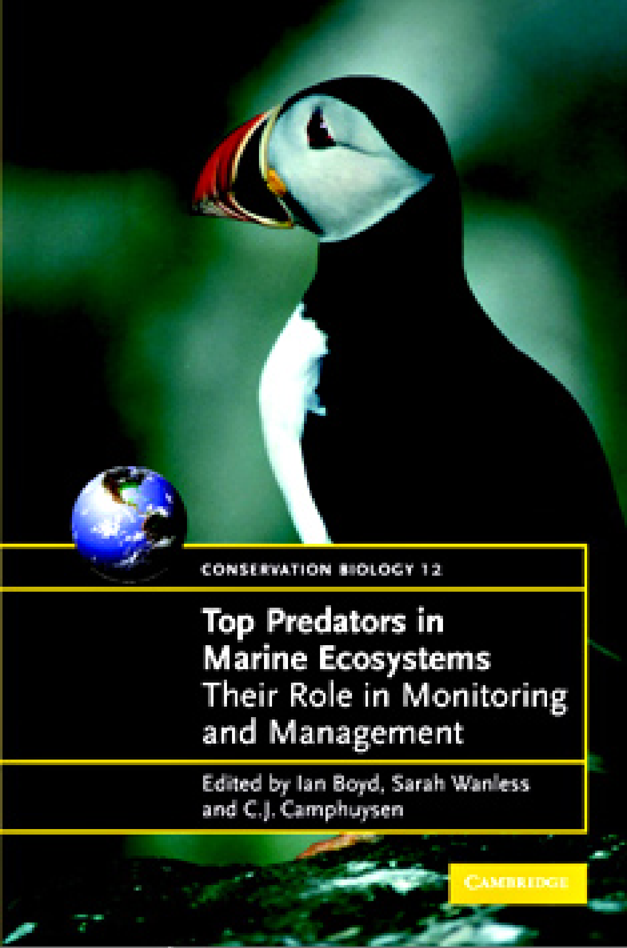

CONSERVATION BIOLOGY 12

Top Predators in Marine Ecosystems
Their Role in Monitoring and Management

Edited by Ian Boyd, Sarah Wanless and C.J. Camphuysen

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The sustainable exploitation of the marine environment depends upon our capacity to develop systems of management with predictable outcomes. Unfortunately, marine ecosystems are highly dynamic and this property could conflict with the objective of sustainable exploitation. This book investigates the theory that the population and behavioural dynamics of predators at the upper end of marine food chains can be used to assist with management. Since these species integrate the dynamics of marine ecosystems across a wide range of spatial and temporal scales, they offer new sources of information that can be formally used in setting management objectives. This book examines the current advances in the understanding of the ecology of marine predators and will investigate how information from these species could be used in management.

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I. L. BOYD, S. WANLESS AND C. J. CAMPHUYSEN

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Preface

This book began its evolution in 1999 when the British Antarctic Survey, where I worked at the time, began a new research programme on the management of marine ecosystems. This programme concentrated upon the krill-based ecosystem at South Georgia which has been the subject of almost continuous study since the Discovery Expeditions in the 1920s. Latterly, international efforts to understand the dynamics of this ecosystem and the wider Southern Ocean have been coordinated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). The daunting task of describing ecosystem dynamics over such a large oceanic area with relatively limited resources led to the establishment of the CCAMLR Ecosystem Monitoring Programme, an internationally coordinated effort at data collection. Among other things, this contained a major component of monitoring the seal and seabird populations in the region. The logic for their inclusion was that they foraged over most of the regions of interest but returned to breed at very well defined locations. By undertaking a series of measurements of these predators at these locations, it was then argued that aspects of the ecosystem dynamics should be reflected by variability in the measurements of the predators. It was hoped that appropriate choices of the predators and measurement variables would provide indicators of the dynamics of their prey at different spatial and temporal scales.

The same concept has been developed in parallel within other ecosystems during the past 20 years. The North Sea, California Current, northwest Atlantic, Bering Sea, Gulf of Alaska and Barents Sea are regions in which long-term monitoring studies of seabirds and seals are recognized as providing insights into ecosystem processes that can then be fed into the process of management. Even though the implementation and use of measurements has differed between regions, there has been a strong recognition that the interpretation of data about predator dynamics in the context of ecosystem dynamics can only be achieved on the back of basic research into the ecology of the species concerned. This book is, therefore, an effort to synthesize across a range of studies that have examined the ecology of predators within the context of ecosystem approaches to management.

