The
UK Terrestrial Biodiversity Surveillance Strategy

Developing the Rationale for Assessing Sampling Coverage in the UK Surveillance Strategy

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In developing the framework of sampling that constitutes the UK Surveillance Strategy, it has been observed that there are a considerable number of difficulties regarding decisions on *how much* and *what types* of biodiversity need to be sampled in order to support the delivery of Biodiversity Strategies. In order to resolve these difficulties, or at least be able to state the assumptions made, a brief review is presented here of the solutions adopted in other countries or from literature sources, which is used to inform a workshop of specialists to further refine understanding. Ideally, following the workshop we need to be in a position to agree what the priority gaps in UK surveillance are, how to design surveillance to fill these gaps, and how to supplement and adapt existing surveillance in order to optimise information gain.

Discussion 1. Assessing the UK Surveillance Strategy Objectives

The first step in developing a rationale for assessing sampling coverage for the UK Surveillance Strategy is to consider the three objectives that have been identified, and how these relate to other frameworks. The objectives were consulted on following the initial publication of a UK Surveillance Strategy in 2006, and are stated as:

1. Measuring the UK and country strategies outcome (that biodiversity is retained as part of healthy functioning ecosystems, in order to identify problems, measure policy effectiveness, and so inform the priorities for future action)
2. Detecting the impacts of the pressures affecting biodiversity through interpreting changes in biodiversity status, in order to provide evidence to support policies/actions to mitigate the pressures, or tackle their drivers
3. Assessing the status of the wide range of species and habitats covered by the sum of the policy, legislative and international conservation commitments.

These three objectives can be viewed as somewhat hierarchical. Objective 1 summarises the totality of our knowledge regarding the state of biodiversity, it measures the outcomes of environmental policy implementation as well as being sensitive to pressures which are emerging problems. It will help set priorities for more detailed research into biodiversity change. Objective 2 looks in a more detailed manner at those pressures which have already been identified, in particular those identified within the Millennium Ecosystem Assessment. These pressures have more clearly understood policy linkages, and surveillance can be more targetted to answering specific policy needs. Objective 3 considers only those species which can be said to be of 'conservation concern', or possibly simply those for which there is a reporting requirement.

It is possible to imagine that all of the information required for reporting on Objectives 2 and 3 could be contained within the sampling designed for Objective 1. It is also possible to imagine that almost the entirety of the sampling framework within Objective 1 could be designed around reporting on Objectives 2 and 3, although there would then be questions regarding whether this would bias the sampling and prevent the identification of emerging problems. The intention is that the Objectives should be viewed as partially hierarchical, with Objective 1 providing the principal sampling framework, and Objectives 2 and 3 identifying any *supplementary* sampling that would be needed in addition to this sampling framework.

A comparison to the approach taken in the Royal Society publication 'Measuring biodiversity for conservation'

A review of the literature suggested that there were few sources in which the complete process of producing a sampling framework, from objective setting through to reporting, had

been considered. In 2003, The Royal Society published their policy document 'Measuring biodiversity for conservation', which includes the complete process of sampling design. In the document they set out a broad framework for designing the assessment of particular components of biodiversity. The first stage in the process that they outline, is the identification of 'valued objects' that are agreed by the stakeholders should be measured in the framework. These 'valued objects' correspond most closely to the three objectives of the UK Surveillance Strategy, basically they describe the outputs that need to be measured by the sampling framework. The UK objectives are broader than the 'valued objects' of the Royal Society document, and Objective 2 seems not to identify an object at all (other than possibly biodiversity), but to relate more to the design stage of selecting measures and to the reporting stage of identifying pressures and drivers. The valued object in Objective 1 is biodiversity within healthy functioning ecosystems, and in Objective 3 it is the sum of the status of 'priority' species and habitats (with priority being defined broadly, rather than relating to UKBAP).

The Royal Society document makes no suggestions on how to select measures for such broad objects, other than to say that the next stage is to identify 'valued attributes' of the objects. The types of attribute that they list (as examples, not exhaustively), are 'species richness and the abundance, range extent and viability of species' for a biodiversity measure, and 'range and population size' for a species of conservation concern. Whilst the Royal Society document contains much that is of interest, particularly with regard to the later stages of designing surveillance, it does not give guidance on designing a framework to answer broad objective questions.

