Appendix 6. Catalogue of recent or current methods of identifying and/or quantifying sensitivity and an assessment of their strengths and weaknesses.

Description of system and references	Strengths	Weaknesses	Notes
Anderson, S. & Moore, J., 1997. Guidance on assessment of seabed wildlife sensitivity for marine oil and gas exploration. *A report to JNCC from OPRU, Neyland, UK. Report,* no. OPRU/18/96. A scale of 1-4 is applied on a matrix of habitats against potential consequences (effects) of oil exploration. For each consequence, a total score is produced and multiplied by a weighting factor of 5, 2 or 1 depending on the likelihood of the consequence occurring to give an overall weighted score.	The approach takes account of likelihood of a factor occurring. Practical experience of likely effects of a wide range of factors likely to occur during oil exploration was used including some workshop material. The matrix is simple to understand.	A key to the 4-point scale could not be found so that it is very subjective. By using a '1' as the lowest score (which presumably means no or little effect likely), summing a column of 1's and then multiplying by 5 (if the factor is highly likely to occur), a very high score is achieved even though impact is likely to be negligible or nil.	Based partly on the methodology from Holt *et al.* (1995) but only in relation to effects of oil and gas exploration.
Carter, I.C., Williams, J.M., Webb, A. & Tasker, M.L., 1993. Seabird concentrations in the North Sea: An atlas of vulnerability to surface pollutants. Use an 'offshore vulnerability index': ovi = 2a + 2b + c + d Where a= % of time spent on the water; b= population size, c= recoverability and d= reliance on marine environment.	Used successfully in mapping vulnerability of seabirds through time. Takes account relative importance of the sea to bird species and recoverability potential of a population.	Not strictly a measure of sensitivity – more of vulnerability. Recoverability is integral component.	Each component scored on a 1-5 scale.
Cooke, A. & McMath, M., 1998. SENSMAP: Development of a protocol for assessing and mapping the sensitivity of marine species and benthos to maritime activities. *CCW Marine Report:* 98/6/1 Development of the method used by MacDonald *et al.* (1996). Use a formula of $S = I \times R^2$. Where S =	Can deal with non-linear effects and effects of multiple factors. Includes confidence values. Refers to 'Species intolerance' as a measure of the inability of a species to endure damage caused by an external factor. Use of simple, modifiable	Recoverability is integral to sensitivity. Vulnerability not yet included. Even though the system uses an objective formula, allocating scores in the first place is subjective. Use of a formula may mean that oversimplification of definitions occurs.	Intolerance is ranked on a scale of 0-10. Recoverability is assessed using three categories scored on 1-4 scale. Intolerance measured by % of population killed or damaged. Matrix table constructed

sensitivity, I= intolerance and R = recoverability Recoverability and intolerance values will exist on a database and then when species and effect information are put in the resulting sensitivity will be the output.	formula to define sensitivity value.		using formula and resulting values placed in five bands. Lack of discrimination may be improved by using a scale that starts at zero.
Dicks, B. & Wright, R., 1989. Coastal sensitivity mapping for oil spills. In: *Ecological impacts of the oil industry* (ed. B. Dicks), pp. 235-259. Chichester: John Wiley and Sons.			Doesn't actually outline a scoring mechanism but does give guidelines that sensitivity mapping projects should follow.
Gundlach, E.R. & Hayes, M.O., 1978. Classification of coastal environments in terms of potential vulnerability to oil spill damage. *Marine Technical Society Journal*, **12**(4), 18-27. A simple 1-10 scale primarily depending on physical characteristics of the shoreline	Simple index – easy to understand. Easy definition of shoreline type. Recoverability is incorporated in the sensitivity scale.	Only useful for the effects of oil spills. Restricted to the shoreline. Only very broad categories. Only begins to take biological characteristics into account.	
Hiscock, K., Connor, D., & Hill, T., 1998. Recovery of seabed wildlife from natural change and human activity – assessing sensitivity and importance. *ICES* CM 1998/V:13. Hiscock, K., 1998. Sensitivity of seabed habitats – assessment and protection (Summary of the presentation). *UK Oceanography '98. University of Southampton. 7-11 September 1998.* (Unpublished.) 6 point scales used.	Recoverability assessed separately to sensitivity. Scores relate to particular effects. Descriptive scales (0-5). Only involves two values (sensitivity and Recoverability). Attempts to deal with multiple species, multiple events and multiple factors (in a descriptive way). Provides stages in an assessment protocol for deciding on importance.	Sensitivity assessment does only specifies factor intensity, frequency or duration descriptively. No clear indication of what variables constitute recoverability or sensitivity. Each is derived from just one value hence somewhat intuitive allocation of scores.	

