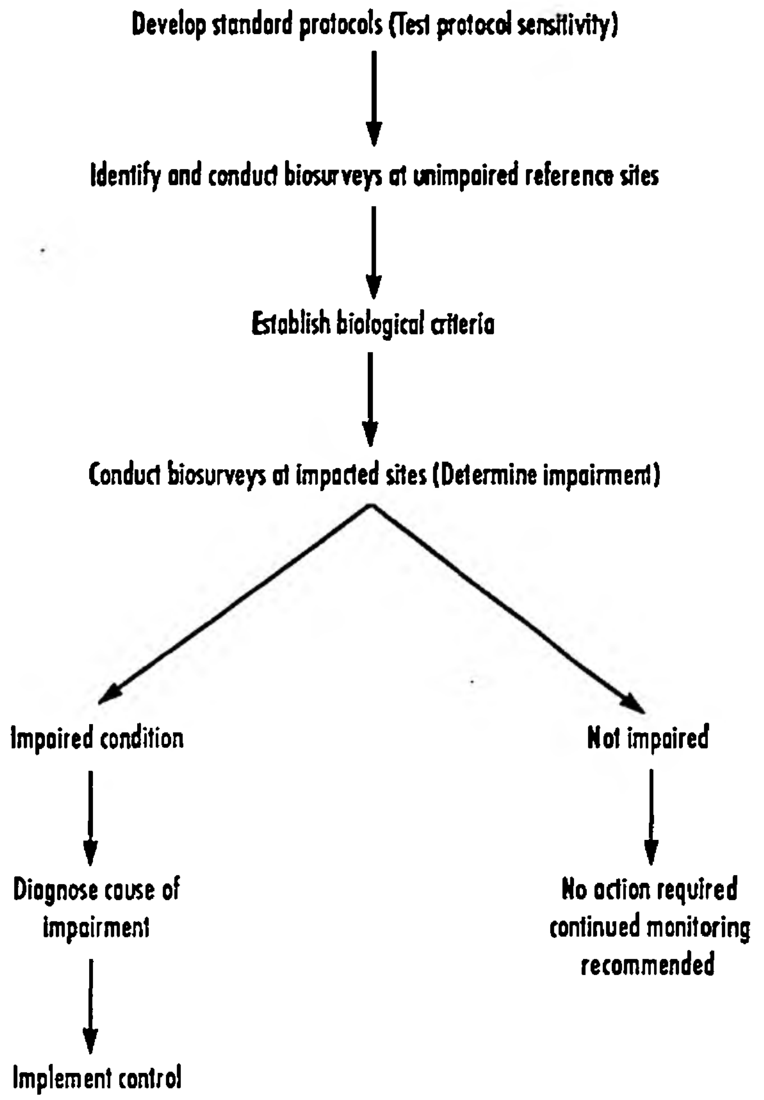
It is suggested that some chemical standards may be required, since certain parameters, such as nutrients may have significant effects on aquatic ecosystems at levels below that at which controls may be exerted through EQSs for other uses, assuming that the water body is designated for other uses. In addition, their inclusion may meet the requirements of certain future directives. The monitoring of oxygen, toxic chemicals and nutrients and therefore the setting of standards may be seen as a requirement of the proposed EC directive concerning the ecological quality of Community surface waters (COM 1991) which states in its operational definitions of the targeted 'high' ecological quality (Appendix A) that: "dissolved oxygen should be optimal for the normal respiration of aquatic organisms"; "concentrations of toxic or other harmful substances in water, sediment and biota should be below levels known to have a deleterious effects on aquatic life, or prevent the normal uses of the water body"; and "there should be no evidence of excessive macrophytic or algal growth due to elevated nutrient levels of anthropogenic origin". Sampling of waters subject to certain waste water discharges is required under the EC Directive concerning urban waste water treatment "where it can be expected that the receiving environment will be significantly affected" (CEC 1991).

Standards for List I substances apply to all waters receiving discharges regardless of the use of those waters. The standards for List II substances are use-related minimum standards and are applicable to those waters receiving discharges.

2.2.2 Biological criteria

This report considers appropriate techniques for the assessment of the quality of aquatic ecosystems (and dependent organisms) in the respective categories of controlled waters (rivers and canals; lakes; estuaries; and coastal waters) for which the use is considered appropriate. Criteria or standards may be established on the basis of the quality of ecosystem recorded using these techniques. For a meaningful assessment of ecosystem quality it has been suggested that a range of organism types should be chosen to allow for varying sensitivities to changes in the aquatic (and riparian) environment and ultimately a range of techniques should be selected that optimises information on the quality of an aquatic ecosystem whilst minimising resourcing requirements (US EPA 1990). As such it may be appropriate to include both primary producers (e.g. algae, macrophytes) and consumers (e.g. invertebrates, fish). The protection of ecosystems from a broad range of impacts requires a comprehensive approach.

Herricks and Schaeffer (1985) defined six criteria that programmes of biomonitoring should meet to be valid:



Implementation of biological criteria requires the initial selection of reference sites and characterisation of resident aquatic communities inhabiting those sites to establish the reference condition and biological criteria. After criteria development, impacted sites are evaluated using the same biosurvey procedures to assess resident biota. If impairment is found, diagnosis of cause will lead to the implementation of a control. Continued monitoring should accompany control implementation to determine the effectiveness of intervention. Monitoring is also recommended where no impairment is found to ensure that the surface water maintains or improves in quality.

Figure 2.1 Process for the development and implementation of biological criteria (after US EPA 1990)

for biological integrity, habitat evaluation has largely been applied to enable interpretation of biological assessments. However, more integration of habitat assessments into the regulatory process by establishing criteria based on desirable physical structure of habitats is recommended (US EPA 1990). Plafkin *et al* (1989) described rapid bioassessment protocols for use in streams and rivers and presented diagrams plotting biological condition (percentage of reference) against habitat quality (percentage of reference).

In Europe biological assessment of water quality has (principally) been based on invertebrate sampling. Metcalfe (1989) reviewed the history and development of biological water quality assessment using macro-invertebrates in Europe, and appraised the principal approaches made. The more important methods described are covered in more detail in Section 2.3.2. The development of invertebrate monitoring techniques such as those using the RIVPACS (River Invertebrate Prediction and Classification System) model enables comparison of reference (predicted) with observed communities. Modelling of reference conditions is also the basis of the HABSCORE model used in upland salmonid fisheries. Such models reduce the variability in assessments that are due to regional or habitat differences and thus low performance due to water quality effects may be more easily identified.

Standards or criteria may not only be used in the protection of ecosystems but also in monitoring the recovery of impacted sites. Thus biological criteria may be used to provide targets in a recovering river, i.e. the re-establishment of a self-sustaining population of salmon in the River Thames is one example. Hughes *et al* (1990) described a regional framework for establishing recovery criteria to enable measurement of the recovery of impacted aquatic ecosystems. A regional approach is certainly required in the US where there is a wide natural range in aquatic ecosystems and therefore the application of general criteria is inappropriate. In the UK a geographical range of aquatic ecosystems is evident, largely determined by past glaciation patterns and current climatic conditions, and as such some biological criteria should have regional considerations.

Bioassays may provide another useful tool in the assessment of ecosystem quality. *In situ* bioassays using organisms ranging from bacteria to fish may provide an indication of short term impacts of water quality on aquatic ecosystems. Bioaccumulation studies provide an assessment of longer term (sub-lethal) impacts of substances on ecosystems and may take into account sediment/water interactions. Bioassays may be used to assess the impacts of specific discharges, either directly, using *in situ* bioassays, or indirectly, through laboratory based toxicological studies. They may be used to identify anomalies between chemical and biological monitoring information and for other site-specific projects. Indeed, standards may be set as the level of response of organisms in toxicological tests. As an example, Nelson and Hansen (1991), to assess the environmental impacts of alternative dredging practices in a Massachusetts harbour, applied the following site-specific, toxicological criteria: percentage survival of a red alga, a mussel, mysid shrimp, and fish species; percentage fertilisation of eggs of a sea urchin; cystocarp production in the alga; scope for growth in the mussel; and growth in the mysid and fish. However, at current stages of development (toxicological) bioassays do not provide suitable methodologies for the general monitoring of surface waters. For a recent review of the applications of bioassays and other toxicological techniques see Crane *et al* (1991).

References: A Stiff *et al* (1990)
B AWA (1986)
C Seager *et al* (1988)
D Cartwright and Painter (1991)

Standards for dissolved oxygen are set at two levels based on the perceived sensitivity of the ecosystem (i.e. the presence of important spawning grounds would demand the higher standard for adequate protection). Standards for dissolved oxygen and ammonia are currently under review and will be considered following the analysis of the 1990 River Quality Survey and the application of the Ecological Quality Index (formerly Environmental Quality Index) or EQI (see Section 2.3.2). For nutrient (i.e. nitrogen and phosphorus) standards a three-option approach is recommended, the choice depending on the availability of information for a river/canal stretch. Nutrients standards can most meaningfully be applied on a catchment-by-catchment and site-by-site basis, due to differing catchment geology and weathering patterns and local (site) characteristics. As such these should be derived where information and resources permit. However, a standstill provision is recommended as an interim measure until site-specific standards can be established, assuming information on nutrient levels is available. The application of retrospective standstill levels could be examined as a possibility, where long data records are available and there is a perceived need to return to former nutrient levels. The use of a single fixed standard is proposed as the third option where information is lacking to adopt the other options. Such a standard should only be used as a guideline, and is only proposed for phosphorus. Nitrogen is subject to other controls, e.g. drinking water abstraction. The determination of site-specific standards should be prioritised to river and canal sites identified as being of conservation value and susceptible to adverse effects from eutrophication. It is strongly recommended that site-specific standards are similarly applied to relevant special ecosystem sites. EQSs for inorganic nutrients were reviewed by Cartwright and Painter (1991).

At sites where the designated uses of a stretch of water course are solely basic amenity and general ecosystem, consideration of further chemical parameters may be required in the setting of appropriate discharge consents and certainly for List II substances. In such cases the 'umbrella' report (Smith *et al* 1991) should be referred to for guidance on appropriate target levels for receiving waters. Standards for List I substances are applicable to all controlled waters regardless of use.

