MONITORING REQUIREMENTS FOR HABITAT CREATION SCHEMES

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This paper contains a summary of the key considerations required when designing and implementing a monitoring programme for habitat creation schemes. The success of habitat creation projects can be defined as progress towards the achievement of targets or objectives. The objectives for an individual scheme vary; thus every scheme poses specific information needs, and monitoring efforts need to be tailored to provide this information. Most of the habitat creation schemes which have been implemented to date have incorporated very different monitoring programmes. To maximize the potential functional gain and understanding of habitat creation schemes a consistent approach is required. Guidance is therefore provided on the selection of appropriate parameters to monitor and the associated monitoring techniques. The results of such monitoring will not only enable the evaluation of current objectives but will inform the design and management of habitat creation schemes in the future.

1. Introduction

Physical pressures such as land claim, shoreline reinforcement and dredging continue to have extensive impacts on the extent of intertidal and other habitats around the UK coastline. Habitat creation aims to alleviate some of these losses. The number of habitat creation schemes in the UK and elsewhere being planned and implemented has increased markedly over the last decade. The relative newness of such schemes means that as yet we do not have an adequate understanding of the processes behind the restoration/ creation of saltmarsh and mudflat habitats. It is only through the monitoring of existing schemes that we will be able to enhance our knowledge of the parameters, and their linkages, that are important to successful habitat creation scheme design.

This paper describes the results of an 18 month study to make recommendations for the monitoring requirements of habitat creation schemes

(Frost *et al*, 2004). Such sites cover the intertidal regions of both estuaries and coastal zones and include saltmarsh and mudflat habitats. This review is aimed at all organisations/ individuals involved with the enhancement, management and conservation of estuarine and coastal zones.

1.1. *Aims and Objectives*

The overall aim of the project was to develop measures of habitat quality and monitoring protocols to implement these. This paper therefore provides guidance for:

- The collection of better data in terms of relevancy, consistency and statistical validity.
- The assessment of the success of habitat creation schemes.
- Providing a basis for consistent monitoring of sites to improve understanding of site development and how this might contribute to the wider functioning of an estuary or coastal system.

Additionally, the outcome of future monitoring will provide guidance to managers to enable corrective action to be undertaken where habitat quality objectives may not be achieved, or to develop alternative quality objectives which better reflect the capacity/ capability of the site. This paper presents a summary of each of the key elements derived from the original project report and further details can be found in Frost *et al* (2004).

2. Success Criteria

The task of determining the success of habitat creation has long been challenging and sometimes contentious because the appraisal of success is dependent on the objectives of the scheme (Kentula, 2000). What may be recognised as a successful scheme by one individual or organisation might be deemed as failure by another, depending on the criteria used.

Lewis (1990) broadly defined success as 'achieving established goals', ideally as specified in quantifiable criteria. Quammen (1986) provided a more detailed definition by distinguishing between compliance and functional success. Compliance success is determined by evaluating whether the project complies with the terms of an agreement whereas functional success is determined by evaluating whether the ecological functions have been restored (Quammen, 1986) and whether the system is biologically viable and sustainable (West *et al,* 2000) and capable of responding to disturbance and human intervention (Mitsch, 1998). Each scheme that is undertaken will therefore have different objectives and consequently different measures of success. Thus, because of the range of objectives which habitat creation schemes can be used to achieve, different schemes are likely to require different monitoring programmes to chart progress towards these objectives.

Success defined by engineers seeking to improve flood defence, or dispose of dredged material, for example, will be determined by how well the scheme serves this purpose. Occasionally such schemes may also include an assessment of some added but often unspecific environmental benefits. More recently within the UK, many intertidal creation schemes aim to compensate or mitigate for damage to existing habitats to meet the requirements of the Conservation (Natural habitats &c.) Regulations 1994, the Wildlife and Countryside Act 1981 or other non-statutory initiatives. The objectives of such schemes need to be agreed by the stakeholders at the outset. In such instances the objective of the scheme could be to provide habitats of comparable type and quality to the habitats damaged or lost. However, in many cases it may be possible to improve on the quality of the habitat which is being damaged. In such cases comparisons may be made with other, more 'ideal' reference sites (Zedler, 1996). Ultimately the success or failure of a scheme will be assessed against the targets detailed at the start of a project. It is therefore important that any targets set for a project are realistic and achievable.

