Marine Pollution Bulletin 128 (2018) 527–538

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Improving the implementation of marine monitoring in the northeast Atlantic

W.R. Turrell

Marine Scotland Science, 375 Victoria Road, Aberdeen AB11 9DB, Scotland, United Kingdom

ARTICLE INFO

Keywords:
Marine monitoring
Monitoring programme design
Ecosystem approach
Integrated monitoring
Northeast Atlantic
Marine Strategy Framework Directive

ABSTRACT

Marine monitoring in the northeast Atlantic is delivered within identifiable monitoring themes, established through time and defined by the geographical area and policy drivers they serve, the sampling methodologies they use, their assessment methodologies, their funding and governance structures and the people or organisations involved in their implementation. Within a monitoring theme, essential components for effective monitoring are governance, strategy and work plan, sampling protocols, quality assurance, and data and assessment structures. This simple framework is used to analyse two monitoring theme case studies; national ecosystem health monitoring, and regional fish stock monitoring. Such essential component analyses, within marine monitoring themes, can help improve monitoring implementation by identifying gaps and overlaps. Once monitoring themes are recognised, explicitly defined and streamlined, travel towards integrated monitoring may be made easier as the current lack of clarity in thematic marine monitoring implementation is one barrier to integration at both national and regional scales.

1. Introduction

It would be impossible within the bounds of one paper to review the vast literature available on the various aspects of marine monitoring. This is particularly true when we consider the number of different components of the marine ecosystem and environment which are monitored by one or more monitoring programmes, and the different scientific disciplines this involves.

For example, in terms of the basic elements of monitoring design, the scientific literature includes aspects such as sampling methods and techniques (e.g. for water quality monitoring - Chapman, 1996), the statistical power of sampling strategies (e.g. for benthic infauna monitoring - Carey and Keough, 2002; for marine contaminant monitoring – Nicholson and Fryer, 1992; for fish community health monitoring – Nicholson and Jennings, 2004), and assessment methodologies (e.g. for biological assessment methods – Borja et al., 2009; Birk et al., 2012; for plankton monitoring – Tett et al., 2015). More esoteric subjects include, for example, how citizen science may be incorporated into monitoring programmes (e.g. Hyder et al., 2015).

Papers addressing the general philosophy of marine monitoring design are fewer in number. Examples from the literature include Segar and Stamman (1986) who discussed the essential elements of the decision and design process for both site-specific and regional marine pollution monitoring programmes. Elliott (2011, 2013) considers marine monitoring programmes from the perspective of the philosophy of marine management. Karydis and Kitsiou (2013) take a more pragmatic approach, focusing on the technical aspects of monitoring design albeit for one sector of marine monitoring; water quality monitoring. However, their approach is similar to the one proposed here, as they consider aspects such as the importance of setting objectives for monitoring programmes, as well as implementation aspects such as data management and analysis.

Several authors have considered the role of new technologies in marine monitoring programmes. For example, Chapman (2015) highlights the emerging “omics” technologies and the future importance of biomarkers in the assessment of ecosystem health. Carstensen (2014) argues that as monitoring budgets decline, and the need to understand the impact of human pressures increases, new technologies such as remote sensing and autonomous vehicles must be utilised in monitoring programmes. This theme is continued by Nilssen et al. (2015) who propose how new technologies can help from data gathering to data assessment using integrated environmental mapping and monitoring.

However, while new technologies will certainly fundamentally alter the nature of many of our monitoring programmes, unless they are utilised in well organised monitoring schemes, their benefits will not be realised. The huge advantages that new technologies may bring can still, unfortunately, be lost by the action of humans within the governance structures of monitoring.

In terms of the funding of marine monitoring, Elliott and de Jonge (1996) and Elliott (2011) note that a key characteristic of a monitoring

E-mail address: bill.turrell@gov.scot.

https://doi.org/10.1016/j.marpolbul.2018.01.067
Received 19 November 2017; Received in revised form 30 January 2018; Accepted 31 January 2018

programme should be cost-effectiveness, and Borja and Elliott (2013) go on to examine how marine monitoring should respond to the general economic crisis in public spending, including a focus on cost-effectiveness. OSPAR (2008) note that many marine institutions in the northeast Atlantic would benefit from cost reductions if better co-ordination was implemented (Zampoukas et al., 2013).

Many authors have noted that the drive towards the ecosystem approach which is being implemented globally (e.g. Borja et al., 2008; Bigagli, 2016) will require coordinated, if not integrated monitoring (e.g. Knol, 2013). In the European Union the ecosystem approach in the marine environment is being implemented through the Marine Strategy Framework Directive (MSFD; EC, 2008). Shephard et al. (2015) discuss extensively how coordinated monitoring, or in their terms "joint monitoring programmes", will be needed in order to implement the MSFD in a cost-effective manner. Zampoukas et al. (2013) noted that despite the plethora of legislation in Europe that require marine monitoring of environmental, habitat and ecosystem components including fish, the coordination of monitoring across these policy areas "is still in its infancy".