The Institute of Freshwater Ecology (IFE) (Wright *et al* 1984) found that parameters of total nitrogen, chloride, alkalinity, sub-stratum and distance from source are some of the most important determinands in the distribution of riverine invertebrate communities. It could be argued that standards could be set for the chemical determinands mentioned as they have been demonstrated to be ecologically relevant and they are currently being measured for RIVPACS assessments. However, standards for alkalinity and chloride are probably inappropriate in that these determinands are largely determined by catchment geology. Newbold and Holmes (1987) proposed extending the IFE database to include higher aquatic plants and thus to develop a predictive model for plants. The use of the Institute of Terrestrial Ecology/Biological Records Centre (ITE/BRC) database of aquatic plants (Croft *et al* 1991) could provide a useful basis for research into the environmental requirements of the plants included in the database. It was further proposed that RQOs for "River Lengths of Conservation Interest" could be set based on the limiting levels of determinands which

Table 2.2 (continued)

Targeted Taxa	Ecological Parameter	Reference of use	Country/Area
Fish	Quantitative/Qualitative sampling	Coles *et al* 1985, NRA 1990	UK
	Fisheries Classification systems	Mainstone and Wyatt 1991	UK
	HABSCORE	Milner *et al* 1985	UK
	Incremental Methodology		
	- PHABSIM	Milhous *et al* 1989	USA
	- Habitat Suitability Indices	Herricks 1985	USA
	Index of Biotic Integrity	Karr 1981	USA
Higher vertebrates	Register of Ornithological Sites	Fuller 1980	UK
	Waterways Bird Survey BTO	Carter 1989	UK
	Indicator Species (e.g. Dipper, Otter)		
Integrated methods, i.e. variety taxa	Saprobic systems	Sladacek 1967, 1973	Czechoslovakia
	Saprobic-based systems		
	- Biologically Effective Organic Loading (BEOL)	Woodiwiss 1980	West Germany
	- Quality Index	Tolkamp 1985	Netherlands
	Index of Biotic Integrity	Karr *et al* 1986	USA
	Indice Biologique Global	AFNOR 1985	France
	River Corridor Surveys		
	- emergent macrophytes	NCC 1985	UK
	- Anglian regional approach	Coles *et al* 1988	UK
	Conservation Potential Index	This report	UK

Invertebrates

The use of macro-invertebrate sampling in rivers has been popular in the UK and used in tandem with indices developed to indicate pollution, e.g. Trent Biotic Index (TBI) (Woodiwiss 1964) and more recently the Biological Monitoring Working Party (BMWP) score (BMWP 1980, Armitage *et al* 1983). Metcalfe (1989) and Newman (1988) have reviewed some of the European water quality monitoring systems involving invertebrates. Similar systems have been developed elsewhere (e.g. Hilsenhoff 1977, 1987 in the USA) using similar principles, but are not considered further as Hilsenhoff's methods involve identification to species level, incurring heavy resource demands. Metcalfe (1989)

Table 2.3 EBI classification table

Extended biotic index		0-1	≤ 5	≤ 10	≤ 15	≤ 20	≤ 25	≤ 30	≤ 35	≤ 40	≤ 45
		Total number of Systematic Units (SU)									
Plecopters	More than one SU	-	7	8	9	10	11	12	13	14	15
	One only SU	-	6	7	8	9	10	11	12	13	14
Efemeropters	More than one SU	-	6	7	8	9	10	11	12	13	14
	One only SU	-	5	6	7	8	9	10	11	12	13
Tricopters	More than one SU	-	5	6	7	8	9	10	11	12	13
	One only SU	4	4	5	6	7	8	9	10	11	12
Gammarus	All above SU absent	3	4	5	6	7	8	9	10	11	12
Asellus	All above SU absent	2	3	4	5	6	7	8	9	10	11
Oligochetos/ *Chironomus*	All above SU absent	1	2	3	4	5	6	7	8	9	10
All above taxa absent		0	1	2	-	-	-	-	-	-	-

Table 2.4 Indice Biologique Global (after AFNOR 1985)

Faunistic groups	Total diversity	≤ 40	39–37	36–34	33–30	29–26	25–22	21–18	17–14	13–10	9–7	6–4	3–1
		12	11	10	9	8	7	6	5	4	3	2	1
Chloroperlidae Perlidae Perlodidae Taeniopterygidae	9	20	19	18	17	16	15	14	13	12	11	10	9
Capniidae Brachycentridae Odontoceridae Philopotamidae	8	19	18	17	16	15	14	13	12	11	10	9	8
Leuctridae Glossosomatidae Goeridae Leptphlebiidae	7	18	17	16	15	14	13	12	11	10	9	8	7

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target of biotic index values of greater than 6 has been set for the Flanders region of Belgium (Herman *et al* 1990).

Table 2.5 Standard table to determine the Belgian Biotic Index (after Herman *et al* 1990)

Faunistic groups		Total number of systematic units present 0-1	2-5	6-10	11-15	≥16
Plecoptera or Ecdyonuridae	1 several SU*	-	7	8	9	10
(+ Heptageniidae)	2 only 1 SU	5	6	7	8	9
Cased Trichoptera	1 several SU	-	6	7	8	9
	2 only 1 SU	5	5	6	7	8
Ancylidae or Ephemeroptera	1 >2 SU	-	5	6	7	8
(except Ecdyonuridae)	2 2 or <2 SU	3	4	5	6	7
Aphelocheirus or Odonata or	All SU mentioned					
Gammaridae or Mollusca	O above are absent	3	4	5	6	7
Sphaeridae)						
Asellus or Hirundinea or	All SU mentioned					
Hemiptera (except *Aphelocheirus*)	O above are absent	2	3	4	5	-
Tubificidae or chironomidae of	All SU mentioned					
the thummi-plumosus group	O above are absent	1	2	3	-	
Eristalinae (=Syrphidae)	All SU mentioned					
	O above are absent	0	1	1	-	-

Note: * SU number of systematic units observed of this faunistic group

Table 2.6 Relationship between Belgian Biotic Index and water quality (after Herman *et al* 1990)

Class	Biotic index	Water quality
I	10 - 9	Lightly or unpolluted
II	8 - 7	Slightly polluted
III	6 - 5	Moderately polluted - critical situation
IV	4 - 3	Heavily polluted
V	2 - 0	Very heavily polluted
-	0	Study impossible: complete lack of bio-indicators

Table 2.7 Biological classification as used in Ireland (after An Foras Forbartha 1984)

The Four Faunal Groupings

Group A - Sensitive Forms

A_1Sub Group (Most Sensitive)
Plecoptera (excluding Leuctra)
Ecdyonuridae, Ephemeridae

A_2Sub Group (Sensitive)
Ephemeroptera (excluding *Baetis rhodani, Cloeon, Caenis, Ephemerella)*

Group B - Less Sensitive Forms

Leuctra, Baetis rhodani, Cloeon, Caenis, Emphemerella, Gammarus
Uncased Trichoperta, Elminthidae Larvae

Group C - Tolerant Forms

Asellus, Sialis
Chironomidae (excluding *Chironomus*
Hiruninea, Mollusca (excluding *Physa*)

Group D - Most Tolerant Forms

Chironomus, Physa, Eristalis,
Tubificidae and other Oligochaeta

Relationship between water quality and the typical riffle fauna

		Group				
Water quality		A1	A2	B	C	D
Good	Q5	+++	+++	++++	+	+
Fair	Q4	+	++	++++	++	+
Doubtful	Q3	-	-	+++	++	+
Poor	Q2	-	-	-	++++	++
Bad	Q1	-	-	-	-	++++

++++Abundant, +++Common, ++Present, +Sparse or Absent, -Absent

In the interest of simplicity three main water quality classes are recognised. These relate to the 5-point Q scale and indicate the degree of pollution in the manner shown below:

Quality ratings	Water quality class	Pollution status
Q5, Q4-5 and Q4	A	Unpolluted
Q3-4, Q3 and Q2-3	B	Slight to moderate pollution at times
Q2, Q1-2 and Q1	C	Serious pollution at times

being little affected by sample size, simple to calculate and requiring a limited degree of taxonomic expertise. Armitage *et al* (1983) assessed the performance of the BMWP score and ASPT with regard to season and sampling effort. Variation in BMWP score and, particularly, ASPT were found to be relatively slight between spring, summer and autumn samples, producing consistent results. Additional sampling at sites added substantially to BMWP scores but had little effect on ASPT, the latter thus producing more information for less effort.

Modified BMWP scores have been adopted for invertebrate monitoring as a Macro-Invertebrate Index (MCI) in New Zealand (Quinn and Hickey 1990). In the UK, sampling methods have altered since the BMWP system's original inception and use. Originally the method was intended to be applied predominantly to eroding zones, i.e. riffles, but new protocols have been established between the IFE and NRA as part of the RIVPACS development and standardisation for national river quality surveys. The current protocol includes sampling of all available and representative habitats, including margins, and the use of standard dredges where kick sampling is not possible. This protocol provides a better overall indication of the diversity of habitats and invertebrate community, but detailed comparison with data obtained using the earlier methodologies are considered unwise.

The IFE has developed the RIVPACS model which, by predicting the probable invertebrate fauna of a site, has enabled predictions of BMWP scores. Comparisons of expected:observed BMWP scores can then be made to derive an Ecological Quality Index or EQI. Similarly EQIs may be based on BMWP score derivatives of ASPT (Average Score Per Taxon) and the number of families or taxa. The EQIs may be used as a basis for standards and classifications. The EQI standard proposed would be an acceptable deviation below an observed to predicted ratio of unity. The variables involved in the use of the EQIs include the choice of seasons for which data are to be used and which of the three EQIs (BMWP, ASPT and number of taxa) to apply. The combining of three seasons (spring, summer and winter) data has been recommended to produce more reliable comparisons of observed:predicted ASPT (Armitage *et al* 1983). However, the combining of seasonal samples may have an averaging effect that hides effects demonstrated in one particular sample. The IFE have proposed a banded classification for each EQI based on the 1990 River Quality Survey data. Overall environmental quality is determined as the median of the classes obtained by each of the three EQIs, with the ASPT EQI determining the overall class in instances where its class is lowest. Thus the value of ASPT as an indicator of environmental quality is applied to downgrade sites, but it is not weighted so as to upgrade sites. As a result such a classification technique may be influenced by the less consistent BMWP score and by the number of taxa, the use of which as a parameter does not seem to have been as widely tested as BMWP or ASPT. Further work may be required to make the optimum use of all three EQIs. Detailed analysis using the 1990 River Quality Survey data may help in this regard.

The EQIs produced by the application of RIVPACS should reflect water quality more so than BMWP scores alone. For instance a kick-sweep sample of a good water quality stream in a poor habitat such as a concrete culvert would generate a low BMWP score but a high EQI-BMWP, a low BMWP score being predicted. However, the current sampling methodology for BMWP and RIVPACS assessments includes sampling of all available

Table 2.9 Metrics used to assess biological integrity of benthic invertebrate communities (after Karr 1991)

A. Invertebrate Community Index (ICI).

Ratings of 6, 4, 2, and 0 are assigned to each metric• according to whether its value is comparable to exceptional, good, slightly deviates from a good, or strongly deviates from a good community.

1. Total number of taxa
2. Total number of mayfly taxa
3. Total number of caddisfly taxa
4. Total number of dipteran taxa
5. Percent mayfly composition
6. Percent caddisfly composition
7. Percent Tribe Tanytarsini midge composition
8. Percent other dipteran and non-insect composition
9. Percent tolerant organisms
10. Total number of qualitative EPT⁺ taxa

B. Rapid Bioassessment Protocol III (after Plafkin *et al* 1989#).

Ratings of 6, 3, and 0, are given based on values of each of the metrics with 6 being high quality and 0 being heavily degraded site.

1. Taxon richness
2. Family biotic index
3. Ratio of scraper/filtering collector
4. Ratio of EPT⁺ and chironomid abundances
5. Percent contribution of dominant family
6. EPT⁺ index
7. Community loss index
8. Ratio of shredders/total

Notes: • Metrics 1 - 9 based on artificial substrate sampler, metric 10 based on qualitative stream sampling
⁺ EPT - taxa in the Emphemeroptera, Plecoptera, and Trichoptera.
Metrics 1 - 7 based on qualitative riffle/run sample: metric 8 based on leaf (CPOM) sample.

