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EuMon
EU-wide **mon**itoring methods and systems of surveillance for species and habitats of Community interest

EuMon policy briefs – No 2

A primer for biodiversity monitoring

(1) Why monitor biodiversity?

The very first step when launching, evaluating, or analysing a biodiversity monitoring scheme is to clearly define the questions that need to be answered. Usually, the questions will fall into one of the following three categories: which policy support, which management problem, or which scientific issue. These questions will constrain all the following characteristics of the monitoring: What to monitor? How to monitor? For the long-term, multi-purpose surveillance can be advantageous to address general questions, such as the status and trend of distribution and abundance of a set of species, and the causes for their changes. Narrowly targeted monitoring schemes may often die with a change in policy priorities and before they can yield the expected results.
Useful references: Elzinga et al. 2001; Yoccoz et al. 2001; Parr et al. 2002; Green et al. 2005; Teder et al. 2007 ; see also Nichols and Williams 2006.

(2) Choice of the biodiversity components to be monitored

The hierarchical decomposition by Noss (1990) of biodiversity into biodiversity components is useful for defining what measures of biodiversity may be monitored. For many management and policy issues *distribution*, *abundance*, *demographic processes*, *and community processes* are among the most important components. Appendix 1 provides guidance on which general data type is particularly appropriate for which of these components.

(3) Use of biodiversity indicators

Biodiversity usually cannot be measured in its full complexity. Therefore, a range of biodiversity indicators has been proposed. Besides species and habitats targeted by national and international legislations and agreements (e.g., Annexes of the Birds and Habitats Directives), birds and butterflies have emerged as the only taxonomic groups for which large-scale state and trend indicators can be assessed with available data. The EuMon database allows an evaluation of current monitoring practices for other candidate groups. EuMon has further advanced the concept of national responsibilities as a basis for setting priorities in monitoring (see Policy brief "Identification of national responsibilities and conservation priorities in Europe").
Useful references: Balmford et al. 2005b; Balmford et al. 2005a; European Environment Agency 2007 and references therein.

(4) Which field methods?

Textbooks and reviews provide practical introductions to standard field methods. These were not covered in EuMon.

Useful references: Cooperrider et al. 1986; Noss 1990; Bookhout et al. 1994; Elzinga et al. 2001)

(5) How to distribute samples in time and space?

This is the crucial step of sampling design and is essential if we want to make reliable inferences from the collected data. It is fundamental for any data collection, including monitoring, but is often neglected in many monitoring schemes (Nichols and Williams 2006; Henry et al. in press). The most important components of sampling design choice are:

a. **Where to monitor?** Sites to be monitored must be representative at the spatial scales relevant for the monitoring targets. Site selection methods yielding unbiased data are random sampling, exhaustive sampling, or systematic sampling; stratification may help to reduce the number of samples needed. The absence of representative site selection impose that monitoring data be post-stratified to achieve unbiased conclusions. It is a serious weakness even in some widely recognised, long-term monitoring schemes (Buckland et al. 2005).
b. **When to monitor?** The designing of monitoring can be as refined in time as in space. Nonetheless, the common practice is to monitor every year (or every 2^{nd} or 5^{th} year for long-lived organisms or habitats, or several times a year for multivoltine organisms). For monitoring changes in phenology, in particular, repeated sampling within a year is required.
c. If the impact of a given **cause of biodiversity change** is to be demonstrated, an experimental design is needed (ideally, a control treatment, or at least before-after comparisons). Otherwise, only correlative tests will provide indications of potential causes of change.
d. Accounting for **error in the measures**. Replicated sampling (i.e., several samples at the same sites) is to be preferred so that measurement error can be accounted for in data analysis. A major source of measurement error in monitoring data is imperfect detection (detection probability < 1). In any monitoring, the recorded value is the product of the true value of the parameter of interest and the detection probability. The sampling design should allow for the estimation of detection probability. Otherwise changes in the recorded value may not reflect the true changes in the parameter but, instead, variations in detection probability. Although detection probability may require considerable field effort, it should be accounted for whenever its variations are expected to confound temporal or spatial changes in the parameter of interest.