It is well recognised that people cannot manage ecosystems but can only manage their own activities within ecosystems. The concerns about the impacts of human activities upon ecosystems made this an appropriate subject for a symposium sponsored and hosted by the Zoological Society of London, and this took place in April 2004. At the same time, there was an opportunity to build upon two major programmes of research: one involving the Southern Ocean predators, mainly of krill, and being led by researchers at the British Antarctic Survey, and one on North Sea predators, mainly of sandeels, being undertaken by a consortium of researchers under the IMPRESS programme. The content of the book therefore reflects the interest in these two contrasting ecosystems but also includes representations from other ecosystems.

Production of this book would not have been possible without the interest and willing participation of the authors of each of the chapters and I am grateful to them for their efforts to share their research results and ideas and for delivering their manuscripts within the time and word limits. Since my background is in Antarctic research, it was essential also to include leadership in the project from the North Sea research community and I was fortunate to have the support of Sarah Wanless and Kees Camphuysen as co-editors of the book. I am grateful to Georgina Mace, Director of the Zoological Society of London, for supporting the proposal that developed into the symposium and this book, and to Deborah Body from the Zoological Society of London for all the assistance she provided in organizing the symposium and in the early stages of the production of the book. I am also grateful to Alan Crowden and others at Cambridge University Press for their encouragement and diligence during the production of the book.

I. L. Boyd

1

Introduction

I. L. BOYD, S. WANLESS AND C. J. CAMPHUYSEN

Marine ecosystems represent a rich assemblage of co-evolved species that have complex, non-linear dynamics. This has made them difficult to manage and the recent record of exploitation of marine ecosystems suggests that the mechanisms currently in place for their management are inappropriate for sustained and intensive exploitation (Pauly *et al.* 2002). Fisheries science has developed sophisticated single- and multispecies approaches to modelling resource dynamics but these have shown mixed success when used to advise about the regulation of exploitation levels. However, it is commonly acknowledged that attempting to model whole or partial ecosystems also has limited utility because the demands this has for data and knowledge about the system far outweigh the financial, logisitical and intellectual resources available (Yodzis 1998). Although some computer-intensive approaches are currently being attempted[1], their ability to improve predictions of the dynamics of marine ecosystems appears to be quite limited.

This whole- or partial-systems approach to modelling marine ecosystems is driven by a belief in the connectivity of predator–prey processes within ecosystems and the conviction that, with appropriate parameterization, the behaviour of these systems can be predicted within bounds of confidence that are sufficiently narrow to convince us that the investment in the modelling effort has been useful. However, to date the cost–benefit analysis of these approaches has not been computed and the few simple systems in which the approach has been applied soon run into trouble. Whole-system approaches to modelling have been largely discredited because there is always insufficient information for adequate parameterization (Plaganyi

[1] The most recent version of an ecosystem-level model to be tested is known as GADGET.

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& Butterworth 2004). The move towards the partial-system (or 'minimum realistic', e.g. Punt & Butterworth 1995) approach leads to a necessity to define a 'horizon of relevance', meaning that components of the ecosystem that lie beyond this horizon are deemed to be of sufficiently low relevance to the focus of management that they will not have an important influence on the outcome of the scenarios being modelled (Schweder (Chapter 21 in this volume)). However, these partial-system models are challenged by the problems of diffuse effects (Yodzis 2000) which mean that the horizon of relevance often lies well beyond our data resources (Plaganyi *et al.* 2001). The problems that dog the whole-system approach to modelling marine ecosystems therefore also dog the partial-system approach.

Like the 'event horizon' in cosmology, we contend that the horizon of relevance in ecosystem modelling is an insurmountable boundary that severely limits the extent to which we will ever be able to model rationally constrained management scenarios for biological resources in the oceans (and perhaps in all complex ecosystems). This is a fairly gloomy outlook but there may be some hope for the future. This hope comes from two directions: one involves the potential/possibility that ecosystem dynamics could be constrained to a narrow set of rules similar to those involved in, or associated with, the allometry of individual organisms (Garlaschelli *et al.* 2003); the other direction, which is the one that is explored in this book, is to reject the reductionist approaches to ecosystem modelling by establishing ecosystem boundaries and only examining ecosystem dynamics at these boundaries. This is like attempting to understand the crustal dynamics of the Earth by only looking at surface features. It may be possible to measure some of the critical outputs of the ecosystem in a way that provides an insight into the internal dynamics and that could lead to some broad predictions about the behaviour of the ecosystem, especially when correlated with known inputs. In biogeochemical terms the inputs and outputs of an ecosystem involve primary production and the products of respiration plus the sequestration of organic carbon, in this case as sediment on the seabed. However, in ecological terms, the outputs could be seen as the terminal links in food chains, sometimes also known as the top of the food chain. Moreover, it may also be possible to understand the outputs from the terminal links in the food chains without the necessity of understanding the intermediate linkages between them and the physical-forcing processes that are the inputs driving the food-chain dynamics. Many who like to model the internal dynamics of these systems will consider this to be a leap of faith but, where the intermediate dynamics have complex properties, there may be no choice.

