Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Risk assessment concerning the welfare of certain free-ranging wild mammals and birds subjected to marking

Opinion of the Panel on Animal Health and Welfare of the Norwegian Scientific Committee for Food Safety

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Persons working for The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM), either as appointed members of the Committee or as *ad hoc* experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Acknowledgements

The Norwegian Scientific Committee for Food Safety has appointed an *ad hoc* group consisting of both VKM members and external experts to provide a background report to make it possible to answer the request from the Norwegian Food Safety Authority. The members of the *ad hoc* group are acknowledged for their valuable work on this opinion.

<u>The members of the *ad hoc* group are:</u>

VKM members

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Assessed by

VKM has asked the *ad hoc* group to prepare a background report concerning the animal welfare of certain free ranging wild mammals and birds subjected to marking. VKM Panel on Animal Health and Welfare has used this report as a basis to answer the request from the Norwegian Food Safety Authority.

Panel on Animal Health and Welfare:

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Summary

The Norwegian Food Safety Authority asked the Norwegian Scientific Committee for Food Safety Panel on Animal Health and Welfare (VKM) for a risk assessment concerning the welfare of certain free-ranging wild terrestrial and marine mammals and birds subjected to marking. To prepare scientific background documents necessary to answer the questions, the Norwegian Scientific Committee for Food Safety, Panel on Animal Health and Welfare, established an *ad hoc* group consisting of both VKM members and external experts. The number of species involved and the number of methods that are described was high and, for most species and methods the scientific documentation is incomplete. In the assessment many species, especially birds and pinnipeds, have been treated as groups and not individual species. In addition, data about some of the population sizes are sparse.

Wild animals are adapted for a life in the free, and hazards that can threaten their life, health or welfare are normal parts of their existence. All free-living animals are subjected to natural challenges such as diseases, starvation or predation or man-made hazards such as hunting, traffic, oil (and other) pollution or destruction of habitat. The overall welfare risk of populations from capture and marking are, in comparison, limited or negligible. The focus of this assessment is anyhow on the welfare risks of individual animals created by the need to catch and mark them in a scientific or management context.

In general, any capture or marking of wild animals will interfere with the normal behaviour of the animal and pose a risk to its welfare. The need for science-based national or international regulation of this practice is relevant.

The Norwegian Food Safety Authority asked the following question:

A. How do the most commonly used capture and handling methods influence the welfare of free ranging wild terrestrial and marine mammals and birds?

The capture and handling procedures that are commonly used are thoroughly described and discussed. Some general conclusions are made:

- Capture techniques should be effective and not involve unnecessary periods of chasing or entrapment.
- The immobilization techniques used should not cause unnecessary pain or stress.
- Chemical restraint can be used when it is appropriate and safe.
- Immobilization should only be performed by properly trained personnel.
- Following immobilization, the animals should be monitored until they are able to behave normally.

The following methods are considered to pose a high risk of negative welfare:

- Darting from helicopter of terrestrial carnivores because of the heavy fear and stress reactions during chasing and the following possibility of mortality from chemical immobilization.
- Use of coil spring traps to capture otters and lynx, because of the heavy stress and pain reactions induced by trapping and the relative high frequency of trauma.

The following methods are considered to pose a medium risk of negative welfare:

- Darting from helicopter of moose and polar bears because of the possibility of mortality from chemical immobilization.
- Darting from the ground of walrus because of the possibility of mortality from chemical immobilization.
- Net traps in water to catch aquatic mammals and birds, because of the stress reactions induced by capture and the possibility of drowning.
- Use of mist nets to capture flying birds because of the stress reactions induced by capture and the possibility of serious damages to feathers, muscles and skeleton when trapped and released.
- Use of box traps for roe deer, arctic foxes and lynx because of the stress associated with trapping and the following negative welfare impact of manual handling and chemical restraint.

B. How do the most commonly used marking methods and procedures influence the welfare of free ranging wild terrestrial and marine mammals and birds?

The marking methods that are commonly used for different wild species are thoroughly described and discussed. Some general conclusions are made:

- It is not possible to mark an animal with a device that has no implications to its welfare, either at the time-point of marking or during the period that the mark is being carried by the animal. However, many of the commonly used marking techniques have negligible negative effects on most species.
- The weight, shape and size of the marking device should be adapted to the animal that carries it, and it should not interfere with normal behaviour, health or welfare.
- If the device does interfere to some extent with the normal behaviour, health or welfare of the individual, the device should be removed as soon as possible, either by a drop off mechanism or by recapture and removal of device.

The following methods are considered to pose a high risk of negative welfare:

- Body harnesses in otters and birds, because of the possible entangling in vegetation and problems related to drop off effects.
- Heat and freeze brands, because of the long lasting pain and recovery time.

The following methods are considered to pose a medium risk of negative welfare:

- Nasal discs and saddles in ducks because of ice buildup under severe winter conditions and entanglement with submerged vegetation.
- Flipper bands in penguins, because of documented negative effects on survival.
- Intraperitoneal implants, because of the hazard connected to the surgical procedure and the possible impact of the implant to the physiological functions of the peritoneal cavity.

Norsk sammendrag

Mattilsynet har bedt Vitenskapskomiteen for mattrygghet ved Faggruppen for dyrehelse og dyrevelferd om en risikovurdering av velferd ved merking av visse ville arter av terrestriske og marine pattedyr og fugler. For å utarbeide de vitenskapelige bakgrunnsdokumentene som var nødvendige for å svare på spørsmålene fra Mattilsynet, nedsatte Vitenskapskomiteen for mattrygghet, Faggruppen for dyrehelse og velferd, en prosjektgruppe bestående av både VKM-medlemmer og eksterne eksperter.

Antallet dyrearter som er involvert og antall merkemetoder som er beskrevet er mange. For de fleste arter og metoder er den vitenskapelige dokumentasjonen som foreligger ufullstendig. I vurderingen er mange arter, særlig fugle- og selarter, blitt behandlet som grupper og ikke som individuelle arter.

Ville dyr er tilpasset et liv i det fri. Å bli utsatt for farer som kan true deres liv, helse og velferd er normaltilstanden. Ville dyr blir utsatt for naturlige utfordringer som sykdommer, sult, predasjon eller menneskeskapte farer som jakt, trafikk, forurensning eller ødeleggelse av habitat. Den samlede velferdsrisikoen for ville dyrepopulasjoner i forbindelse med innfangning og merking er, til sammenligning, begrenset eller ubetydelig. Fokus for denne vurderingen har imidlertid vært på risikoen for dårlig velferd for enkeltindivider på grunn av behovet for å fange og merke dem i en vitenskapelig eller forvaltningsmessig sammenheng.

Generelt vil enhver fangst eller merking av ville dyr forstyrre deres normale adferd og utgjøre en risiko for dyrets velferd. Det er derfor et behov for vitenskapelig basert regulering av virksomheten.

Mattilsynet har bedt VKM om å vurdere følgende spørsmål:

A. Hvordan påvirker de mest brukte fangst- og håndteringsmetodene velferden til ville terrestriske og marine pattedyr og fugler?

De vanligste fangst- og håndteringsprosedyrene er grundig beskrevet og diskutert i vurderingen. VKM har kommet fram til noen generelle konklusjoner:

- Fangstmetodene skal være effektive og ikke medføre unødvendige tidsperioder med jaging eller innfanging.
- Immobiliseringsteknikker skal ikke medføre unødig smerte eller stress.
- Medikamentell immobilisering kan brukes når det er hensiktsmessig og trygt.
- Immobilisering skal kun utføres av kompetent personell.
- Etter immobilisering skal dyrene overvåkes inntil adferden er normalisert.

Følgende innfangingsmetoder anses å utgjøre en høy risiko for dårlig dyrevelferd:

• Påskyting med injeksjonspil fra helikopter på terrestriske rovdyr. Dette på grunn av de alvorlige frykt- og stress reaksjonene under jakten og påfølgende muligheter for dødelighet forårsaket av medikamentell immobilisering.
• Bruk av fotsaks til fangst av oter og gaupe på grunn av stress- og smertereaksjoner indusert

av fangsten samt den relativt høye frekvensen av traumer.

Følgende metoder anses å utgjøre en middels risiko for dårlig dyrevelferd:

• Påskyting med injeksjonspil fra helikopter av elg og isbjørn, på grunn av muligheten for dødelighet ved medikamentell immobilisering.
• Påskyting med injeksjonspil av hvalross på grunn av muligheten for dødelighet ved medikamentell immobilisering.
• Fangstnett i vannet for å fange vannlevende pattedyr og fugler, på grunn av stressreaksjoner indusert ved fangst og muligheten for drukning.
• Bruk av fangstnett for å fange flygende fugler på grunn av stressreaksjonene indusert ved fangst og muligheten for alvorlige skader på fjær, muskler og skjelett.

• Bruk av båser (box traps) for rådyr, fjellrev og gaupe på grunn av stress forbundet med fangst og manuell håndtering samt fare for dødelighet ved medikamentell immobilisering.

B. Hvordan påvirker de mest brukte merkemetodene velferden til ville terrestriske og marine pattedyr og fugler?

De vanligste merkemetodene som benyttes for de ulike arter er grundig beskrevet og diskutert. VKM har kommet fram til noen generelle konklusjoner:

- Det er ikke mulig å merke et dyr uten konsekvenser for dyrets velferd. Flere av de mest brukte merketeknikkene har imidlertid ubetydelige negative konsekvenser.
- Vekten, formen og størrelsen på merket skal tilpasses dyret, og det skal ikke forstyrre dets normale oppførsel, helse eller velferd.
- Hvis merket forstyrrer normal adferd, helse eller velferd skal merket fjernes så snart som mulig, enten ved en drop-off mekanisme eller, hvis mulig, ved gjeninnfanging av dyret og deretter fjerning av merket.

Følgende metoder anses å utgjøre en høy risiko for negativ dyrevelferd:

• Seletøy på oter og fugler, på grunn av muligheten for å sette seg fast i omkringliggende vegetasjon og fordi seletøyet ikke faller av som planlagt.
• Brenne- og frysemerker på grunn av langvarig smerte- og rekonvalesenstid.

Følgende metoder anses å utgjøre en middels risiko for negativ dyrevelferd:

• Neseplater og nesesadler på ender på grunn faren for å sette seg fast i vegetasjon og muligheten for isdannelse på nebbet under krevende vinterforhold.
• Vingebånd på pingviner på grunn av dokumenterte negative effekter på overlevelse.
• Intraperitoneale implantater på grunn av faren forbundet med det kirurgiske inngrepet og den mulige påvirkning implantatet kan ha på de fysiologiske funksjonene i bukhulen.

Beskrivelse av metoden som er brukt for å beregne og rangere risiko finnes på side 128. Grafisk fremstilling av risiko knyttet til innfangings- og merkingsmetoder finnes på side 129-130.

Keywords

Animal welfare, wild animals, wild birds, capture methods, marking methods, marking devices

Contents

Background

In recent years, the marking of free-ranging wild animals for conservation, research and management purposes has increased in Norway. Along with the development of highly sophisticated capture techniques, new and equally sophisticated marking methods have been developed. Wild animals may be fitted with instruments ranging from simple tags to telemetric cameras, GPS packages and transceivers to provide position and other basic information to scientists and others that may need this information.

Animal welfare concerns associated with these activities not only relate to the marking methods, but also to the required capture and handling procedures prior to, during, and after marking and release. Also there might be possible long-term effects from the operations combined. Additionally, there might be animal welfare concerns related to marking and re-marking, both on the level of the individual animal and at population level.

The Norwegian Food Safety Authority is planning a new regulation pertaining to the marking of free-ranging wild animals. The new regulation shall ensure good welfare for wild animals subjected to marking in compliance with the rules laid down in the new Animal Welfare Act. Only proper marking methods that do not cause any behavioural limitations or unnecessary suffering to the animal should be used. According to the legislative background of the Act, Proposition to the Odelsting No.15 (2008-2009), marking means a change in the appearance of the animal or fixing objects to the animal to make it easier to identify it, the animal's owner, or to provide its position. The rules on marking should be seen in connection with those regarding medical and surgical treatment and the use of animals in research and education. The new regulation may include a command for or prohibition of marking as well as general conditions and procedures for the use of certain marking methods.

The Norwegian Food Safety Authority requested the Norwegian Scientific Committee for Food Safety to assess the risk of impairing the welfare in wildlife subjected to marking for research, conservation, or management purposes.

To prepare the scientific background necessary to answer the questions from the Norwegian Food Safety Authority, the VKM Panel on Animal Health and Welfare established an *ad hoc*-group consisting of both VKM members and external experts. The group was chaired by Dr. Kristian Hoel from the Panel on Animal Health and Welfare. VKM Panel on Animal Health and Welfare used the report from the *ad hoc* group as a basis to answer the request from the Norwegian Food Safety Authority.

This risk assessment is conducted according to the intensions layd down in EFSAs "Guidance on Risk Assessment for Animal Welfare" (2012).

Terms of reference

Description of the assignment

In order to base new legislation upon scientifically based knowledge, the Norwegian Food Safety Authority requests the Norwegian Scientific Committee for Food Safety, Panel on Animal Health and Welfare to assess the risk of impairing the welfare of the following wildlife species when subjected to marking for research, conservation, or management purposes:

Terrestrial mammals

Moose (*Alces alces*)

Red Deer (*Cervus elaphus*)

Reindeer (*Rangifer tarandus tarandus*)

Svalbard Reindeer (*Rangifer tarandus platyrhynchus*)

Roe Deer (*Capreolus capreolus)*

Fallow Deer (*Dama dama*)

Musk ox (*Ovibos moschatus*)

Brown Bear (*Ursus arctos*)

Grey Wolf (*Canis lupus*)

Wolverine (*Gulo gulo*)

Lynx (*Lynx lynx*)

Arctic Fox (*Vulpes lagopus*)

European Otter (*Lutra lutra*)

European Beaver (*Castor fiber*)

Marine mammals

Polar Bear (*Ursus maritimus*)

Pinniped species belonging to the *Phocidae* (earless seal) and *Otariidae (eared seal)* families

Cetacean species belonging to both the *Odontoceti* (toothed whale) and *Mysticeti* (baleen whale) suborders

Birds

Bird species belonging to the following orders:

Falconiformes (falcons)

Accipitriformes (eagles, hawks, and buzzards)

Strigiformes (owls)

Anseriformes (geese, swans and sea-ducks)

Charadriiformes (waders, gulls and auks), and

Sphenisciformes (penguins).

The commission should be limited to pinniped, cetacean, and bird species belonging to the Norwegian fauna, including those on Svalbard, Jan Mayen and the dependencies, which have been subjected to marking in recent years.

The assessment should include:

Methods

The assessment should focus on and include description of marking methods or the combination of methods relevant to each species. In cases where the same marking methods are relevant in several closely related and comparable species, the risk of impairing the welfare in these species may be assessed jointly. Information should be given for any relevant method although documentation as far as animal welfare is concerned, is scarce.

These methods may be

1. used externally as simple tags attached to neck, leg, flipper, or wing, and/or telemetric equipment/other equipment attached as:
    a. ear tags, tail tags, or collars (expandable, breakaway), or other (for terrestrial mammals),
    b. glue-on models (back or head mount), models attached using a hole into the flippers, or other (for marine mammals),
    c. necklace, backpack, leg or neck band models, or other (for birds), or
2. placed internally as:
    a. subcutaneous implants
    b. peritoneal, rumen or vaginal implants, or other.

Any significant risk of impaired welfare in the individual animal in connection with marking should be addressed, including risks related to the most commonly used capture and handling techniques for each species. The cumulative risk of impaired welfare from these operations combined, both in a short and long-term perspective, should provide background for the assessment. Animal age, weight, gender, reproductive status, and season should be taken into consideration. Where relevant, additional welfare risks to the individual animal and its population related to recapture and re-marking should also be addressed.

Risk factors

A. Marking methods and procedures

Special attention should be given to the following risk factors related to the marking methods and procedures:

– the skills of the person marking the animal
– the procedure/surgical technique used to attach or implant the marking device, including

postoperative complications and pain management

- the marking device, i.e.:
    - the weight, shape and suitability in relation to the animal carrying it
    - the pain or discomfort it causes
    - whether it:
        - restricts the animal's ability to breathe naturally, to move naturally in its natural environment/element, to search for food, or to rest naturally
        - causes lesions or disease
        - makes the animal more prone to injuries and accidents
        - alters the animal's behaviour
        - causes changes in social structure, such as rejection from the group
        - causes mortality
        - causes altered predator/prey relationships
        - usually works as expected
- possible impacts from post-marking tracking activities

B. Capture and handling procedures

Special attention should be given to the following risk factors related to the capture and handling procedures:

- the skills of the person or persons capturing and handling the animal
- the tracking method and duration, including risks related to the animals´ experience from earlier capture episodes
- the chasing and capture methods (physical or chemical capture), and duration of both. Special attention should be given to the animals´ susceptibility to adverse physiological changes or fatal consequences from excessive running, struggling and exertion
- in case of physical capture: the restraint and handling procedures
- in case of chemical capture and restraint: impact from the dart, possible harmful effects from the immobilizing drugs used, the importance of both monitoring the anesthetised animal and possibility of emergency treatment
- sampling procedures, including pain management
- post-capture
    - risks related to possible:
        - changes in the animals´ mobility, behaviour, social structure, and predator/prey relationships
        - injuries, accidents, abortion, disease (e.g. capture myopathy), and mortality
    - follow-up procedures and duration
    - recapture and re-marking the same animal

The need for more research should be stated where relevant.

Summarised The Norwegian Food Safety Authortity want answers to the following questions:

A. Capture and handling procedures

How do the most commonly used capture and handling methods influence the welfare of free ranging wild terrestrial and marine mammals and birds?

B. Marking methods and procedures

How do the most commonly used marking methods and procedures influence the welfare of free ranging wild terrestrial and marine mammals and birds?

Introduction

> "*Fundamental to basic and applied ecology is an understanding of the physiology, behaviour and energetic status of unrestrained organisms in the natural environment*" (Cooke et al. 2004).

While much biological research on animals is done in the laboratory using animals bred under strictly controlled conditions and especially for the purpose, there is also an essential need to study and understand the lives of animals in their natural environment. Through very selective breeding, laboratory animals are often adapted to laboratory life and their morphology, physiology and behaviour are no longer representative of their wild-living conspecifics with many having lost their natural traits and ability to survive in the wild. As such, to understand a given species' life-history, behaviour, ecology and adaptations to the natural environment, and the variation of these among individuals, it is essential that studies are also carried out on free-living animals. Such studies are often aimed at or, in the case of pure scientific studies, can contribute to developing optimal managerial or conservation strategies for species under the threat of human-caused changes of the environment, their habitat, food-base, etc. As such, the animals studied and perhaps others that share their habitat may benefit from the research. As stated by Fair et al. (2010) "*Whether the primary motivation of the study is the advancement of scientific knowledge or the acquisition of information used for management purposes, wildlife research yields results that are directly relevant to the welfare and conservation of the species, communities, and ecosystems studied. Indeed, species conservation would not be possible without a solid base of information derived from field studies and it could be argued that conservation decisions and actions made without the benefit of a scientific basis could be ineffective or even harmful*".

Scientific studies of animals often require that the animals are captured to gather morphometric data and to collect samples for pathological, genetic, and biogeochemical analysis. These data and samples can be used to understand evolutionary relationships, genetics, population structure and dynamics, comparative anatomy and physiology, adaptation, behaviour, parasites and diseases, geographic distributions, migration, and the general ecology of wild populations of animals. This knowledge informs us about animal biology and natural history and is necessary to effect science-based conservation and management policies for game and non-game species, endangered species, economically important species, and animal habitat conservation (paragraph adapted from Fair et al. 2010).