Useful references: Appendix 2 of EuMon Deliverable 2 (eumon.ckff.si); BioMAT module 3; Caughley 1980; Olsen et al. 1999; Parr et al. 2002; Yoccoz et al. 2001; Margurran 2004; Buckland et al. 2000; Buckland et al. 2005; Nichols and Williams 2006; Henry et al. in press.

(6) **How to analyse monitoring data**?

Key messages are:

a. Use of **generalized linear models**. It allows testing and accounting for temporal trends with incomplete time series (missing data). Including the effect of site identity as a random effect partly compensates for among-site variations (e.g., observer effect, detection probability variations) without introducing biases, and only lowering the precision of the estimate. Appendix 3 in Deliverable 2 and BioMAT module 2 provide guidance on which statistical method may be used depending on data characteristics.
b. Use of **spatial interpolation**: it allows production of biodiversity estimates even for areas not monitored.
c. Use of statistical models that account for **measurement error** (i.e., detection probability).
d. **Considering spatial variation in the temporal trend** of the biodiversity indicator. An average value of the indicator can always be computed, but major spatial variations in the trend should not be neglected because of their major implications in terms of environmental policy.

Recommendations of suitable statistical methods for monitoring data are presented in EuMon Deliverables 2 and illustrated in Deliverable 12. They are integrated in BioMAT module 2. Further useful references: Olsen et al. 1999; Parr et al. 2002; Yoccoz et al. 2001; Margurran 2004; Buckland et al. 2000; Buckland et al. 2005; Nichols and Williams 2006).

Popular programs:

- for abundance trend analyses with count data: TRIM www.cbs.nl/nl-NL/menu/themas/natuur-milieu/methoden/**trim**/manual-**trim**.html
- for demographic and abundance trend analysis with capture-mark-recapture data: MARK http://www.cnr.colostate.edu/~gwhite/software.html

(7) Need for **more integration of monitoring output across monitoring schemes.**

Meta-analysis tools are particularly suitable for data integration, but they remain under-used in the context of biodiversity assessment. Avenues and methods for integration are presented in Henry et al. in press (compiled from EuMon Deliverables 16 & 18). BioMAT module 2 will further provide web-based guideline for integration of output across monitoring schemes (available at eumon.ckff.si end of 2008).

(8) **How to evaluate a monitoring scheme**?

To assess the reliability of monitoring results, the underlying monitoring scheme should be evaluated in terms of the criteria listed above under items (5) and (6). A framework for such an evaluation of monitoring schemes has been proposed in EuMon Deliverable 17. This framework additionally considers criteria for time- and cost-effectiveness. The Deliverable is available at eumon.ckff.si and the framework will be implemented in BioMAT module 3 (available end of 2008).

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Appendix 1. Link between functional parameters to be monitored (rows) and measures to be taken (columns).

	Presence/absence	Counts of individuals	Age or size-structure	Individual follow-up (cf. Capture-Mark-Recapture)	Advantages	Disadvantages
Distribution	**Optimal**	Not used	Not used	Not used	Basic information required for status identification	Trends are detected late, after local extinction or colonisation only
Abundance	Appropriate but lower power to detect trends than counts of individuals	**Optimal**	Not used	Ideal but field intensive	Trends detected early, before local extinction or colonisation	No cues on demographic processes driving changes if only count data are available; if complementary information is available, inferences on demographic processes may be possible
Demographic processes	Appropriate for estimation of population growth rate inducing range extension / restriction only	Appropriate for population growth rate estimation only	Appropriate	**Optimal**	Detailed understanding of processes driving trends	Data consuming
Community dynamics	**Optimal**	Appropriate but theory to account for relative abundances in community parameters still need to be advanced further	To be developed	To be developed	Understanding of changes in biodiversity components across broad taxonomic groups	Community dynamics theory under development
Advantages	Large coverage because easy to implement	Large coverage because easy to implement	Intermediary level of detail	Highest level of detail		
Disadvantages	Poor precision	Limited information	Usually involves unrealistic simplifications for parameter estimation; Intermediary coverage	Restricted coverage due to intensity of field work		