When considering the wider legislative systems within which marine monitoring is embedded, Elliott (2011, 2013) considered several aspects of marine monitoring in the context of effective marine management, taking lessons from business management concepts or "tenets". He noted that marine monitoring should be included in adaptive monitoring/modelling/management systems in order to deliver successful marine management. The cost of monitoring must be considered in relation to ensuring marine management is "economically viable". Monitoring to measure the success of management must also be "technologically feasible".

In order that marine management is "socially desirable and tolerable", the cost-effectiveness of management, and hence of monitoring, must be demonstrated, and demonstrated to stakeholders and the public. In order that marine management is "politically acceptable", management systems, and hence associated monitoring programmes, must not be "gold plated". For marine management to be "effectively communicable", it must not only do the best for the environment, but be seen to be doing the best, i.e. it must be open and transparent to the public and stakeholders. This equally applies to marine monitoring which supports management.

Finally, successful marine management must be "administratively achievable". When considering marine monitoring programmes, this translates into statutory bodies being clear concerning their role and responsibilities in relation to implementing, and/or funding, monitoring and how their contribution relates to others serving the same management outcomes.

Table 1 summarises the ten tenets of (Elliott, 2011, 2013) and what they imply for the implementation of marine monitoring. In summary, marine monitoring needs to be well governed, cost-effective, organised, transparent, open, and "fit for purpose". All of these ideas are taken up in the proposed framework for assessing the effectiveness of monitoring presented below.

1.1. Definition of monitoring

Up until this point the term "marine monitoring" has been assumed to be self-explanatory. However, many papers, reports, guidance documents and statutory instruments attempt their own definitions of monitoring. In some respects trying to reach a precise definition is not a particularly fruitful exercise.

Many of the published definitions of monitoring (e.g. see Table S1, Supplementary Material), all partly succeed and partly fail to inclusively describe all the monitoring that can take place in support of marine management. For example, Elliott (2011) defined 10 types of monitoring, which only partly agree with other published definitions.

It is not considered particularly useful trying to develop in this paper yet another definition of marine monitoring and its various types. Karydis and Kitsiou (2013) suggested a very general description of marine monitoring, as any activity that is routinely (regularly) performed, assesses either a pressure or an impact on the marine ecosystem, is based on sound experimental design and is sustained over a number of years. This definition is used here, and the remainder of the paper is relevant to any activity that fits this definition.

Within the definition of "monitoring", Lindenmayer and Likens (2009, 2010) define three classes of monitoring; curiosity driven (or passive) monitoring, mandated monitoring and question driven monitoring. Using these three categorisations, this paper is most relevant to "mandated monitoring" which Lindenmayer and Likens define as "monitoring where environmental data are gathered as a stipulated requirement of government legislation or a political directive", although some if not all of the general principles of what is proposed here can equally apply to the other two categories.

1.2. This paper

Despite the vast array of literature discussing varied aspects of marine monitoring, few address the underlying basic structures needed for the real-world organisation and implementation of efficient, well delivered marine monitoring. This paper proposes two "back to basics" methods to improve the monitoring that we currently have and to facilitate moving current monitoring on to a future more-integrated approach, especially in the northeast Atlantic where marine monitoring has evolved over time rather haphazardly.

The first method involves recognising that our present day monitoring can be brigaded under overarching "themes", thus bringing

Table 1
The 10 tenets for integrated and sustainable marine management from Elliott (2011, 2013), and interpretations of how they relate to the implementation of marine monitoring programmes which inform and underpin such management.

	Tenet	Implication to marine monitoring
1	Ecologically sustainable	Management must not only protect ecosystem structure but also function. Hence monitoring should address both the structure and function of an ecosystem – leading to **integrated monitoring**.
2	Economically viable	The cost of monitoring must be included in assessing the cost of management programmes and measures. Hence monitoring must be **cost-effective** and **efficient**.
3	Technologically feasible	Monitoring must constantly assess the use of **new technologies** to improve the efficiency and scope of monitoring.
4	Socially desirable/tolerable	Monitoring programmes need to demonstrate they are cost-effective to the public and stakeholders. All stages of monitoring must be **open and transparent** to stakeholders.
5	Legally permissible	Monitoring programmes must be properly **governed**, and be open to external scrutiny and audit.
6	Administratively achievable	Statutory bodies must have **clear roles and responsibilities** in relation to implementing, or funding, monitoring and how their contribution relates to others serving the same management outcomes.
7	Politically expedient	'Gold plated' monitoring is unacceptable to the tax payer. Monitoring must be "**fit for purpose**" and **cost-effective**, **ethically governed**, **open and transparent**. Monitoring programmes should consider using **citizen science**.
8	Ethically defensible (morally correct)	
9	Culturally inclusive	
10	Effectively communicable	Monitoring programmes should **actively communicate** their purpose, implementation and results.