To enable identification of individuals, a wide variety of marking techniques have been developed through the years, a variety that is paralleled by that of techniques developed to capture those individuals. In recent years, the development of microtechnology has further enabled researchers to deploy a wide variety of tracking and logging devices that has revolutionized remote data collection from free-living animals, and provided unforeseen insight into e.g. migration patterns, ecophysiology, feeding ecology, interspecies relationships, behaviour, etc.

This risk analysis describes commonly-used marking and capture techniques for birds and marine and terrestrial mammals and discusses the effects they may have on the animal's well-being and survival. While examples and literature references are drawn from studies throughout the world, focus is put on animals caught and studied in Norwegian territories, i.e. Norwegian mainland, Svalbard and parts of the Antarctic.

There are five principle avenues that researchers are obliged to follow to minimize and monitor effects induced by capture and marking wild animals:

1. All animal “experiments” in Norway (including Svalbard and including all protocols that involve tissue sampling (other than blood), tagging etc. of wild animals) are regulated under the Animal Welfare Act.

2. All researchers at Norwegian universities and research institutes conducting experiments on live vertebrates in Norway must have gone through appropriate education and training according to the recommendations by FELASA (Federation of European laboratory animal science associations). All participants i.e. the persons planning and designing the experiments and the persons handling the animals shall/ must have appropriate education in accordance to these recommendations (Norwegian Animal Research Authority, pers.comm).

3. All research projects involving extraordinary marking or instrumentation of animals in the Norwegian system must be approved by the Norwegian Animal Research Authority (NARA - “Forsøksdyrutvalget”, http://www.fdu.no). NARA must approve all experimental procedures and all approved projects must report results of their programmes annually, deals with matters of principle (including justification for using any animal “model”), provides practical advice in “best practice” and has the legal right to conduct on-site inspections of any approved research project. NARA also helps to develop better handling protocols and provides courses, meetings, workshops etc. related to animal research in the laboratory and the field. NARA’s approval committee includes lab-animal practitioners, medical researchers, wild-animal researchers, veterinarians, and representation from an animal-welfare NGO.

4. Funding agencies such as the Norwegian Research Council (NRC) pay a lot of attention to the ethical treatment of animals and experimental designs and protocols that minimize potential effects of animal handling in research programmes. It is essential that wild animal handling follows "best practise" methodologies to get funding to conduct field research. Ethics and potential environmental impact must be addressed in all NRC applications, which are judged by expert panels or a series of external, expert reviewers. Unacceptable handling methodologies or risks of impacts that would significantly alter an animal’s behaviour or survival post-treatment would be deemed unacceptable scientific protocol.

5. The broader, international scientific community also promotes and closely monitors "best practice", both through protocol manuals being published by learned societies and via journals demanding minimal (ideally NO) handling impacts in animal experiments (for an example see Gales et al. 2009, Sikes et al. 2011). Experiments conducted within natural systems that are thought to be impacted by the experimental protocols themselves will not meet approval for publication. It is also quite normal for scientific studies to explore potential impacts of capture or marking procedures etc. to improve codes of practice within the scientific community and to ensure robust results that are not compromised by the experimental protocol (e.g. testing for potential influence of the number of recapture events on growth records of young animals, exploring survival rates with different marking protocols, etc.).

A rich and varied array of scientific literature exists regarding minimizing impacts of research activities on animals. The most recent major review was published 2012 in a volume of the journal PLoS ONE entitled "*Animals, Research and alternative Measuring Progress 50 years later*". The 50-year time frame refers to the period since 1959, when William Russel and Rex Burch published the seminal book "*The Principles of Humane Experimental Technique*", which started the 3-R paradigm under which animal research is conducted throughout most of the developed world. It follows the principles of Reducing (minimize the number of animals involved), Refining (use best practice) and Replacing (where possible not having animals directly involved) animal models in research. Most studies of effects of handling and ethical treatment of animals stems from medical research using laboratory animals. But, in the past few decades there has been increasing attention placed on best practise in wildlife research as well (Ferdowsian and Beck 2011).

Risk Identification and Characterisation

Terrestrial mammals

General

This assessment is based on a request to focus on the following free-ranging species of terrestrial mammals:

Brown Bear (*Ursus arctos*)

Gray Wolf (*Canis lupus*)

Wolverine (*Gulo gulo*)

Eurasian Lynx (*Lynx lynx*)

Arctic Fox (*Vulpes lagopus*)

Eurasian Otter (*Lutra lutra*)

Eurasian Beaver (*Castor fiber*)

Moose (*Alces alces*)

Red Deer (*Cervus elaphus*)

Reindeer (*Rangifer tarandus tarandus*)

Svalbard Reindeer (*Rangifer tarandus platyrhynchus*)

Roe Deer (*Capreolus capreolus)*

Fallow Deer (*Dama dama*)

Muskox (*Ovibos moschatus*)

Because fallow deer occur only in captivity in deer farms in Norway, except for a very few escapees, they are not covered in this report. Also, captive red deer in deer farms, arctic foxes in fur farms, and domestic reindeer are not covered in this report.

Terrestrial mammals have been captured and marked for research as long as scientific wildlife research has been conducted. Nevertheless, capturing and handling a free-ranging individual is likely to be one of the most stressful events of their lives and can provoke responses that may confound any clear-cut answer to the research question being addressed (Morellet et al. 2009). Moberg (2000) defined stress as "the biological response elicited when an individual perceives a threat to its homeostasis". In fact, stress responses are adaptive responses to potentially life-threatening events, such as the presence of a predator, and at least ungulates may be well adapted to short-term stress (Omsjoe et al. 2009). However, sometimes stress results in distress (Moberg 2000), when the animal incurs a biological cost so large that it must divert resources away from normal biological functions to cope with this stress factor (threat) (Morellet et al. 2009). The awareness of these problems is growing and researchers are striving to improve their methods of capture, immobilization, and marking to reduce resulting stress, with considerable success. Some excellent and recent reviews of this subject include Kreeger (2012), Millspaugh et al. (2012), Schemnitz et al. (2012), and Silvy et al. (2012).

The effects of capture and marking often have been reported in terms of capture mortality. However, immediate mortality is really the most drastic consequence (Cattet et al. 2008). Fear, pain, hyperthermia, hypotermia, hypoxemia, and respiratory and cardiovascular depression are all potential stressors resulting from pursuit, physical restraint, and chemical immobilization that do not necessarily result in death (Arnemo and Caulkett 2007). Therefore, researchers studying large and medium-sized terrestrial mammals have also been focusing on the effects of capture and marking in terms of short- and long-term stress and effects on life-history parameters. Although most of the published research is based on VHF radiotelemetry, it is a paradox that it is the modern GPS technology and implanted physiological sensors that are providing researchers with the best tools to document the effects of capture and marking. An important weakness of all of this research, however, is the general lack of a control group consisting of uncaptured/unmarked animals (Côté et al. 1998).

The research to date on the short- and long-term effects of capture and marking (defined here as the capture itself and effects of capture and marking beyond the day of capture, respectively) on medium- and large-sized mammals has yielded variable results, which seem to vary by individual, age, species, taxonomic group, method of marking, capture method and procedure, drugs used, etc. Generally, the capturing of mammals becomes more difficult as the size of the individuals increases (Schemnitz et al. 2012). Also physical restraint seems to induce greater stress than chemical restraint and chemical immobilization from a helicopter may be the least stressful capture method for a wide range of large- and medium-sized mammals (Arnemo and Caulkett 2007). Nevertheless, many results from this type of research are difficult to generalize. For example, chemical immobilization of mountain goats (*Oreamnos americanus*) with xylazine hydrochloride 1-5 months before the rut decreased kid production the following year, but only for 3- and 4-year-old females, and did not affect survival, foraging efficiency, or time spent alert. Carrying a radiocollar in itself, however, had no effect on kid production, female dominance status, survival, foraging efficiency, or time spent alert, although there was a suggestion that it might influence kid survival (Côté, et al. 1998). In moose (*Alces alces*) calves, however, some types of marks do not seem to affect calf mortality (expandable neck collars, Larsen and Gauthier 1989; plastic ear tags, Swenson et al. 1999), whereas others do (ear-tag mounted radiotransmitters, Swenson et al. 1999). In Scandinavia, few effects of capture, handling, and immobilization have been documented for adult moose, although rectal palpation seems to reduce fetal and neonatal survival (Solberg et al. 2003). Pelletier et al. (2004) found that chemical immobilization with xylazine and ketamine seemed to negatively affect the fighting ability and social rank of male bighorn sheep (*Ovis canadensis*) during the rut, despite their apparent full recovery. Researchers have been able to counteract many of these documented problems. For example, changes in immobilization drugs and standardization of dosages contributed to a more than ten-fold reduction in the capture-related mortality rate of brown bears (*Ursus arctos*) (Arnemo et al. 2006) and changes in trap construction contributed to a three-fold reduction in the capture-related mortality rate of Eurasian lynx (*Lynx lynx*) (Odden et al. 2007).

In this review, Scandinavian studies have been given priority over others, because capture-caused mortality rates are often lower in Scandinavia than elsewhere (Arnemo et al. 2006). Also, capture and marking methods not used in Scandinavia are not usually included.

Recommened drugs and doses for immobilizing terrestrial animals in Norway are found in Arnemo et al. (2010).

In Norway, researchers who capture and mark mammals must have completed and passed a course given under the auspices of the Norwegian Food Safety Authority (Mattilsynet). In addition, chemical immobilization of mammals must be conducted under the supervision of a veterinarian who has successfully completed a course given under the auspices of the Norwegian Food Safety Authority. At the time of writing, the Norwegian Food Safety Authority is considering changes to these regulations (Arnemo and Søli 2012). Most of the capture and marking discussed in this section is conducted with funding from management agencies, especially the Norwegian Directorate for Nature Management, with the aim to improve the level of knowledge on which to base management decisions.

Table 1.

Species	Number with functioning transmitters in 2012	Source	Population size in Norway (year)	Source	Proportion with functioning transmitters
Brown bear	1 [a]	Jon Swenson	Min. 151 (2011)	Tobiassen et al. (2012)	0.3% [a]
Gray wolf	1	Petter Wabakken	28-32 + 28-32 border wolves[b] (2011/2012)	Wabakken et al. (2012)	2.1-2.3% [b]
Wolverine	5	John Odden	360-370[c] (2011)	Flagstad et al. (2012)	1.4%
Eurasian lynx	10	John Odden	384-408[c] (2012)	Brøseth and Tovmo (2012)	2.5-2.6%
Arctic fox	0	Nina Eide	100 (2011)	Flagstad et al. (2011)	0
Eurasian otter	0	Jiska van Dijk	20-25,000 (2012)	Jiska van Dijk (pers. comm.)	0
Eurasian beaver	0	Frank Rosell	>70,000 (2012)	Halley et al. (2012)	0
Moose	<150	Erling Solberg	117,000[d] (2000)	Solberg et al. (2005)	~0.1%
Red deer	130-150	Erling Meisingset	130,000[d] (2004)	Andersen et al. (2010)	0.01%
Wild reindeer	58	Olav Strand and Roy Andersen	25,000[d] (2004)	Andersen et al. (2010)	0.2%
Svalbard reindeer	37	Leif Egil Loe	11,000 (1986)	Øritsland and Alendal (1986)	0.3%
Roe deer	10-20	John Linnell	126,000[d] (1999)	Austrheim et al (2008)	Appr. 0.01%
Muskox	0	Jon M. Arnemo	170 (2004)	Andersen et al. (2010)	0

[a] This bear, captured and marked in Sweden, but with part of its home range in Norway was counted as 0.5 for this calculation
[b] The border wolves that live in both Norway and Sweden were counted as 0.5 each for this calculation
[c] Before the hunting season
[d] After the hunting season

Table 1: Proportion of the populations of terrestrial mammals in Norway with functioning transmitters in 2012 covered in this report, and the most recent population estimates for Norway. Animals with nonfunctioning transmitters or ear tags are not included here, because these numbers cannot be verified. It is important to stress that the proportion of radiomarked animals can vary greatly from year to year, depending on research activity, and within the year, because population size changes during periods of birth and death (such as hunting) and when radiotransmitters are deployed and removed. The arctic fox on Svalbard is not in the table, because there is no population estimate.

Brown Bear (*Ursus arctos*)

Purpose of marking

Brown bears are captured and marked in Norway and Sweden for research purposes, although they may be captured and marked only for management purposes in Norway. A long-term research project, the Scandinavian Brown Bear Research Project (SBBRP, http://www.bearproject.info/), began in 1984 in Sweden and became a Scandinavian project in 1987. It is based on following marked brown bears, many from the age of 1 year until death. The results of this project are used for the management of brown bears in both countries.

Population size and the frequency of marking

There are at present (2011) 151 bears in Norway. The number of bears with transmitters is at present one, which means that the probability of being radiomarked is 0.3% (Table 1).

Who marks the animals?

All bears in Scandinavia are captured and marked by personell of the SBBRP, usually including veterinarians in Sweden and always conducted by veterinarians in Norway.

Marking methods and procedures

Most of the information given here is based on the standard protocol for capturing and marking large carnivores in Scandinavia and is based on long experience working with brown bears (Arnemo et al. 2012). In addition, a number of papers have been published from this work (Arnemo et al. 2006, Fahlman et al. 2010, 2011, 2012, Painer et al. 2012). Unless some information is cited specifically from the literature, it comes from this protocol and these papers. Please refer to the protocol for detailed information.

Brown bears captured in Scandinavia are marked with radiocollars containing GPS-GSM, GPS-satellite, or VHF radiotelemetry devices (Fig. A). The collars are individually fitted around the bear’s neck, so that they can be pulled on and off over the head, and it is possible to pass a flat hand between the collar and the neck. The ends of the collars are fastened with screws. The radiocollars weigh 500-1600 g, depending on the type and battery size, and never exceed 2% of the animal's body mass. For growing bears and bears of unknown age, a weakness zone (double cotton webbing in males, single in females, Fig. A) is inserted in the collar. This will disintegrate within a year or so, and the collar will fall off. This is a safety feature in case the transmitter fails. A microchip is implanted s.c. at the base of the nose of brown bears with a standard applier and the insertion hole is sealed with a drop of tissue or super glue and tested with the scanner after implantation. All brown bears are tattooed with a unique ID number on the inside of the lip using standard tattoo pliers and ink. Individually numbered ear tags were used previously, but this practice has been discontinued, because some of the bears showed signs of infection or irritation (redness, swelling or discharge, Fig. B.).

Transmitters are implanted into some individual brown bears. At this time, this is carried out only in Sweden. Intraperitoneal radiotelemetry transmitters are implanted routinely into young bears (Fig C.) to avoid capturing them annually to change collars during the ages of maximum growth, because there is evidence that brown bears' body condition may be affected negatively by repeated captures (Cattet et al. 2008). In addition, some bears used for special projects receive implanted temperature loggers, ECG monitors, and/or physiological sensors.

A).  B). 

Fig. A. Neck collar used on brown bears (this one has a GPS device), showing a cloth weakness zone. Fig. B. Damage to a bear's ear caused by an eartag. Photos by Jon Arnemo (A) and Åsa Fahlman (B).

Capture and handling

Brown bears are usually captured in early spring, shortly after emergence from their winter dens by darting from a helicopter using a remote drug delivery system (Dan-Inject®) (Fig. D). Although brown bears are sometimes immobilized during summer or autumn, such captures are more difficult due to lack of snow cover, open water, high ambient temperatures and increased dose requirements due to seasonal changes in physiology and body fat. To avoid stress and physiological side effects (hyperthermia, lactic acidemia) during immobilization, intensive chasing are kept to a minimum, and the total time of pursuit (the time from initial observation, including alternating periods of intensive and extensive pursuit) never exceeds 30 minutes (Arnemo et al. 2012).

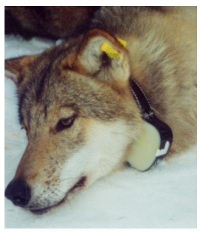
C).  D).  E). 

Fig. C. Insertion of an implanted receiver into a brown bear. Fig. D.) A brown bear being darted from a helicopter. Fig. E). A wolf with a VHF transmitter mounted on a collar and an ear tag. Photos by Jon Arnemo.

Brown bears are not captured in the den during hibernation in Norway, but this is done in Sweden as part of a research project using brown bears as a model species for human medical research. For safety reasons, the SBBRP only captures subadult hibernating bears, 2 to 4 years old and weighing 20-70 kg. Hibernating bears are located using GPS and VHF collars or implants and are darted with a CO_2-powered dart gun while in the den (Evans et al. 2012).

Sedation and anesthesia

Currently, the following standard doses of medetomidine (M) (Domitor® 1 mg/ml, Zalopine® 10 mg/ml) and tiletamine-zolazepam (TZ) (Zoletil®) are used for immobilization of free-ranging bears in April-May: Yearlings (15-45 kg) 1.25 mg M + 62.5 mg TZ; small bears (2-3 years, 45-70 kg) 2.5 mg M + 125 mg TZ; adult females and small males (70-120 kg) 5 mg M + 250 mg TZ; medium-sized adult males (120-200 kg) 10 mg M + 500 mg TZ; large males (> 200 kg) 15 mg M + 750 mg TZ. A fixed M:TZ ratio is used so that doses can be split or combined. For capturing bears late in the fall, the spring dose is usally increased by 25-50% and longer needles are used, but the injection site is probably the most important factor to avoid delayed absorption from subcutaneous fat. For hibernating bears in late winter, the spring dose is reduced by 50% and ketamine is added. For 45-65 kg subadult bears, the combination of 1.25 M + 62.5 T + 75 mg ketamine provides sufficient anesthesia; for small subadults, 20-30 kg, half of this dose is used.

Hypoxemia (low levels of oxygen in the blood) is a common side effect documented by arterial blood gases in both captive and free-ranging brown bears immobilized with different doses of MTZ. Intranasal oxygen supplementation markedly improves the arterial oxygenation and is routinely given throughout anesthesia, as part of the standard field procedure for the SBBRP. Preliminary studies indicate that in wintertime 0.5 L/min is probably sufficient for all bears up to 50 kg. In addition to oxygen cylinders, a portable battery driven oxygen concentrator (EverGoTM Portable Oxygen Concentrator) is being used to efficiently provide supplemental oxygen to immobilized bears in Scandinavia.

Tiletamine-zolazepam was formerly the drug combination of choice for immobilization of the bear species. Tiletamine-zolazepam has a wide margin of safety and has no major cardiopulmonary or thermoregulatory side effects in bears. The main disadvantage of this combination is extended recovery times. However, in combination with medetomidine, the effective dose of tiletamine-zolazepam can be reduced by as much as 75%, and atipamezole (Antisedan®), the antagonist for medetomidine, is used to shorten the recovery times.

Immobilized animals are monitored and clinically examined by professionals with experience in wildlife medicine. Possible side effects include hypoxemia (inadequate amount of oxygen in the blood), respiratory depression (hypoventilation; increased carbon dioxide levels in the blood) and thermoregulatory dysfunction (hyperthermia or hypothermia). Drug overdose in individuals with poor body condition, aspiration of vomitus/saliva, and pneumothorax due to misplaced dart are other possible complications. If several animals are being captured at the same time (e.g. members of a family group), they are brought together for monitoring and processing.

