Despite its remote and seemingly rigorous environment, the Antarctic is the world's most important habitat for seals, currently supporting more seals than all other parts of the world combined. As various national Antarctic programmes were established to study these animals, the need to standardize techniques became apparent. This book, arising from work by the Scientific Committee on Antarctic Research (Group of Specialists on Seals), gives a detailed account of well-tried and, where possible, agreed methodologies, techniques, procedures and rationale for the collection and initial analysis of data on the biology and population ecology of Antarctic seals. This volume will not only help facilitate comparisons between different regions of Antarctica, but will also provide a guide for those studying seals in other parts of the world and those carrying out research on other large mammal species.

ANTARCTIC SEALS

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research methods and techniques

Edited by

R.M. LAWS
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Preface

The need for a handbook to standardize techniques for studying Antarctic seals was recognized during the initial meetings of the SCAR Group of Specialists on Seals. Even during various discussions between experts about the results from various national Antarctic programmes, it became clear that a lack of standardization sometimes made it difficult to make direct comparisons between studies. For example, even apparently small variations, such as the use of different types of tags placed in flippers for long-term identification of individuals had the potential to cause differences in estimates of population parameters. The problems of lack of standardization in data collection were even more critical when less experienced persons were involved. In remote areas such as the Antarctic where the number of personnel on a base or a ship may be limited, scientific and non-scientific staff with no training in pinniped research are sometimes required to record various types of observations on seals. Similarly, from time to time, non-experts may have unique opportunities to record very important observations on seals. Without a standardized format that could be readily available to everyone; it was clear that valuable opportunities and data would be lost and the full scientific value of some studies might not be realised. Consequently, the SCAR Group of Specialists on Seals undertook to produce a handbook of standardized techniques for the study of Antarctic seals, the benefits of which would also carry over to the study of Arctic seals and facilitate more bi-polar comparisons.

Completion of this volume has taken longer than was originally envisaged. Meetings of the Group of Specialists were often dominated by current issues and needs which, at the time, seemed more pressing. The limited resources that were available for this task also meant that everyone had to make sacrifices of their own time and funds to facilitate completion

of the handbook. Similarly, as the volume was being developed, rapid advances were being made in several areas such as immobilization techniques, population estimation and genetics; to mention just a few. Consequently, the chapters have all undergone several revisions to make them as complete, practical and relevant as possible.

The resulting volume is a unique and comprehensive work that covers the techniques, procedures and rationale for the collection of data on the population ecology and biology of Antarctic seals. It will be of value for years to come as new and old seal scientists alike design and execute their research. It will be essential for less formally trained observers who, nonetheless, are required, or simply have the opportunity, to record important observations.

Recently, Dr Richard Laws stepped down as Convenor of the SCAR Group of Specialists on Seals. His contributions to the study of Antarctic biology as a whole, and the study of seals in particular, have been enormous. His critical eye and extensive experience that guided the production of this volume have significantly contributed to the quality of the final product. Recently, I became Convenor of the Group of Specialists and in that capacity I take great pleasure in congratulating Dr Laws and the other authors on the production of this valuable book.

Convenor *Donald B. Siniff*
SCAR Group of Specialists on Seals

Introduction

R.M. LAWS

The Antarctic Treaty System – the Antarctic Treaty and related international conventions – provides a legal and diplomatic regime for the Antarctic region. Its non-governmental counterpart, which is responsible for promoting scientific co-operation, is the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU). SCAR is the single international, interdisciplinary, non-governmental organization which can draw upon the experience and expertise of an international mix of scientists across the complete scientific spectrum. For over 30 years SCAR has provided scientific advice to the Antarctic Treaty System. The membership of SCAR comprises the National Committees of those national scientific academies or research councils which are adhering bodies to ICSU and which are, or plan to be, active in Antarctic research, together with the relevant Scientific Unions of ICSU. SCAR meets every two years to conduct its administrative business and agree policy and strategy. The majority of the scientific work of SCAR, however, is carried out by the Working Groups and Groups of Specialists. Groups of Specialists are created by SCAR in response to specific scientific problems and their members are appointed for the experience and expertise they can bring to the group. Laws (1986) has reviewed these arrangements in relation to Antarctic conservation and the Antarctic Treaty System.