Macrophytes

Haslam (1990) advocated the use of aquatic macrophytes in environmental assessment. The same author has described standard methods for the use of macrophytes in the assessment of water quality that may be used to generate indices of a Plant Score and Plant Community Description or PCD (Haslam *et al* 1987). The Plant Score is based on ascribing scores of between 1 and 10 (as in the BMWP invertebrate assessments) to macrophytes found in surveys of defined bank length (0.5 km is recommended). The scores are dependent upon their estimated tolerance to nutrient enrichment and/or organic enrichment. Indeed, Plant Scores correlate well with BMWP Scores. An ASPT may also be derived. The PCD is predictors for plants are unlikely to be identical to those for invertebrates. The development of such a model obviously requires the collection of data on plant distributions and physical and chemical determinands. The former NCC have conducted much relevant work in this regard. Holmes (1983, 1989) identified fifty-six typical river floristic compositions from which ten major river types were determined (Table 2.10). Modelling of plant communities would be unlikely to predict the presence of particular rare species and thus would lose its value in more detailed conservation evaluation. However, the development of macrophyte assessment techniques should be considered to provide a complementary measure to invertebrate monitoring.

Table 2.10 A botanical classification of British rivers (Holmes 1989)

Type I	Group A1	Lowland rivers with minimal gradients, in England
Type II	Group A2	Clay rivers
Type III	Group A3	Chalk and oolite rivers
Type IV	Group A4	Rivers with impoverished ditch floras, in lowland England
Type V	Groups B1 and B2	Rivers on rich geological strata in Scotland and northern England
Type VI	Groups B3 and B4	Rivers on sandstone, mudstone and hard limestone in England and Wales
Type VII	Groups C1 and C2	Mesotrophic rivers downstream from oligotrophic catchments
Type VIII	Groups C3 and C4	Oligo-mesotrophic rivers, predominantly upland
Type IX	Groups D1, D3 and D4	Oligotrophic rivers of mountains and moorlands
Type X	Groups D2	Ultra-oligotrophic rivers in mountains

Algae

A number of schemes have been proposed for a sensitive assessment of environmental status based on benthic diatom communities (e.g. Descy and Coste 1988). Round (1991) presented a recent review of the use of diatoms in river water monitoring studies. Two major approaches have been used for community analysis, the direct sampling of communities on plant surfaces (epiphyton), stone surfaces (epilithon), sand surfaces (episammon) and silt surfaces (epipelon) and the sampling of artificial sub-strata, e.g. glass slides. However, the absence of a clearly identifiable methodology and the identification skills required, i.e. laboratory identification to species level, make it unlikely that schemes would be widely acceptable for routine assessments of the general ecosystem quality of rivers. Algae are produces a Habitat Utilisation Index (HUI) based on the difference between the predicted population levels and those observed in quantitative electrofishing. The HUI could potentially be the basis for an ecological standard and this could be considered further upon the development of a national model.

Another sophisticated fishery assessment, PHABSIM (PHysical HABitat SIMulation) has been developed in the USA (Milhous *et al* 1989). PHABSIM is part of the Instream Flow Incremental Methodology (IFIM) programme developed by the US Fish and Wildlife Service, which use measures of aquatic habitat to assess instream flows required by aquatic life (Herricks 1985). PHABSIM is a computer model that predicts the usable fish habitat of rivers subject to flow variation. Predictions of usable habitat area for different age classes of fish species may be estimated from measurements of depth, velocity and substrate and are related to stream discharge. Standards relating to abstractions or compensation flows may thus be related not only to dilution requirements, but also to the maintenance of fish habitat. The applications of this model in the UK are currently under investigation. A basis of IFIM techniques is the derivation of Habitat Suitability Indices which relate an HSI scoring of between 0 and 1 to a particular environmental parameter, e.g. water velocity, depth and substrate in the PHABSIM model. These would vary with fish species and, sometimes, age. Overall habitat suitabilities, and hence fish numbers, may be assessed by combining the HSIs of the relevant parameters for a particular fishery. There may be some scope for the application of HSIs and other aspects of the Incremental Methodology in the future. These applications may be applicable to organisms other than fish. However, the logical application of standards may be limited to the planning and control of river works, abstraction and compensation flows rather than being more widely applicable.

Another North American system, the Index of Biological Integrity (IBI; Karr *et al* 1986) may be applicable in the UK. The IBI is an index that has been used to describe assessments of biological integrity in running waters. The index, used widely by federal and state agencies throughout the United States and Canada, was designed to include a range of attributes of fish assemblages and has twelve parameters or metrics. Together these describe species composition, trophic composition, and fish abundance and condition. For each parameter at a given site a number rating is assigned, depending on how the parameter compares with what would be expected at an unimpacted or relatively unimpacted site. Scores for different parameters are given in Table 2.11. The index was developed for use in rivers in the Midwest of the USA, but it is described in this report as its principles may be applied in other locations.

Indeed, Oberdorff and Hughes (submitted 1990) suggested a modified index for use in the French Seine basin (see Table 2.12 for metrics applied). In addition, modifications to this index may produce a methodology applicable to waters other than running waters and taxa other than fish.

[e] Sunfish (Centrarchidae, exclusive of black basses *Micropterus*) are thought to be particularly responsive to the degradation of pool habitats and other aspects of habitat such as instream cover. Salmonids, may be substituted, being pool dwelling, where a diversity of sunfish does not exist.

[f] Suckers (Catostomidae) are long-lived and thus give a multi-year perspective and are also regarded as intolerant of habitat and chemical degradation.

[g] Intolerant species are generally the 5 to 10 % of species that are selected on account of susceptibility to such major types of degradation as siltation, lowered flow, low dissolved oxygen, and toxic chemicals. Identification of such species may be aided by comparison of records from different decades, a reduction in abundance or range as a result of perturbation being indicative of intolerance. Fish species already with a reduced range may not necessarily be intolerant but may be limited for other reasons, e.g. glacial relics.

[h] Green sunfish (*Lepomis cyanellus*) are relatively tolerant of the degradation of streams and may therefore increase in relative abundance in response to impacts. Other tolerant species, e.g. carp and goldfish may be substituted.

[i] Omnivores are defined here as species with diets composed of >=25% plant material and >=25% animal material. Examples are some *Pimephales*, *Cyprinus*, *Dorosoma* and *Carassius* species. Values applied to proportions of these and other trophic categories in fish communities should be re-evaluated regionally.

[j] The relative abundance of insectiverous cyprinids is reduced by stream degradation, either directly, by affecting the fish themselves, or indirectly, by affecting their food supply.

[k] An abundance of piscivores (e.g. smallmouth bass *Micropterus dolomieui*, walleye *Stizostedion vitreum*, pike *Esox* spp) is indicative of a healthy, trophically diverse community. The diet of some of the fish included may include invertebrates, crayfish and amphibians.

[l] Expressed as catch per unit of sampling effort, where effort may be expressed per unit area, per length of reach or per unit of time. Generally catches are reduced by stream degradation.

[m] Degradation may alter reproductive isolation amongst species. However, this parameter may be difficult to determine and historical data may lack this information.

[n] Degradation will lead to a greater proportion of individuals as indicated by these factors.

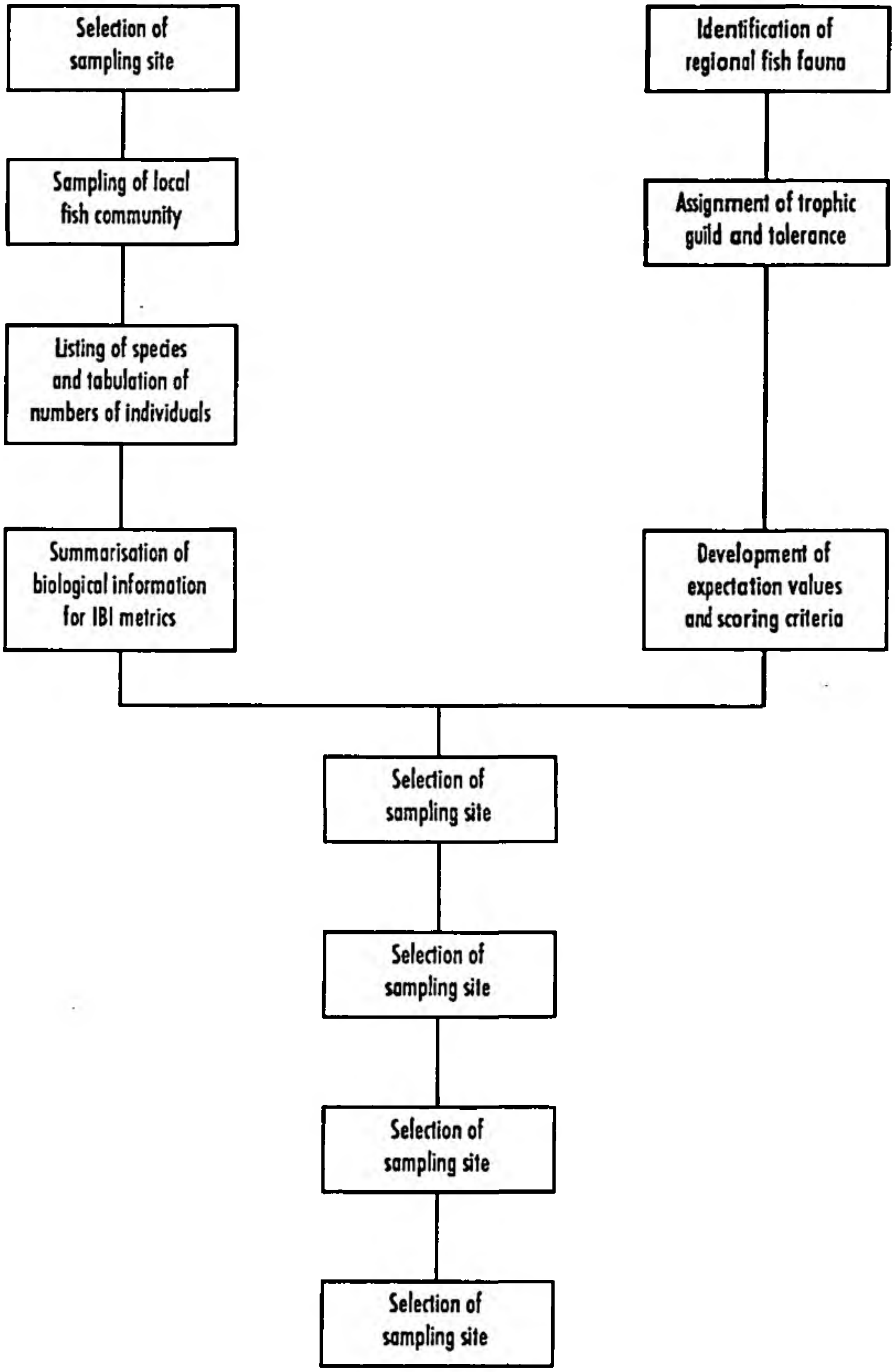

Figure 2.2 Sequence of activities involved in calculating and interpreting the Index of Biotic Integrity for a stream segment

for invertebrates in rivers. The IBI approach may be best suited to invertebrates in the UK. Standards may be selected at levels of IBI, though the usefulness of IBIs as indices of water quality *per se* is reduced by their sensitivity to other causes of environmental degradation.

