Ocean & Coastal Management 105 (2015) 75–83

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

Review

Temperate Marine Protected Areas and highly mobile fish: A review

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ARTICLE INFO

Article history:
Received 29 August 2013
Received in revised form
16 December 2014
Accepted 21 December 2014
Available online

Keywords:
Connectivity
Effectiveness
Reserve
Porbeagle
Cod

ABSTRACT

Marine Protected Areas (MPAs) have been widely used to protect benthic habitats and sedentary species. They have also been used as fisheries management tools. Historically, MPAs alone have been considered ineffective for the protection of highly mobile species, because MPAs are unlikely to cover the range of a highly mobile species for a sufficient proportion of time. Recent studies, however, have shown MPAs to be successful in the protection of certain mobile species. The majority and most successful of these examples tend to focus on tropical reef species because there is currently a lack of understanding about mobile species from temperate climates. Questions therefore remain regarding their success for the wide ranging and migratory species found in temperate regions. We reviewed the relevant literature and discuss the critical factors that should be considered during MPA designation, but focus on how these relate to highly mobile fish species in particular. We use examples from both tropical and temperate regions to illustrate how current knowledge can be a useful starting point in MPA design where information is lacking. We conclude that using studies from tropical waters can fill some gaps in scientific data for some temperate species, but that scientific evidence is crucial to MPA success in temperate areas.

1. Introduction

In 1993, the Convention on Biological Diversity (CBD) entered into force with the aim of protecting global biodiversity. One of the targets of the CBD is 'At least 10% of each of the world's ecological regions effectively conserved (CBD Decision VII/30, Target 1.1)' (Convention on Biological Diversity, 1993). This includes marine and coastal waters and Marine Protected Areas (MPAs) are indicated as being the main tool to achieve this aim. This target, to be achieved by 2020, was reaffirmed in October 2010 by all 193 contracting parties (Fox et al., 2012). In general usage, MPA is a broad umbrella term for 'any area of intertidal or sub-tidal terrain, together with its overlying waters, and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment' (IUCN, 2008). Typically, because of this broad definition, MPA is typically associated with conservation of biodiversity. However, other terms that are included within the definition of MPA include 'no-take zones' (McCook et al., 2010) specifically for areas where no extractive activity can occur, 'marine reserve' (Fenberg et al., 2012), and 'marine parks' (Smallwood and Beckley, 2012), usually large areas of protection which could comprise various zones, each with different levels of protection.[1] Furthermore, the legal definition of an MPA varies between countries because spatial management measures for marine environments are often accounted for by multiple legal instruments. In consequence, different stakeholders can have different views of MPAs as a management tool.

To date almost 6000 MPAs have been designated across the world's seas and oceans, located in almost every major marine habitat and covering 1.17% of the ocean (Fox et al., 2012). An important consideration of MPAs is that they offer protection to the diversity of fish that live within them, or move through them. However, there are 25,000 species of fish known to exist worldwide (Eschmeyer, 1998), with a complex array of life-history characteristics. Accounting for the diversity of life-history strategies when designing MPAs or MPA networks is therefore a challenging task.

When we come to consider mobility and habitat choice in the

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[1] For clarity in this paper, where we refer specifically to such legislation the appropriate term will be used but, regardless of legislative name, the term MPAs will generally be used to describe all types of area closures.

http://dx.doi.org/10.1016/j.ocecoaman.2014.12.021
0964-5691/

context of MPA design, understanding the terms for different types of movement is important. Dispersal (or 'ranging') (Dingle, 1996) is movement away from a particular area. This usually occurs because conditions have become unfavourable, either because the habitat has changed (e.g. resources have become scarce, or because predators or competitors have become more numerous) or because the individual has changed (e.g. from a feeding state into a breeding state). Within the concept of dispersal, migration usually implies some regular, cyclical element to spatial movement, on daily, annual or life-cycle timescales. Migrations tend to be highly predictable in *both* space and time, so the decision about when to migrate may not be based on any deterioration of local habitat conditions, but due to some timing cue (e.g. day length and/or temperature) or physiological status (e.g. spawning condition). de Klem (de Klem, 1994) defines migratory species as those which perform cyclical movements between two distinct geographical areas, one of which is usually the area in which they breed. Most fish species, including many that live on coral reefs, show limited dispersal and migration during their adult life, presumably because the costs and risks involved in large-scale migration out-weigh the potential benefits (Sutherland, 1996). For these species MPAs offer an ideal tool for protection against fishing mortality. However, a number of species (perhaps no more than 200–300, (Harden Jones, 1980) make extensive migrations that take them across regional or national boundaries. For these species, improved survival and reproductive success are achieved by moving between different habitats, and these species have therefore evolved a migratory life history and show some ontogenetic and/or seasonal changes in habitat use. In temperate waters, species such as herring (*Clupea harengus*), mackerel (*Scomber scombrus*), cod (*Gadus morhua*) and plaice (*Pleuronectes platessa*) make extensive movements over several hundreds of kilometres whilst some species migrate over distances of several thousands of kilometres. Examples include diadromous species such as Atlantic salmon (genus *Salmo*), Pacific salmon (genus *Oncorhynchus*) and eels (*Anguilla* species), which move between fresh water and the open sea, and the various species of tuna, billfishes and large sharks that make extensive trans-oceanic migrations. For iteroparous species (e.g. plaice, cod and tuna), migrations are repeated annually once they have reached sexual maturity, while semelparous species (e.g. European eels and Pacific salmon) undertake only a single migration to their spawning ground where, having spawned, they die. These examples are all highly mobile fish, but with clearly different migratory or dispersal characteristics. There is no formal (legal or otherwise) definition of 'highly mobile fish' and so, for the purposes of this paper we have defined highly mobile fish species (hereafter HMFS) as 'marine fish species, both commercial and non-commercial which move over large distances through the course of their life history, through dispersal, migration or because as individuals they have a wide range.'