The populations of Antarctic seals are believed greatly to outnumber all other seal populations in the world (Laws, 1984) and following the decline of the great whales are currently the largest group of animals feeding on krill – the staple food of most vertebrates in the Southern Ocean. The SCAR Group of Specialists on Seals, which developed from a subcommittee of the SCAR Working Group on Biology, has a dual role in research and management. It was formally constituted in 1974 to

enable SCAR to discharge its responsibilities under the Convention for the Conservation of Antarctic Seals (CCAS), part of the Antarctic Treaty System, for under this convention, SCAR has a significant role as an independent source of scientific advice (Articles 3–5). It is probably unique for a non-governmental body to be specified to fill such a role in an international convention of this kind.

This convention (the text of which is given in appendix 16.5) arose because the conservation measures (the Agreed Measures for the Conservation of Antarctic Flora and Fauna, 1964; text given in appendix 16.4) and other arrangements under the Antarctic Treaty could not give any protection to seals in the sea or on floating ice (Laws, 1986). This is owing to the fact that the Antarctic Treaty expressly reserves the rights of states under international law with regard to the high seas. CCAS was signed in 1972 and entered into force in 1978. It applies to all species of Antarctic seals and SCAR seal biologists played an important part in bringing it about.

The SCAR Group of Specialists on Seals has the following terms of reference:

1. To encourage the exchange of scientific data and information, to recommend research programmes, to co-ordinate seal research undertaken by SCAR nations, with particular reference to marking programmes, and to encourage standardization of techniques.
2. To scrutinize figures for the number of seals killed and to compile periodic summaries of these for publication.
3. To review the status of Antarctic seal stocks. If commercial sealing begins: to analyse catch returns, estimate and report to SCAR the dates by which the permissible catch limits are likely to be exceeded; to report to SCAR when the harvest of any species of seal is considered to be having a significantly harmful effect on the total stocks of such species, or on the ecological system in any particular locality.
4. To consider what statistical and biological information should be collected by sealing expeditions, and if necessary to make arrangements for its processing and analysis; to liaise with biologists accompanying sealing expeditions.
5. To report on methods of sealing and to make recommendations with a view to ensuring that the killing or capturing of seals is quick, painless and efficient.

6. To recommend amendments to the Annex to the Convention on the Conservation of Antarctic Seals.
7. To maintain liaison with international organizations concerned with marine mammals, such as IUCN and FAO.

Thus, through SCAR the group would, in the unlikely event of commercial sealing starting in the Antarctic, provide initial advice to control such exploitation, until the governments participating in CCAS established their own scientific advisory committee. The work of the group also has relevance to the aims of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) (appendix 16.6), because of the key role of seals in the Antarctic marine ecosystem. The group has responded to requests for advice from the scientific committee of CCAMLR, particularly in respect of ecosystem monitoring and the effects of marine debris.

In order to discharge these responsibilities the Group of Specialists on Seals has held eleven meetings since 1974 and has discussed problems by correspondence.

Thus, the group is concerned about research and conservation issues that focus on the seven Antarctic and sub-Antarctic seal species. Four of these species, the Ross, Weddell, leopard and crabeater seals, occupy the pack ice zone. The southern elephant seal and two species of fur seals have a more northerly distribution and breed mainly on the peripheral Antarctic and sub-Antarctic islands (Laws, 1984). The Antarctic seals are important in global terms for they are thought to be more abundant, in terms of both numbers and biomass, than all other seals in the world combined. The Group of Specialists is interested in research on all aspects of the biology of Antarctic seals: population ecology, behaviour, reproduction, growth and age, feeding and diet, and energetics. A major objective for Antarctic seal research is to use measures such as growth rates, reproductive rates, survival, foraging areas, feeding depths, energetics and general health, as indicators of ecosystem conditions. This is very relevant to the work of CCAMLR. Although a modern Antarctic sealing industry has not developed, the work of the group is particularly important in the face of commercial harvesting of fish and krill, and the increasing pressures of tourism and other human activities.