Higher Vertebrates

Fuller (1980) described a methodology for assessing the conservation interest of ornithological sites. He described the methodology used to assess sites documented in British trust for Ornithology's (BTO) site recording scheme, the Register for ornithological sites. Though not specifically designed for aquatic sites the method could be applied to sites with controlled waters. The method involves describing the sites by means of attributes of population size, diversity and rarity. Quantitative criteria are applied to each attribute in terms of five levels of conservation importance: international, national, regional, county and local.

The Waterways Bird Survey of the BTO and part of the Common Bird Survey covered 363 km of rivers and canals in the UK in 1988/1989 (Carter 1991). Such data provides information about long term population trends of waterways birds. Methods are described by Taylor (1982) and Carter (1989).

The National Wildfowl Count is organised by the Wildfowl and Wetlands Trust (WWT) based in Slimbridge. The counts, largely done on a monthly basis between September and March, are made on a variety of wetland habitats including estuaries and coastal bays, reservoirs, lochs/loughs, gravel pits, fresh water marshes, rivers, canals and ponds (Kirby 1991).

The NRA may include bird population assessments as part of river corridor surveys (see Integrated Methods below). In addition, birds (e.g. dipper) and other species (e.g. otter) may be seen as indicators of environmental (including water) quality. However, surveys of birds provide at best an indirect assessment of aquatic ecosystem quality. As such the use of bird and other vertebrate surveys may be restricted to identifying and evaluating areas for conservation purposes, rather than for the development of biological standards for the ecosystem uses.

Integrated methods

Integrated methods provide assessments of general ecosystem quality though are less likely to reflect water quality effects alone, habitat features often being the major determining factor. River corridor surveys, primarily vegetation mapping following the methodology of the Nature Conservancy Council* (NCC 1985) have been widely applied, but do not provide a quantitative assessment from which standards could be derived. Such surveys are of great value in the evaluation of sites subject to land drainage works.

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* The NCC has been replaced by the Joint Nature Conservation Committee (JNCC), English Nature, Countryside Council for Wales and the Nature Conservancy Council for Scotland.

2.4 Lakes

The application of common standards to ponds, lakes and reservoirs may not strictly be appropriate due to the differences of scale. However, the quality of still water ecosystems is perceived to be largely based on trophic status, particularly with regard to changes in status through cultural eutrophication.

2.4.1 Chemical standards

Chemical standards for the protection of lake ecosystems should include those to protect the ecosystem against damage through eutrophication. Changes in trophic status are usually towards eutrophy and there is an underlying assumption of ecosystem degradation through enrichment. Simple formulae have been proposed (e.g. OECD 1982) to relate lake characteristics (i.e. retention time) and nutrient inputs to trophic status. The Organisation for Economic Cooperation and Development (OECD 1982) proposed a classification of lakes based on trophic status (Table 2.14). Tentative chemical standards for the protection of lake ecosystems are presented in Table 2.15. Again two separate standards are proposed for dissolved oxygen and a three-tier approach to nutrient standards.

Table 2.14 Trophic classification scheme for lake waters based on the concentrations of Total Phosphorous and Chlorophyll a and on Transparency (after OECD 1982) (Annual Values)

	Total Phosphorus mg/m^3	Chlorophyll a mg/m^3		Transparency m	
Lake Category	Mean	Mean	Max	Mean	Min
Ultra-Oligotrophic	≤ 4	≤ 1.0	≤ 2.5	≥ 12	≥ 6
Oligotrophic	≤ 10	≤ 2.5	≤ 8	≥ 6	≥ 3
Mesotrophic	10-35	2.5-8	8-2.5	6-3	3-1.5
Eutrophic	35-100	8-25	25-75	3-15	1.5-0.7
Hypereutrophic	≥ 100	≥ 25	≥ 75	≤ 1.5	≤ 0.7

Table 2.16 Biological assessment techniques that may potentially be used in the measurement of ecological quality and setting of EQSs for Ecosystem uses of lakes

Targeted Taxa	Ecological Parameter	References	Country/Area of Use
Macrophytes	Macrophyte surveys Pollen analysis (historical)	Jones *et al* 1989	UK
Algae (Live)	Chlorophyll a		Worldwide
	Phytoplankton communities	Reynolds 1984	UK
	Live and paleolimnological diatom analysis	Smol *et al* 1986, Stevenson *et al* 1989	UK
Invertebrates	Modified river indices Chironomid community	Aagaard 1986	
Fish	Quantitative/qualitative sampling Habitat Suitability Indices		
Higher Vertebrates	Indicator Species Modified Bird Surveys Register of Ornithological Sites	Fuller 1980	UK
Integrated Methods	Pond Action (1989)		

Macrophytes

Macrophyte surveys and data treatment similar to that for rivers could be applied. A RIVPACS-approach could be applied to the prediction of plant communities. No workable system is currently available. Analyses of pollen in sediments permits an assessment of the historical flora and trophic status of the lake and surrounding area.

Algae

Direct measurements of chlorophyll a are more appropriate for lakes than rivers (see Section 2.3.2). However, algal blooms may be short-lived and chemical sampling as a measure of the potential of blooms is more appropriate than regular sampling of chlorophyll.

Higher vertebrates

Bird surveys may be performed using established or modified techniques. Other vertebrates may also be used as indicators of lake quality, but as for rivers such methods are not suitable for routine monitoring and assessing compliance with general ecosystem use. However, site specific counts of bird or other species may be used as a yardstick of quality and changes in populations should prompt investigative action.

Integrated methods

The study of ponds and development of suitable assessment procedures are currently being addressed by Pond Action, which is coordinating a National Pond Survey. Relevant objectives of the National Pond Survey are: to develop a classification of ponds based on their (macro-invertebrate) fauna and flora; to investigate the principal abiotic and biotic factors influencing pond communities; and to use the classification to develop a system for assessing the importance of individual ponds for nature conservation (Pond Action 1989). Standardised methods for pond surveys were presented. These methods involve limited chemical water quality measurements, vegetation mapping and identification, and invertebrate identification to species level in most groups. As such the methodology would probably not be suitable for the NRA in its current form. However, the data from the National Pond Survey could be used to develop a RIVPACS approach for pond assessments.

2.5 Estuaries

Estuaries are considered in quinquennial river quality surveys (e.g. DoE 1986) using a classification system based on a combination of simple aesthetic, water quality and biological criteria (Table 2.17). This system is generally regarded as insensitive. Proposals for an updated scheme were put forward by the WAA Estuarine Working Party, but were rejected by the DoE as they did not allow for an absolute comparison of water quality between estuaries. A more acceptable classification system is currently being formulated. The proposed scheme includes aesthetic, water and sediment quality and biological considerations (WQSG 1990b). The water quality parameters considered include dissolved oxygen, ammonia and nutrients. Estuaries are defined as extending from the downstream limit of rivers (the boundary at which the chloride level does not exceed 200 mg/l at high water of mean spring tides during low fresh water flow) to the seaward limit as laid down in the Clean Rivers (Estuaries and Tidal Waters) Act 1960.

2.5.1 Chemical standards

Water quality may be a problem and it is often the lowest reaches of rivers and their estuaries that are most seriously polluted. In estuaries not subject to more severe pollution eutrophication may cause problems, particularly in estuaries or inlets with low water exchange rates, where excessive growths of green algae can smother inter-tidal sediment communities and may displace flora and fauna. Eutrophication may contribute to lowered oxygen levels and blooms of toxin-producing algae, e.g. dinoflagellates. Though chemical standards are to be applied (under the migratory fish use) to protect migratory fish temporarily using estuaries, the needs of resident fish are poorly researched.

Tentative standards for dissolved oxygen, ammonia and nutrients are presented as Table 2.18.

Table 2.18 Tentative chemical standards for the general ecosystem use of estuaries

Parameter	Units	Tentative Standard		References
Dissolved Oxygen	mg O_2/l	5[1]	AA	[A]
		2[1]	95P	[A]
		9[2]	AA	[B]
		5[2]	95P	[B]
Ammonia (un-ionised)	mg N/l	0.021	AA	[C]
Nitrogen (total)	mg N/l	SSC		
		STL		
		0.20		[D]
Phosphorus (total)	mg P/l	SSC		
		STL		
		0.03	AA	[D]

Notes: P Percentile
AA Annual Average
SSC Site Specific Criteria
STL Standstill provision
1 For less sensitive waters
2 For more sensitive waters, i.e. important nursery grounds

References: A Stiff *et al* (1990)
B Alabaster (1972)
C Seager *et al* (1988)
D Cartwright and Painter (1990)

Again, two levels of standards for dissolved oxygen are recommended, with a higher standard recommended where sensitive communities or spawning grounds are identified. Standards with compliance criteria of both annual averages and 95 percentiles are suggested. Nutrient standards are again suggested with a three tier approach (see Section 2.3.1).

Table 2.19 Biological assessment techniques that may potentially be used in the measurement of ecological quality and setting of EQSs for Ecosystem uses of estuaries

Targeted Taxa	Ecological Parameter	Reference	Country/Area of Use
Macrophytes	Saltmarsh surveys		UK
Algae	Benthic algae	Wilkinson and Rendell 1985	UK
Invertebrates	Predictive modelling		UK
	Biological Quality Index (BQI)	Jeffrey *et al* 1985	Ireland
	Diversity Measures		
	Rarefaction Curves	Gray and Pearson 1982	UK/Europe
	SAB curves	Pearson and Rosenburg 1978	UK/Europe
	ABC method	Warwick 1986	UK/Europe
	Multivariate methods - ordination/classification	Warwick and Clarke 1990, Roddie 1986	Worldwide
Fish	Fish Community Assessments	Potts and Reay 1987	
	Index of Biotic Integrity		
Higher Vertebrates	Birds - NW Count	Kirby 1991	UK
	- BoEE counts		UK
	- Register of Ornithological Sites	Fuller 1980	UK
	Indicator organisms		
Integrated Methods	Index of Biotic Integrity		
	Benthic Resources Assessment Technique (BRAT)	Lunz and Kendall Kendall 1982	USA
	AMOEBA approach	Ten Brink 1991	Netherlands
	Standardised MNCR techniques	Hiscock 1990	

The BQI is calculated according to the formula:

$BQI = antilog_{10}(c-a)$

Rarefaction curves (Gray and Pearson 1982) display the distribution of individuals among species, or any taxonomic group, such that excessive dominance by few species, typical of disturbed conditions, is demonstrated.

SAB curves (Pearson and Rosenburg 1978) illustrate trends in species number (S), total number of individuals (A) and biomass (B) with respect to organic pollution gradients. Idealised responses to organic pollution are known. Ratios of variables may give secondary information, for example A:S gives an indication of dominance, B:A gives an indication of the average size of the fauna. A high A:S ratio indicates dominance of relatively few species and a low B:A ratio indicates a low average size of animal.

The ABC method (Warwick 1986) is a further development of the use of the k-dominance curves of Shaw *et al* (1983). The method compares the distribution of abundance and biomass of each species in a sample. Typical arrangements for disturbed, intermediate and undisturbed conditions have been suggested.