Hyperthermic brown bears (rectal temperature (RT) > 40.0°C) are cooled by applying snow (or water in summertime) to the axilla, groin, and/or tongue. If the hyperthermia is not resolved within 15 minutes, or the animal has an RT > 41.0°C, i.v. fluid therapy is initiated

(10-15 ml/kg of Ringer®-acetat). Oxygen supplementation is given to hyperthermic animals. Hypothermic animals (RT < 36.0°C) are protected from wind and cold surfaces to avoid further cooling using a Wolverine Bag®. Hot water bottles are placed in the groin and axilla as an external heat source in the field. In case of prolonged immobilization and recovery, hypothermic animals are warmed, and prewarmed fluid (38°C) (Ringer®-acetat) is administered intravenously.

Hibernation. Bears are darted dens using medetomidine at 0.02-0.06 mg/kg and zolazepam-tiletamine at 0.9-2.8 mg/kg for anesthesia. In addition to medetomidine-zolazepam-tiletamine, ketamine at 1.5 mg/kg is hand-injected intramuscularly or included in the dart at 1.1-3.0 mg/kg. Once anesthetized, bears are removed from the dens. Some bears show hypoxemia, which is corrected with supplemental oxygen. The den entrances are covered with branches and snow and bears are left to recover. Capture of hibernating bears was possible using 25% of the doses used for helicopter darting of the same bears during the active period in June (Evans et al. 2012).

Awakening and release

For reversal of immobilization in animals that have received medetomidine-combinations, 5 mg of atipamezole (Antisedan®) per mg of medetomidine is administered i.m. Due to the long elimation time of tiletamine-zolazepam, atipamezole is not given until earliest 50-60 min after darting. In an emergency, atipamezole can be given at any time, but recovery may then be rough, with possible incoordination, excitation and convulsions. Such an animal can be calmed by administration of midazolam (Midazolam®) i.m. (suggested dose 0.1-0.2 mg/kg). Immobilized animals are usually left to recover undisturbed at the site of capture. Possible side effects and dangers during and immediately after recovery include hypothermia (especially in animals with a small body mass relative to body surface or in case of extended procedures), hyperthermia (due to extensive chasing prior to capture, sun and/or high ambient temperatures), intraspecific strife, open water, lack of fear, traffic, and poaching. All GPS and radio-instrumented bears are checked the day after capture.

Long-term effects of marking

The capture-related mortality rate for brown bears in Scandinavia, based on 1,079 captures during 1984-2004, was 0.9%, including direct and indirect capture-related mortality due to stress, hyperthermia, and/or respiratory depression, shock/circulatory failure, drowning, pneumothorax from dart misplacement, and one case of a bear shot for human protection after a sudden and unexpected recovery. Since 1992, when the drugs and dosages listed above have been used, the mortality rate dropped to 0.3%, compared with 3.8% prior to 1992 (Arnemo et al. 2006). Powell (2005) documented that the injury rates sustained by American black bears (*Ursus americanus*) during capture with foot snares and in winter dens were well below the accepted international limits. As foot snares cause more injuries than helicopter-based capture (Powell 2005, Cattet et al. 2008), which is the only method used in Scandinavia, it is reasonable to assume that the injury rate also is within acceptable levels. Cattett et al. (2008) found that 14% and 18% of brown bears captured using darting from a helicopter in Canada had blood serum concentrations above normal reference values for aspartate aminotransferase (AST) and creatine kinase, respectively, which suggests muscle injury associated with capture. No extreme values (>5 times reference values) were found in the group captured by helicopter, nor did multiple captures affect these results. There was no statistical evidence to suggest that exertional myopathy affected long-term mortality rates, although there was a weak trend in that direction. Cattett et al. (2008) also found that daily movement rate was on average 57% lower than normal immediately after capture and peaked at 28 days after capture. Reduction in daily movement rate was not related to the type of capture, but was related to the estimated degree of muscle injury and was only evident in bears with serum AST levels >3 times above the upper limit of the reference interval.

Evans et al. (2012) reported that 11 of 13 bears captured during hibernation in Sweden left their dens on average 3.2 days after capture. Bears that left their original dens used on average 1.9 intermediate resting sites, during 6.2 days before entering a new permanent den. The new permanent dens were located on average 730 m from the original dens. Thus, there are increased energetic costs associated with den abandonment and disturbance when capturing hibernating brown bears.

Cattett et al. (2008) found that the age-related change in body condition in brown bears declined in direct proportion with increasing number of captures. Type of capture (helicopter, leghold snare, culvert trap) did not affect this relationship, but the affects increased with increasing age of the bear. The decline in body condition was equivalent to 14% for a 9-year-old bear captured 3 times, in relation to one captured once, and 25% for one captured 5 times.

Concluding remarks

Effects of capture and marking have been better studied in the brown bear than in most other species of terrestrial mammals. The mortality rates associate with immobilization from a helicopter are well below the 2% rate recommended as an upper limit by Arnemo et al. (2006). It is clear that leghold trapping has greater negative effects than helicopter darting, as measured by blood serum measurements indicating stress and muscle injury (Cattet et al. 2003, 2008, Chow et al. 2010, Macbeth et al. 2010), but none of these effects have been put into a life-history perspective; ie. we know little about whether the documented effects influence subsequent reproduction and survival. Brown bears reduce their movement rate for up to a month following capture (Cattet et al. 2008), but they also reduce their movement rate after being observed from a helicopter, without being captured, in contrast to moose (*Alces alces*), which increase their movement rate by 10 times for the first 2 hours after being observed from a helicopter and also move into more rugged terrain (Støen et al. 2010). Just meeting a person in the forest causes brown bears to flee from the site (Moen et al. 2012) and change their diurnal and movement behaviour for 6 days afterwards, compared to before the meeting (Ordiz et al. submitted manus). Also, the start of the hunting season causes brown bears to immediately change their diurnal activity, becoming more nocturnal during the important berry-foraging period when they fatten for the winter (Ordiz et al. 2012). Thus, any human contact seems to affect brown bear behaviour, which makes it especially difficult to evaluate the effects of handling and marking in relation to how a bear perceives threats and stress.

The probability for capture-related mortality is small in brown bears and immobilization from a helicopter, the method used in Scandinavia, has been documented as the least intrusive capture method (the other common capture methods are capture with foot snares and in culvert traps). However, one study has suggested that capture can affect subsequent movements and body condition (Cattet et al. 2008). Further research is required before the risks associated with capture and marking can be evaluated fully and the SBBRP is planning research with Cattet and his colleagues to investigate this further, using the SBBRP database. New technology, such as better batteries, duty-cycle based collars, and drop-off functions, will reduce the required frequency of capture of brown bears and other terrestrial mammals. Nevertheless, for demographic studies of bears, better results will be obtained by following a number of individuals and recapturing them as needed, rather than capturing a larger number of individuals only once.

Gray Wolf (*Canis lupus*)

Purpose of marking

Wolves are marked in Norway and Sweden for research purposes, although in some cases they can be marked for management needs. A long-term cooperative Scandinavian research project, SKANDULV (http://skandulv.nina.no/), conducts the research, which is primarily based on following marked wolves. The results of this project are used for the management of wolves in both countries.

Population size and the frequency of marking

There are at present (2011) 28-32 gray wolves in Norway. The number of wolves with transmitters is at present one which means that the probability of being marked is 2.2% (Table 1).

Who marks the animals?

All wolves in Scandinavia are captured and marked by personnel of SKANDULV, including veterinarians, in both Norway and Sweden.

Marking methods and procedures

Most of the information given here is based on the standard protocol for capturing and marking large carnivores in Scandinavia (Arnemo et al. 2012). This protocol is based on long experience working with wolves. Unless some information is cited specifically from the literature, it comes from this protocol.

GPS radiocollars weighing 600 g, ca 1.5% of the animal's body mass, are placed on the wolves (Fig. E). The minimum collar circumference is 44.5 cm for females and 48.0 cm for males. The biologists ensure that there is enough space for two fingers (4 cm) between the collar and the neck and then the collar is secured with bolts. A microchip is implanted s.c. at the base of the right ear and is tested with the scanner after implantation.

Capture and handling

Wolves are immobilized by darting from a helicopter in winter on snow-covered ground. To avoid stress and physiological side effects (hyperthermia, lactic acidemia) during immobilization, intensive chasing is kept to a minimum, and the total time of pursuit (the time from initial observation, including alternating periods of intensive and extensive pursuit) never exceeds 30 minutes.

Sedation and anesthesia

Animals ≥6 months of age, regardless of sex and body mass, are darted with 250 mg tiletamine-zolazepam (Zoletil®) per animal using a remote drug delivery system (Dan-Inject®). A 3-ml dart syringe with a 1.5 x 25 mm barbed needle is used. Once recumbent, administration of 0.5-1.0 mg medetomidine or 0.3 mg/kg midazolam i.m. may be required to induce complete immobilization. Supplemental dosing depends on the situation. Animals that are not down 15 minutes after the intial dose are redarted with a full dose. If the animal is down but incompletely immobilized, administration of additional drugs is usually necessary. Wolves are usually easy to handle, even if they are not completely immobilized (often the case after darting with tiletamine-zolazepam). To reduce stress and to facilitate sampling, 1 mg medetomidine (Domitor®) i.m. is used to induce complete immobilization. In case of a prolonged procedure or signs of spontaneous recovery, 0.5-1.0 mg medetomidine (Domitor®) i.m. is given to keep juvenile and adult wolves immobilized for another 15-30 minutes.

Immobilized animals are monitored and clinically examined by professionals with experience in wildlife medicine. Possible side effects include hypoxemia (inadequate amount of oxygen in the blood), respiratory depression (hypoventilation; increased carbon dioxide levels in the blood) and thermoregulatory dysfunction (hyperthermia or hypothermia). Drug overdose in individuals with poor body condition, aspiration of vomitus/saliva, pneumothorax due to misplaced dart, and vomiting are other possible complications. If several animals are being captured at the same time (e.g.: members of a pack), they are brought together for monitoring and processing.

Thermoregulation is monitored by frequent measurements of the rectal temperature (RT). Hyperthermic animals (RT > 40.0°C) are cooled by applying snow (or water in summertime) to the axilla, groin, and/or tongue. If the hyperthermia is not resolving within 15 minutes, or the animal has an RT > 41.0°C, i.v. fluid therapy is initiated (10-15 ml/kg of Ringer®-acetat). Oxygen supplementation is used for hyperthermic animals. Hypothermic animals (RT < 36.0°C) are protected from wind and cold surfaces to avoid further cooling using a Wolverine Bag®. Hot water bottles are placed in the groin and axilla as an external heat source in the field. In case of prolonged immobilization and recovery, hypothermic animals are warmed, and prewarmed fluid (38°C) (Ringer®-acetat) is administered intravenously.

Awakening and release

For reversal of immobilization in wolves that have received medetomidine-combinations, 5 mg of atipamezole (Antisedan®) per mg of medetomidine is administered i.m. Due to the long elimation time of tiletamine-zolazepam, atipamezole is not be given until earliest 50-60 min after darting. In an emergency, atipamezole is given at any time, but recovery may then be rough with possible incoordination, excitation and convulsions. Such an animal can be calmed by administration of midazolam (Midazolam®) i.m. (suggested dose 0.1-0.2 mg/kg).

Immobilized wolves are usually left to recover undisturbed at the site of capture. Possible side effects and dangers during and immediately after recovery include vomiting, hypothermia (especially in animals with a small body mass relative to body surface or in case of extended procedures), hyperthermia (due to extensive chasing prior to capture, sun and/or high ambient temperatures), intraspecific strife, open water, lack of fear, traffic, and poaching. Wolves are observed by trained personnel until full recovery is evident. This may take several hours in wolves immobilized with tiletamine-zolazepam. All GPS and radio-instrumented animals are checked the day after capture.

Long-term effects of marking

The capture-related mortality rate for 89 immobilizations of gray wolves in Scandinavia was 3.4% during 1998-2004 (Arnemo et al. 2006), but the present mortality rate is 1.3%, based on 154 immobilizations in Sweden (H. Sand, pers. comm.). These included direct immobilization mortalities due to hyperthermia and shock development, but only with captures using medetomidine-ketamine. One wolf was hit by a car 10-12 km from the capture site 6 h after he left the capture site apparently fully recovered; this was considered to be a secondary mortality (Arnemo et al. 2006).

Concluding remarks

With the present capture protocol, the capture-related mortality rate is below the threshold of 2% recommended by Arnemo et al. (2006). No long-term effects of capturing and marking gray wolves have been reported.

For demographic studies, better results will be obtained by following a number of wolves and recapturing them as needed, rather than capturing a larger number of individuals only once.

Wolverine (*Gulo gulo*)

Purpose of marking

Wolverines are marked in Norway and Sweden for research purposes, although in some cases they can be marked for management needs in Norway, usually associated with lethal control operations, when managers follow a radiomarked mother to the natal den to find and kill the entire family. The results of research are used for the management of wolverines in both countries.

Population size and the frequency of marking

There are at present (2011) 360-370 wolverines in Norway. The number of wolverines with transmitters is at present five, which means that the probability of being marked is 1.4% (Table 1).

Who marks the animals?

Most wolverines in Norway are captured and marked by researchers in the Norwegian Institute for Nature Research (NINA), either with or without an approved veterinarian. SNO personnel are allowed to immobilize wolverines for management purposes without an approved veterinarian present.

Marking methods and procedures

Most of the information given here is based on the standard protocol for capturing and marking large carnivores in Scandinavia (Arnemo et al. 2012) and Fahlman et al. (2008). The protocol is based on long experience working with wolverines. Unless some information is cited specifically from the literature, it comes from these two sources.

VHF and GPS collars are fitted on wolverines according to the size, age and sex of the animal. The weight of the radiocollar does not exceed 2-3% of the animal's body mass. The circumference of the animal's head and neck is measured before fitting the collar and the circumference of the collar is adjusted so it is slightly less than the circumference of the head, but larger than the circumference of the neck. The biologists ensure that the collar is not too tight (and make room for one finger between the neck and the collar) or that it can be pulled over the head of the animal (backwards). In some cases the difference in circumference of the head and neck is very small (especially in males) and fitting the collar can be difficult. Because the presently available commercial drop-of mechanisms are unreliable, a weakness zone consisting of woven cotton fabric is inserted into the collar. This will decay and allow the collar to drop off within 1 to 2 years. A microchip is implanted s.c. at the base of the right ear and is tested with the scanner after implantation.

Intraperitoneal transmitters. VHF intraperitoneal transmitters are used in Sweden and have been used in Norway. The weight of the implant never exceeds 2% of the animal’s body mass. The radiotransmitter is tested with the receiver before implantation. Implants are gas sterilized or disinfected by soaking in 10 mg/ml benzalkonium chloride (nonproprietary). They are prewarmed and, in the case of chemically disinfected implants, thoroughly rinsed with sterile saline before being placed aseptically into the peritoneal cavity. The skin wound is covered with a spray dressing (OpSite®).

Capture and handling

Adults and juveniles (> 8 months) are usually immobilized from a helicopter or in den sites (only secondary dens for research, never primary natal dens) under boulders or snow. Cubs caught in dens are restrained manually and then injected using a hand syringe. To avoid stress and physiological side effects (hyperthermia, lactic acidemia) during immobilization from a helicopter, intensive chasing is kept to a minimum, and the total time of pursuit (the time from initial observation, including alternating periods of intensive and extensive pursuit) never exceeds 30 minutes. Total handling time averages 76 minutes for darted adults and 68 minutes for hand-injected juveniles. Earlier, wolverines were caught in Norway in baited box traps made of wood or stone or using padded leg-hold traps (Soft-Catch™) (Landa et al. 1998).

Sedation and anesthesia

Wolverines are darted with an initial dose of 4 mg medetomidine (Zalopine®) + 100 mg ketamine (Narketan 10®) per animal using a remote drug delivery system (Dan-Inject®). A 1.5 ml dart syringe with a 1.5 x 25 mm barbed needle is used. Recumbancy occurs within about 5 minutes. Juveniles (up to 5-6 kg) are manually restrained, weighed and immobilized with 0.1 mg/kg medetomidine (Domitor®) + 5 mg/mg ketamine (Ketalar®) i.m. (induces 30-40 min of immobilization). Hypoxemia is a common side effect in wolverines immobilized with medetomidine-ketamine, as documented in an arterial blood gas study. Drug-induced physiological changes and high altitude (500-1,300 m above sea level) contributes to the low levels of oxygen in the blood. Supplemental oxygen is used to prevent hypoxemia and improve safety for immobilized wolverines.

Animals immobilized for research are monitored and clinically examined by professionals with experience in wildlife medicine. Possible side effects include hypoxemia (inadequate amount of oxygen in the blood), respiratory depression (hypoventilation; increased carbon dioxide levels in the blood), and thermoregulatory dysfunction (hyperthermia or hypothermia). Drug overdose in individuals with poor body condition, aspiration of vomitus/saliva, and pneumothorax due to misplaced dart are other possible complications. If several animals are being captured at the same time (e.g. members of a family group), they are brought together for monitoring and processing.

Thermoregulation is monitored by frequent measurements of the rectal temperature (RT). Hyperthermic animals (RT > 40.0°C) are cooled by applying snow (or water in summertime) to the axilla, groin, and/or tongue. If the hyperthermia is not resolving within 15 minutes, or the animal has an RT > 41.0°C, i.v. fluid therapy is initiated (10-15 ml/kg of Ringer®-acetat). Oxygen supplementation is used for hyperthermic animals. Hypothermic animals (RT < 36.0°C) are protected from wind and cold surfaces to avoid further cooling using a Wolverine Bag®. Hot water bottles are placed in the groin and axilla as an external heat source in the field. In case of prolonged immobilization and recovery, hypothermic animals are warmed, and prewarmed fluid (38°C) (Ringer®-acetat) is administered intravenously.

Awakening and release

For reversal of immobilization in animals that have received medetomidine-combinations, 5 mg of atipamezole (Antisedan®) per mg of medetomidine is administered i.m. The first signs of recovery are observed after about 15 min after reversal. Due to the long elimation time of tiletamine-zolazepam, atipamezole is not given until earliest 50-60 min after darting. In an emergency, atipamezole is given at any time, but recovery may then be rough with possible incoordination, excitation and convulsions. Such an animal can be calmed by administration of midazolam (Midazolam®) i.m. (suggested dose 0.1-0.2 mg/kg).

Immobilized wolverines can usually be left to recover undisturbed at the site of capture. Possible side effects and dangers during and immediately after recovery include hypothermia (especially in animals with a small body mass relative to body surface or in case of extended procedures), hyperthermia (due to extensive chasing prior to capture, sun and/or high ambient temperatures), intraspecific strife, open water, lack of fear, traffic, and poaching. All GPS and radio-instrumented animals are checked the day after capture.

Long-term effects of marking

The capture-related mortality rate for 461 captures of wolverines in Scandinavia during 1990-2004 was 2.8%. This included anesthetic mortalities due to possible resedation with subsequent hypothermia, asphyxia during recovery, and one cub that was found dead shortly after a transmitter had been surgically implanted intraperitoneally. The carcass had been scavenged, so it was not possible to document the cause of death, but it was included as an anesthetic mortality. In addition, 1 adult died from pneumothorax due to misplacement of the dart, for an overall direct mortality rate of 1.3%. The secondary mortality rate was 1.5% and included a death from postoperative complications after implantation of an intraperitoneal transmitter, one as a result of wearing the radiocollar, and the euthanasia of 5 cubs whose mothers had died as the result of direct effects of immobilization (above).

Concluding remarks

With the present capture protocol, the direct mortality rate is close to the threshold of 2% recommended by Arnemo et al. (2006), even with the euthanasia of dependent young, which is not generally a relevant problem for the other large-carnivore species. Besides mortality, possible negative long-term effects of capture and marking have apparently not been investigated. For wolverines, implanted transmitters may be more appropriate for longer-term studies than transmitters mounted in collars.