The present publication arises as a result of activities of the group relating to the first, fourth and fifth terms of reference, particularly the desirability of standardizing techniques and co-ordinating seal research. The summaries called for under the second term of reference have been published in the *SCAR Bulletin* (*Polar Record*, vol. 16 (101), pp. 343–5;

vol. 16 (105), pp. 901–2; vol. 18 (114), pp. 318–20; vol. 20 (125), pp. 195–8; and vol. 23 (146), pp. 622–7). These cover the period 1964–85. Subsequent summaries have been published in the reports of meetings of the SCAR Group of Specialists on Seals. The third term of reference – the review of the status of Antarctic seal stocks – is addressed at meetings of the Group and conclusions are published in the reports of these meetings.

The Group submitted a detailed report to the first Review Meeting held under the CCAS, in London, 12–16 September 1988. This had two purposes, first to describe how SCAR, through the Group of Specialists on Seals, has discharged its responsibilities under Article 5 of the Convention and paragraph 7 of its Annex. Secondly, the report offered information and views on scientific matters relating to the Convention and its Annex, and to the Agenda and papers for the Review Meeting.

Some published reviews of the biology of Antarctic seals are by Ridgway & Harrison (1981), King (1983), Laws (1984), and Reidmann (1990). Comprehensive information on diving physiology is given by Kooyman (1981), and Laws (1985, 1989) has reviewed the broad environmental and ecological background to studies of Southern Ocean ecosystems. The present publication does not address biological research on the Antarctic seals as such, but is specifically concerned with recommending tried, and where possible agreed, methodologies and techniques to be used in such research. There is an intentional bias towards field work, but relevant, sophisticated laboratory methods are also included. Thus, it is hoped that it will be helpful to non-specialists, who have the opportunity to make useful contributions. It also draws attention to new and developing techniques. We hope that it will encourage research, promote the adoption of standard techniques and the development of better ones. We expect that the information will also be useful to workers on other mammalian groups.

Following this introductory chapter, there is advice on the field identification of seven species: the southern elephant seal, *Mirounga leonina*; Weddell seal, *Leptonychotes weddellii*; Ross seal, *Ommatophoca rossii*; crabeater seal, *Lobodon carcinophagus*; leopard seal, *Hydrurga leptonyx*; Antarctic fur seal, *Arctocephalus gazella*; and the sub-Antarctic fur seal, *Arctocephalus tropicalis*. From the information and illustrations given, distance identification of adults should be possible; other information is provided to enable confirmation of the species in doubtful cases, if a closer approach is possible, if the animal is dead, or if only a skeleton or skull is found.

A knowledge of animal abundance is vital to all ecological studies and is particularly important for determining population trends and to formulate management and conservation policies; this is addressed in chapter 2. Ground, ship-based and aerial counting methods and population estimation are different for land-breeding and ice-breeding species. Mark–recapture techniques are also described in this chapter. Methods of extrapolating from density estimates to total population size are also treated, taking account of practical considerations relating to the polar environment.

For a number of purposes connected with research it may be necessary to restrain or immobilize a seal and this is dealt with in chapter 3. The categories of drugs available and the best methods of administering them are described, with special reference to both southern phocid seals and the fur seals. Other methods of capture, such as the use of a restraining sack may be adequate or appropriate for certain studies and are described.

Chapter 4 deals with marking techniques and programmes including: branding (hot-iron, freeze and explosive), punching and tattooing, tagging with plastic and metal tags, vital staining to establish rate of deposition of layers in teeth, the use of natural marks, paint, dyes and hair clipping to identify individuals. Some recommendations are made for standardizing numerical marking. A central seal tagging database is maintained through the Group of Specialists.

Rapid advances in the field of electronics in recent years, in particular the miniaturization of solid state circuitry through semiconductor technology, has made it feasible to deploy highly sophisticated instruments on free-ranging animals. Chapter 5 briefly outlines the types of instruments deployed in research. The main categories of instrument described are radio-telemetry (transmitters, receivers and recorders), sonic devices (recording vocalizations, sonic transducers and transponders), self-contained recorders (time-depth recorders, gastro-thermo recorders, geolocation by daily light levels, satellite linkage and transmission). A section on attachment methods is also included (harnesses, bracelets, glues and epoxy resins).