Question 1: Are the three objectives identified in the UK Surveillance Strategy sufficient for designing a sampling framework, or is it necessary to have more clearly defined 'attributes' before further design is possible? See Table 1 in the Appendix for a possible breakdown of Objective 1 into sub-objectives with the requirement for sampling against each of these sub-objectives.

Discussion 2. Assessing balance of coverage: Pragmatism, functionality, niches and trophic levels

A wide range of different methods for assessing complementarity between biodiversity measures has been proposed. Some schemes would focus on providing a wide range of different functional groups, such as canopy producers or pollinators; others would look at the range of niches that were represented, and the scale of those niches; another possibility (widely used in freshwater assessments) is to consider representation from the majority of trophic levels. However, all sampling frameworks rely to some degree on a pragmatic assessment of which taxonomic groups it is possible to sample. Balancing pragmatism with understanding ecosystems is a particularly intransigent problem.

One approach that is often advocated is a focus on animal species higher in the food chain, as these are considered to 'integrate' the various environmental problems, and thus be sensitive to change. However, this integration presumably comes at the cost of a loss of precision in identifying the underlying causes of change. This would tend to argue for a balance between 'trophic levels', in order to balance sensitivity to change against the ability to assign cause.

How should we rework the requirement for sampling in Objective 1 (see Table 1 in the Appendix) to reflect the need for balance?

A comparison to the Swiss Biodiversity Monitoring programme

Like the UK, Switzerland is a developed Western European country, and is therefore likely to encounter many of the same issues in designing a biodiversity sampling framework, despite

the different habitats encountered in the two countries. The framework that has been devised includes 32 indicators, covering pressures, states and responses. The state indicators are heavily biased towards species measures, with only two genetic diversity measures (of domesticated species) and two habitat measures. Further information regarding habitat quality and change is considered to be derivable from the species measures.

The main focus of the species measures is to ensure a balance between measuring α-, β- and γ-diversity. The Swiss framework postulates that a balance between these diversity measures is required in order to understand biodiversity change. α-diversity is defined as the total species diversity present in the country. Monitoring change in this measure requires only that extinction of rare species be recorded, as well as colonisations. This work requires specially targetted survey for each species, and can be considered similar to that proposed for measuring the UK Objective 3.

The Swiss framework suggests that this is an important measure for reporting, but is not as useful in identifying environmental pressures. β-diversity is measured as the species diversity per 1 km^2, and is considered to be a measure of between-habitat diversity, determined by the heterogeneity of the different habitats involved, the length of borders between the habitats, the quality of the transitional areas and the size of each defined area type. It is likely to be dominated by effects on widespread but uncommon species, and particularly sensitive to changes in connectivity and fragmentation. β-diversity has variable coverage within current UK sampling, with some taxonomic groups, such as vascular plants, only achieving such coverage at long time intervals. γ-diversity is the species diversity within habitats, and can provide information regarding habitat condition, it is most similar to the type of coverage achieved in Countryside Survey.

In addition to looking at different levels of diversity, the Swiss sampling framework also had to select groups to be sampled; this selection appears to be based on pragmatic grounds. To quote Weber, Hintermann and Zangger (2004), commenting on the Swiss sampling framework, which at a local level measures diversity of vascular plants, mosses, and snails:

"The choice of the three taxa mentioned is mainly due to the available methods and the costs. Other taxa would be too expensive and/or the methodological precision would not be satisfactory. … It is not yet known whether and how the variability in diversity of the chosen taxa correlates to the variability in diversity of all species of animals, plant, and fungi. There are indications that plants correlate well with insects at the local scale …, but not with molluscs … Therefore it probably was a good idea to add molluscs to the plants (and not an insect group)."

The question of balancing coverage also relates to how much we should sample. As sampling moves towards total census, the level of extra information regarding the environment gradually decreases. Is it possible to identify the optimal trade-off point?

Questions within this discussion area should be looked at in conjunction with the requirements for sampling in Table 1 of the Appendix.

Question 2.1: How should the UK balance species sampling and habitat sampling? Can habitat sampling be considered as a summation of species sampling? Alternatively, if habitats are the main focus of the sampling, how much of biodiversity would be poorly understood due to its reliance on ecotones or microhabitats?