Eurasian Lynx (*Lynx lynx*)

Purpose of marking

Lynx are only marked in Norway and Sweden for research purposes, although the Directorate for Nature Management has permission to capture lynx for management purposes. Researchers in NINA have conducted a long-term research project on lynx and cooperate with Swedish lynx researchers in a cooperative effort called SCANDLYNX (http://scandlynx.nina.no/). This research is based on following marked lynx and the results are used for the management of Eurasian lynx in both countries.

Population size and the frequency of marking

There are at present (2011) 384-408 lynx in Norway. The number of lynx with transmitters is at present ten, which means that the probability of being marked is 2.5 % (Table 1).

Who marks the animals?

All lynx in Scandinavia are presently captured and marked by personnel employed by, or contracted by, the institutions cooperating in the SCANDLYNX research project.

Marking methods and procedures

Most of the information given here is based on the standard protocol for capturing and marking large carnivores in Scandinavia (Arnemo et al. 2012). This protocol is based on more than 20 years of experience working with lynx capture and resulting publications (Arnemo et al. 1999, Odden et al. 2007, Léchenne 2012). Unless some information is cited specifically from the literature, it comes from this protocol and these papers.

VHF and GPS collars are fitted to lynx according to the size, age and sex of the animal. The weight of the radiocollar never exceeds 2-3% of the animal's body mass. When changing the collar, the neck is examined for hair loss and possible skin irritation. During 1995-2004, 3 subadult lynx died after their mandibles became caught under the radiocollar (Arnemo et al.

2006), therefore it is essential that collars are not too loose (i.e. to permit a mandible or a foot to get stuck), or too tight to constrict growth. The minimum collar circumference is 26 cm for females and 32 cm for males (based on measurements taken from hundreds of marked lynx). Researchers ensure that at least one finger can be passed between the collar and the neck of all animals. If an animal is too small to carry a collar with such a circumference, it is either not marked or receives an implanted transmitter (see below). The currently available drop-off mechanisms are unreliable or too heavy. Therefore, it is now common practice to use weakness zones, and these are required in Norway. These weakness zones are currently made of woven cotton that decays with time, usually dropping off within 1-2 years of attachment (range 0.5 – 4 yrs). The drop-off situation is being constantly monitored for new and reliable products. A microchip is implanted s.c. at the base of the right ear and is tested with a scanner after insertion.

Intraperitoneal transmitters. The weight of intraperitoneal implants for lynx kittens varies from 7 to 20 g and does not exceed 1.5% of the body mass of the smallest kitten. The radiotransmitter is tested with a receiver before implantation. Implants are gas sterilized or disinfected by soaking in 10 mg/ml benzalkonium chloride (nonproprietary). They are prewarmed and, in the case of chemically disinfected implants, thoroughly rinsed with sterile saline before being placed aseptically into the peritoneal cavity. The skin wound is covered with a spraydressing (OpSite®).

Capture and handling

Since 1995, five main techniques have been used to capture lynx (Odden et al. 2007).
1) Spring loaded foot-snares that have been specifically developed for lynx during the last 30 years are placed around large prey items killed by lynx and to which the lynx is expected to return. These are monitored using VHF-radio alarms. The capture team waits in the immediate vicinity and can normally react within 5-20 minutes. The lynx is then manually restrained using a net, so that drugs can be injected using a hand-held syringe, which permits careful placement and full delivery of the drugs.
2) Walk through box traps (c. 100x80x200 cm) made of solid wood are placed on trails that lynx frequent. A lure, such as cat-nip or lynx urine, is placed inside. The trap is monitored with SMS alarms that immediately alert researchers when the trap has been activated. A local contact checks the trap at once and releases nontarget species. If a lynx has been captured, the capture team is notified. Drugs are injected remotely using a blowpipe or gas-powered pistol / rifle through special holes in the trap. Average reaction time (time in the box) is 5 hours. Maximal reaction time is 12 hours, which corresponds to reaction time used in the legal hunting using box traps.
3) Dogs have been used to chase lynx into trees, where they can be immobilized using remotely injected drugs. In situations where the lynx can fall far, a net is hung below the tree.
4) Helicopters are the main technique used in northern Scandinavia, where the terrain is open. Lynx are localized by the radio (in cases of recaptures) or by snow-tracking, gently steered into an area with suitable open terrain, and then darted from the helicopter.
5) Neonatal kittens (3-6 weeks old) are captured in the natal lair, which are located using telemetry data from the mother. Kittens are captured by hand and manually restrained for the standard procedures of measurement and microchipping. If kittens are to receive intraperitoneal implants, the procedure of Arnemo et al. (1999) is used.

F).  G).  H). 

Fig. F. Wooden box trap to capture lynx. Fig. G. Uncovered snares placed near a lynx-killed prey to capture lynx. Fig. H. The same site after the snares have been covered. Photos by SKANDLYNX.

During 1993-1995 padded leg-hold traps (with jaws) were also used, but they caused a relatively high frequency of injuries (Nybakk et al. 1996) and are no longer used for lynx. A few lynx have been darted from a car window. To avoid stress and physiological side effects (hyperthermia, lactic acidemia) during immobilization, intensive chasing by helicopter or dogs is kept to a minimum, and the total time of pursuit (the time from initial observation, including alternating periods of intensive and extensive pursuit) never exceeds 30 minutes for helicopter captures.

Special care is given to avoid accidents or physiological side effects due to prolongation of the capture attempt. The metal box traps used earlier were based on those used in Central Europe, but they often caused minor damage to the claws. These traps are now no longer used. Present traps are constructed entirely of wood and this problem has disappeared (Odden et al. 2007). To date there have been no mortalities of animals caught in box traps.

Sedation and anesthesia

Adults (males 18-28 kg, females 14-19 kg) are darted with an initial dose of 4 mg medetomidine (Zalopine®) + 100 mg ketamine (Narketan 10®) per animal using a remote drug delivery system (Dan-Inject®). For adults captured in box traps (calm animals) and juveniles (6-12 months 9-16 kg, yearlings 12-21 kg), the doses are reduced to 2 mg medetomidine + 50 mg ketamine. A 1.5 ml dart syringe with a 1.5 x 25 mm barbed needle (Dan-Inject®) is used. Kittens (4-5 weeks of age; mean body mass 1.5 kg) are captured by hand in their natal lairs, weighed, and, if they are to be immobilized, 0.1 mg/kg medetomidine (Domitor®) + 5 mg/kg ketamine (Ketalar®) i.m is used.

Immobilized animals are monitored and clinically examined by professionals with experience in wildlife medicine. Possible side effects include hypoxemia (inadequate amount of oxygen in the blood), respiratory depression (hypoventilation; increased carbon dioxide levels in the blood), and thermoregulatory dysfunction (hyperthermia or hypothermia). Drug overdose in individuals with poor body condition, aspiration of vomitus/saliva, and pneumothorax due to misplaced dart are other possible complications. If several animals are being captured at the same time (e.g.: members of a family group), they are brought together for monitoring and processing.

Thermoregulation is monitored by frequent measurements of the rectal temperature (RT). Hyperthermic animals (RT > 40.0°C) are cooled by applying snow (or water in summertime) to the axilla, groin, and/or tongue. If the hyperthermia is not resolving within 15 minutes, or the animal has an RT > 41.0°C, i.v. fluid therapy is initiated (10-15 ml/kg of Ringer®-acetat). Oxygen supplementation is recommended for hyperthermic animals. Hypothermic animals

(RT < 36.0°C) are protected from wind and cold surfaces to avoid further cooling using a Wolverine Bag®. Hot water bottles are placed in the groin and axilla as an external heat source in the field. In case of prolonged immobilization and recovery, hypothermic animals are warmed, and prewarmed fluid (38°C) (Ringer®-acetat) is administered intravenously.

Awakening and release

For reversal of immobilization in animals that have received medetomidine-combinations, 5 mg of atipamezole (Antisedan®) per mg of medetomidine is administered i.m. Due to the long elimation time of tiletamine-zolazepam, atipamezole is not given until earliest 50-60 min after darting. In an emergency, atipamezole is given at any time, but recovery may then be rough with possible incoordination, excitation and convulsions. Such an animal can be calmed by administration of midazolam (Midazolam®) i.m. (suggested dose 0.1-0.2 mg/kg).

Immobilized animals are usually left to recover undisturbed at the site of capture. Possible side effects and dangers during and immediately after recovery, hypothermia, hyperthermia, intraspecific strife, open water, lack of fear, traffic, and poaching. All GPS and radio-instrumented animals are checked the day after capture.

Long-term effects of marking

The capture-related mortality rate for 380 captures of Eurasian lynx in Scandinavia was 4.2% during 1995-2004 (Arnemo et al. 2006). This mortality rate included direct mortality (2.4%) due to pneumothorax due to misplacement of the dart, stress with hyperthermia and/or circulatory failure, possible hyperthermia during recovery, one that fell from a tree during induction and was euthanized due to a leg fracture, an immediate death following darting, and two lynx that were found dead close to the capture site within a few days. Secondary mortalities (1.8%) included 2 unanesthetized animals that were euthanized because of receiving leg fractures after being captured in snares, 3 juveniles that died because the mandible became caught under the radio-collar, and 2 that died after the implanted transmitter became trapped in the pelvis, causing intestinal obstruction. As with the other large carnivore species, researchers have worked to reduce injuries and mortalities from capture and handling. For lynx, primarily improvements in the spring-loaded foot snares and their placement in the field have contributed to reducing of the capture mortality rate from 3.7% during 1995-2002 (107 captures) to 1.4% during 2003-2007 (70 captures) (Odden et al. 2007).

Arnemo et al. (1999) surgically implanted intraperitoneal transmitters into 9 neonatal lynx kittens, aged 4-5 weeks, without any noticeable problems. All survived at least 3 months after the operation. However, Léchenne et al. (2012) found that free-floating implants can become lodged within the pelvic canal, causing a mechanical blockage, which resulted in the death of two yearlings. One adult female also died, due to dystocia, because the pelvic canal was blocked when parturition began, leading to uterine rupture and subsequent peritonitis.
Implants of the size that caused these problems are no longer used, and after changing implants from Telonics® IMP/150/L to Telonics® IMP/400/L (95 g, 9.7 x 3.3 cm), no further mortalities were documented after 58 implantations (Léchenne et al. 2012). Post-mortem examinations of implants carried by lynx for several years indicate that lynx do not seem to react to the implants.

Moa et al. (2001) studied whether capture of Eurasian lynx with foot snares and box traps in Norway affected the subsequent use of the capture area (a circular area comprising about 10% of the animal's home range). They found that captured animals left the capture area on average 6.1 days following capture, which was not significantly different from the time that elapsed before they left similar random areas. However, an average of 179 days elapsed before they reentered the capture patch (and 3 of 9 never did), which was significantly longer than it took to reenter random areas (36 days). Thus, capturing may have had a small-scale effect on spatial use. However, this study was based on a very small sample size and very little was known about the individuals' area use prior to capture. Based on data from other species, there is reason to believe that capture probabilities are higher in areas outside the animals' core areas, so caution is needed when interpreting these data. No other obvious long term effects on behaviour or reproduction have been reported, however, the SCANDLYNX team is currently beginning to explore their substantial data set for any subtle effects.

Concluding remarks

Using the present capture and marking protocols, the probability of capture mortality is at present low (1.4% during 2003-2007) for lynx and below the threshold of 2% recommended by Arnemo et al. (2006). No other effects have been reported, other than the spatial avoidance of capture sites (Moa et al. 2001). For demographic studies, better results will be obtained by following a number of individuals and recapturing them as needed, rather than capturing a larger number of individuals only once.

Arctic Fox (*Vulpes lagopus*)

Purpose of marking

Arctic foxes are only captured and marked for research purposes in Norway and on Svalbard.

Population size and the frequency of marking

There are at present (2011) 100 artic foxes in Norway. The number of foxes with transmitters is at present zero, which means that the probability of being marked is 0 (Table 1).

Who marks the animals?

Researchers working for research institutes and/or academic institutions capture and mark arctic foxes. Capturing and marking are currently done in connection to the captive breeding program on arctic foxes at the Norwegian Institute for Nature Research. The Norwegian Polar Institute has conducted research on Svalbard previously.

Marking methods and procedures

The captive breeding program on arctic foxes, which is the only project capturing and marking arctic foxes currently, marked some foxes with VHF-senders and released them in autumn 2007, but has not used radiotelemetry since. All released foxes have been tagged with colored ear tags (unit codes, giving the identity on the foxes), as well as received a chip under the skin on the neck. The neck collars weighed 80-190 g (A. Landa and N. Eide, pers. comm.).

NINA's artic fox captive breeding program equipped juvenile foxes with VHF mortality collars when released in 2006 (2), 2007 (15), and 2008 (25), but has not used radiotelemetry since. Collars were manufactured by Televilt AB with expanding collars (stapled) or Telonics collars with a weakness zone of woven cotton. All released foxes are tagged with colored ear tags (Dalton Roto Tag) (unit codes, giving the identity on the foxes, Fig. I), as well as a microchip placed under the skin on the neck. No mortality related to handling or marking has been recorded, but some animals were recaptured with worn fur around the neck, as well as two cases of wounds due to ice formation on the collars. These foxes were kept in captivity until the wounds had healed. There were also some wounds associated with the use of ear tags. These ear tags were removed and the wounds were treated. After the protocol for ear tagging had been changed (disinfectification of tools and tags in alcohol and using antibacterial cream (Brulidine 15%)), no wounds associated with ear-tagging have been found (A. Landa and N. Eide, pers. comm.).

I).  J).  K). 

Figure I. An arctic fox with colored roto ear tags and the face masked used to calm the animals while handling them. Photo by N. Eide. Figure J. An otter with a GPS collar attached to a harness (from Quaglietta et al. 2012). Fig. K. The harness used to radiomark otters in Norway. Photo by J. van Dijk.

Transmitters that were 6.3 cm long x 2.3 cm wide and weighed 44 g, or about 1% of a fox's body weight have been implanted in arctic foxes in Svalbard to record physiological data in an ecophysiological study (Fuglei et al. 2002). Thirteen transmitters were placed in bags of mersilene net (Ethicon GmbH and Co., KG, Norderstedt, Germany) to ensure firm adhesion to the abdominal wall through ingrowth of connective tissue. However, when the animals were reoperated to change the transmitters, the connective tissue ingrowth was found to be extensive and in some cases extended to other organs, such as the liver, spleen, and stomach, and caused excessively vascularized tissue to grow around the transmitter and thus cause excessive hemorrhage. The effects of this were unclear, because the animals showed normal behaviour in the weeks and months following the surgery and survived for at least 2 years after the conclusion of the studies. Nevertheless, Fuglei et al. (2002) recommend that this method not be used and began using a thick multifilament nonabsorbable suture (Mersilence® Ethicon 1 UPS) that they formed into three parallel belts around each transmitter. Each belt had two small loops on opposite sides of the transmitter to facilitate attachment to the abdominal wall. This caused much less connective tissue growth.

Capture and handling

Arctic foxes in Norway and on Svalbard have been captured in baited walk-in live traps (Landa et al. 1998, Fuglei et al. 2002). The most used model is a Tomahawk raccoon trap (Model 608). On Svalbard, foxes were also captured using a net that was released using a remote-control device or a modified leghold trap combined with a foot snare (Jepsen et al. 2002). The animals were restrained manually during handling and the authors did not report any effects of capture and marking on the animals.

Sedation and anesthesia

Arctic foxes are not sedated during handling in Norway (except to surgically implant transmitters). A face mask (Fig I.) is placed over their eyes, which makes them become very calm and easy to work with. However, Aguirre et al. (2000) administered 50 µg/kg medetomidine combined with 2.5 mg/kg ketamine to anesthetize 6-8 week-old arctic fox cubs for a mean time of 18 minutes. Serially recorded heart rate, respiratory rate, temperature, and pulse oximetry were stable throughout the anesthetic period for all cubs and anesthetic depth was reported to be suitable for safe handling and minor clinical procedures, including venipuncture.

Twelve wild-caught arctic foxes were anesthetized a total of 24 times to surgically implant transmitters that recorded body temperature and heart rate while the foxes were held in captivity on Svalbard (Fuglei et al. 2002). Four of these surgeries were performed with a mixture of xylazine (Rompun® 20 mg/ml, 1.2 mg/kg, i.m.) and ketamine (Ketalar® 50 mg/ml, 25 mg/kg, i.m.), which was hand-injected while the animals were under manual restraint in their cages. This mixture caused tonic convulsions, vomiting, and spontaneous recovery. In addition, 1 of the 4 foxes anesthetized with these drugs died 80 minutes after the beginning of the surgery. Therefore, use of this drug combination was terminated.

Twenty surgeries were performed using an anesthetic mixture of medetomidine (Domitor® 1 mg/ml, 0.05 mg/kg, i.m.) and ketamine (Ketalar® 50 mg/ml, 3 mg/kg, i.m.), injected into the thigh while the animals were in their outdood holding cages. This mixture induced effective and reliable anesthesia, except that 3 of the foxes died and one fox did not achieve a surgical plane of anesthesia, even after several supplemental doses. Mortality had not been observed earlier using this mixture in wild arctic foxes (Aguirre et al. 2000) or captive blue foxes (Jalanka et al. 1990). Potential side effects of medetomidine include bradycardia, decreased cardiac output, hypotension, emesis, hypersalivation, loss of thermoregulatory ability, and decreased respiration rate, but when medetomidine is combined with ketamine, immobilization is more complete and the potential for side effects is reduced (Fuglei et al. 2002).

Awakening and release

No postoperative analgesics were administered to the foxes that received surgery and they remained in captivity (Fuglei et al. 2002). Aguirre et al. (2000) administered 250 µg/kg atipamezole to reverse a dosage regimen of 50 µg/kg medetomidine combined with 2.5 mg/kg ketamine in 6-8 week-old arctic fox cubs, with the result that all were standing within an average of 12 minutes and fully recovered at a mean of 27 minutes. Jalanka et al. (1990) also used atipamezole to reverse a mixture of medetomidine and ketamine in adult captive blue foxes.

Concluding remarks

The arctic fox seems to be easy to capture and work with. No problems have been reported when capturing and marking foxes with radiocollars, nor have long-term effects been reported.

Eurasian Otter (*Lutra lutra*)

Purpose of marking

Eurasian otters are captured and marked for research purposes.

Population size and the frequency of marking

There are at present (2011) 20-25000 otters in Norway. The number of otters with transmitters is at present zero, which means that the probability of being marked is zero (Table 1).

Who marks the animals?

Otter research is conducted by researchers of the Norwegian Institute for Nature Research (NINA).

Marking methods and procedures

Otters cannot be marked with neckcollar-based radiotransmitters, because their necks and head have similar circumferences (Ó Néill et al. 2008). Therefore, Ó Néill et al. (2008) tested three methods to attach radiotransmitters; harness-mounted, glued-on, and surgically implanted. The external radiotransmitters measured 3.5x2.5x1.5 cm and weighed 15 g (0.3% of the weight of the smallest otter caught); with the harness, the combined weight was 130 g (3.25%). The glue used was thick flexible cyano-acrylate (Loctite Contact® 4860). The implanted radiotransmitters were encased in cylindrical, round-ended, silicone and polycarbonate tubes measuring 8.5x2 cm and weighing 28 g (0.7% of the smallest otter caught).