Recent evidence shows that there is a real threat to many fish species, including sharks, that are highly mobile (White and Kyne, 2010). Conservation of such species is particularly important because they are either the basis of important capture fisheries, or are apex predators that reside at the top of the food web. Changes in the population size of commercial species, or of apex predators can affect the entire ecosystem (Anadon et al., 2011; Block et al., 2011), and also have an economic effect due to the long-term reductions in commercial fish catches (Cardinale et al., 2012). However, while there are a large number of MPAs aimed at protecting benthic habitats and site attached fish species (Ceccherelli et al., 2006), there are very few examples of MPAs designed to protect HMFS. This could be because, historically, MPAs have been thought to be ineffective for such mobile species (Game et al., 2009). Indeed, some studies have shown that, compared to their efficacy for benthic or sedentary species, mobile species do not benefit from MPAs to the same degree (Chan et al., 2012).

The aim of this review is to outline relevant issues regarding MPAs and their use in HMFS protection with a particular focus on the UK and Europe. In particular we try to answer three questions pertinent to MPAs and highly mobile fish species. These are:

1. Is there legislation in place to ensure HMFS are adequately protected within MPAs?
2. Are MPAs suitable for the protection of HMFS?
3. If so, what information do you need to create effective MPAs for HMFS?

To answer these questions we provide a background into the current legislation for HMFS in European and UK marine policies and provide information on the MPAs designated specifically for the protection of HMFS. We review relevant literature from both temperate and tropical regions to show examples of MPAs being suitable and unsuitable for protection of HMFS. We also use this literature to discuss how existing information might be used to close gaps in evidence for MPA designations in the UK and Europe. Finally, we present two case studies aimed at highlighting difficulties with MPA designation and how we can use existing knowledge as the evidence base from which effective decisions can be made. Since we have also included commercial species in our definition, the topic of fisheries management is also relevant for consideration in MPA designation. However, there are already comprehensive reviews available which cover fisheries management (Higgins et al., 2008) and while we briefly outline the topic in Section 5.7 to provide context and background, we do not review this topic in detail.

2. Methods

A search for relevant literature for this review was carried out in several ways. Initially, a scientific publications database was used to search for relevant keywords and combinations of these which would return relevant papers. Keywords used for this search included: "fish", "Marine Protected Areas", "marine reserves", "no-take zones", "mobile", "wide-ranging", "sharks" and "effectiveness". Use of connectors such as 'AND' and 'OR' were used to search for combinations of these keywords. Relevant papers were read and any specifically suitable publications found within these were searched for and obtained from the publications database. Other literature was found by speaking to relevant experts and asking for suitable publications to be forwarded. A grey literature search was carried out using internet search engines and similar keywords and combinations to ensure that non-peer reviewed literature was also taken account of. Finally, where specific references were needed, for example in the case study section, more specific searches using specific keywords were carried out using internet search engines and the publications database. Examples of such keywords would be "cod", "habitats directive" and "porbeagle shark".

3. Highly mobile fish species legislation in the UK

Table 1 lists forty HMFS commonly found in the UK and for which information is available. All species have been listed because they have been recognised to be of conservation importance to the OSPAR list of threatened or declining species and/or the UK Biodiversity Action Plan (BAP). To provide a more focused review, and to illustrate gaps in legislation in relation to HMFS, we have looked more closely at the UK case specifically for this list of species.

The EC Habitats Directive (92/43/EEC) requires Member States to designate Special Areas of Conservation (SACs) based on a list of