This naturally leads on to behaviour studies and in chapter 6 recommendations are made, mainly on the terrestrial aspects of seal behaviour (aquatic activities requiring telemetry are discussed in chapter 5). Behavioural observations are very relevant to interpreting population ecology as well as several other aspects of seal biology. Recommendations cover necessary background information that should be collected, recording vocalizations in air and underwater, detailed intraspecific

behaviour, including territorial and reproductive activities, and interspecific behaviour. Sampling methods and techniques for recording data are discussed.

For some research studies, however, seals have to be killed, and one of the terms of reference of the Group of Specialists was to make recommendations with a view to ensuring that the killing or capturing of seals by sealing expeditions or by research workers is quick, painless and efficient. Chapter 7 gives recommended methods of shooting, chemical euthanasia and clubbing. Under the Agreed Measures for the Conservation of Antarctic Flora and Fauna and the CCAS, seals can only be killed or captured under permits issued by national authorities, and the results are included in the exchange of information under Article XII of the Agreed Measures and Article 5 of CCAS.

If an animal is killed, whether for scientific or other purposes (for example for food for people or dogs in the Antarctic) it is important to try to make the fullest possible use of it that time and resources permit. However, there is little point in people collecting material which they do not intend to process themselves, without having made prior arrangements for its subsequent treatment. Some analyses are time-consuming or expensive, or both, and it may not be possible to find another research worker to process the material. Much time and effort can be saved by undertaking this preliminary advance planning. Chapter 8 advises on four basic collection needs most relevant to population ecology in research and management. The fundamental data to be recorded for each specimen include the recommended basic measurements and weights, the basic material to be collected and the recommended preservatives. The need to minimize the risk of infection (such as 'seal finger') is emphasized. Detailed instructions are given for collecting material for age determination (teeth and toe nails) which is fundamental to most studies. Priorities and methods of collection for skeletal material are recommended (skull, skeleton and baculum). Priority for collecting reproductive specimens is given to female material because it contributes more to the understanding of essential population parameters such as pregnancy rates and age at first reproduction. (More specialized requirements are given in some later chapters, for example chapters 9 to 13.)

Chapter 9 is concerned with genetic-based studies which contribute to meeting the basic need of distinguishing between stocks, because both in terms of basic population biology and for management studies it is desirable or essential to establish the unity and integrity of the stocks concerned. Sample size and related considerations are discussed, and

an outline of methods of collecting and preparing blood, plasma and serum samples is given. Gel eletrophoresis techniques are referenced. The analysis of polymorphic data is considered and an expression to estimate the genetic similarity of two populations is given.

With the increasing concern about pollutants in the environment and the demonstration of accumulation of such substances in the tissues of Antarctic animals, opportunity may be taken to collect samples for determination of pollutant levels, when seals are killed for other reasons. The contaminants include organochlorine residues and heavy metals, and recommendations for collecting and preserving samples are given in chapter 10.

As mentioned earlier, age determination is a basic tool in population biology research on mammals, particularly in studies of body growth rates, age-specific reproductive rates and other aspects of population dynamics. Chapter 11, on age determination, concentrates on the best proven method, depending on incremental lines in the teeth. The tooth structure and methods of preparing sections for examination are described, with literature references. There is a need to reduce confusion and ambiguity, particularly in relation to complex dentine structures; cementum has a much simpler structure. Aspects covered include: collection and storage, use of external and internal structures (direct sectioning, etching, decalcification and staining). Because of its importance the recommended methodology for preparation and reading is given for each species. The methods are not without error, and reliability and validation are specifically addressed. Other methods described more briefly are nail markings, laminated bones, body length, eye lens weight, suture closure, baculum development, ovarian structure (treated in greater detail in chapter 12), pelage and general appearance.