The increasing recognition of wider benefits which the environment provides has given rise to a more functional assessment of managed realignment schemes. Functional success is a measure of whether the ecological functions of the system have been restored or created. These functions include, for example, the ability of intertidal habitats to support food chains, to attenuate storm action and to improve water quality. Whilst maintaining ecological functioning is the key to sustaining a healthy environment, a major challenge yet to be overcome is how to determine and quantify, given constraints of time and incomplete knowledge, the functions and values of natural and restored marshes (Atkinson *et al,* 2001). Success criteria need to include physical, spatial and temporal considerations as well as take into account the dynamic nature of coastal and estuarine habitats. It is also important to recognise that we do not currently have a full understanding of all elements of ecosystem functioning.

Ideally a completely successful created habitat would, in time, be indistinguishable in all respects from corresponding natural habitats (Atkinson *et al*, 2001). In other words biological, chemical and physical characteristics would be within the range of those characteristics found at equivalent natural sites. This requires an understanding of the variation which exists in the natural environment in order to determine achievable ecological function. Practical measures of habitat quality therefore encompass a suite of physical and biological parameters as well as statistical measures.

3. Important Parameters

Coastal and estuarine systems are highly complex due to the feedback which exists between the various physical, chemical and biological processes. Previous work has demonstrated that successful habitat creation depends on both physical and ecological criteria as well as the linkages and processes in operation. However, physical criteria including hydrodynamics, morphology and sedimentology, are perhaps the most fundamental in determining the overall success of schemes, since these affect the physical and chemical processes occurring within a site. These processes influence ecological structure and function of the created habitat, affecting both the establishment of primary colonisers and, ultimately, the use by higher consumers. The elevation of the substrate for example, can influence the extent and types of saltmarsh that establish, which in turn will affect site usage by invertebrates and ultimately animals such as fish and birds (Atkinson *et al* 2001). It is important to note, however, that many plants and invertebrates have wide habitat tolerances and ranges in terms of, for example, salinity, elevation, sediment type, but their distribution and abundance can be determined by biological processes, notably dispersal potential, bioturbation, competition and predation.

Successful habitat creation should embody a holistic rather than atomistic approach. In other words, the whole must be greater than the sum of the parts, in order to create a functional ecological system. In this context it is also important to consider the implications of a scheme on the estuarine system as a whole, not just the proposed site.

4. Current Practice

Most of the habitat creation schemes which have been implemented to date have incorporated some degree of monitoring. The number of parameters monitored at each scheme is, however, highly variable. The intensity of the monitoring programmes are also quite different depending on the nature of the scheme. The most commonly measured parameters for UK based schemes are the distribution and usage of the site by invertebrates and birds. In the USA similar parameters have been measured, although greater emphasis appears to have been placed on the assessment of fish populations. In contrast parameters that have rarely been monitored at such schemes include water and sediment quality. These apparent differences, between schemes, highlights that currently there is no consistent approach adopted for defining monitoring programmes.

5. Appropriate Monitoring

As previously stated habitat creation schemes are undertaken for a number of purposes and as such each scheme has its own unique set of objectives. Every scheme poses specific information needs, and monitoring efforts need to be designed to provide that information. This makes it difficult to provide categoric recommendations of what to monitor at a site. This section provides guidance on the selection of appropriate monitoring tools and establishes a minimum set of core monitoring at all sites irrespective of their purpose.

It is important to recognise that not all habitat creation schemes undertaken will have formal requirements for monitoring. In some instances where schemes are undertaken for flood and coastal defence or for the enhancement of existing nature conservation interests, for example, there may be no statutory monitoring requirements associated with the project. However, in the interest of scientific understanding, it is proposed that monitoring should be undertaken at as many schemes as possible following comparable sampling protocols. This would allow maximum experience to be gained relating to the development and subsequent functioning of managed realignment sites. The development of core monitoring protocols would form the basis of a research agenda from which results would require collating and publishing in the public domain in order to gain maximum benefit.

The monitoring of habitat creation sites needs to cover a range of core parameters that describe the key aspects of the site. In addition to these core parameters, individual schemes may opt for, or be required to, perform a more detailed investigation of specific parameters. The choice of these additional measures will depend on the nature of the scheme and its objectives. For example, if the objective of a scheme were to provide habitat for juvenile fish, then the monitoring would need to be tailored to meet this requirement. The following section therefore provides guidance on the parameters that should be monitored at individual sites.

5.1. *Core Monitoring*

It is recommended that, as a bare minimum, changes in elevation and broad habitat types which establish across a site should be monitored. Elevation is an important parameter as it plays a key role in determining the range of hydrodynamic and sedimentological environments experienced at a site. Such factors ultimately influence the habitat types and species that colonise and use an individual site. Habitats such as saltmarsh also play an important role in flood and coastal defence by reducing wave attenuation across a site. The monitoring of saltmarsh extent therefore helps to estimate the degree of functionality provided by this habitat type. It is unlikely that monitoring outside the boundary of the site would be appropriate at such schemes.