Harness-mounted radiotransmitters were retained for a mean of 20 days and 3 transmitters failed (N=11). Five harnesses were retrieved from submerged snags, where they were securely entangled. Although all the otters had escaped, this represents a risk of drowning for otters with harness-mounted transmitters (Ó Néill et al. 2008). One otter was killed by traffic 45 days after receiving a harness-mounted transmitter and had an open sore on the inside of one foreleg caused by abrasion with the leather strap of the harness. Two glued-on transmitters remained attached for 15 and 17 days. All of the 7 otters marked with externally mounted transmitters stayed within their home ranges around the trapsite (Ó Néill et al. 2008).

Quaglietta et al. (2012) also marked 6 otters with harness-mounted transmitters (Fig. J). They stayed on the otters for an average of 9 days and they observed no mortalities, entangling in snags, or fur abrasion from the harness. One female gave birth to young and began lactating while in the harness or immediately after it had fallen off.

Ó Néill et al. (2008) surgically implanted radiotransmitters into the peritoneal cavity of 15 otters. All surgeries were performed successfully (lasting 55-60 min) and without serious complications. One otter killed in traffic 12 days later showed a failure of the continuous horizontal mattress cubcuticular suture, apparently because the otter had bitten it off. The wound was sealed, secure, showed no clinical evidence of infection, and was healing normally. They concluded that the death was unrelated to the surgery. Nevertheless, they adopted a more secure discontinuous suture pattern for the other 14 otters. Another otter was recaptured after 13 days and showed no clinical evidence of infection and the surgical would was apparently fully healed. Three transmitters failed and all other individuals remained in the vicinity of their capture site.

Van Dijk (2012) placed a harness-mounted transmitter on 1 otter in Norway in 2011 (Fig. K). This transmitter was retrieved from a snag in an underground hole used as daybed after 86 days. The otter had worked herself out of the harness, probably because the leather was becoming loose and one of the buttons had come off.

Arnemo (1991) surgically implanted intraperitoneal radiotransmitters in 5 otters in Norway in 1989. They were cylindrical, ca. 3cm in diameter and 10 cm long, and weighed ca 100 g. Onewas found 5 days after release with the incision torn open and some of the abdominal organs hanging out of the wound. Another drowned in a fish trap almost 9 months after surgery. It showed no pathological conditions and the transmitter was lying free ventrally among the abdominal organs.

Capture and handling

Otters in Norway are captured using Victor SoftCatch® coil spring traps, either number 2 or 3 (Ó Néill et al. 2007, van Dijk 2012). Ó Néill et al. (2007) documented that when using this method, combined with a GSM-based trap alarm that allowed the researchers to respond on average 22 min after capture, the mean trauma score was 5.9 points and incidence of moderate to severe trauma was 5.6%, both of which were much better than the recommendations for United States Best Management Practice (BMP) for animal welfare (IAFWA 2006). However, when the alarm malfunctioned, the researchers found the otters within 24 hr and the corresponding values were 77.7 points and 70%, both of which were worse than the BMP requirements. Thus, they recommend this method, with reliable trap alarms, for capturing Eurasian otters. Ó Néill et al. (2007) also reviewed the literature and reported that box traps were inefficient in capturing otters and Hancock traps were unpopular, due to safety concerns for both animals and humans.

Sedation and anesthesia

Ó Néill et al. (2008) immobilized captured otters using a mixture of ketamine (3 mg/kg) and midazolam (0.08 mg/kg) intramuscularly while restraining the otter with a handling tong (1-m long, with a 12-cm diameter opening, lined with soft rubber, when the jaws were closed). No complications ensued for any animales sedated with this dose. A mixture of ketamine and medetomidine has been reported to be lethal for highly stressed wild-caught otters (Ó Néill et al. 2008). Eleven of 36 animals became hyperthermic due to exertion.

To induce light surgical anesthesia, Arnemo (1991) used a mixture of ketamine hydrocholoride (Ketalar®, 50 mg/ml) and xylazine hydrocholoride (Rompun®, 20 mg/ml). The doses were 20 mg ketamine/kg and 2 mg xylazine/kg. Especially “aggessive” individuals need higher doses. This drug combination was found to be a safe and efficacious anesthetic regime (Arnemo 1991).

Van Dijk (2012) used a mixture of ketamine (100 mg/ml) and diazepam (5mg/ml). The doses were 0.1 ml/kg diazepam and 0.1–0.12 ml /kg ketamine, which were injected intramuscularly while restraining the otter with a handling tong. The animal was released from the tong 3-5 minutes after injection. No complications ensued.

Awakening and release

Otters are released at the site of capture following marking. Van Dijk (2012) gave no additional drugs doses. Handling time was intentionally set to a maximum of 45 minutes after injection, so the animal could wake up gradually. The otter recovered totally in a box trap, and when it was active, it was released on the river bank.

Long-term effects of marking

Ó Néill et al. (2008) reported that, of the four lactating female Eurasian otters with surgically implanted transmitters, three rejoined with their dependent offspring and raised them successfully; the status of the fourth was inconclusive. Also Reid et al. (1986) concluded that all stages of the breeding cycle of North American river otters (*Lontra canadensis*), copulation, embryonic and fetal development, and lactation, could proceed successfully with a radiotransmitter in the peritoneal cavity.

Concluding remarks

The body form and aquatic habits of otters make them a poor candiate for mounting radiotransmitters or other devices externally, at least for longer time periods. Ó Néill et al. (2008) agreed with the general consensus in the literature that surgical implantation was the best approach for tracking studies of otters. Glued-on and harness-mounted transmitters have such a short retention time that it is difficult to justify capturing the otters for such little data. Also, the harnesses represent a risk for drowning. Nevertheless, harnesses are being improved, and may be more effective in the future. Highly stressed otters seem to be difficult to sedate and work with. The otter may be the species that is most affected by marking, of those considered here.

Eurasian Beaver (*Castor fiber*)

Purpose of marking

Eurasian beavers are only marked for research purposes in Norway, although some have been captured for reintroduction projects in other countries.

Population size and the frequency of marking

There are at present (2011) 70 000 beavers in Norway. The number of beavers with transmitters is zero, which means that the probability of being marked is zero (Table 1).

Who marks the animals?

Beavers are captured and marked by researchers at Telemark University College.

Marking methods and procedures

Beavers are marked with numbered plastic colored ear tags (1 or 3.5 cm, Dalton Continental B.V., The Netherlands) and/or monel metal eartags (1.5 cm, National Band and Tag Co., Newport, Kentucky) (Fig. L) and receive a microchip (1cm) in the neck (Rosell and Bjørkøyli 2002, Sharpe and Rosell 2003). These marks do not appear to affect the animal's behaviour.

Beavers have fusiform bodies, tapered necks, and use aquatic habitats that have many entanglement hazards; all of these make the species poor candidates for externally mounted radiotransmitters, especially radiotransmitters mounted on neck collars (Rothmeyer et al. 2002). Campbell-Palmer and Rosell (2012) recommended that radiotransmitters and their attachment mechanisms not exceed 1% of the animal's weight. Accelerometers are also attached to beavers to document behaviour.

Rothmeyer et al. (2002) recommended attaching modified ear-tag radiotransmitters to beavers' tails, after drilling a hole in the tail. They reported that the beavers showed no visible distress and that the retention time averaged 104 days. Only 1 tag (of 57) was chewed off by the beaver. Baker (2006), however, found tail-mounted transmitters to be of limited success for life-history studies of North American beavers (*C. canadensis*) and did not recommend them for long-term monitoring. Arjo et al. (2008) added neoprene washers between the tail and the transmitter and increased the retention of modified ear-tag transmitters mounted to the tails to 89%, with an average retention time of 343 days. Tail-mounted transmitters have also been used in Norway (Sharpe and Rosell 2003).

Radiotransmitters may be attached by gluing to the fur of the lower back using a two-component epoxy resin or high-tech araldite (Fig. M). Coarse-meshed polyester or other solid flexible material is usually used to cover and secure the units and protecting the skin from contact with the glue (Campbell-Palmer and Rosell 2012). The glue can cause chemical burns to the skin. This method is only useful for short-term attachment.

Intraperitoneal transmitters. Ranheim et al. (2004) implanted intraperitoneal radio transmitters in adult beavers in the field in Norway. These were Alterra® TX30.3A1 implants, which are egg-shaped, 65 x 34 mm, weighed 73 g, and were equipped with temperature and movement sensors. One out of 22 animals died postoperatively due to circulatory failure, but the movement or behaviour of the other beavers did not seem to be affected by the implant procedure, except that they spent more time in their lodges during the first few days postsurgery. All the beavers stayed in their original territories for 17-24 months following surgery or until they died. However, Campbell-Palmer and Rosell (2012) advise subcutaneous implants.

Capture and handling

A large variety of traps have been used to capture beavers (Rosell and Kvinlaug 1998). The recommended method in use in Norway today is capturing beavers using hand-held nets (Fig. N) (Rosell and Hovde 2001). Two people work together from a motor-powered boat, locating the beavers at night with a spotlight and headlights. The beavers are captured on land and in the water using 2 main types of nets, i.e. the diving and the landing net (Rosell and Hovde 2001). Upon capture the beavers are transported ashore, if not captured on land, in cloth sacks. Unless they will undergo surgery, they are not immobilized. Beavers are restrained in a hessian sack for handling, which keeps the animal relaxed and provides more safety for the handlers (Campbell-Palmer and Rosell 2012).

L).  M).  N). 

Fig. L. A beaver marked with ear tags. Fig M. A transmitter that has been glued to the back of a beaver. Fig. N. A hand-held net used to capture beavers. Photo by F. Rosell.

Sedation and anesthesia

Normally, beavers receive no sedation when captured and handled, unless they are to be immobilized for surgery. The recommended drugs and dosages (Kreeger and Arnemo 2012) are derived from the study of Ranheim et al. (2004) in Norway. Kreeger and Arnemo (2012) recommend a combination of 5 mg/kg ketamine, 0.05 mg/kg medetomidine, 0.1 mg/kg butorphanol, and 0.25 mg/kg midazolam for anesthesia. Induction time is about 8 minutes. Anesthetized beavers may develop severe hypoxemia, so supplement oxygen should be considered.

Intraperitoneal transmitters. The surgical implantation of intraperitoneal transmitters into beavers has been described by Ranheim et al. (2004).

Awakening and release

Atipamezole (0.25 mg/kg) is used as an antagonist and beavers are kept in a wooden box in a dark and quiet area until recovery. They are then released into the water at the capture site (Ranheim et al. 2004).

Long-term effects of marking

Rosell and Hovde (2001) reported no injuries or obvious symtoms of severe stress when capturing 84 beavers in Norway with hand-held nets during the night. All of the captured beavers swam away in a normal fashion following release. To date, over 1000 beavers have been captured with this method without problems (F. Rosell, pers. comm.). Guynn et al. (1987) reported that, of 10 North American beavers receiving implanted intraperitoneal transmitters, 1 died of an intestinal obstruction. The others were recaptured after 0.5-28 months and showed gains or small losses (≤3%) in body mass and exhibited no signs of pathology in the peritoneal cavity. Ranheim et al. (2004) reported that 1 out of 22 beavers implanted with intraperitoneal radio transmitters in Norway died.

Concluding remarks

Beavers are easy to capture safely. However, as for the Eurasian otter, the body form and aquatic habits of beavers complicate the mounting of external radiotransmitters or other devices, at least for longer time periods. Tail-mounted modified ear-tag transmitters with neoprene washers seem to be the best long-term external markers. Internally implanted transmitters are another option. Glue-on transmitters work for shorter studies.

Moose (*Alces alces*)

Purpose of marking

The moose is an economically important wildlife species in Norway and elsewhere, and a large number of projects have been conducted for research and management reasons. The first moose was immobilized in Norway as soon as in 1976, and 1,898 immobilizations of wild moose were carried out in 10 Norwegian counties in the period 1976-2004 (Arnemo 2004).

Population size and the frequency of marking

There are at present (2011) 117 000 moose in Norway. The number of moose with transmitters is at present < 150, which means that the probability of being marked is 0.01% (Table 1).

Who marks the animals?

Capturing and marking of moose in Norway is carried out by qualified veterinarians. The projects may be conducted by researchers at academic institutions or research institutes or by public or private management organizations.

Marking methods and procedures

Moose are marked with collars with an individually fitted circumference. These collars almost always carry radio-transmitters and may be marked with a number that is visible from a distance. Calves receive expanding collars to account for growth. In addition, all the moose are marked with standard plastic ear tags used for cattle for identification in case the collar falls off (Fig. O). Solberg et al. (2011) examined 19 adult moose for loss of hair and sores due to rubbing against the neck collar. They found only 1 instance of this, where hair had been rubbed from the lower neck region of a male with a neck collar that rotated, so that was turned upside down on the moose. The hair loss was moderate and there was no sore from rubbing. There was no sign of rubbing sores or hair loss on the other 18 moose.

Capture and handling

Moose are usually captured during the winter, when the ground is snow-covered, by darting from a helicopter using a remote drug delivery system (Dan-Inject®). Rarely, moose are darted from a car, snowmobile, from the ground, sometimes at feeding sites or using dogs (Arnemo 2004). Moose generally show little fear of the helicopter when it is far away and the helicopter can be used to steer the moose to a more open area for darting. If this is not possible, that individual moose is not pursued further. When the moose is in an appropriate open place, the helicopter approaches rapidly for 1 min or less and the moose is darted from a distance of 5-15 m. After darting, the helicopter raises to a high vantage height where the moose is observed until it lies down, which usually takes 4-6 minutes. If it has not lain down within 10-15 minutes, the procedure is repeated with a new dose of sedatives (Solberg et al. 2011). Neumann et al. (2011) reported mean induction times of 13 minutes using the same sedatives. Rostal et al. (2012) found that, using this method of capture, rectal temperatures were positively correlated with chase and induction times, but blood cortisol levels, a measure of short-term stress, was not. This may be due to the fact that most of the animals were chased for <5 minutes and induced within 5 minutes.

Sedation and anesthesia

The recommended drug for immobilizing moose is etorphine (7.5 mg etorphine, with half dose for calves). Increased mortality and complications have been observed when underdosing with etorphine (Keeger and Arnemo 2012).

Awakening and release

An antagonist is always given to reverse the effects of the sedative. The antagonist depends upon the chosen immobilization drug. The antagonist for etorphine is diprenorphine (12 mg; half dose for calves) (Keeger and Arnemo 2012). Reversal of the immobilization usually takes 0.5-5 minutes (Solberg et al. 2011); Neumann et al. (2011) reported a mean of 1 minute. It generally takes about 30-40 minutes from the animal is approached for darting until it the immobilization drug has been reversed and the moose is standing (Neumann et al. 2012). This includes marking, taking samples, weighing, etc. Field personnel ensure that the moose is up and walking before they leave it.

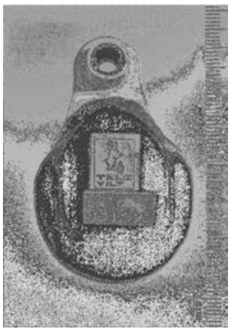
O).  P).  Q). 

Fig. L. Adult moose with a radiocollar and ear tag. Photo by J. Arnemo. Fig. M. Ear-mounted mortality transmitter used on moose calves. From Swenson et al. (1999). Fig. N. A male red deer with a radiocollar and ear tag. Photo by Erling Meisingset.

Long-term effects of marking

The mortalty rates associated with capturing and immobilizing moose are extremely low. Based on 2,816 captures in Scandinavia during 1984-2004, Arnemo et al. (2006) reported an overall mortality rate of 0.7%, which consisted of drug-related deaths due to respiratory depression (0.2%), indirect effects of capture due to drowning or dart trauma (0.2%), and secondary effects, due to exertional myopathy, bear predation, and deaths of unknown causes within 30 days postcapture. Neumann et al. (2011) assessed the short-term effects of capture and immobilization on activity and movement patterns of 15 marked adult female moose that were recaptured in Sweden. They found that moose were more active up to 7 hours postcapture and increased their spatial displacement for 4.5 days, compared to precapture patterns. They concluded that the moose moved from the area of capture and recommended not to use movement data during the first 5 days postcapture. Støen et al. (2010) found that moose also reacted to helicopter approaches, even when they were not captured, by increasing their movement rate up to 10 times immediately after the approach and moving to more rugged terrain. The increased rate of movement disappeared after 2 hours. Solberg et al. (2003) analyzed data from 227 immobilizations of moose on Vega Island, Norway, and concluded that the immobilization of moose from helicopter with etorphine in winter can be considered a safe procedure, because no individuals died during capture or handling nor were found dead within 6 weeks of the procedure.

Swenson et al. (1999) studied the effects of marking moose calves $\leq$3 days old with a radiotransmitter, with a mortality function, mounted on an ear tag (Televilt model TXP-2M; the entire assembly weighed 29 g, Fig. P) and a colored, plastic ear tag weighing 3.5 g. The entire procedure took about 5 min. An analysis of the survival of 427 calves in 5 areas in Sweden showed similar neonatal mortality rates between control calves (17%) and those with plastic ear tags (17%), but significantly higher rates for the calves with ear-tag mounted transmitters (71%). Mortality was higher in areas with bears, but this did not have an additive effect on the mortality of those with radiotransmitters. The reason for the higher mortality among calves with ear-tag mounted radiotransmitters was not known, although Swenson et al. (1999) speculated that the clicking sound made by the iron switch may have negatively affected the mother-calf bond (silent mercury switches are not allowed in Sweden). They did not recommend using this type of radiotransmitters on moose calves. Larsen and Gauthier (1989) did not find negative effects of capturing and marking neonatal moose calves with radiotransmitters mounted on expandable neckcollars on their survival.

Solberg et al. (2011) analyzed data from 362 immobilizations of 216 individual moose during 1992-2010 on the island of Vega, Norway, to examine the effects of multiple immobilzations and long-term collar use. These data resulted from a long-term study where >95% of the moose on the island were radio-marked from their first winter of life. Each moose carried a radiocollar for an average of 2.7 years (1-13 years). They experienced only 1 death (0.3% mortality rate) during capture, when a male drowned during the induction phase, and no secondary deaths. The radiomarked moose population on Vega has very high age- and sex-specific body masses and twinning rates and low natural mortality rates, compared with other Norwegian populations, and neither body mass nor recruitment rates have declined during this study. In addition, they found no significant relationships between the age- and sex-specific carcasses masses of harvested moose and the number of lifetime immobilizations (0-8 per individual) or the number of years they carried a collar (0-13 years). They concluded that immobilization and radiocollaring had no major effects on the short- and long-term welfare of the moose on Vega; ie. the stress involved was not sufficient to affect the vital population rates. An earlier study on Vega, Solberg et al. (2003) found lower reproductive rates and calf survival related to capture and handling of some age classes of moose cows in winter, however they concluded that the main reason for the loss of fetuses and neonatal calves was the use of rectal palpation, possibly in combination with the weighing prodecure, using a helicopter, to obtain body mass.

Concluding remarks

Studies of the mortality associated with capture and immobilization and the short- and long-term effects of this and carrying collars strongly suggest that moose are little affected, at least at the scale of the studies. Researchers should not use movement and habitat data during the first 5 days after capture and first 2 hours following a helicopter approach, however. The results of the available studies agree with the conclusion of Solberg et al. (2011); “the current marking process is sound in an animal welfare perspective”.

Red Deer (*Cervus elaphus*)

Purpose of marking

Wild red deer are marked for research and management reasons. Captive red deer are kept in commercial deer farms and are marked as part of the farmer’s animal husbandry activity. Only wild red deer will be dealt with in this section.