In practical terms, this means using the species at the top of marine food chains as our indicators of ecosystem status and performance. We refer to these species as 'top predators' but this is synonymous with 'upper-trophic-level predators'. For most purposes here we refer to top predators as pinnipeds (true seals, sea lions, fur seals and walrus), seabirds, cetaceans and some large predatory fish. In general, they are species beyond the level of secondary consumers. This approach has advantages and disadvantages as outlined below.

Advantages

(1) By definition, top predators are downstream, in terms of energy flow, of changes within an ecosystem. This means that changes in ecosystem structure that also affect the energy flows through the system are likely to be reflected in changes at the top of food chains.

(2) Top predators often exploit marine resources at similar spatial and temporal scales to those used by man, thus increasing the potential for competition. It is a truism of marine-ecosystem management that it is only possible to manage the activities of man; however, the data we collect about the marine ecosystem – data that come from these activities – are collected at similar spatial and temporal scales to those that are relevant to understanding how resource variability is likely to affect other predators that also forage at the same scales.

(3) Many predators are accessible during important parts of their life histories mainly because they have terrestrial breeding seasons. This also constrains their foraging ranges because of their need to return regularly to the breeding site. Not only does this make it relatively easy to provide consistent indices of population sizes, it also allows estimation of regional productivity from the productivity of the predators themselves. This advantage applies only to seabirds and pinnipeds, and has the effect of narrowing the focus of interest in using top predators as measures of ecosystem outputs to these groups. This bias is reflected in many of the following chapters.

(4) Most of the species used for measuring the outputs from ecosystems command a high level of public interest and studies of them are likely to attract support over the long time periods needed to measure these ecosystem outputs.

Disadvantages

(1) Measuring the changes in top-predator populations or in the behaviour, performance or productivity of predators does not necessarily titrate the effects of different management interventions within ecosystems.

(2) Top-predator responses are not necessarily predictive so they are difficult to use in the context of classical fisheries science to set catch levels, although there may be some circumstances where they can help define the broad boundaries of catch limits (e.g. Boyd 2002).
(3) Not all situations in which there is a need for management have an appropriate community of predators available for study. In fact, predators appropriate for use in the context of fisheries management are mainly confined to temperate and subpolar regions and even then they are likely to be of most relevance to coastal and shelf-seas management.
(4) By their very nature, top predators may be several trophic links remote from the main drivers of change in ecosystems, especially if these drivers affect the distribution and abundance of primary production. This could lead to attenuation of signals from variation in inputs to the ecosystem, either through the effects of physical forcing or through the effects of management actions.
(5) Responses of different predators to the same management or environmental drivers may differ, not only in terms of magnitude but even in some cases in the direction of response. In reality, many predator studies are of single species – or at best groups of similar predators – and this makes it difficult to assess consistency of responses. Ideally the emphasis should be on integrated multispecies approaches but securing funding for this is often problematic.

This book sets out to explore the hypothesis that top predators can be used in a whole-system approach to managing marine ecosystems. In some circumstances these predators may also provide information relevant to the management of specific resources. The emphasis on this hypothesis does not preclude other approaches or imply that measuring predator responses will always be informative. However, such an approach could potentially be part of the set of measures, insights and interpretations used within sophisticated management systems. Such an integrated approach is particularly useful where there is a need to balance the competing demands for adequate precaution in setting resource exploitation levels against the economic and social demands to increase these levels of exploitation still further. It takes the focus of attention away from the resource being managed and places it onto the ecosystem in a way that is comprehensible to most components of the decision-making hierarchy of the management structure and to the public.

The book represents a collection of case studies and reviews of top predators as indicators of marine-ecosystem dynamics. Many of these studies are