Holt, T.J., Jones, D. R., Hawkins, S.J. & Hartnoll, R.G., (1995, 1997). The sensitivity of marine communities to man-induced change. (1995 Report No. 65 for CCW, 1997 Irish Sea Forum) Holt *et al.* used four criteria (longevity, fragility, stability and intolerance) to assess 'damage', while recoverability was assessed separately.	Scoring of life forms provides a compromise between resolution and practicality. 'Damage' and recoverability treated separately. Allows variable weighting. Very useful as a source of information on effect of impacts such as oil, general chemicals and temperature. Also identifies factors most important to habitat types and biotope complexes.	Compromised by a requirement to assess sensitivity against 'life forms' and, partly because of the coarseness of such a classification, they found that none of the life forms was particularly sensitive. 'Life forms' not readily applied to many situations. No inclusion of vulnerability. Over-simplification of definitions used in scoring inevitable. Problems reconciling inter-relationships between categories –Provides only an all-round sensitivity rating. No discussion of the importance of individual species in determining sensitivity within life forms or communities.	Lack of discrimination may be improved by using a scale that starts at zero. Could be applied to a variety of detrimental effects.
MacDonald, D.S., Little, N., Eno, C., & Hiscock, K., 1996. Disturbance of benthic species by fishing activities: a sensitivity index. *Aquatic Conservation*, **6**, 257-268. Developed a sensitivity index for seabed species in relation to mobile bottom fishing gear. 'Recoverability' was especially weighted in their formula because it was such an important factor. Their index of sensitivity (*S*) was: $S = (F \times I)\, e^{R}$ where *R* is *recovery* (scored on a scale of 1 to 4, equivalent to short, moderate, long and very long recovery period or no recovery likely), *F* is *fragility* (scored on a scale of 1 to 3, equivalent to not very fragile, moderately fragile, and very fragile and *I* is the *intensity of the impact* (scored on an arbitrary scale of 1 to 3,	The approach provides a structured integration of the main factors determining likely sensitivity and is an improvement on complete subjectivity. Convenient single score for comparisons. Quite good for the effects of fishing which can be easily categorised.	The three variables in the equation are subjective and different scores might be given by different workers. Also, raising the recoverability score to the power of *e* is a crude way of weighting. Based on the assumption that the disturbance has a linear effect on sensitivity. Doesn't separate sensitivity and recoverability – fixed weighting for recoverability. Limited to single species, single factor, single event. Use of formula may mean that oversimplification of definitions occurs.	MacDonald *et al.* (1996) were able to identify a small number of species likely to be highly sensitive to certain types of fishing gear.

equivalent to low, moderate and high intensity).			
OSPAR Workshop on species and habitats. Texel. February 24-28, 1997. Identified example habitats and species and their 'importance' in terms of 'Ecological value' and 'Status' including sensitivity/ poor recoverability which was scored as 'Local effect', 'sensitive', 'Very sensitive'.	Expert European group.	Sensitivity/ recoverability was a small part of the work of the group. The scoring system for sensitivity was restricted in extent.	'Very sensitive' = if adversely affected by human activities will only recover over a long period (.25 years). 'Sensitive' species = will only recover in 5-25 years.
Michel, J. & Dahlin, J. 1993. Guidelines for developing digital environmental sensitivity index atlases and databases. Research Planning Inc. 1998. Environmental Sensitivity Index (ESI). Http://www.Researchplanning.com/esi/esi.htm Http://www.Nos.noaa.gov.hazmap/oiltour/esi1.htm1 Designed for the impact of oil spills. Sensitivity ranking is based on: • Relative exposure to wave and tidal energy. • Shoreline slope. • Substrate type. • Biological productivity and sensitivity. The ESI scale is 1 (Exposed impermeable vertical substrates) to 10 (vegetated wetlands).	Widely used in the USA and the approach is used world-wide. Therefore must be considered practical and authoritative. Includes some subtidal aspects. The map-based approach is easily used and rapidly available in the event of an accident.	Restricted to oil spill effects on the shore, sea surface and shallow subtidal (although 'interest' features are relevant to any adverse activity). Likelihood of damage to biological resources and potential for recovery potential not obvious from material inspected. No clear scoring system for sensitivity or recoverability of any individual biotopes or species.	A more comprehensive inclusion of biological characteristics than (Gundlach & Hayes 1978) but still only using broad categories. Maps show shoreline types and locations where sea mammals and seabirds congregate and/or breed and areas used for recreation, management (for conservation), resource extraction, aquaculture, and archaeological or other cultural use. Similar approach to the UK Oil spill sensitivity atlas.

Weslawski, J.M., Wiktor, J., Zajaczkowski, M., Futsaeter, G. & Moe, K.A., 1997. Vulnerability assessment of Svalbard intertidal zone for oil spills. *Estuarine, Coastal and Shelf Science.* **44** (Supplement A), 33-41. Provides a system for estimating a coasts vulnerability to oil spills. Considers both physical and biological parameters. Up to 19 factors considered.	Simple, easy allocation of scores to both biological and physical factors. Clear descriptions of factors. Worst case scenario approach used for squares with special features. Capacity to deal with varied habitats within a square.	Only deals with 5x5 Km squares. Problems associated with transforming point data into 25km^2 If different habitats occur within a square then a compromise has to be reached as to the score allocated. Biological and physical vulnerabilities scored independently. No seasonal aspect. Scoring bands for physical and biological vulnerability are different. Only deals with intertidal effects.	Factors ranked by importance (principal, important and secondary). For each factor three vulnerabilities were identified; low (1) medium (2) and high (3) To calculate a score the factor was multiplied by the vulnerability value. Factors were weighted as follows principal (6), important (3) and secondary (1). The mean values for each factor category are summed. Scores are divided into four bands