Multivariate measures of community structure may be applied. Univariate and graphical approaches require the condensation of data matrices into single figure summary statistics. Multivariate methods of comparison preclude this loss of information and methods of ordination and classification relate sites to each other in terms of their multivariate similarity. These techniques can equally be applied to meiofauna as macrofauna. Warwick and Clarke (1990) and Roddie (1986) reviewed methods for the statistical analysis of marine survey data. Such techniques may be useful in the development of a RIVPACS approach.

Fish

Fish assessments are most commonly made by the use of trawls, a method limited to suitable substrates in the case of demersal (bottom) trawls. A variety of other techniques exist, including beach seines. Potts and Reay (1987) describe some of the methods available. The capture of fish on intake screens of generating stations and industrial installations may provide useful data on species richness, i.e. the increasing number of species caught in intakes has proved a useful indicator in monitoring the recovery of the Thames. Quantitative techniques are difficult. Species richness alone would not be suitable for a general ecosystem assessment, though may provide additional information on the value or condition of estuaries. The IBI (Index Of Biotic Integrity) approach may be applicable to UK estuarine fish communities (and other taxa besides). The principle involves the combination of several measures with an assumed or known pattern of response to degradation. This has been applied to fish in rivers (Section 2.3.2) and estuaries. Modifications of the IBI needed when applied to estuarine areas of Louisiana included variation in salinity régimes and estuary size (Karr 1991). Further IBI metrics consider aspects of fish residency, presence of nearshore marine fishes and large fresh water fishes, and a measure of seasonal variation in community structure (Karr 1991). The inclusion of a metric of disease frequency may be particularly applicable to estuaries and coastal waters.

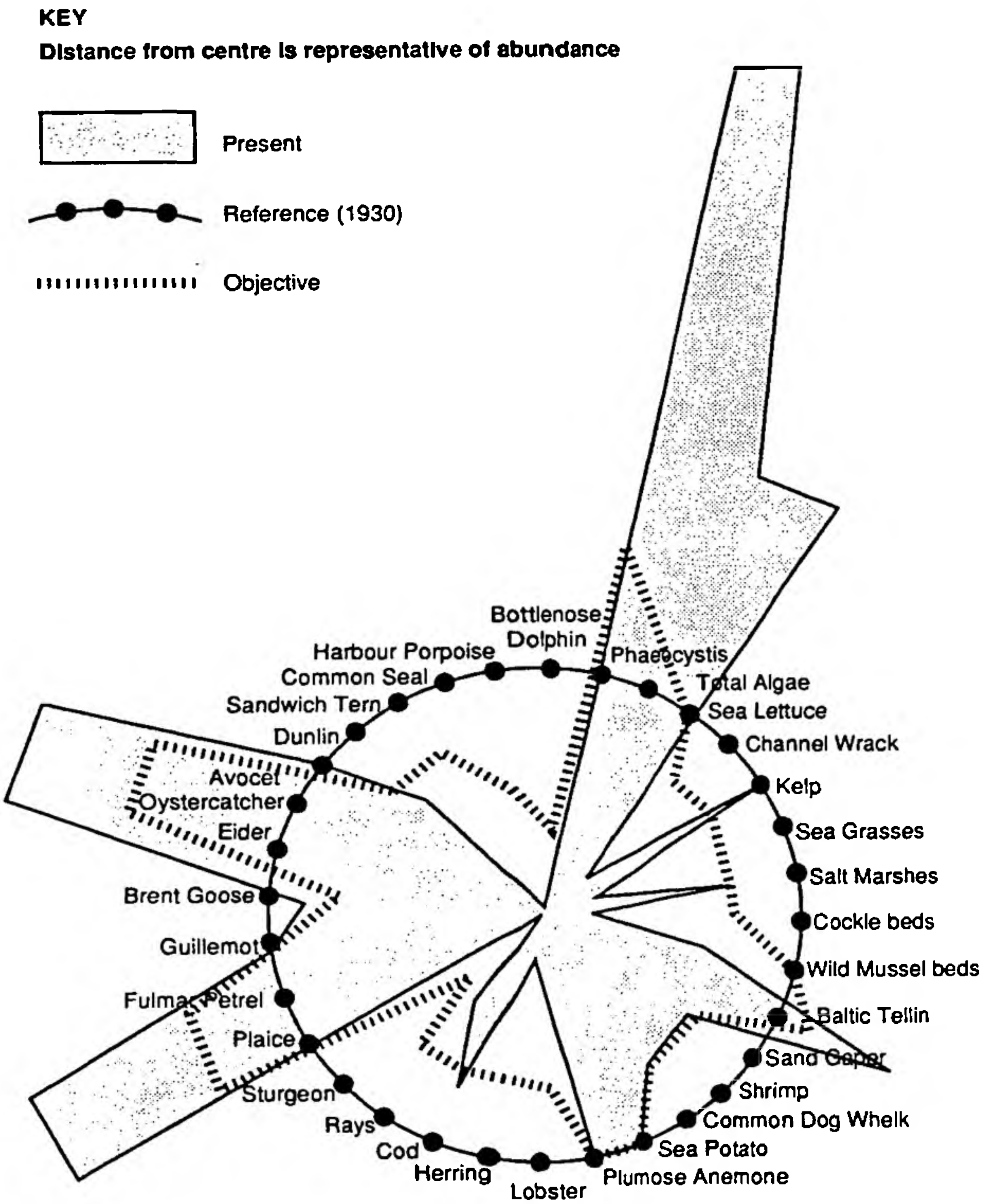

Figure 2.3 The AMOEBA approach applied to a marine ecosystem (after Ten Brink et al 1991)

Information that can be used in the setting of EQSs for coastal waters is limited. The tentative standards proposed for estuaries are reproduced with the exception of a phosphorus standard. Phosphorus limitation of plant growth in coastal waters is uncommon. However, studies to establish site specific or standstill criteria may demonstrate instances where this may occur. Modelling is again advocated in the derivation of standards.

2.6.2 Biological criteria

A list of potential biological assessment techniques from which standards may be drawn is presented in Table 2.21.

Table 2.21 Biological assessment techniques that may potentially be used in the measurement of ecological quality and setting of EQSs for ecosystem uses of coastal waters

Targeted Taxa	Ecological Parameter	Reference	Country/Area of Use
Algae	Community studies		
Invertebrates	RIVPACS-based approach		
	Infaunal Index	Word 1978, Bascom 1982	USA
	Trophic Diversity Index (TDI)	Le Bris *et al* 1990	France
	Marine Biotic Index		
	SAB curves	Pearson and Rosenburg 1978	UK/Europe
	Rarefaction curves	Gray and Pearson 1982	UK/Europe
	ABC method	Warwick 1986	UK/Europe
	Multivariate measures of community structure	Warwick and Clarke	Worldwide Clarke 1990
Fish	Fish community assessments	Potts and Reay 1987	
Higher Vertebrates	Register of Ornithological Sites	Fuller 1980	UK
	Breeding Seabird Surveys	Prater and Lloyd 1987	
	Beached Bird Surveys	Prater and Lloyd 1987	
	Indicator species		
Integrated Methods	IBI		
	Benthic Resources Assessment Technique (BRAT)	Lunz and Kendall 1982	USA
	AMOEBA approach	Ten Brink 1990	Netherlands

In the past, biological monitoring in the UK has predominantly been based on the use of invertebrate scores. These scores were generally calibrated against organic pollution and thus may lead to a false impression of a river polluted by other toxicants. In addition, reliance on invertebrates as indicators does not necessarily protect other organisms from water quality or other effects (e.g. habitat degradation). However, RIVPACS though modified for use in conjunction with the BMWP score (an index which has been criticised) seems to be a very useful approach for assessing the ecological quality of flowing fresh waters. Further testing of RIVPACS and its assumptions are recommended. It is also recommended that options are investigated for non-macro-invertebrate taxa. The assessment of macrophytes may represent the most suitable compliment to invertebrate sampling, but the increase in sampling demands and skills required in species identification may make such assessments impracticable. Methods such as the CPI, which do not require identification to species level, may have potential in this respect.

The suitability of the RIVPACS approach for slower flowing waters, e.g. canals, and for ponds and lakes also requires assessment. Development of the RIVPACS approach may also be appropriate for other controlled waters, e.g. estuaries and coastal waters, but research to develop such models is only at a preliminary stage. Techniques used elsewhere on different faunal assemblages such as the IBI used in the USA undoubtedly need adapting to be applicable to British ecosystems.

3. SPECIAL ECOSYSTEM USE

3.1 Objective

The special ecosystem EQO is applicable to all surface waters (i.e. it is not applicable to groundwaters). The EQO for special ecosystem use has been defined (WQSG 1990a) as:

Water	EQO	Explanatory notes
Rivers	Maintain water quality so as to safeguard the special conservation interest for which the river is designated	Applies only where rivers contain statutorily designated areas
Lakes	Maintain water quality so as to safeguard the special conservation interest for which the lake is designated	Applies only where lakes contain statutorily designated areas
Estuaries	Maintain water quality so as to safeguard the special conservation interest for which the estuary is designated	Applies only where estuaries contain statutorily designated areas
Coastal waters	Maintain water quality so as to safeguard the special conservation interest for which the coastal water is designated	Applies only where coastal waters contain statutorily designated areas

3.2 Selection criteria

The proposed criteria for the identification of "special" sites for all controlled waters are given below. Sites with statutory designations (SSSIs and MNRs) should certainly be included. Other non-statutory designations should be considered for inclusion. The Code of Practice on Conservation, Access and Recreation (DoE/MAFF/WO 1989) lists "sites of importance for conservation" (Table 3.1). However, not all of these are 'special' in the ecosystem sense and this list is therefore only used as a guide. Sites of other "special interest" to conservation, i.e. for landscape, geomorphological or archaeological reasons should be adequately protected through planning controls. Possible selection criteria for special ecosystem sites are listed in Table 3.2.

3.2.1 Sites of special scientific interest

For guidance on the identification of controlled (surface) waters for Special Ecosystem use the guideline criteria for the selection of Sites of Special Scientific Interest (SSSIs) (NCC 1989a) is taken as a lead. The objective of the notification of SSSIs is to safeguard sites, i.e. to protect and manage the most important areas for wild flora and fauna and their habitat. Since 1981 SSSI designation has been applied to all National Nature Reserves (NNRs) and to all those sites deserving NNR status as listed by Ratcliffe (1977). However, the majority of SSSIs are in private hands with no other conservation status. The intention of the biological series of SSSIs is to establish a national network of areas throughout Great Britain in which the features of nature, and especially those of greatest value to wildlife conservation, are most highly concentrated or of highest quality. This does not necessarily exclude other sites from Special Ecosystem Use and there are some areas where SSSI selection could be, and is being, extended. SSSI selection is not the product of a rigid application of a set of rules but more a matter of informed judgements and hence is subjective to an extent. As a matter of informed best opinion site selection *per se* is without a legal framework. Primary selection criteria used by the NCC are shown in Table 3.3. Secondary criteria include recorded history, position in an ecological/geographical unit, potential value and intrinsic appeal.