Question 2.2: Should the UK consider α-, β- and γ-diversity when designing its sampling framework? Does the UK need to have a better balance in measuring these three components of diversity? For instance, what extra information could be gained if we had adequate surveillance of β-diversity within vascular plants?

Question 2.3: What framework for balancing sampling gives the most information regarding 'healthy functioning ecosystems'? Is it possible to move away from traditional taxonomic groupings, towards functional groupings, or niche-based models? Do we have sufficient information on species attributes to achieve such models?

Question 2.4: What assumptions are being made when we state that animals at higher trophic levels 'integrate' environmental changes and provide a sensitive measure? Are these assumptions justified? How should we balance sensitivity with precision?

Question 2.5: To what extent is it the case that rare species monitoring does not provide adequate information regarding environmental pressures and the overall state of biodiversity? Would it be possible to design a framework for measuring Objective 1 that focussed almost entirely on the species and habitats within Objective 3? What problems and biases might this introduce?

Question 2.6: Is it possible to design a 'risk-based' method of assessing the level of extra information that would be provided by inclusion of a sample group, against the costs of sampling that group? How might this change our view of the 'value' of our current sampling?

Discussion 3: Ecosystem services and Objective 1 of the Strategy

The very mention of 'ecosystems' in Objective 1 of the UK Surveillance Strategy leads some to assume that an 'ecosystem approach' is being taken, or that the Strategy should measure 'ecosystem services'. Currently neither of these assumptions is correct. There is a considerable drive to assess ecosystem services, and thus provide an aspect of biodiversity valuation. Ecosystem services are here defined as the benefits provided by ecosystems to humans, and are grouped according to the Millennium Ecosystem Assessment into provisioning, regulating, cultural and supporting services.

The services vary in the complexity of their relationship with biodiversity, with some directly related to the balance between population and exploitation levels (*e.g.* wild plant and animal products), and others with a poorly defined relationship with multiple components of biodiversity (*e.g.* air quality regulation). Some of the more direct relationships to ecosystem services will be easy to extract from the data gathered as a part of UK biodiversity sampling, such as trends in those 'high profile' species and habitats that contribute to cultural services.

Whilst increasing the understanding regarding the linkage between biodiversity conservation and the provision of ecosystem services is a useful aim, it is not something that can be addressed by the UK Surveillance Strategy. The aim of the Surveillance Strategy should be to provide as comprehensive assessment as possible of the components of biodiversity, including landscape mosaics of habitats, individual habitats, and the species that make up habitats. It is to be hoped that such an assessment will be of great assistance to those who are attempting to make the links between conservation and the provision of services.

Question 3.1: Is it correct to exclude an explicit incorporation of ecosystem services into the UK surveillance rationale? Are there a number of simple measures (species exploitation, high profile species and habitats, pollinators) that we should include in the framework?

Discussion 4: Deciding between co-sampling and correlation of covariates

The supplementary sampling needed for Objective 2 that is additional to the framework of Objective 1 needs careful evaluation. It is tempting to design tightly-focussed sampling for each of the pressures, with co-sampling of the pressure and the impact at each network site,

however it is unclear how much additional information this provides compared to the correlations between variables measured within the Objective 1 framework. The balance between co-sampling and correlation may rely on the burden of proof required by each individual policy.

Consideration is given in Table 2 (see Appendix) to three of the five main pressures identified in the Millennium Ecosystem Assessment that are likely to be most relevant for co-sampling measures : Habitat Transformation; Climate Change; and Pollution.

Question 4.1: How can we compare value of covariable sampling with correlation of separately measured extensive sampling? Do we need more widespread species sampling to better detect and attribute change, or more covariable measurement?

Case-study: the development of the Canadian sampling framework

In the last ten years a number of studies have been completed in order to help design a sampling framework for biodiversity in Canada. The framework is intended to provide:

- A national perspective on Canadian ecosystems
- An early warning system that identifies new ecosystem changes as they emerge
- Consistent, nationwide information related to the success of, or need for, improved environmental management initiatives
- Timely recommendations for appropriate follow-up studies to investigate the causes and significance of the ecosystem changes observed.

This is not dissimilar to Objectives 1 and 2 of the UK Surveillance Strategy.