Population size and the frequency of marking

There are at present (2011) 130 000 red deer in Norway. The number of red deer with transmitters is at present 130-150, which means that the probability of being marked is as low as 0.01% (Table 1).

Who marks the animals?

Red deer in Norway are immobilized by research biologists and veterinarians.

Marking methods and procedures

Wild red deer in Norway are normally fitted with a GPS radiotransmitter mounted on a neck collar with a drop-off capacity and a plastic or metal ear tag for individual recognition (Fig. Q). The neck collars are made of plastic or kevlar and come in 50-cm and 70-cm circumferences for females and males, respectively. The collars and transmitters weigh 700-875 g, depending on the size, battery weight, whether there is a drop-off function, etc. There are lighter collars for use on calves. The collar is fitted based on the size of the animal's neck; it should be loose, but not too loose. This is especially important for males, because their necks vary in size during the year. No mortality due to the collar has been recorded in Norway (E. Meisingset, pers. comm.). Few animals show sign of sores or hair loss from the collars; when it does happen, it seems to be due to a collar that is too loose and moves too much on the neck (Fig R).

R).  S).  T). 

Fig. R. A red deer 2 years after receiving a radiocollar, showing moderate wear on the hair. Photo by Erling Meisingset. Fig. S. A reindeer with a radiocollar and ear tag. Fig. T. A Svalbard reindeer with a radiocollar. Photos by J. Arnemo.

Capture and handling

Wild red deer in Norway are normally darted from the ground or a vehicle in winter (January-April) at feeding sites using a CO_2-powered dart gun (Arnemo et al. 1994, Godvik et al. 2009). The feeding sites are located near a barn or house, so the deer become used to human activities and artificial light is used, because the deer usually come to the feeding site when it is dark. The feeding sites are in the open, at some distance from forest, so that the deer can be watched after they have been darted. They resume normal behaviour within a couple of days.

Sedation and anesthesia

The recommended drug for the immobilization of wild red deer in Norway is a combination of xylazine-tiletamine-zolazepam, with 250 mg xylazine and 250 mg tiletamine and zolazepam per 100 kg body mass (Rosef et al. 2004). Studies have documented significantly higher levels of blood parameters that reflect stress levels in red deer captured physically compared with red deer captured chemically (Arnemo et al. 1994, Marco and Lavín 1999, Topal et al. 2010).

Awakening and release

The recommended antagonist to the recommended drug, given above, is 2 mg/kg tolazoline (Kreeger and Arnemo 2012).

Long-term effects of marking

Blanc and Brelurut (1997) studied the short-term effects (8 days) of marking captive female red deer with GPS transmitters mounted on neck collars weighing 3.4 kg, ie. 3.5% of their body mass. They had been together for 2 weeks before the experiments began. They found that wearing the neck collar had no effect on the females' hierarchial ranks, but there was an increase in the hourly frequency of agonistic encounters received, a reduction in nonagonistic encounters exchanged with conspecifics, a decrease in grazing activity and trough feeding rate, and a desynchronization of grazing activity compared with unmarked females. Thus, they documented a short-term effect of marking on social and foraging behaviour in captive female red deer.

Concluding remarks

The present protocol for the capture and marking of red deer seems to be safe and recommendable, with no documented long-term life-history effects.

Reindeer (*Rangifer tarandus tarandus*)

Purpose of marking

Wild reindeer are marked for research and management reasons. Domestic reindeer are marked as part of the owner's husbandry program. Only wild reindeer will be covered in this section.

Population size and the frequency of marking

There are at present (2011) 25 000 wild reindeer in Norway. The number of reindeer with transmitters is at present 58, which means that the probability of being marked is 0.2% (Table 1).

Who marks the animals?

Wild reindeer are captured and marked by a veterinarian as part of a research team.

Marking methods and procedures

Reindeer are marked with radiotransmitters mounted on neck collars and individually identifiable ear tags (Fig S).

Capture and handling

Arnemo et al. (2011) described capturing wild reindeer from a helicopter using a CO_2-powered dart gun (Dan-Inject®). To minimize stress and handling time, they spotted the herds from high altitude and then immediately approached them with the helicopter. The reindeer were visibly excited and stressed from helicopter chasing.

Sedation and anesthesia

Arnemo et al. (2011) immobilized wild reindeer with a combination of medetomidine (Zalopine® 10 mg/ml) and ketamine (Ketavet® 100 mg/ml) with initial doses of 12 or 14 mg medetomidine and 60 or 70 mg ketamine per animal with a fixed ratio of 1:5, respectively. Three of 29 animals did not show signs of sedation from the original dart and were given a second full dose. All animals showed a hypoxemic response at some time during immobilization. The same drugs are used for domestic reindeer, but at lower doses, because the domestic animals are not as stressed as the wild animals (Ryeng et al. 2002, Arnemo et al. 2011).

Awakening and release

Arnemo et al. (2011) reported that reversal of medetomidine with atipamezole (Antisedan® 5 mg/ml) at 5 mg per 1 mg of medetomidine resulted in a smooth and uneventful reversal. All recoveries were calm and the animals stood up and walked away in a coordinated manner.

Long-term effects of marking

All 10 female wild reindeer that were captured from a helicopter and radiocollared by Arnemo et al. (2011) survived for at least 24 months (5 captured the first year) or 12 months (5 captured the second year). At least 6 of the 10 females that were pregnant in 1995 were observed with a live calf in summer 1996, and good reproduction was also observed the following year, when half of the females had been captured the previous winter. Valkenburg et al. (1983) also found no significant effect of darting from a helicopter and chemical immobilization (using etorphine hydrocholoride or that in combination with Rompum®) on subsequent natality or calf survival.

Concluding remarks

The present protocol for the capture and marking of wild reindeer seems to be safe and recommendable, with no documented long-term life-history effects.

Svalbard Reindeer (*Rangifer tarandus platyrhynchus*)

Purpose of marking

Svalbard reindeer are captured and marked for research purposes.

Population size and the frequency of marking

There are at present (2011) 11 000 Svalbard reindeer in Norway. The number of reindeer with transmitters is at present 37, which means that the probability of being marked is 0.3% (Table 1).

Who marks the animals?

The animals are captured and marked by researchers working for research institutes or academic institutions.

Marking methods and procedures

Svalbard reindeer are marked with individually numbered ear tags and neckmarker straps filled with numbered sleeves (Omsjoe et al. 2009) or with radiocollars or plastic collars (Arnemo and Aanes 2009) (Fig. T).

Capture and handling

Two methods of capturing Svalbard reindeer have been described in the recent literature; one with and one without the use of immobilizing drugs. When not using drugs, the reindeer are captured in late winter (April and May) by shepherding them into a suitable area for capture using 2-3 snowmobiles. Then a targeted individual is chased by 2 snowmobiles with a net held between them until it is caught in the net. It is removed from the net as soon as possible and restrained by foot straps around all four feet to enable processing (Omsjoe et al. 2009). This study documented significant increases in a number of physiological parameters indicative of short-term stress. For example, body temperature was affected by the physical activity involved in the chase and to a lesser degree by the stress of restraint and handling. About half of the animals had body temperatures >40°, indicating exercise hyperthermia. Levels of several indicators of physiological stress found in the blood were also elevated (eg. blood corticol, glutamate dehydrogenase, and γ-glutamyltransferase). Nevertheless, no symptoms of clinical illness were observed (Omsjoe et al. 2009).

When using drugs, the animals are approached to 15-25 m on foot and the drugs are administered into the heavy muscles of the shoulder or thigh with a CO_2-powered rifle (Dan-Inject®) (Arnemo and Aanes 2009). The animals are docile and can be easily approached at close range, especially in late fall. They did not run away after being hit by the dart.

Sedation and anesthesia

When the reindeer are captured with nets, medications or sedatives are not used (Omsjoe et al. 2009). When they are darted, Arnemo and Aanes (2009) recommended a mixture of medetomidine (0.113 mg/kg) and ketamine (2.26 mg/kg), which had an induction time that averaged 6.5 minutes. Time from darting to administration of the antagonist averaged ca 30 minutes. Arnemo and Aanes (2009) observed no major clinical or physiologic side effects, although they found a mild hypoxemic response and recommended the use of supplemental inspired oxygen.

Awakening and release

After processing, the reindeer received atipamezole (Antisedan® 5 mg/ml) at 5 mg/l mg of medetomidine for reversal. It was administered half intramuscularly and half subcutaneously (Arnemo and Aanes 2009). They reported that all recoveries were calm and the animals were on their feet about 13 minutes, on average, after receiving atipamezole. They were watched for 2 hours after reversal.

Long-term effects of marking

Omsjoe et al. (2009) examined the effect of capturing 230 pregnant female Svalbard reindeer near the end of pregnancy by chasing them and catching them using snowmobiles on their subsequent reproductive success. Although capture and handling caused heat stress and raised levels of stress-related blood parameters, there was no indication of a significant impact of raised cortisol levels on the maintence of pregnancy or fetus viability, as measured by the probability of having a calf at foot 3-4 months following capture. Tyler (1991) estimated that flight from an approaching snowmobile (not capture) in late winter resulted in only a 0.4% increase in Svalbard reindeer’s daily energy expenditure and a 0.4% loss of daily grazing time.

Concluding remarks

Svalbard reindeer seem to be exceptionally docile and easy to capture. No long-term effects of capture and handling on reproduction have been found.

Roe Deer *(Capreolus capreolus)*

Purpose of marking

Roe deer are mainly marked for research purposes in Norway. A few animals have been marked over the years in connection with management projects, such as introduction in new areas.

Population size and the frequency of marking

There are at present (2011) 126 000 roe deer in Norway. The number of roe deer with transmitters is at present 10-20, which means that the probability of being marked is 0.01% (Table 1).

Who marks the animals?

Researchers capture and mark roe deer.

Marking methods and procedures

Roe deer are equipped with VHF and GPS collars weighing 300-450 g, or about 1.7, 1.9 and 2.4% of the body mass of adults, yearlings and fawns, respectively (range: 1.3-2.2% for adults, 1.7-2.3% for yearlings and 1.9-4.0% for fawns) (Morellet et al. 2009). Collars are made of smooth plastic to reduce rubbing and prevent water absorption (Fig. U). Drop-offs have been used in some cases, although the present commercial models are not reliable. New models are being tested as they become available. In addition, animals are ear tagged. Usually this is done using a small metal ear tag designed for small livestock, although in some studies where visual recognition from long distance is needed, a large yellow plastic ear tag has been used in addition.

Capture and handling

In Norway, roe deer are mainly captured in autumn and winter using baited box traps (Fig. V) or baited drop nets (Mysterud 1999). In addition, canon nets (placed beside bait) and drive nets have been used. There has been only one capture- or marking-related mortality when using baited box traps to capture several hundred roe deer in southeastern Norway. Box traps are checked at least twice per day, so animals can potentially be in the box for a few hours before being processed, but in all cases animals appear to be quiet when found. Canon nets and drop nets have been associated with a small number of mortalities, <3% for canon nets and <1% for drop nets (based on unpublished data up to 2004). Drive nets are widely used in Europe with few reported problems, although an early attempt to use them in Norway led to 15% mortality in one operation. It appears that mortality rates are highly variable between locations and the manner in which the method is utilized. This is an important method in areas with little snow. Mortality causes are almost entirely caused by postcapture myopathy, although a few have been caused by physical injury. Studies from central Europe have shown that capturing roe deer in box traps seems to be much less dangerous and stressful than capture using drive nets (López-Olivera et al. 2009), and the effects of this stress is difficult to control with tranquilizers (Mentaberre et al. 2010). With all net captures (drop, canon, drive) people are present when the animal is captured and they are processed immediately. In Norway, roe deer are manually restrained in all capture methods, without the use of tranquilizers or sedatives (Fig. V). This permits a very rapid handling and release (usually less than 5 minutes per animal), which seems to prevent stress and mortality.

Neonatal roe deer fawns are captured by hand by stalking radiocollared does or by spotting fawns that are seen suckling unmarked does. Fawns are fitted with two-stage expandable radiocollars, the smallest of which also have weakness zones (Panzacchi et al. 2009). One death was caused by a very early version of the expanded collar becoming caught in the fawn’s mouth. The only mortality causes are from abandonment, but this has not been a problem once the protocols for capture and handling were refined.

Sedation and anesthesia

Roe deer are not sedated during handling.

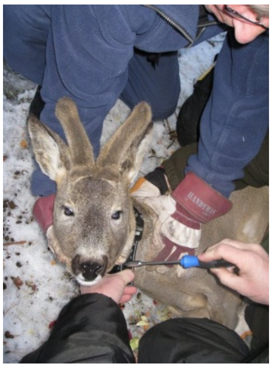
U).  V). 

Fig. U. A roe deer receiving a radiocollar. Fig. V. A restrained roe deer next to the box trap in which it had been caught. Photos by J. Odden.

Long-term effects of marking

Apart from the mortality issues identified above, few negative effects have been identified. Morellet et al. (2009) evaluated the effect of capture by driving into nets in winter and handling on 112 roe deer equipped with GPS collars in France during a period of 50 days postrelease. The entire process took 100-400 min. They compared the behaviour of the roe deer during the first 10 days after release with the subsequent 40 days. They found pronounced differences in terms of spatial behaviour, habitat use, and overall activity level between the two periods in GPS-monitored roe deer, including differences in terms of spatial displacement between the sexes, with females responding less than males, and among age classes, with yearlings responding most and fawns least, to the capture and handling event. Immediately following capture, roe deer were located further from the center of their home range than normal. This displacement of the home range was more pronounced among yearlings than among adults and fawns. In addition, spatial displacement of roe deer increased with openness of the habitat due, in part, to the scarcity of available shelter in open areas. They concluded that the roe deer exhibited a strategy consisting of seeking a refuge and waiting before returning after capture and handling, with displacement towards a refuge habitat, in or near woodland, avoidance of sources of human disturbance, and reduced activity levels. Based on these findings, Morellet et al. (2009) recommended removing data during the first ~10 days of monitoring due to behavioural alterations due to capture and handling. This method is not used in Norway today.

The only documented effect of marking in Norway concerns hair loss caused by collar rubbing. The winter coat of roe deer consists of very brittle hairs. In late winter, when these hairs stop growing, they become loose, but would normally only fall off in stages during spring after the summer coat has grown up underneath. The presence of a collar rubbing on the neck can cause the winter coat to be rubbed away from the neck earlier than normal, in extreme cases before the summer coat has developed fully, resulting in a lack of hair or short hair on parts of the neck for about a month in late winter—early spring. Very rarely, this has led to some skin abrasion on the top of the neck. This occurred only when the heavy GPS collars, 450 g, with a combination of poor collar design from the manufacturer (too round shape) and too loose attachment. These heavy collars are no longer used in Norway. Morellet et al. (2009) speculated that the reduction in activity and change of habitat use that they observed likely resulted in a reduction in food intake, perhaps causing a temporary nutritional stress, in addition to the stress of being captured and fitted with a collar. This could potentially have a detrimental long-term impact for roe deer in some situations.

Concluding remarks

The studies of Morellet et al. (2009) suggest that roe deer may show a greater reaction to capture and marking than moose and red deer. This has not been documented, and further research is necessary.

Muskox *(Ovibos moschatus)*

Purpose of marking

Wild muskoxen have not been captured in Norway or Sweden for marking, although a few have been captured for moving. Two animals were radiomarked while in captivity in Sweden and later released. There is presently no research on wild muskoxen based on marking in either Norway or Sweden. However, captive muskoxen on Rya Island, Troms, are immobilized routinely (Blix et al. 2011).

Population size and the frequency of marking

There are at present (2011) 170 muskoxen in Norway. The number of muskox with transmitters is at present zero, which means that the probability of being marked is zero (Table 1).

Capture and handling

The muskoxen owned by the University of Tromsø on Rya Island are driven into a 2-da enclosure, approached by foot, and darted one at a time with a CO_2-powered dart gun (Dan-Inject®) at a range of 20-30 m (Blix et al. 2011). Clausen et al. (1984) darted muskoxen in Greenland from the ground after they had been chased by husky dogs until they formed a group and Reynolds (1998) darted them from a helicopter in Alaska.

Sedation and anesthesia

Blix et al. (2011) recommend a mixture of etorphine (M99, 9.8 mg/ml) and xylazine (Rompun®) and a dose of 0.05 mg/kg etorphine and 0.15 mg/kg xylazine in summer and a dose of etorphine that is reduced by 30-50% in winter. They reported only one overdose of 133 immobilizations, when the body mass was underestimated. They also reported that respiration was depressed during the initial 10-15 minutes, which compromises both oxygenation and thermoregulation.

Awakening and release

Blix et al. (2011) used diprenophine (12 mg/ml) and atipamezole (Antisedan®, 5 mg/ml) as antagonists. The muskoxen were standing an average 6 minutes after receiving the antagonists.

Long-term effects of marking

Nothing has been reported.

Concluding remarks

Immobilization should be avoided on warm and sunny days (Blix et al. 2011, Kreeger and Arnemo 2012). Otherwise there is no evidence of negative effects of capture or marking muskoxen.

General concluding remarks for terrestrial mammals

Generally, the capture, immobilization, and marking protocols used on these terrestrial mammals in Scandinavia seem to provide good animal welfare protection to the individuals involved, based on the rate of capture-related mortalities. Capture and immobilization always involves the danger of mortality; capture-related mortality in five species of large free-living terrestrial mammals in Scandinavia ranged from 0.7 to 3.4%, compared to anesthesia-related mortality rates of 0.01-0.05% for humans, 0.1% for dogs and cats, and 1% in horses operated on under controlled conditions (Arnemo et al. 2006), and several of these mortality rates have decreased in recent years due to improvements in capture protocols. Arnemo et al. (2006) recommended using <2% mortality as a standard when capturing free-living large mammals. The border of >2% mortality is anyhow a standard under discussion and in the future a capture related mortality more equal to what is obtained under controlled conditions is the Golden standard.

Of course, more studies of the subtle effects of capture and marking, particularly effects on physiological status, life history, and behaviour, are needed for almost all of these species. We need more general knowledge about the short- and long-term effects that capture- and marking-induced stress have on wild-caught mammals to evaluate the trade-offs between animal welfare, needs for scientific knowledge, and effects of capture and marking on research results. Scandinavian researchers have a great potential to address these questions and help solve the problems they identify. It is evident that, where the researchers have identified problems with the methods they have used, they have also usually implemented countermeasures to avoid these problems in the future.

Marine mammals

Polar Bear *(Ursus maritimus)*

Marking methods and procedures

Individual identification:

All polar bears captured in current Norwegian research programs are drugged and equipped with plastic ear tags that have an individual ID number (see figure 1). These tags consist of two small discs (22 and 16 mm, respectively), which weigh about 5 g; they are deployed using special pliers. The ear tags are supposed to stay in for the whole lifespan of the animal.

Figure 1. Ear tags for polar bears. Each tag has its own individual identification number. Right panel shows the tags on a swimming bear. Photo: left panel: Magnus Andersen; right panel: Kit Kovacs/Christian Lydersen.

In addition, all polar bears except cubs are tattooed with a unique ID number on the inside of the upper lip using standard tattoo pliers and ink (see figure 2). Additionally, all polar bears caught in Norway also have a PIT tag implanted in the neck area, behind the ear, for further individual identification.

Figure 2. Lip tattooing a polar bear for individual identification. Photo: left panel: Magnus Andersen; right panel: Jon Aars.