For certain controlled waters, such as rivers and some lake complexes, the NCC (1989a) considered it appropriate to use minimum standards of quality (choosing the best examples) for the selection of SSSIs, as these are continuous or abundant, unlike some terrestrial, wetland or pond sites which may be small and fragmented, particularly in highly developed lowland areas. Examples of habitats may be selected by region. Whilst there is some tendency to select representative areas in proportion to the remaining extent of each main type, proportionally larger areas of habitats with international importance (e.g. estuaries, blanket bogs) also need to be selected. The NCC (1989a) point to the recent rise in popular interest in nature and that popular concern tends to emphasise the larger and more attractive plants and animals, rather than the lower organisms. However, selection of special ecosystem sites needs to reflect scientific criteria as well as taking public opinion into account. The selection criteria used by the NCC to assess the importance to nature conservation* of rivers have been based primarily on the comparative distribution of macrophytes (Newbold and Holmes 1987). Indeed, the NCC intends to use the National Vegetation Classification or NVC (Rodwell in preparation, cited NCC 1989a) as a framework for reference for the evaluation and selection of those habitats which can be defined in terms of plant communities.

The geographic sub-division of England and Wales by the NCC is into Areas of Search (AOS), generally by counties in England and districts in Wales, and there may be anomalies compared with the interests of NRA regions due to their different scale. The NRA could opt to have and use alternative 'areas of search', most conveniently on a regional or, possibly, catchment basis. As such the identification of special interest sites by AOS may differ from those of the NCC's successor bodies. NCC (1989a) state that "within each AOS, a minimum aim will be to represent all the different habitats and species that are present by at least one - and preferably the best - example or population". It is also recognised that "for many habitats and species, the minimum of one example or population per AOS will not be enough, and the guiding principle is that, as rarity or other special value increases, so does the need to notify a larger proportion of the total remaining area or population."

Usher (1986) presented an examination of wildlife conservation evaluation techniques including scoring systems, which should be regarded with some caution due to their hidden subjectivity (despite objective claims) when applied generally. However, they were regarded as useful in the ranking of sites of similar type in order of importance. If not quantified, the determination of special interest at least requires an initial descriptive (but standardised) recording of the biological attributes and controlling physical features of an area. These can then be compared to agreed criteria for nature conservation value. Periodic review of nature conservation values are necessary as they are both dynamic and evolving.

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* Nature conservation and conservation interest are here defined as strictly fauna and flora and not places of special earth science.

over 1 hectare (Withrington, NCC, personal communication). Though SSSI designation is the principal means of protecting sites for conservation interest, the concept has only recently been applied to riverine environments.

For the selection of standing waters the guidelines recommend that in a particular AOS selection should be made primarily on open water vegetation community types (largely related to trophic status) with a lesser consideration of emergent vegetation. Features that may warrant special interest include: species-richness (relative to expected community); lack of alien plant species; naturalness of site, e.g. a natural site would be selected instead of a canal with similar flora; naturalness of catchment; paleolimnological features; constituent of ecological series; and size, which may be important to mobile species such as birds.

Features important in the selection of ditch systems include: species richness with 15 or more species in a 20 m ditch length indicating an exceptional site and 10 or more species indicating an exceptional brackish site; a wide range of ditch types as identified by their vegetation; range of ditch sizes; and permanence of high water levels.

Flowing waters have been classified into 10 major types (Table 2.10) after Holmes 1983. The NCC guidelines propose a dual system of selecting 'whole river SSSIs' (rivers showing classic and representative transitions of eutrophy along their length) and 'sectional SSSIs' (shorter sections of river). Selection is based on the findings of plant surveys with additional information on the value of the corridor for birds, otters and invertebrates being considered. The NCC intends to select a national series of 'whole river SSSIs' and the better examples of river stretches of a particular type in a particular NCC region (NCC 1989). Boon (1991) considered the role of SSSIs in the conservation of rivers and presented data on the lengths of river SSSIs in a number of categories of aquatic interest (Table 3.5).

Table 3.5 The length of river (km) in four SSSI categories (after Boon 1991)

SSSI category	England	Wales	Scotland
River SSSIs[1]	382	144	450
River Valley SSSIs[2]	195	71	223
Rivers "adding interest" to SSSIs[3]	218	68	112
Rivers in SSSIs where interest unknown/incidental[4]	560	315	1086

Notes: [1] where running water was the main (or one of the main) reasons for notification given in the citation
[2] sites including the watercourse and the majority of its valley
[3] where the citation clearly states that the river contributes to the biological interest of the site, substantiated with records of plants, animals or habitats of interest
[4] running water not mentioned in the citation - little information available. Artificial habitats have been classified into those agricultural or non-agricultural and into dry land, riparian and aquatic ecosystems. Selection criteria are principally those for their semi-natural or natural equivalents, e.g. reservoirs and gravel-pits equate with standing waters

No reptiles dependent on the aquatic environment regularly occur in the British Isles. Two of Britain's six native amphibian species are listed on Schedule 5 of the Wildlife and Countryside Act 1981, i.e. the natterjack toad *Bufo calamita* and the warty or great crested newt *Triturus cristatus*. The NCC guidelines state that sites regularly supporting these species in significant numbers should be considered for SSSI selection. Also sites scoring 10 or more using the system in Table 3.6 should be considered.

Table 3.6 Scoring system for the selection of sites with amphibians (after NCC 1989a)

Species	Assessment method	Low population Score 1	Good population Score 2	Exceptional population Score 3
Warty newt	Seen or netted in day	<5	5 - 50	>50
	Counted at night	<10	10 - 100	>100
Smooth newt	Netted in day } Counted at night }	<10	10 - 100	>100
Palmate newt	Netted in day } Counted at night }	<10	10 - 100	>100
Common toad	Estimated count	<500	500 - 5000	>5000
	Counted	<100	100 - 1000	>1000
Common frog	Spawn clumps counted	<50	50 - 500	>500

Notes: Scores have to be for breeding sites observed during the breeding season. Daytime netting should be made during a 15 minute period for sites with less than 50 m of water's edge, for 30 minutes for sites with 50 - 100 m, etc. To compute the total score for a site, add the scores for individual species and add one point to four of these species present and two points for five species. If natterjack toads are present, add two more points.

The NCC are currently funding research into the status and distribution of rare fish in Britain (NCC 1989a). The NCC (1989a) considered that species diversity was generally not a valid criterion for SSSI selection, due to stocking practices, though in exceptional cases (e.g. extreme isolation or high research potential) SSSI selection would be applicable on community grounds. It was considered that the following qualified for site selection:

1. populations of arctic charr in North Wales, the Lake District and certain sites in Scotland;

2. possible post-glacial relic races of brown trout in northern Scotland;

3. spine-deficient form of three-spined stickleback in the Outer Hebrides;

network even where they do not fulfil quantitative criteria such as supporting 1% of the total British population (Davidson *et al* 1991). By August 1990 the UK had designated 39 SPAs of the 216 identified (Stroud and Mudge 1991).

Provisions for a similar international network of wetland sites was established under the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat 1971. Contracting Parties to the Convention are required to designate wetlands of international importance and promote their conservation and 'wise use'. In practice, sites in the UK that were already SSSIs have been further designated as SPAs and/or Ramsar sites as appropriate without any further requirements upon owners and occupiers beyond those applying to SSSIs under the Wildlife and Countryside Act 1981. Indeed, the majority of proposed Ramsar sites are also proposed or designated SPAs (Stroud *et al* 1990). Of the 150 candidate Ramsar sites identified by the NCC the UK had designated 44 by August 1990 (Stroud and Mudge 1991).

To protect birds in their areas of distribution SPAs on estuaries need to cover sub-tidal areas as well as inter-tidal and terrestrial habitats, but SSSI designation can only incorporate the terrestrial and inter-tidal parts of an estuary (Davidson *et al* 1991). Under the Ramsar Convention's definition of wetlands sites can include areas of marine waters to a depth of six metres at low tide (beyond the low water mark limit of SSSIs), and areas deeper than six metres can be included if they lie within the wetland boundary, especially where these have importance as waterfowl habitat. Wetland is interpreted as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water to a depth of which does not exceed six metres" (cited Stroud *et al* 1990). A site is considered to be internationally important if it regularly supports 20 000 waterfowl or 1% of the individuals of one species or sub-species of waterfowl. The Ramsar criteria have been extended beyond birds, and one site was recently designated due its population of fen raft spiders (Anon 1991).

3.2.3 Marine Nature Reserves and Marine Consultation Areas

As mentioned above the SSSI procedure cannot be used for areas below low water mark. Although a number of coastal SSSIs exist, most are designated for littoral or terrestrial maritime features and there is currently under-representation of sub-littoral sites. However, the Wildlife and Countryside Act 1981 made provisions for the creation of Marine Nature Reserves (MNRs) under Sections 36 and 37 and Schedule 12, thus enabling statutory designation to sub-littoral areas. Two areas have been declared statutory MNRs (the waters around Lundy Island and those around Skomer Island and the Marloes Peninsula). Further proposed MNRs include the Isles of Scilly, St Abbs, Loch Sween, the Menai Strait and Bardsey Island with part of the Lleyn peninsula (Fisher and Bolt 1990). Though MNRs can be designated out to the three mile limit and, by an "Order in Council" out to the twelve mile limit, in practice only nearshore and comparatively small sites have been put forward for designation or have been designated (Davidson *et al* 1991).

Marine Consultation Areas (MCAs) were introduced in Scotland by the NCC, largely to draw attention to the importance of selected sea lochs on the west coast in the face of ever increasing pressure from fish farming. There are currently 29 MCAs in Scotland (NCC

Table 3.7 Marine site conservation assessment criteria

This table gives notes on the 14 comparative site assessment criteria (from Mitchell 1987) which are currently used to express the perceived conservation of marine habitats, communities and species.

Ecological/scientific criteria

Naturalness	An area which is unmodified by human influence is desirable. Management techniques aimed at increasing diversity or maintaining a community at a sub-climax stage may thus be at variance with this criterion. Naturalness is found widely in the marine environment and this criterion will, for many types of biocenosis, be less important than other ones, although a necessary first qualifying attribute for a site in the selection process. (Biocenosis is equivalent to the word community or association.)
Representativeness	It is not only necessary to choose areas which are in some way unusual or unique, but it is also desirable to represent the typical and ordinary sites which contain habitats, communities and species which occur commonly or are widespread. These areas may be particularly important for experimental purposes or may be desirable in monitoring programmes.
Rarity	While rarity on a national scale might be the grounds for the establishment of 'species reserves' it is probably better to regard rare species as a bonus on sites selected for other reasons. It is necessary to understand what factors are operating to make a species rare before it is given weight in an evaluation exercise or its management needs are defined.
Fragility	This criterion reflects the sensitivity of habitats, communities and species to environmental change and has particular application to areas of low water exchange (e.g. saline lagoons and enclosed sea lochs) and low energy systems (e.g. low turbidity estuaries and sheltered inlets) which might be easily degraded by pollution, physical, destruction or natural events.
Size	Below a certain minimum size the communities or species conserved may be adversely affected by adjacent activities - the 'edge effect'. There is therefore a certain minimum size necessary to ensure the integrity of the site - the 'viable unit' concept.

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Fisheries controls provide some protection for sites of importance as sea fish nursery areas. It may be appropriate to identify such areas as potentially special sites. Under legislation introduced in 1990 to protect sea bass (*Dicentrarchus labrax*) nursery areas, 34 estuaries and inlets are protected under Section 5 of the 1967 Sea Fish (Conservation) Act.