The first step in designing their sampling framework was to evaluate a very large number (1770) of possible monitoring variables (both biotic and abiotic), that were either currently used in one of the ongoing sampling programmes within Canada, or which had been used in a sampling programme in another country. These monitoring variables were assessed against three primary criteria, and any variables that did not meet all three criteria were rejected; this reduced the number of variables to be assessed to 188. The primary criteria were:

- The monitoring variable will provide meaningful data on changes in Canadian ecosystems (sensitive, integrates ecosystem stresses over space and time, scientifically valid and accepted)
- The monitoring variable can be applied across a range of ecosystem types
- The monitoring variable is cost effective to monitor and evaluate.

It is notable that at this early stage in the assessment of the variables, a pragmatic criterion had already been adopted.

The remaining variables were then subjected to a more complex assessment using secondary criteria related to the likely data quality, the breadth of applicability, the ease of data collection, the cost-effectiveness of any analysis, the availability of existing data, and the overall cost. These criteria were scored, and hence it was possible to rank the possible monitoring variables. The intention was to identify a 'top 25' that could then be used as the sampling framework. However, it was at this stage that problems begin to emerge. The top ranked variables were mapped against the ecosystem framework, containing both abiotic and biotic components, including structural and functional components. This showed that the top ranked variables left many gaps in the framework, most notably climatic variables, genetic diversity measures, population measures and ecosystem function components. These had all been rejected as complex or expensive.

Further testing of the top ranked variables was undertaken to assess their ability to detect ecosystem stress due to a number of known stressors. These results were more positive, suggesting that all of the stressors could be detected, even though some direct measures of the

stress were not included as monitoring variables. Species richness and species diversity measures scored particularly highly as being sensitive to environmental stress. This aspect of the study led to some new monitoring variables being suggested, in order to provide better sensitivity and balance.

Question 5.1: Are there any lessons that we should learn from the Canadian experience? Is their approach of scoring many monitoring variables one that we should adopt?

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APPENDIX: Extracts from an analysis of the UK Surveillance Strategy objectives.

Table 1: ANALYSIS OF OBJECTIVE 1
Measuring the UK and country strategies outcome that biodiversity is retained as part of healthy functioning ecosystems, in order to identify problems, measure policy effectiveness, and so inform the priorities for future action

Analysis of the objective	Sub-objectives	Requirement for Sampling
Objective 1 establishes the main framework of sampling to: a) determine if three key principles of the conservation strategies are working; b) identify problems early and; c) access the contribution of responses (eg: agri environment, site protection, spatial planning). The principles are taken from the country strategies using text adapted from *Conserving Biodiversity – The UK Approach* The UK and country strategies work on 3-6 year reporting and review cycles. They use suites of indicators that are compatible with indicator frameworks identified by the CBD and European Council. However, objective 1 of the surveillance strategy does not use current indicators to wholly determine sampling need. Sampling should ensure effective indicators can be maintained, but must also provide broadly based measures of strategy outcome that can be further interpreted to ensure strategy objectives are being achieved. The UK and country strategies place a strong emphasis on public awareness and participation. Sampling biodiversity cannot determine awareness and participation, but objective 1 does take into account the need for biodiversity sampling to include components of biodiversity that have good public recognition, and can	To maintain, create, and restore functional combinations of habitats that will provide ecosystem services and reduce the vulnerability of isolated habitats and species populations	**Q: Do we have the functional combinations of semi natural habitat we require in the landscape and how is this changing?** **Actions:** • Sample habitat pattern and conversion rates to obtain a representative picture at country and UK scales • Map or measure habitat area, distribution, patch size distribution (fragmentation) • Measure rates of conversion between habitat types • Measure heterogeneity and connectivity at landscape and regional scales
	To make sites more robust to environmental change by improving their quality and condition, reducing the impact of other pressures in the surrounding areas, buffering and where appropriate making them larger	**Q: Is the quality of semi natural habitat sufficient to maintain its function and species diversity, and how is this changing?** **Actions:** • Sample structural, functional and species composition measures of quality to obtain a representative picture by habitat country and UK scales • Measure habitat dependent combinations of vegetation composition, structure, and function • Supplement sampling to obtain a representative picture of the contribution of site and incentive measures. • Supplement sampling to obtain local scale picture for spatial planning and local sites • Target sampling as a feedback into the management of individual sites when needed. • Select habitat and function measures that are relevant to quality and where possible can be linked to the delivery of ecosystem services.
	To first halt the decline of species diversity, and then maintain it, allowing for climate adaptation. This outcome is delivered mainly by the first two principles and targeted action.	**Q: Are species across ecosystem functions, and dependent on different scales of habitat (from micro habitat to migratory) being sustained within the landscape and how are their populations changing?** **Actions:**