These elements of core monitoring provide very basic information from which it may be possible to infer site usage and functionality. They would also provide useful data for the purposes of inter-site comparisons and support a general research agenda to help enhance and develop our understanding of habitat creation sites. In addition the results from such monitoring would allow an assessment of whether the objectives of a scheme have been met and would indicate whether remedial action needs consideration.

5.2. *Statutory Requirement for Monitoring*

A large proportion of habitat creation schemes that are undertaken will have statutory requirements for monitoring. Schemes requiring a formal Environmental Impact Assessment (EIA), for example, are likely to have monitoring requirements attached to the planning permission of the scheme. Where monitoring forms a requirement for the scheme there is a shift in emphasis from the quantity to the quality of what develops at a site. For example, it may be appropriate to monitor the species composition of the saltmarsh and the invertebrate assemblages of the mudflat rather than just habitat extents. In this respect more is actually determined and less is inferred about site usage and functioning at higher trophic levels than with the core measurements. The monitoring required will therefore have a greater degree of sophistication and result in more detailed data for the site.

Where an EIA is required the study will examine all aspects of the baseline environment and make predictions on the likely environmental impacts of a scheme. The types of parameters that should be monitored include not only those core ones previously identified above but also those for which impacts are predicted. For example, if the EIA predicted large changes in the patterns of erosion and deposition the associated monitoring would need to focus on this aspect of site development. Where no impacts are predicted there is unlikely to be any requirement for further monitoring of a particular parameter. The parameters monitored would also be a reflection of the overall purpose and objectives of a scheme and would be highly variable between schemes. This again allows an assessment of whether the objectives of a scheme have been met and would indicate whether remedial action needs consideration.

Where the purpose of a scheme forms part of a compensation package for an alternative development detailed monitoring will be required at the site. The parameters and the techniques to be used will require prior agreement with statutory bodies. This is usually agreed prior to the commencement of the scheme and in the early stages of planning. With compensation schemes a higher degree of certainty of what is going to be achieved is required. The monitoring is typically aimed at compliance criteria, that is determining if specific standards are being met. A higher degree of precision will therefore be required from the techniques which are employed for each parameter. The parameters to be measured will reflect what the scheme is designed to compensate for and any impacts that are predicted to arise from the scheme itself. These parameters will be identified from the associated EIAs.

For schemes that are funded, either by a third party or through an associated initiative (e.g. Countryside Stewardship Scheme) there may be requirements to deliver set targets. As with all sites the parameters of interest can be highly variable and the level of accuracy required is also likely to vary depending on the source of funding and the location of the site. Impacts predicted as a result of the scheme will also require some degree of monitoring. This again allows an assessment of whether the objectives of a scheme and the associated funding requirements have been met.

6. Monitoring Tools

A large number of the attributes identified as important for the development of an ecologically successful scheme can be measured and monitored. Indeed there are a number of techniques available to measure each of the key parameters that have been identified. Each of the available tools has a differing degree of accuracy, strengths and weaknesses and associated practicality of use. A full review of the techniques available is too lengthy to include here and can be found in Frost *et al* (2004).

6.1. *Selection of appropriate tools*

The ability of a monitoring programme to meet its aims successfully hinges on the selection of an appropriate method, together with its deployment strategy, to measure each attribute (Davies *et al*, 2001). The selection of a technique to use for a specified scheme will therefore be influenced by a number of factors, including:

- The purpose of the scheme.
- Degree of accuracy required.
- Site specific issues.
- Available budget.
- Available equipment.
- Previous site work.

Where the scheme is undertaken with no formal requirement for monitoring it is probable that the most cost effective, low technology method of data collection would be used. The period and frequency over which the monitoring would be conducted is also likely to be restricted. In contrast, where the monitoring is designed for impact verification, or to assess compliance with an agreement, the techniques used would be required to permit a more detailed assessment of the site. Equipment that can detect the level of change predicted through the impact assessment or to meet an agreed compensation measure would be required. The technique to be used may also require prior agreement with the relevant statutory bodies. Where monitoring is a statutory requirement, the duration and frequency of the monitoring programme is also likely to be predetermined. Typically monitoring periods are set for a period of five years post inundation, with a review of data collected at this time and the requirements for future monitoring assessed. Where ecosystem elements develop over longer timescales, for example, there will be a requirement for monitoring over longer time periods. Similarly where a target condition has been achieved it may be possible to review the monitoring programme at this time.