Voluntary marine nature reserves could be selected as special ecosystems. Often these are proposed MNRs with voluntary codes of conduct adopted by some users, e.g. scuba divers.

3.2.4 Other designations

Designations such as Areas of Outstanding Natural Beauty (AONB) and Heritage Coasts do not necessarily imply any special ecosystem importance and are not considered further. Similarly Environmentally Sensitive Areas do not necessarily imply special aquatic interest though such areas may have such interest. Local Nature Reserves, Wildlife Trust Reserves, and RSPB reserves are all sites with non-statutory designations, but may often have aquatic interest. It is recommended that such sites be considered for inclusion as special ecosystems on a site-by-site basis.

Worldwide designations of sites of importance include World Heritage Sites and Biosphere Reserves. The Convention concerning the protection of the world cultural and natural heritage, the 'World Heritage Convention' in 1972 aimed at protecting sites that are outstanding for natural or cultural reasons. The ecological criterion is for habitats where populations of rare or endangered species of animals or plants still survive (IUCN 1982). No current UK sites are identified on the basis of this latter criterion or come under NRA jurisdiction, though the Wash and North Norfolk Coast is one of six proposed sites. Biosphere Reserves were promoted by UNESCO in 1974 for an international network of protected sites for conservation and the exchange of scientific information (UNESCO 1974). All the 13 Biosphere Reserves in Britain are also NNRs, a designation that affords the necessary long term legal protection as there is no additional legal protection for Biosphere Reserves.

3.2.5 Priority species lists

Selection criteria for special ecosystem sites may include the presence of species found on various lists. The Wildlife and Countryside Act 1981 has priority list or Schedules for birds (Schedule 1), other animals (Schedule 5) and plants (Schedule 8). These are updated at five yearly intervals, and are currently being reviewed. The current Schedules 5 and 8 are presented as Table 3.8. This includes additions made since the 1981 Act including the allis shad. However, the presence of other species may also be worthy of consideration. For example, sturgeon, houting and twaite shad were considered by Maitland (1974) to be rare or of restricted distribution and therefore of particular nature conservation interest. Upon the identification of the utilisation of sites by scheduled or other species considered rare it may be appropriate to assign special ecosystem status.

Table 3.8 (continued)

Common name		Scientific name
Cat	Wild	Felis silvestris
Cicada	New Forest	Cicadetta montana
Crayfish**	Atlantic Stream	Austropotamobium pallipes
Cricket	Field	Gryllus campestris
	Mole	Gryllotalpa gryllotalpa
Dolphins		Cetacea
Dormouse		Muscardinus avellanarius
Dragonfly	Norfolk Aeshna	Aeshna isosceles
Frog*	Common	Rana temporaria
Grasshopper	Wart-biter	Dacticus verrucivorus
Leech	Medicinal	Hirudo medicinalis
Lizard	Sand	Lacerta agilis
	Viviparous***	Lacerta vivipara
Marten	Pine	Martes martes
Moth	Barberry Carpet	Pareulype berberata
	Black-veined	Siona lineata (or Idaea lineata)
	Essex Emerald	Thetidia smaragdaria
	New Forest Burnet	Zygaena viciae
	Reddish Buff	Acosmetia caliginosa
	Viper's Bugloss	Hadena irregularis
Mussel****	Fresh water Pearl	Margaritifera margaritifera
Newt	Great Crested (Warty)	Triturus cristatus
	Palmate*	Triturus helveticus
	Smooth*	Triturus vulgaris
Otter	Common	Lutra lutra
Porpoises		Cetacea

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Table 3.8 (continued)

Common name		Scientific name
Plants protected under Schedule 8 of the Wildlife and Countryside Act, 1981		
Adder's tongue	Least	Ophioglossum lusitanicum
Alison	Small	Alyssum alyssoides
Broomrape	Bedstraw	Orobanche caryophyllacea
	Oxtongue	Orobanche loricata
	Thistle	Orobanche reticulata
Cabbage	Lundy	Rhynchosinapis wrightii
Calamint	Wood	Calamintha sylvatica
Catchfly	Alpine	Lychnis alpina
Cinquefoil	Rock	Potentilla rupestris
Club-rush	Triangular	Scirpus triquetrus
Colt's-foot	Purple	Homogyne alpina
Cotoneaster	Wild	Cotoneaster integerrimus
Cottongrass	Slender	Eriophorum gracile
Cow-wheat	Field	Melampyrum arvense
Crocus	Sand	Romulea columnae
Cudweed	Jersey	Gnaphalium luteoalbum
	Red-tipped	Filago lutescens
Diapensia		Diapensia lapponica
Eryngo	Field	Eryngium campestre
Fern	Dickie's bladder	Cystopteris dickieana
	Killarney	Trichomanes speciosum
Fleabane	Alpine	Erigeron borealis
	Small	Pulicaria vulgaris

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Table 3.8 (continued)

Common name		Scientific name
Lily	Snowdon	Lloydia serotina
Marsh-mallow	Rough	Althaea hirsuta
Marshwort	Creeping	Apium repens
Milk-parsley	Cambridge	Selinum carvifolia
Naiad	Holly-leaved	Najas marina
Orchid	Early Spider	Ophrys sphegodes
	Fen	Liparis loeselii
	Ghost	Epipogium aphyllum
	Late Spider	Ophrys fuciflora
	Lizard	Himantoglossum hircinum
	Military	Orchis militaris
	Monkey	Orchis simia
Pear	Plymouth	Pyrus cordata
Pennyroyal		Mentha pulegium
Pigmyweed		Crassula aquatica
Pink	Cheddar	Dianthus gratianopolitanus
	Childling	Petroraghia nanteuilii
Ragwort	Fen	Senecio paludosus
Ramping-fumitory	Martin's	Fumaria martinii
Restharrow	Small	Ononis reclinata
Rock-cress	Alpine	Arabis alpina
	Bristol	Arabis stricta
Sandwort	Norwegian	Arenaria norvegica
	Teesdale	Minuartia stricta
Saxifrage	Drooping	Saxifraga cernua
	Tufted	Saxifraga cespitosa

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Red Data Books present further lists of rare species. The categories used in the Red Data Books (Table 3.9) are those developed by the IUCN and do not necessarily correspond with those used in the Wildlife and Countryside Act 1981 (Shirt 1987). The categories are designed to represent degree of threat and not degree of rarity. The Red Data Book for insects covers most insect taxa in Great Britain except the majority of Diptera. A Red Data Book is also available for plants (Perring and Farrell 1983). A list of rare plants was presented by Palmer and Newbold (1983) who catalogued nationally uncommon or rare aquatic macrophyte species by water authority areas (i.e. by NRA Regions) and this would form a basis for regional site selection on the basis of plants. A more up-to-date assessment of the rarity aquatic plants may be found in Croft *et al* (1991).

Table 3.9 Red Data Book definitions and Criteria (after Shirt 1987)

Category	Definition	Criteria
1. Endangered	Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating	Species which are known as only a single population within one 10 km square of the National grid. Species which only occur in habitats known to be especially vulnerable. Species which have shown a rapid and continuous decline over the last twenty years and now exist in five or fewer 10 km squares. Species which are believed extinct but which if rediscovered would need protection.
2. Vulnerable	Taxa believed likely to move into the Endangered category in the near future if the causal factors continue operating	Species declining throughout their range. Species in vulnerable habitats. habitats. Species whose populations are low.
3. Rare	Taxa with small populations that are not at present Endangered or Vulnerable are at risk	Species which exist in only fifteen or fewer 10 km squares.
4. Out of danger	Taxa formerly meeting the criteria of one of the above categories, but which are now considered relatively secure because effective conservation measures have been taken or the potential threat to their survival has been removed.	
5. Endemic	Taxa which are not known to occur naturally outside Britain. Taxa in this category may also be in any of Categories 1 - 4.	
Appendix	Taxa which were formerly native to Britain but have not been recorded since 1900.	

would argue that slight increases in nutrient levels at some more biologically sensitive sites constitute "becoming eutrophic". The proposal for the Directive included "areas of high ecological quality due to the flora and fauna present and other areas which are important from a scientific or nature protection point of view" as sensitive areas, but this definition does not appear in the final Directive. The NRA should prioritise efforts to the most biologically sensitive sites in the case-by-case identification of what standards should be applied to the special ecosystem use sites or reaches. Biological standards, e.g. EQIs, should be applied if appropriate in addition to chemical standards.

Sites may need protection through a number of NRA functions, e.g. water quantity and groundwater levels are important to many aquatic sites. For sites with bird or mammal interest, disturbance may be an important factor and may require consideration. More generally, major land use changes (e.g. afforestation) may fundamentally affect water quality so that standards become impracticable to achieve. Thus NRA input to the planning and environmental impact assessment procedures is required to ensure that meaningful standards may be applied in the long term.

4. DISCUSSION

The report reviews the application of biological assessment methods that may be applied to determine general ecosystem quality and considers the application of standards to these. A variety of biological methods are available to describe various aspects of environmental quality. As measured by biological assessment, environmental quality includes both the quality of the ecosystem itself and the capacity of a site to support ecosystems. Biological techniques may be used that seek to minimise the influence of environmental factors other than water quality, e.g. riffle sampling for BMWP scores. However, the technique remains influenced by substrate differences between riffles, the geology of the catchment concerned, the geographic location and degradation by factors other than water quality such as water quantity. Such confounding factors mean that most biological assessment techniques should be considered as tools for the monitoring of more than just water quality. The setting of standards based on biological assessment techniques thus requires the encompassing of the concept of protection of ecosystems beyond water quality controls alone. The high degree of biological variability inherent in any biological measurement including biological monitoring may be reduced by predictive modelling based on reference conditions. Models such as RIVPACS and HABSCORE provide a means of the monitoring of environmental quality that takes environmental variability due to physical and chemical factors into account and may more reliably demonstrate environmental degradation caused by water quality. As such, the use of Ecological Quality Indices (EQIs) derived from RIVPACS is recommended for flowing waters, though further research into the assumptions and performance of the RIVPACS method should be undertaken. Methods for other categories of controlled surface waters need to be developed and a RIVPACS-type approach seems the most promising. The use of a Conservation Potential Index (CPI), such as that presented for assessing the conservation value of rivers and canals, may potentially be used as a complement to the invertebrate-based RIVPACS assessment. The CPI approach should be applicable to other categories of controlled surface waters.

It is recommended that standards be applied for dissolved oxygen, ammonia and nutrients. The use of a three-tier approach to the application of site-specific standards considers both the limitations of the data available and the resource requirements to derive suitable standards. Chemical standards should be applied to both general and special ecosystems. The determination of site-specific standards should be prioritised and focus on river and canal sites identified as being of greater conservation value. It is strongly recommended that relevant site specific standards, particularly for nutrients, are applied to special ecosystem sites.

Special ecosystem sites should be chosen on the basis of criteria describing raised ecological quality or conservation value. Protection of such sites must be achievable by the application of appropriate and rigorous site-specific standards. The differences in priorities and area of interest between the Joint Nature Conservation Committee and the NRA will result in differing interpretations of 'special' sites though aquatic sites of Special Scientific Interest and Marine Nature Reserves should be areas of common agreement.