foster public understanding of biodiversity strategy outcomes.		• Sample widespread species from different trophic levels to obtain a representative picture of distribution and population change at habitat, landscape, country and UK levels. • Measure distribution, and population trend of the selected species with sensitivity to moderate change eg: 25% in 25 years. • Select species sampled to include a reasonable proportion that have good public recognition • Select species where we know or can build up quickly, good knowledge of their ecology to help interpret the factors affecting range or population change • Supplement sampling if necessary get a representative picture of the effect of incentive measures that aim to change management for biodiversity.

Table 2: ANAYLSIS OF OBJECTIVE 2
Detecting the impacts of the pressures affecting biodiversity through interpreting changes in biodiversity status, in order to provide evidence to support policies/actions to mitigate the pressures, or tackle their drivers.

Analysis of the objective	Requirement for sampling
Habitat transformation Habitat transformation includes conversion i.e.: switching between habitat types, often leading to the loss of semi natural habitat e.g.: urbanisation, but it also involves more subtle effects of changes in land management e.g.: cessation of felling, gazing. Changes in management are probably the biggest driver of change for biodiversity, and the impacts will intensify as land management responds to *climate change* e.g.: for mitigation – bio-fuels, or as different types of agriculture become viable. The approach in the biodiversity strategies is to modify/help land use management changes in production lands to retain biodiversity, minimise conversion/fragmentation of semi-natural habitat to less diverse land uses, and create/restore semi-natural habitat where it will help retain biodiversity at landscape scales. The main role of sampling is to provide evidence of the scale of impact of different factors driving habitat transformation in order to influence policy.	**Q: What are the types and rates of habitat conversion?, and what are the economic or policy drivers of this change?** **Q: What are the changes within habitats in structure and species composition that are linked to management change?, and what are the economic or policy drivers of this change?** o Habitat conversion and habitat structure/composition change is measured by objective 1 and no supplement is needed for objective 2. o To determine the economic or policy drivers for the observed change in habitats, analysis is needed before considering sampling o Has research established a link between the type of observed change, and factors driving land use change? o Are the available social economic or conservation measure data able through correlation to establish likely factors driving change? o Does the character of the observed change help target research or further sampling? o If analysis and research cannot explain the change what is most

	economic way of adding co-variable sampling? (i.e. habitat/species and economic/land management sampling at the same locations)
Climate Change The approach of the biodiversity strategies is to help biodiversity to adapt to climate change, e.g.: using the principles suggested for UK BAP by Hopkins et al 2007, a) protection of existing biodiversity, including protected areas and other wildlife habitat of high value, b) reduction of other sources of harm (pollution, in appropriate management, over exploitation of resources c) development of ecological resilient landscapes through establishment of ecological networks.. The main impact of climate change on biodiversity is likely to be through land use change, see habitat transformation above, but climate change is also predicted to affect species and habitat composition by: (adapted from Monarch) o Change in climate space – i.e.: rainfall, temperature, storm event frequency o Phenological change and knock on effects on interactions between species o Changes in composition and structure of communities including invasive species o Species capacity to adapt physiologically and behaviourally to climate change o *{Implications of rare and chance long distance species dispersals?}* o Effects of extreme weather events The main role of surveillance (sampling) is to determine firstly if the adaptation outcomes eg: ecological networks, are developing, and to detect what actually happens to biodiversity under climate change as a feedback into adaptation policy, and management. (*need to mention something about the climate change bill and adaptation measurement responsibility)*	**Q: Are land use changes linked to climate change actually effecting biodiversity (e.g.: switches in crop types, increases in flood prevention)?** **Actions:** o The measures of habitat change in objective 1 are adequate to quantify change, no supplement needed. The steps above for determining the factors driving habitat transformation should pick up the climate driven factors. **Q: Are the developing ecological networks helping biodiversity adapt to climate change (i.e.: move, sustain populations)?** **Actions:** o Habitat pattern at landscape scales is being measured by objective 1 o Improving knowledge of the requirements of different species e.g.: dispersal, may change what it is worth measuring to judge network effectiveness and growth, but the first step is to see if the measurements can be determined using existing sampling. **Q: Are species and habitats moving as predicted within their climate space and what are the likely factors restricting them?** **Q: Is the change across the whole range of the species and habitats (e.g.: across Europe) different from within the UK so changing our relative responsibility for them?** **Actions:** o The combined habitat and species sampling for objective 1 will measure range change within UK o To determine how this correlates with climate space change, the first step is to determine if co-analysis with available meteorological data helps explain change or develop better predictive models of change o Access to sample data throughout the range of species (e.g.: Europe) will help modelling/predicting change are needed to pick up how change across the range influences within UK priority. **Q: Are extreme weather events and phenological effects between species significant drivers of the observed change, and so adaptation/management needs to incorporate these changes rather than attempt to correct them?** o Extreme weather event data are available as part of meteorological data. Picking out their effect emphasises the need for a