Each individual site will have a unique suite of physical and ecological characteristics. This will in turn affect the most suitable technique for taking measurements/ samples at a site. Similarly the majority of methods that are available are best suited to a range of environmental conditions. The relative specificity of the methods will, however, differ between each of the techniques. Other site specific issues include the accessibility of the site in order to take the necessary measurements. Some sites may be inaccessible on foot, for example, and require equipment such as a hovercraft in order to collect the required samples. Access points to a site, and health and safety more generally, also require careful consideration when selecting the parameters to be measured and the associated monitoring tools to be used.

The methods available to measure each of the parameters also differ in their relative costs in both obtaining and deploying the equipment as well as the subsequent analysis and reporting. The costs assigned to the monitoring aspect of the project are again likely to be a function of the purpose of the scheme and the statutory requirements for monitoring. The number of replicate samples taken for each parameter will also be limited by the associated costs. Typically a balance is required between sampling effort and the available funding for monitoring. The equipment that is already available for use is likely to affect the selection of a sampling method, especially as budgets are generally constrained. In addition the sampling methods used at a site should be consistent with the methods that have already been used to collect the associated baseline information. This ensures that consistency is maintained throughout a dataset and facilitates the further interpretation of the data. Similarly in the selection of an appropriate technique it should be decided whether that same method (and strategy of deployment) should be used for the entire duration of the monitoring programme regardless of technological advancements.

The factors listed above are all important considerations for the selection of a monitoring method for each of the possible parameters. Due to the wide range of reasons for monitoring and the number of methods available it is impossible to make recommendations for which technique would be applicable for individual sites.

7. Design and Implementation

There are a number of further considerations that need to be taken into account in developing a monitoring programme and these are discussed in more detail below.

To improve the ability to determine the success of a scheme there is a need for long term data sets before and after the scheme commences and similar data for reference sites for comparative purposes. The more data that are available the better the chance of being able to separate the effects of the scheme from natural background variability operating within the system. Such variation can be particularly high for many aspects of coastal and estuarine environments. Ideally it would be advisable to collect several years pre-realignment data. The collection of data at reference sites also allows the results to be put into context with changes that may be occurring throughout the system. The duration of monitoring programmes for habitat creation schemes is typically in the region of five years post construction, although it can be more than this depending on the purpose of the scheme. As with all data the longer the available time series the more useful the information can potentially be.

For the majority of parameters that are monitored representative samples are taken as indicative of the condition of the entire parameter. Sampling stations that are selected for detailed analysis need to be representative of the parameter of interest. The natural variation over different temporal scales, seasonal and annual for example, also has to be taken into account. This combined with the patchy spatial distribution of intertidal habitats and species results in considerable variability which needs to be taken into account when designing a monitoring plan. More than one sampling unit per parameter is required, and replicate recordings at each sampling station are advisable. The use of reference sites (Zedler, 1996) allows comparisons with data in natural neighbouring locations and allows the distinction between natural and created variability to be made. A more detailed review of the issues associated with the design and implementation of a sampling strategy can be found in Krebs (1999) and Brown (2000). The statistical validity of the sampling design also requires careful consideration.

It is also important to remember that monitoring programmes can be expanded or reduced by varying the number of parameters that are measured, the frequency of monitoring, and the number of sampling stations. A monitoring programme may be quite extensive at the start of a project and the results collected may allow the procedures to become more focused, with efforts concentrated on the key parameters at a site in later years. In contrast for some schemes it may be determined that there is the need to consider additional parameters within the monitoring programme as time progresses, for example, where scheme progress against objectives is slower than predicted, or site development does not follow the expected path.

The timing of the monitoring of each of the selected parameters needs to ensure that there will be no conflicting monitoring at a site at any one time. For example, if birds are being counted at a site there should be no additional disturbance caused by the simultaneous measurement of other parameters. The monitoring schedule therefore needs to be designed to eliminate the potential for such conflicts.

The cost, expertise of personnel and background knowledge of how best to sample will all determine the adequacy of the monitoring programme. It is therefore important that the people involved in the development of monitoring programmes are fully aware of the factors that need to be considered. Quality assurance procedures also need to be put in place to ensure that the data collected and subsequent analysis is of a sufficiently high standard. In addition the development of monitoring programmes to meet specified targets should involve consultation with the appropriate statutory organisations to ensure that the work undertaken is appropriate. Consideration of all of these factors will ultimately lead to a more successful monitoring programme.

8. Conclusions

There are a number of benefits which can be achieved through a consistent approach to monitoring including the enhancement of current understanding, a true assessment against scheme objectives and adaptive management where required. This paper has reviewed the selection process of parameters to be monitored and provides recommendations on the selection of appropriate measurement techniques. The results of such monitoring will inform the design and management of habitat creation schemes in the future.

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