An understanding of the salient features of the reproductive cycle is fundamental to several aspects of seal biology, especially population ecology and behaviour. Reproductive status, pregnancy rate and reproductive success, and changes in the age at maturity are examples of the kind of quantitative data it is necessary to acquire. Chapter 12 provides an introduction to the seal reproductive cycle and organs of reproduction which should enable newcomers to the subject to find their way about. First the male reproductive system, including the gross and fine anatomy of the testis, epididymus, prostate, penis and baculum (the penis bone), is described. Then the fine and gross anatomy of the female reproductive tract – ovaries (and their follicles, corpora lutea, the corpus albicans and its regression) the uterus and vagina. Delayed implantation of the

blastocyst, foetal growth and the estimation of foetal age, and the phenomenon of neonatal gonad hypertrophy are also covered. Quantitative aspects relate to the estimation of pregnancy rates, the secondary sex ratio, puberty and sexual maturity. A standard method of calculating the average age at sexual maturity is given so that meaningful comparisons between populations and time periods can be made. Recent developments in DNA technology have revealed very powerful methods of studying relatedness between individuals, with a resolution capable of accurately assigning a pup to one or both parents. This is known as DNA fingerprinting and is particularly important in determining paternity and hence reproductive success of individual males. It also has other applications such as the serial identification of individuals. These methods are summarized in this chapter. Finally some basic histological and analytical methods are given, including specific instructions for collecting material for electron microscopy.

Estimation of food consumption is a very important aspect of Antarctic seal studies because of the history of perturbations and interactions in the Southern Ocean ecosystem (Laws, 1985, 1989). It is usually approached by combining dietary data, dealt with in chapter 13, with metabolic energy requirements, considered in chapter 14, but much research still needs to be done before we have adequate quantitative information on the diet and its quality in energetic terms.

Chapter 13 recommends methods of obtaining, recording and preserving material suitable for these studies, from complete stomachs and intestines of killed seals, partial samples from stomachs of live seals, and the collection of faecal droppings or regurgitations. The ultimate aim is to record the weight and/or volume of individuals of each prey species, together with information on their size, age and reproductive status. Recommended methods of sorting and identification of food samples (including fragmentary material such as eyes, otoliths and beaks of crustaceans, fish and squid) are given with appropriate literature references. Biochemical techniques have also been used for very detailed studies. Finally, the problems and biases likely to be encountered in quantifying and interpreting the results of these studies, and ways of compensating for them, are outlined. An index of relative importance (IRI) and a modified volume index (MVI), which are useful compromises, are described and compared.

Chapter 14 is concerned with bioenergetics, which provides a common currency for comparative studies and is a powerful method of quantifying many aspects of animal life histories. The kinds of questions that may

be addressed in such studies are outlined, namely: the costs of reproduction in the two sexes, the energetics of foraging and year to year changes in energy availability and use. The methods described include: estimation from change in mass (converted to energy terms); radioisotope dilution method, based on the difference in water content of lean and adipose tissue; measurement of correlates of energy expenditure, by means of activity budgets and heart rate telemetry; the relation between food intake and water influx, using radioisotopes; swimming energetics using time-depth recorders coupled to heart rate telemetry; the assessment of animal condition in terms of energy stores, using blubber layer thickness and radioisotope dilution to estimate water; and energy consumption, also using radioisotope methods.

The last chapter is concerned with the development of techniques for research. The objectives and the types of research programmes needed to meet them are outlined. They relate both to improved understanding of the basic biology of seals and to meeting the perceived needs of two international conventions within the Antarctic Treaty System, on the conservation of seals and other elements in Antarctic marine ecosystems (appendices 16.5, 16.6). The suggested research programmes are broadly framed so as to indicate where methodology and techniques particularly need to be improved. Emphases may well change as existing technical problems are solved, new research problems arise and new opportunities are grasped.

Finally, there are seven appendices covering the origins of the scientific names of the species of Antarctic seals, their vernacular names in different languages, and the scientific names of mammal species referred to, as well as the texts of the Agreed Measures for the Conservation of Antarctic Flora and Fauna, the Convention for the Conservation of Antarctic Seals, the Convention for the Conservation of Antarctic Marine Living Resources and the SCAR Guidelines on Animal Experimentation in Antarctica.

The changing membership of the Group of Specialists on Seals over the period of preparation of this publication included: J.L Bengtson, M.N. Bester, I.L. Boyd, H. Burton, J.P. Croxall, A.W. Erickson, R.M. Laws, A.W Mansfield, Y. Naito, T. Øritsland, L.A. Popov, D.B. Siniff, D. Torres Navarro and D. Vergani. R.M. Laws and D.B. Siniff were respectively Convenor and Deputy Convenor of the Group until 1988, when D.B. Siniff became Convenor; J.L. Bengtson was Secretary from 1988.

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