	proportion of objective 1 sampling to be based on annual time series. o For phenological effects between species – measure phenological events across multiple species of different trophic levels at an experimental scale (i.e.: intensive sampling at a small number of locations)
Pollution – diffuse Diffuse pollutants e.g.: heavy metals, ozone, SO2, ammonia, nitrous – have a broad scale impact and reducing levels has significant economic cost and is achieved through complex regulation and policy. The pollutants are known, and their effects on biodiversity are largely established through experimental research. The main requirement is to know the level of current impact to see if existing policy is adequate, or contribute to the case for further mitigation. The approach to determining level of impact and the role of sampling needs further investigation. A suggested sequence is provided in the requirements column.	**Q: Are specific sources of pollutants having an impact on the condition of a specific site/sites or area of habitat so that evidence is available to support mitigation or reduction of pollution through regulation?** **Action:** o Sampling at the site level using diagnostic tools for detecting both the pollutant and assessing bio-indicators of its effect **Q: What are the impacts of diffuse pollutants with chronic effects on biodiversity and does the scale suggest more/better regulation/mitigation?** **Actions:** o Determining impact and discriminating it from other factors e.g.: land use change, climate related changes in a representative (i.e.: fairly extensive) sampling scheme may ultimately be the requirement, but this is an expensive option as it would significantly change objective 1 sampling to requiring a much higher degree of co-variable sampling o So a set of investigations is suggested to determine sampling need and to determine the level of confidence that the impact is occurring needed for a policy response. o Is research evidence of impact well established and is this sufficient together with modelled or actual sampling of the pollutant sufficient evidence for a policy response? o If policy response requires evidence of actual impact in the environment to biodiversity objectives, are there indictors ie: species that show impact simply, that can be sampled to provide the evidence? o If the policy response requires evidence that the impact is affecting the species and habitats of conservation value, rather than just indicators, is sampling to show the effect on a limited scale adequate?
Pollution – chemicals – general, veterinary, biocides, plant protection. A risk assessment approach has been proposed to help detect those approved chemicals that are	**Q: What is the evidence of the actual level of impact or potential impact for chemicals where any one factor e.g.: research, usage levels, chemical risk, unexplained biodiversity declines, triggers a risk assessment for the chemical?**

beginning to create significant impacts on biodiversity. The aim is to provide evidence to allow re-examination of their approval. Risk assessment combines evaluations of chemical risk factors, actual usage, presence in the environment and relevant species, and population effects. .	**Actions:** o The majority of the parameters for risk assessment are provided by non biodiversity research or sampling. Eg: usage, chemical risk factors, direct measures of the chemical in the environment. o Objective 1 provides long term species sampling, and the chemical risk assessment process emphasise the need for this to contain higher food chain organisms (for bioaccumulating chemicals) and a range of other trophic levels, to have populations that will respond to other chemical impacts e.g.: chemicals affecting plant reproduction. The difficulty in predicting which chemicals will pose a risk after approval means that it is not worth supplementing objective 1 sampling with possible target organisms for different pollutants. o For bioaccumulative chemicals there is a particular case for a tissue bank accumulating material for selected high food chain species with samples having good temporal and geographical representation, this allows risk assessments to hind cast, ie see at the point of risk assessment the profile of accumulation and sub lethal effects.