An experiment is currently being conducted in Alaska to explore whether Radio Frequency Identification (RFID) technology will permit identification of individual polar bears at a distance, without recapturing them (Quakenbush et al. 2009). For this experiment, bears were equipped with a radio-transmitter built into an ear tag, which transmits a tag identification number every 2 s. Life-time of the tag is expected to be up to four years. The tag ID can be read from aircraft, other vehicles or fixed stations. If this system proves to be functional, it would be an inexpensive, animal-friendly method for use in mark-recapture studies and it could also potentially provide tracking data on male polar bears where traditional neck collars are of little use (see below). VHF transmitters used in ear tags have proven useful for recapturing animals over shorter time-frame experiments such as the immunology study by Lie et al. (2004). VHF transmitters are also common tools that are integrated into many neck collars to find a specific individual (active tracking) or retrieve a collar that has fallen off or is attached to bear that has died (and is sending mortality mode signals).

Tracking individuals:

The most common method for tracking polar bears for studies of movement patterns or habitat use is by equipping the bear with a neck collar carrying various types of instruments, usually including a satellite-linked location determining component. The collar is made of leather, or sometimes a synthetic material, and weighs around 1.5 kg (varying some depending on which instruments and how many batteries it contains, figure 3).

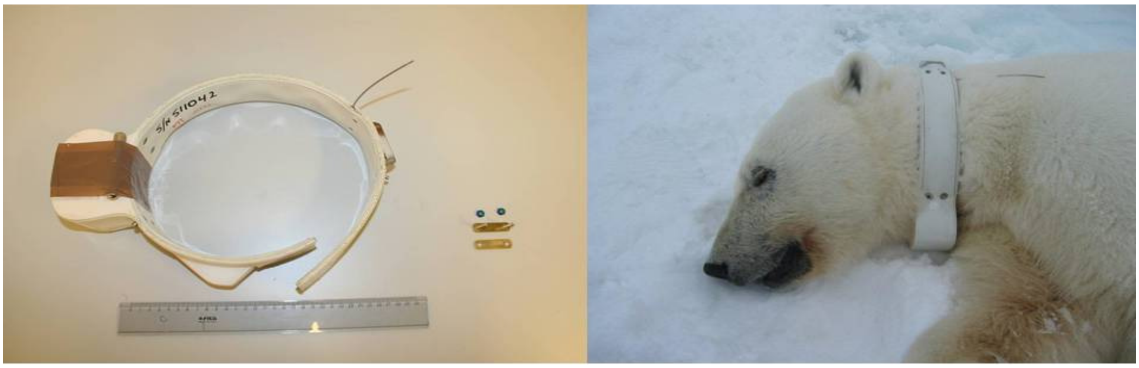


Figure 3. Example of a collar used for satellite tracking of polar bears. Photo: Magnus Andersen.

The collar is fitted around the neck of the bear and secured with metal bolts that will oxidize and eventually result in the collar falling off. The time this process takes depend on the metal/alloy of the bolts and on how much time the collared bear spends in saltwater. In newer models a programmable collar release mechanism is a standard option (http://telonics.com/products/collarReleases) and when used in Norwegian polar bear studies this mechanism is set to be enabled after 4 years. One severe limitation for polar bear research using neck collars is that it is only applicable to adult female bears. Male polar bears have a powerful neck, with a diameter that is larger than the head, so collars simply slip off. Subadult animals are still growing and are therefore not suited to this type of instrumentation. Expandable collars have been explored for other species, but to date none have been deployed on polar bears.

The most common system for tracking polar bears is via the ARGOS satellite system (Argos 1996), where the Doppler shift phenomenon is used to calculate the position of the bear (see f. inst. Wiig 1995, Mauritzen et al. 2002, 2003). This method gives relatively crude positions where the accuracy is among other things dependent on the number of satellites and uplinks from the tag that are available for each calculation. Best case scenarios give a precision of ± 150 m. Recently, GPS technology has been built into polar bear collars and the GPS positions calculated in situ are then transmitted via the Argos satellite systems to the user (Andersen et al. 2008). These instruments provide much more precise locations and thus enable more detailed habitat use studies of the polar bears (Durner et al. 2011, Freitas et al. 2012). At present, Norwegian scientists are testing GPS technology in combination with Iridium satellites (ATS G301IC/GPS collar Advanced Telemetry Systems http://www.atstrack.com) instead of ARGOS (Aars, J., Norwegian Polar Institute, unpublished data). ARGOS is a one-way system where the transmitting tag receives no information with regards to whether information is received by the satellites. Use of the Iridium system opens the possibility for two-way communication, enabling the users to communicate with the tag via the satellite system. This would allow users to change the sampling protocol of the tag and enable a real-time drop-off system that could be used to make the collar fall off the bear at a specific time, allowing the researcher to choose the place. It also allows for much more efficient data recovery because both sides of the system are "aware" of data that has been sent and received so redundancy in sending information can be eliminated.

Tracking polar bears of age/sex groups other than adult females have been attempted using several methods, with variable success. Satellite transmitters (ST-10 Telonics http://www.telonics.com, 5cm x 2.5cm x 13 cm, weighing 190 g) were surgically implanted into 7 adult male polar bears in Alaska (see Mulcahy and Garner 1999 for details). Anticipated battery life was 9-12 months. However, all tags failed prematurely with lifetimes varying from 30-161 days (mean 97 days, Mulcahy and Garner 1999). None of the tagged bears were recaptured later to assess possible reasons for the relativity short lifetime of the implanted tags. However, electronic failure, removal or expulsion of the tags from the bears, and antennae breakage were considered the most plausible explanations (Amstrup et al. 2001). No other published data exists in the literature from surgically implanted instruments for tracking polar bears . Recently, small satellite transmitters (SPOT-5, Wildlife Computers http://www.wildlifecomputers.com) have been deployed on both subadult and adult male polar bears by either gluing the tag onto the fur of the animal using quick setting epoxy, or attaching it on the ear via piercing (Born et al. 2010).

Figure 4. Satellite transmitter attached to the ear of an adult male polar bear. Photo: Erik Born.

Tags glued to the fur (weighing 32 g) transmitted for about one month, while those attached to the ear (weighing 58 g, same tag but with a mounting bracket) lasted for several months (Born et al. 2010). Attachment using glue was abandoned after the initial trial due to short tracking times, while the ear-mounted tags have been used annually on subadult animals of both sexes and on adult males since 2007 with average data transmission durations of 2-3 months and a maximum record of 158 days (Born et al. 2010)

Other biologging instruments:

Other aspects of the behaviour of polar bears have been explored using various sensors and instruments, which have been integrated into satellite-tracking collars. A crude assessment of activity is often measured by integrating a mercury switch into the collar. This type of instrument counts the number of times it becomes tilted and keeps a cumulative count of these tilts. This information is transmitted via whatever satellite system is used, and basically informs the scientists about when the bears are in motion versus when they lay still. Many polar bear collars also have an integrated temperature sensor that transmits ambient temperature together with the position of the bear. These temperature determinations are often influenced by heat loss from the bear and thus they are higher than ambient. However, these readings are useful indicators of whether the bear is in a den or not. Recently, Sea Mammal Research Unit (http://www.smru.st-and.ac.uk) Satellite Relay Data Loggers, made for seals, have been integrated into polar bear neck collars to provide data on how much time bears spend in the water versus on land or ice, how deep and long the bears dive (in addition to the locations of the bears). These instruments have shown that polar bear females spend up to 13% of their time in the water and dive down to 12 m (Aars et al. 2007).

In addition to integrating sensors into the collars and transmitting information via satellites, various data logging units have been attached to bear collars or ear tags. These loggers must be retrieved (or interrogated at close-range) in order to collect the data they store. Activity of polar bears has been measured using 3-D accelerometers (Mini-Mitter http://www.minimitter.com) attached to collars that, in combination with other sensors, enables identification of different activities such as separating swimming from walking (Durner et al. 2011). Time-Depth-Recorders (TDRs, Wildlife Computers) have been glued to polar bear collars in Svalbard for many years and provide very detailed information on aquatic activity of the animals carrying these instruments. Geolocation tags, often used to study bird migrations, have been integrated into the ear tags of adult polar bear females to study denning biology (Migrate Technology Ltd www.migratetech.co.uk, Aars, J. Norwegian Polar Institute, unpublished data). A light sensor and a clock inside the tag enable crude measurements of positions in areas of the globe where there is a “normal” day-night light cycle. In the case of the polar bears the light sensors are used to study when the females emerge from their den in spring, and maybe (at least in combination with temperature sensors) also when the female enters the den the previous autumn/winter. These tags weigh 9.5 g including the outside washer (Figure 5).

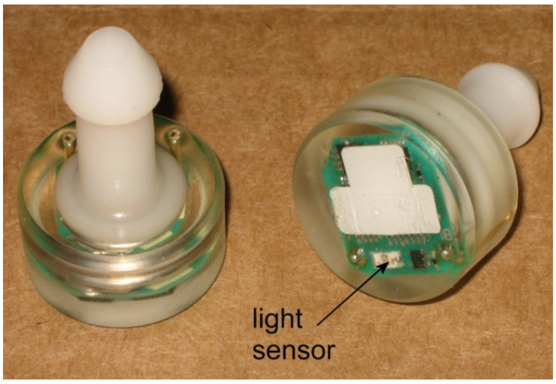


Figure 5. Geolocation sensors built into an ear tag for polar bears to study denning behaviour. Photo: Jon Aars.

In order to study cub behaviour, especially with regards to when they leave their mothers or if they die before the nursing period is over, so-called proximity tags (Sirtrack http://www.sirtrack.com) have been used on polar bears in Svalbard (Aars, J. Norwegian Polar Institute, unpublished data). In this experiment cubs were fitted with ear tags that contained a UHF transceiver (weighing 13 g) that transmitted to a receiving station integrated into the collar worn by the mother. If the cubs are more than 10 m away from the station (i. e. the mother) no signal will be received. This enables studies of the dynamics of the mother-cub units and will provide information with regards to whether the cub disappears prematurely from the family (i. e. dies).

Temperature sensors have been used to study subcutaneous rump temperature in free-living polar bears (Durner et al. 2011). These data loggers were surgically implanted and thus had to be retrieved. They provided information on thermoregulatory properties of the polar bears.

Capture and handling

Almost all polar bears that are captured and handled for scientific studies today are located and immobilized from helicopters. In earlier times bears were immobilized from boats or from the ground (usually from snowmobiles) or they were trapped in leg snares. Once an animal is located, the helicopter remains at a distance of some 100s of m while a dart is filled with an immobilizing agent.

Figure 6. A polar bear approached by helicopter during a darting session. Photo: Jon Aars.

When the shooter is ready the helicopter quickly approaches the bear and the dart is fired from a specially designed gun at 5-10 m distance. The helicopter then retreats and hovers distantly again until the immobilizing agent kicks in, normally after 2-7 minutes (Aars, J. pers. comm.). In the case of large males, two darts are delivered within an approximately 30s interval to ensure a high enough dosage of the drug. Sometimes an additional dart(s) is needed to get an animal properly immobilized. The drug of choice for immobilizing polar bears is Telazol® (Stirling et al. 1989), sometimes referred to as Zoletil®, although some other immobilizing agents have been used in the past (see f. inst. Lentfer 1968, Cattet et al. 1997). Telazol® works very effectively on polar bears and has minimal associated mortality (1 in 1000 in the combined international community). Once the bear is immobilized the helicopter lands close to the animal, the dart is removed and the process of tagging, instrumenting, measuring and collecting other biological materials starts. This process normally takes 30-60 minutes depending on what is collected and whether it is a lone animal or a female with cubs that also require attention (Aars, J. pers. comm.).

Figure 7. A radio collar has just been removed from a female polar bear showing some wear and some yellow discolouration of the hair from a 2-year long deployment. Photo: Magnus Andersen.

Potential effects of polar bear drugging and handling have been explored in a variety of studies in the scientific literature. Ramsay and Stirling (1986) found no detectable impacts in their assessment. Similar results have been reported by Derocher and Stirling (1995), Lunn et al. (2004), Amstrup (1993) and Rode et al. (2007). The most exhaustive assessment of potential impacts of research on polar bears via capturing, tagging and radio-collaring, has been conducted by Messier (2000), on behalf of the Government of Nunavut and Northwest Territories. This study involved tagging records for over 3,000 bears. Its major conclusions included: 1) some short-term effects of handling are unavoidable, including stress associated with pursuing animals, bruises from darts and minor wounds incurred when tissue sampling or applying various tags and marks 2) family cohesion was unaffected by capture events 3) the mortality for routine handling was negligible (1/1000), though complex handling protocols associated with physiological studies elevated mortality 4) long-term effects of handling and marking were explored in-depth and no negative effects were found. Messier (2000) claimed to have detected a tendency for radio-collared females to experience lower reproductive success based on litter size and cub survival. There is however no statistical support for any such effects in his analysis (p-values in tests varying between 0.2 -0.73). Messier considered the overall effects of marking and radio-collaring not measurable or negligible, given the conservation value of the data secured through these research efforts. The small number of bears handled in Svalbard limits the possibility for similar in-depth analyses specific to the Norwegian Arctic.

Pinniped species belonging to the *Phocidae* (earless seals), *Odobenidae* (walruses), and *Otariidae* (eared seals) families.

Marking methods and procedures

<u>Individual identification:</u>

Most seals that are live captured during Norwegian research programmes (and also in most international programmes) are equipped with plastic (or sometimes metal) tags with an individual ID number. These tags weigh a few grams and are usually deployed using special pliers (Figure 1). In phocid seals and walruses they are generally attached though the webbing of the hind-flippers, while in otariid seals they are normally attached to the back side of a fore-flipper (see Figure 2). These tags are designed to stay on for the entire life span

Figure 1. Left panel: standard flipper tag for seals. Middle panel: pliers used for deploying flipper tag. Right panel: head tag . Photos: Dalton http://www.thetags4u.com/.

of the seal, while head tags used for identification of animals at sea (Figure 1; right panel) are glued to the fur on the head of the animal (Hall et al. 2000) and fall off during the seal's annual moult.

Figure 2. Left panel: Flipper tag attached to the fore-flipper of a New Zealand fur seal (*Arctocephalus forsteri*). Right panel: Flipper tag attached to the hind-flipper of a ringed seal (*Pusa hispida*). In this case there is also a VHF tag that has been deployed to track the seal when it is hauled out of the water. Photo: Left panel: http://www.biol.wwu.edu/mbel/?page=mrs.-acevedo-blog; right panel: Kit Kovacs/Christian Lydersen.

Another method that has been used to individually mark animals in many places (not in Norway) is hot- or cold-iron branding. This method is similar to what has been used for centuries for branding cattle and horses where metal branding irons of various letters, numbers or shapes are either heated until red hot (Merrick et al. 1996) or cooled in liquid nitrogen (or other cooling agents)(Daoust et al. 2006) before being applied to the seal's skin for some seconds. The brand damages the hair follicles, creating a scar that is either naked skin or differently coloured hair, which creates a mark that is visible from a good distance throughout the animal's life (see Figure 3); this marking method has been used for many mark-recapture type life history studies f. inst. in harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals (Harkonen et al. 1999, Härkönen and Harding 2001, Bowen et al. 2006).

Figure 3. Branded California sea lion (*Zalophus californianus*) female. Photo: http://www.oceanwideimages.com

PIT (Passive Induced Transponder) tag implants have also been used for individual identification of seals, f. inst. in southern elephant seal (*Mirounga leonina*) pups, where the transponder chips have been implanted at the base of the hind-flippers (Galimberti et al. 2000).

A shorter-term tagging technique involves using a mobile phone tag glued to the head of a seal. This has been tested on grey seals, as a new way of collecting mark-recapture data using inexpensive mass media GSM technology (McConnell et al. 2004). In this initial study the tags were set to send an SMS message once every two days resulting in a "re-sighting" every time the seal was within GSM coverage. Similar to other glue-on applications, these tags fall off during the annual moult. Other short-term methods for individual identification of seals involve painting, bleaching or in other ways making recognizable marks in the pelage of the animals. For example, paint in various colours have been used for recognizing individual white-coated pups of grey and harp (*Phoca groenlandica)* seals for behavioural studies based on direct observations (Kovacs 1987a, b). Bleaching the fur has been used as an individual marking method when estimating pup production based on mark-recapture techniques in dense colonies of various fur seal species, f. inst. of Antarctic fur seals (*Arctocephalus gazella*) on Bouvetøya (Hofmeyr et al. 2005). Small patches of guard-hair removal on the head region of generally dark coloured fur seal pups (exposing their white underfur), is another method that has been employed for identification of groups of individuals for mark-recapture studies, as shown in Figure 4 below.

Figure 4. Left panel: A New Zealand fur seal pup gets the dark guard hairs clipped using scissors, exposing the white underfur. Right panel: a mix of marked and unmarked New Zealand fur seal pups. Photo: Kit Kovacs/Christian Lydersen.

Tracking individuals:

VHF-technology was the first tracking tool available to wildlife ecologists and is still one of the most widely used methods for tracking studies of pinnipeds. Depending on the producer and the battery choice, these tags normally weigh some few 10s of grams and are most often glued to the fur of the study animal with some brand of quick setting epoxy - although subcutaneously implanted tags have also been explored (Lander et al. 2005). Flipper tag mounts of VHF tags, as shown in Figure 2, have also been used for studies during moulting or for longer-term deployments of VHFs (right panel). VHF tags have been used in many studies concomitantly with biologging devices, in order to relocate the seals with data loggers so that they can be recaptured and the loggers retrieved (see f. inst. Lydersen and Hammill 1993, Lydersen et al. 1994). Haul-out patterns of various seal species have been studied using VHF technology, where signals are normally received by an automated receiving station that documents whether the seals are hauled out (signal) or are in the water swimming and diving (no signal) (see f. inst. Reder et al. 2003, Carlens et al. 2006). Analyzing results from such studies with respect to effects of season, time of day, weather parameters etc. are often used as the basis for making correction factors for animals in the water during aerial surveys of hauled out seals for populations size estimations (see f. inst. Krafft et al. 2006). The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) Environmental Monitoring programme (CEMP) is a huge circumpolar Antarctic monitoring programme of krill-eating predators that started in 1985. Norway is part of this programme and follows the CEMP protocols each time there is an expedition to Bouvetøya, collecting information on Antarctic fur seals and two species of penguins. As part of this protocol 40 fur seal females are instrumented with VHF tags, and attendance patterns (time on shore vs time in the ocean feeding before coming back and nurse the offspring) during the lactation period are monitored by automated receiving stations (Krafft et al. 2002a). Data from the attendance patterns, combined with other information such as mass gain of the pups and mass loss of the females, are vital parts of the CEMP monitoring programme. The purpose of this monitoring effort is to ensure that human krill harvests are not negatively impacting krill-dependent predators.

Diving behaviour can also be inferred from VHF tracking if one assumes that the seal is always in the reach of one or more receiving stations when it is at the surface. The VHF signal will then be lost when the seal dives and will be heard again when the seal returns to the surface to breathe, enabling measurements of dive times (see f. inst. Hyvärinen et al. 1995, Bekkby and Bjørge 2000). Additionally, using several receiving stations simultaneously makes it possible to calculate the position of the VHF tags via triangulation and one can thus study space use and calculate home ranges for seals that stay within the reach of a set of receiving stations (see f. inst. Bjørge et al. 2002).