5. RECOMMENDATIONS

It is recommended that:

1. Chemical standards should be applied for both general and special ecosystem uses.

2. Standards should be applied to dissolved oxygen, ammonia and plant nutrients.

3. Nutrient standards are most meaningfully applied on a site-by-site basis.

4. The derivation of site specific standards should be prioritised to focus on sites of higher ecosystem quality or conservation interest.

5. Biological assessment of the environmental quality of rivers and canals should use a RIVPACS approach.

6. Research should be initiated to derive suitable standards from RIVPACS outputs of EQIs for BMWP scores, ASPT scores and number of taxa.

7. Further research should be conducted on the underlying assumptions of the RIVPACS model, its methodology and on the use of BMWP scores.

8. Suitable methods to assess the quality of surface waters other than rivers and canals should be developed using an approach similar to RIVPACS.

9. Complementary techniques to assess the quality of ecosystems should be developed that are based on habitat features or taxa other than invertebrates.

10. Protocols for the identification of special ecosystem sites should be established based on conservation criteria, e.g. SSSIs and MNRs, and/or high ecological quality as assessed by ecological assessment techniques.

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APPENDIX A - ECOLOGICAL QUALITY - OPERATIONAL DEFINITIONS (after COM 1991)

Within the scope of the present directive, ecological quality (EQ) is an overall expression of the structure and function of the biological community taking into account natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities. The aesthetics of the area should also be taken into account.

A high EQ is considered the EQ inherent to a common ecosystem which is demonstrated not to be significantly influenced by human activities. High EQ of water ecosystems is defined as including the following mandatory elements:

1. Dissolved oxygen should be optimal for the normal respiration of aquatic organisms.

2. Concentrations of toxic or other harmful substances in water, sediment and biota should be below levels known to have a deleterious effect of aquatic life, or prevent the normal uses of the water body.

3. There should be no evidence of elevated levels of disease in animal life, including fish and plant populations due to anthropogenic influence.

4. The status of the benthic/planktonic/macro-invertebrate community should be representative of the undisturbed state and key species/taxa, normally associated with the natural condition in the ecosystem should be present.

5. The status of aquatic plant communities should be representative of the undisturbed state and key species/taxa normally associated with the natural condition in the ecosystem should be present. There should be no evidence of excessive macrophytic or algal growth due to elevated nutrient levels of anthropogenic origin.

6. The fish population should be sustainable and key species/taxa normally associated with the natural condition of the ecosystem should be present. There should be no hindrance to the passage of migratory fish caused by human activity.

7. The surface water environment should permit a higher vertebrate community representative of the undisturbed state of the ecosystem.

8. The structure of the sediment should not be significantly disturbed by human activity.

9. The status of the river banks should either reflect the absence of significant influence of human activity, or the care for the preservation of the biological community and for the aesthetics of the site.

APPENDIX B - CONSERVATION POTENTIAL INDEX

Conservation Potential Index

The proposed Conservation Potential Index (CPI) is divided into two components, one of conservation potential in terms of the existing value of a site, the other of its scope for enhancement. A major criticism of proposals for any grading river corridor sites has been the tendency to neglect low scoring (conservation) stretches, when they might be viewed as great opportunities for enhancement (Ap Rheinallt 1990). The dual approach proposed should reduce such criticism.

Originally coined the 'Conservation Quality Index' (CQI) it was considered more appropriate to describe the index as the Conservation Potential Index (CPI) as the proposed system measures very little actual conservation quality directly, rather more the potential to realise it. A methodology involving direct measurements of conservation quality was considered, relevant criteria including diversity and rarity. However, such a methodology would involve identification to species level in detailed surveys. It is intended that the CPI would be a field assessment that could be rapidly performed by staff that are not necessarily experienced botanists, which thus prohibits such detail.

Some criteria of conservation importance are included in the CPI, i.e. potential value as scope for enhancement, naturalness, size as riparian width. Other criteria used for the selection of sites of conservation importance (i.e. rarity, education value, recorded history, typicalness, representativeness and fragility) are not really considered, though these to some extent may be covered under the 'Additional Information' heading (see Figure B1.1).

The CPI is based primarily on an assessment of the vegetation and geomorphic features of a site. Indeed, the conservation value of river corridor sites has widely been assessed subjectively by the use of surveys of macrophytes, either by directly attributing importance to the presence of particular species or through the identification of habitats on the basis of macrophyte communities. However, like the presence of a healthy instream invertebrate community does not necessarily infer healthy instream vertebrate and macrophyte communities, the nature of the riverbank macrophyte community does not necessarily infer health of the whole river corridor community. It would be unrealistic to attempt to measure the entire community and the CPI may provide a useful adjunct to a more direct measurement such as the (instream) EQI. The intention is that the CPI should be suitable for widespread application.

The methodology of the CPI is presented as a field ticklist, to be used on 500 m stretches of river corridor (the water body and associated riparian area) and examination of both banks. Assessments should be made under relatively standard and suitable flow conditions, i.e. summer flows when water clarity would also enable assessment. Two levels of complexity are presented as alternative but related approaches; a CPI with scope and a summarised CPI without scope for enhancement (Figures B1.1 and B1.2). For each accompanying notes would be provided, and these would be based on those given below.

C. NATURALNESS

1. Bank type as proportion of bank length

	0	1/3	2/3	1
Concrete	0	0	0	0
Reinforced	0	1	2	3
Natural	0	4	6	10

2. Flow

Regulated	Unregulated
3	6

3. Channel form

	Yes	No
Straightened	0	5
Overwidened	0	5

4. Vegetated riparian buffer zone

As a proportion of channel width

0	1/3	2/3	>1
0	1	5	10

As an absolute width (metres)

<1	1 - 10	11 - 20	>20
1	3	6	10

Figure B1.1 (continued)

D. VEGETATION

1. Type

(a) Bankside

Proportion of bank length	0	1/5	2/5	3/5	4/5	1
Trees/shrubs	0	3	4	5	6	8
Long sward	0	3	4	5	6	8
Short sward	0	2	3	4	5	6

(b) Emergent

Proportion of surface area	0	5	8	8	5	4

(c) Floating

Proportion of surface area	0	5	6	4	3	2

(d) Submerged

Proportion of surface area	0	5	6	6	8	8

2. Diversity

Type	Low	Moderate	High
Bankside	2	7	17
Emergent	1	3	6
Floating	1	2	5
Submerged	1	3	6

E. ADDITIONAL INFORMATION

Detail any known relevant information concerning: previous surveys done; previous flood defence work; the presence or recorded presence of rare species; the presence of alien plant (e.g. Japanese knotweed, Azolla) or animal (e.g. mink) species; dominant plant species; the presence of breeding birds; the presence of aarchaeological, geomorphological or landscapes features; reasons why survey incomplete (e.g. inaccessible banks) or uncertain (turbid water).

Figure B1.1 (continued)

CPI with Scope for Enhancement (Figure B1.1)

This site assessment consists of sections A - E and the scope for enhancement of sections A - C. Some sections require written details, for others a choice is presented and the most fitting option(s) should be ticked or circled on the recording sheet which has a provisional scoring scheme discussed later.

Site Assessment

Site details

1. Site name - this should indicate nature of water body as well as a locality's general name.

2. Catchment - the river catchment.

3. Location (NGR upstream and downstream) - grid references of upstream and downstream points of survey.

4. Classified stretch - Classified stretch number or U for unclassified stretches.

5. Width (m) - the estimated average width of a stretch in metres.

6. Gradient (from OS 1:50 000) - 1:50 000 maps should be used unless 1:10 000 maps are available for all locations. The gradient is calculated from taking the difference between contours (in metres) upstream and downstream of a site and dividing this by the distance (along the watercourse) between the contours (in kilometres).

7. Recorder - the recorders name or initials should be noted for future reference, i.e. should queries arise.

10. Adjacent land use

	BANK*	
	Left	Right
Rough pasture		
Improved pasture		
Urban		
Arable		
Coniferous plantation		
Broadleaf wood		

*Left/right bank when looking downstream

11. Vegetation diversity e.g. variety of species

	Low diversity	Moderate diversity	High diversity
Bankside			
Instream			

Figure B1.2 (continued)

Water Quality - though a visual assessment of water quality may be made in the field this should be entered as the reported chemical (and biological) water quality classification of the stretch.

Adjacent Land Use - a visual assessment of land adjacent to both banks should be made and proportions estimated. For 'other (specify)' the land use should be specified and a score (most likely between 0 and 5) applied that is in concert with the other scores for land use categories.

Vegetation

Criteria are applied to describe, by visual assessment, the vegetation features of a site, i.e. types and an indication of diversity. Without identification to species level, an assessment of diversity can only be of apparent rather than measured species richness.

Type - the proportion of banklength covered by vegetation categories of trees/shrubs, long and short swards.

- the proportion of instream surface area covered by emergent, floating and submerged plants. Domination by a single plant type, particularly floating plants, is judged to reduce conservation value.

Diversity - a visual assessment of the range of species of bankside, emergent, floating and submerged plant types.

Additional information

A non-scoring but potentially important section to include information relevant to the assessment of conservation potential. This should include comments on aspects known to the recorder of: previous surveys; previous flood defence work; the presence of rare species at a site; the presence of breeding birds; the presence of archaeological features of interest; notable features of landscape or geomorphology; any reasons (e.g. high river flow, inaccessible bank) why the survey results are uncertain or incomplete; and any other information thought to be appropriate.

Such appropriate information might include the identification and percentage cover of dominant plants, e.g. Japanese Knotweed (*Reynoutria japonica*) on banksides and *Lemna* sp. as a floating species, though the reduction in conservation would be reflected by low diversity scores. A note of the presence of invasive species may be important. Beerling (1991) commented on the adverse affects of Japanese Knotweed as an alien species on sites of high conservation and amenity value. Notes on dominant and/or invasive species may also act as a pointer to suitable vegetation management as part of scope for enhancement.

Scope for Enhancement

Assessments should be made on the potential (low, moderate, high) for improvements to water quality, physical habitat and vegetation.

status) has a total maximum score of 200 that may simply be divided by two to a value out of 100. The Scope for Enhancement has a total maximum score of 100. The upper limits of 200 and 100, respectively, have more meanings than the lower (minimum) limits of 14 and 5, which may preferably be scores of zero.

These scores may be broken down as follows:

Parameter type	CPI Min	CPI Max
Habitat Diversity	5	62
Naturalness	4	72
Vegetation	5	66
Total	14	200

Parameter type	Scope Min	Scope Max
Water Quality	2	32
Physical Habitat	0	36
Vegetation	3	32
Total	5	100

The CPI will inevitably require validation and adjustment through consultations both within and outside the NRA and through its practical application in the field. As such, the methodology presented is not intended to be definitive. In early consultations on the derivation of an index of conservation value, conservation bodies stressed the importance of criteria such as diversity and rarity. These are, however, unsuitable for the system proposed, i.e. for a rapid field assessment. Further valuable input from conservation bodies may be sought on refining weightings of the scores applied to a system derived by the NRA and suited to the NRA monitoring resource. In the short term the system is insufficiently developed to form the basis of standards, but in the longer term a conservation standard may be applied to NRA internal assessments of conservation value and eventually, perhaps, national classification systems.

Summarised CPI without Scope (Figure B1.2)

This summarised form of the ticklist may be used for rapid assessments. The more important (and higher scoring) criteria are included.