Because of the large ranges used by most seal species, or their extensive migration patterns, the most common method for tracking seals today for studies of movement patterns and habitat use is by equipping the animals with some sort of satellite-linked data logger. These satellite tags transmit information on the location of the animal, and sometimes also information on diving performance and even environmental data from various types of sensors, to circulating satellites where they are then stored, downloaded and supplied to owners. Data from these instruments are continuously surprising scientists around the world with regard to the aquatic capacity of the various tagged seal species in terms of movement and dive performance. For instance, it has been discovered that elephant seals (*Mirounga spp.)* conduct annual foraging trips that average about 10,000 km and they can dive longer than 2 h to depths that exceed 2 km (Costa et al. 2009). Data from a huge US satellite tracking programme (TOPP – tracking of Pacific pelagics) was recently published where 4,306 tags were deployed on 23 species of marine animals including several seal species (Block et al. 2011). The TOPP article demonstrates the power such studies have for identifying critical habitats across multinational borders as well as showing how top predators exploit their environment in predictable ways, thereby providing a foundation for spatial management of large marine ecosystems. Published results from such studies from Norwegian waters are available for walruses (*Odobenus rosmarus*, Wiig et al. 1996, Freitas et al. 2009), ringed seals (Gjertz et al. 2000a, Freitas et al. 2008) bearded seals (*Erignathus barbatus*, Gjertz et al. 2000b), harbour seals (Gjertz et al. 2001a), harp seals (Folkow et al. 2004, Nordøy et al. 2008) and hooded seals (*Cystophora cristata*, Folkow et al. 1996, 2010) from the northern hemisphere, and from Antarctic fur seals (Biuw et al. 2009) southern elephant seals (Biuw et al. 2010), leopard seals (*Hydrurga leptonyx*, Nordøy and Blix 2009), Ross seals (*Ommatophoca rossi*, Blix and Nordøy 2007) and crabeater seals (*Lobodon carcinophagus*, Nordøy et al. 1995) from the southern hemisphere.

In the older studies, positions were generally calculated via the Argos satellite system using Doppler shift calculations, while in newer studies GPS technology is increasingly used, with data being transmitted via the Argos system (especially in polar areas) or via the mobile phone net in areas of the world where such coverage exists. Normal GPS technology has been tested for use on seals (Sisak 1998), but generally speaking seals are at the surface for a period that is too short for standard GPS units to find the orbiting satellites. A novel method for addressing this problem, so-called Fastloc™ technology (http://www.wildtracker.com/fastloc.htm), has been developed very recently where less than a second is needed to acquire the information required to calculate a location because the tag actually processes the information on-board after is has left the surface. The three main producers of satellite tags for seals are Sea Mammal Research Unit (http://www.smru.st-and.ac.uk), Wildlife Computers (http://www.wildlifecomputers.com) and Sirtrack (http://www.sirtrack.com/); details regarding the various satellite tags can be found on the homepages of these organisations. Generally speaking, these tags weigh from 30 to 5-600 g depending on how many batteries they contain and what types of sensors are incorporated within the tags. These satellite transmitters are generally glued to the fur of seals. On larger animals the tags are often glued to the head (which gives the best signals to the satellite since this part of the body is exposed at every surface-breathing interval). While on smaller seals the tags are usually glued to the body trunk, dorsally, close to the neck of the animal (see Figure 5).

Figure 5. Left panel: Satellite tag on a ringed seal (75 kg) glued onto the body trunk dorsally, close to the neck. Right panel: Satellite tag glued onto the head of a female southern elephant (350 kg). Photo Left panel: Kit Kovacs/Christian Lydersen; right panel: Martin Biuw.

Specially designed tags have been created for walruses (see Lydersen et al. 2008), which are attached to the tusk of the animal with hose clamps (see Figure 6, right panel). Due to problems associated with drugging walruses on small ice floes (possibility of the animal to leave the floe before the drug acts and problems with the drugging itself, see below) small satellite tags that are anchored into the skin have been deployed with a crossbow or a lance to get simple haul-out behaviour information in connection with aerial surveys (Jay et al. 2006). These tags normally only work for some few weeks before they fall off the animals. Some of the smaller satellite tags, such as SPOT5 from Wildlife Computes that only weigh 30 g can be attached to the flippers of seals in a manner similar to the VHF tag shown in Figure 2. For short-term deployments of various instruments (including satellite tags), various types of harnesses have been used, especially on otariid seals (Figure 6, left panel).

Figure 6. Left panel: Various instruments carried by a Steller sea lion (*Eumetopias jubatus*) using a harness. Right panel: Satellite tag attached with hose clamps to the tusk of a walrus. Photo Left panel: http://www.marinemammal.org ; right panel: Kit Kovacs/Christian Lydersen.

In order to get more insight into the choices marine mammals make with regard to space use various other sensors are now commonly incorporated into satellite tags. Oceanographic sensors that measure temperature and conductivity (to calculate salinity) through the water masses the seals move through has given us new insight into habitat use and foraging behaviour (See f. inst. Biuw et al. 2007, 2010). These CTD (Conductivity, Temperature, Depth) tags were originally developed for white whales (*Delphinapterus leucas*) in Svalbard (Lydersen et al. 2002a). Extensive deployments of these tags during the International Polar Year and in a few other major research programmes have provided vast amounts of ocean data to the oceanographic community from water masses in especially difficult to reach, remote ocean sectors, including ice-covered polar waters (see f. inst. MEOP http://www.meop.info) that are essential for many climate-change related studies. In the Southern Ocean elephant seals have collected hundreds of thousands of CTD casts that totally dominate the World Oceanographic Database from south of 60º S. These data have resulted in several important oceanographic scientific papers (e.g. Charassin et al. 2008, Nøst et al. 2011) and for the last 5-6 years oceanographic data collected by seals have been the basis for weather forecasting in both the northern and southern hemisphere. Because of the vast potential for data collection, seals are included as standard "platforms" for oceanographic sampling, similar to Argo buoys, other drifting buoys, oceanographic moorings and research vessels in huge global observing systems. An example of such as system is the Global Ocean Observing System (GOOS http://www.ioc-goos.org/) which is the oceanographic component of the Global Earth Observing System of Systems (GEOSS http://www.earthobservations.org/index.shtml). This vast data collection system is sponsored by the UN and UNESCO (among other organizations). GOOS is a permanent global system for observations, modeling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible, and is a major component in the basis for forecasts of climate change.

Other sensors that have been incorporated into satellite tags worn by seals include fluorometers for measuring chlorophyll (a proxy for primary production) in the water masses the seals occupy and also oxygen sensors to measure oxygen content in the same water masses. Geolocation loggers (GLS) have also been used for tracking seals, and in combination with deployment of traditional satellite tags for comparison of performance, have been shown to be a useful and cheap way to study dispersal at large scales for Antarctic fur seals (Staniland et al. 2012). These tags weigh only 13 g and are attached to traditional flipper tags fixed through the skin of the fore-flippers. Many Time-Depth Recorders (TDRs, see below) with light sensors have also been used to for crudely determining position. These are archival tags that have to be retrieved, and the light level records have been used to study movement patterns in f. inst southern elephant seals (Jonker and Bester 1998, Hindell et al. 2003).

Acoustic telemetry has been used on several occasions to track seals underwater to study simple diving (Lydersen 1991) or more sophisticated studies of 3-D space use (i.e. Harcourt et al. 2000, Simpkins et al. 2001). For the latter type of studies the seals are instrumented with acoustic transmitters and by using an array of hydrophones (Wartzok et al. 1992) one can track their movement in three dimensional space and do things such as calculating the size of underwater home ranges for these seals (Kelly et al. 2010). These small acoustic transmitters weigh about 30 g and are glued to the fur of the seals, similar to other tag types described above. Some recent efforts using acoustic telemetry include vast global ocean tracking networks such as Ocean Tracking Network (OTN, http://oceantrackingnetwork.org/) based out of Canada and the Pacific Ocean Shelf Tracking (POST, http://www.postcoml.org/) network based out of USA. The OTN is at present a 168-million dollar conservation project, where all sorts of marine animals including seals will be instrumented with small electronic transmitters that are surgically implanted or attached externally, and can operate for up to 20 years. Acoustic receivers will be arranged 800 m apart in invisible “listening lines” at strategic locations along the sea floor in 14 ocean regions off all seven continents. These receivers will pick up coded acoustic signals identifying each tagged animal that passes aline. Tags and receivers can also be outfitted with sophisticated sensors that measure the ocean's temperature, depth, salinity, currents, chemistry, and other properties. OTN plans to collect the data from the receivers and ocean-sensing instruments by a variety of methods. The OTN research program focuses on themes like ocean physics and modeling, biology and behaviour of highly migratory marine living resources, impact of climate change and resource management. This is a recent effort, and no details are as yet available on the OTN internet site regarding what tags will be used.

Another type of transmitter that has recently been developed is the so-called archival Life History Transmitter (LHX) (Horning and Hill 2005). These tags are implanted in the abdominal cavity of the animal and record data throughout its life. The LHX tag stores whatever data it is set to record in a memory and does not try to transmit until after the animal is dead (Horning et al. 2008). When the tag is extruded from a corpse the tag, which is positively buoyant, will reach the surface and transmit stored data via satellites. These tags weigh 115 grams and surgical implanting procedures are described in detail in Horning et al. (2008). A paper dealing with juvenile mortality in Steller sea lions based on LHX tags has been published recently (Horning and Mellish 2012). Here transmitted data on light levels, surrounding medium and temperature profiles across mortality events, and time to transmission, made it possible to distinguish predation (rapid temperature drop, immediate sensing of air and light, immediate transmission) from non-traumatic deaths (gradual temperature decline while surrounded by tissue, delayed sensing of light and air and onset of transmission).

Other biologging instruments:

A whole suite of various other biologging instruments have been attached to various pinniped species to study aspects of their biology; some of the most commonly used instruments are described below.

Time-Depth Recorders (TDRs) are the most common instruments used to study detailed diving behaviour. These instruments provide very precise information on dive depth, duration, ascent and decent rates, dive profiles, swimming speed, water temperature, light levels etc., but TDRs have to be retrieved to access the data. Figure 7 shows a state-of the art TDR (MK-9, Wildlife Computers) that is widely used on various species of pinnipeds and other marine animals. It weighs 30 g in air and measures depth, temperature, light levels and

Figure 7. Left panel: A MK-9 Time-Depth Recorder (TDR) from Wildlife Computers. Right panel: A ringed seal pup with a TDR and a VHF transmitter to facilitate recapture. Photo left panel: http://www.wildlifecomputers.com. Right panel: Kit Kovacs/Christian Lydersen.

differentiates between wet and dry conditions. It has a minimum 64 Mbytes memory. When sampling all these parameters are performed every 30s, 8.7 years of data can be stored, and the data are maintained in the internal memory for at least 25 years even if the batteries are exhausted. These TDRs are generally glued to the fur of seals and thus will be on the animal for less than a year, so the sampling intervals for these parameters can be set to read them every 1 s for the expected duration of sampling. TDRs have been used for many studies of pinnipeds within Norwegian territories, and have provided detailed insight into diving behaviour of harbour, ringed, bearded seals, walruses etc. (in walruses the TDRs are attached to the tusk) in Svalbard (Lydersen and Hammill 1993, Lydersen et al. 1994, 2002b, Krafft et al. 2000, 2002b, Gjertz et al. 2001b, Jørgensen et al. 2001) and Antarctic fur seals on Bouvetøya (Biuw et al. 2009).

To get even more detailed information on dive and swimming behaviour 2- or 3-axis accelerometers can be integrated into TDRs and deployed on various seal species. Since these animals live and operate in a 3-D environment, their 3-D dive paths can be reconstructed in great detail from these instruments based on headings, pitch angles, depth and swimming speed data (see Mitani et al. 2003). Information regarding their swimming behaviour,

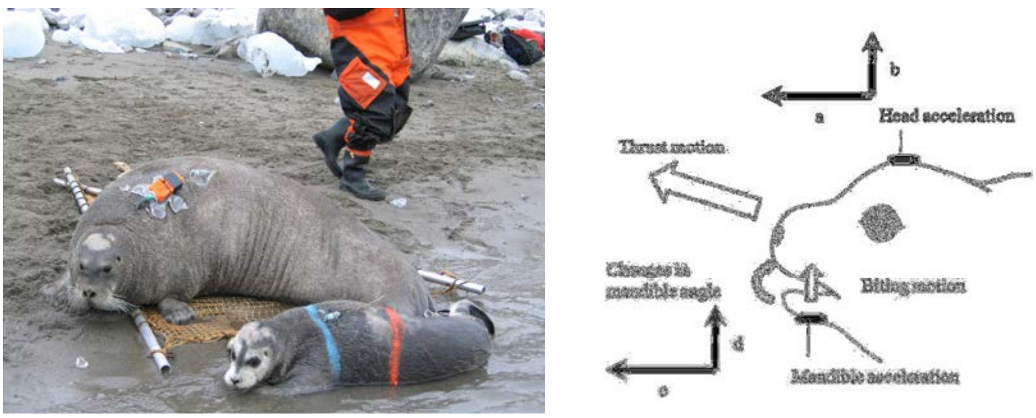


Figure 8. Left panel: An adult bearded seal female with a TDR with incorporated 2-axis accelerometer and camera. This instrument package has a remote release system and will be on the animal for a short time; typically 24 h. The pup has a VHF transmitter to facilitate recapture. Right panel: Schematic drawing showing

accelerometer placements for detecting prey captures by captive hooded seals. Photo left panel: Kit Kovacs/Christian Lydersen, right panel: from Suzuki et al. 2009.

such as active swimming vs gliding is easily inferred from these accelerometers. Detailed ontogeny of diving in bearded seal pups has been studied using this technique in Svalbard (Figure 8, Watanabe et al. 2009). Other types of accelerometers have been used to study feeding events. Here, two accelerometers are attached to the head of the seal, one on top of the head and one under the jaw and when a prey is ingested (mouth opened and closed) this is recorded by the accelerometers (Figure 8). To date this type of instrumentation has still mainly been used in controlled experiments (Suzuki et al. 2009, Viviant et al. 2010).

Another method for detecting foraging success in seals that is used in the wild is ingestion of a so-called stomach temperature pill. Seals are homeothermic animals and they experience a drop in stomach temperature when ingesting (a relatively cold) fish prey and this drop in temperature can be recorded by thermistors in the stomach temperature transmitter. This information is then transmitted to a recorder glued to the fur of the seal, thus provide information on when ingestion of prey takes place (for more details see: Hedd et al. 1996, Kuhn et al. 2009) and in some cases the size of the meal (Bekkby and Bjørge 1998). The stomach temperature pills weigh 30-50 g and are sometimes modified with foam to increase retention time (see Kuhn et al. 2009). If one combines stomach temperature pills with TDRs and satellite transmitters, 3-d space use can be explored and the depth where food was ingested can be determined, as has been demonstrated in an elegant study of grey seals in eastern Canada (Austin et al. 2006).

Cameras, both still pictures and video, has been used for some time to get insight into underwater behaviour of seals (see f inst Davis et al. 1999). “Crittercam” equipment from National Geographic has been deployed on many species of marine mammals (Marshall et al. 2007) and the resulting footage has in addition to being published in scientific journals also been shown in many nature documentaries. These are relatively large instruments, but they are usually deployed on animals for short periods. Prey capturing, handling and mating behaviour have been documented via such video footage (see: Bowen et al. 2002, Boness et al. 2006). In combination with TDRs and accelerometers, video cameras enable studies of prey capture in minute detail (see f. ints. Fuiman et al. 2007). Smaller still cameras have revealed previously unknown details about foraging behaviour of various seal species such as Weddell seals (*Leptonychotes weddellii*) foraging on invertebrate fauna underneath the Antarctic ice shelf at 145 m depth (see f. inst. Watanabe et al. 2006).

Studies of various aspects of physiology have been conducted with the help of sensors either glued onto or implanted into wild seals. Several efforts have been made to record heart rate for longer periods in attempts to measure metabolic rates in free-living seals. The background to this is that there is a relationship between oxygen consumption and heart rate. If this relationship is calibrated on animals under controlled conditions then collection of heart rates in free-living seals could be used to estimate energy consumption (see f. inst. Butler et al. 2004). This concept was tested on captive California sea lions where a good relationship was established between these two parameters (Butler at el. 1992). This method was then used on another otariid, the Antarctic fur seals, in the wild (Boyd et al. 1999). The relationship between heart rate and oxygen consumption was measured in the field both on land and in water (in a specially built water channel) using a respirometer. Then the animals were equipped with the heart rate logger (and TDRs) and released into the wild. There are not many details available on the size of these instruments, but the set-up consists of a small logger glued to the fur on the back of the animal, two electrodes with electronic connections between them and the logging unit. In a study by Boyd et al. (1999) the electrodes were two stainless steel needles places under the skin along the dorsal side of the animal, some 10s of cm apart, at approximately the level of the heart. These electrodes were held in place by a single suture and covered with epoxy. The connecting electrodes and the logger were also covered in epoxy. The results were highly variable in terms of individual heart rates; which the researchers suggested was based on variation in morphometrics among individuals. Trials have also been made with implanted heart rate loggers under controlled conditions to investigate the potential for use on free-living pinnipeds (Green et al. 2009). This custom-made logger weighed 25 g (and had two 17 and 19 cm long electrodes attached to it) and was coated in wax and medical-grade silicone before being implanted subcutaneously while the animals were under anesthesia (see. Green et al. 2009 for details).

Several studies on diving physiology have been conducted on Weddell seals in Antarctica where a “wild” seal has been captured and transported to a man-made hole in the fast ice at a site where no other breathing holes are available (see Kooyman et al. 1980). The seal must then come back to breathe in the man-made hole, which permits a lot of sophisticated physiological studies to be performed, many of which have involved instrumentation of the seals. Some of the camera deployments mentioned above has been done under these circumstances. In addition, heart rates of diving seals have been studied using a microprocessor controlled monitor (10x10 cm) glued to Weddell seals using this semi-wild set up (Hill et al. 1983). A special blood sampler that can serially sample arterial blood during a dive was developed by Hill (1986). This involved inserting a sterile catheter into the aorta via the fore-flipper artery, which was connected to a backpack containing a computer, a peristaltic pump and blood sampling tubes. Blood samples could then be drawn at preset intervals during the dive and collected when the seal surfaced to breathe. Other instruments such as a heart rate recorder and TDR have been integrated into this package. There are not many details on size and weight of these packages, but they are always on the seal subjects for very short periods of time. Several classical diving physiology studies were conducted using this isolated hole set-up (Falke et al. 1985, Guppy et al. 1986, Quist et al. 1986, Hill et al. 1987).

Capture and handling

Methods for capturing pinnipeds vary a lot from species to species and within a species depending on age, sex and time of the year (often capture of adults is easiest during the breeding season). Generally, seals that are hunted or live in areas with surface predation (e.g. polar bears in the Arctic) are harder to capture than seals in areas with no hunting or surface predation. Thus, Antarctic seals can generally be approached easily by humans on foot, while most Arctic species flee when approached by humans. Many Antarctic species are caught by walking straight up to them and catching them in a head bag (see Figure 9), hoop net or a pole net. The animal is weighed and then drugged (with doses based on its body mass) before instrumentation. Many different drugging agents have been used (see f. inst. Kreeger et al. 2002 for details), but Telazol® administrated either intramuscularly or intravenously is the drug of choice in many recent studies conducted by Norwegian researchers in studies of crabeater, Ross and leopard seals (Nordøy et al. 1995, Blix and Nordøy 2007, Nordøy and

Blix 2009). For the latter species the drug was administrated using a dart gun since this seal species is relatively dangerous to capture in a hoop or pole net. Another way of administrating drug is by using a blow tube, as is shown in the figure below where a southern elephant female receives a dose of Telazol®. For many large otariid species it is common to use a dart gun to give them an initial anesthesia with f. inst. Telazol® and then keep them down with

Figure 9. Upper left: capturing a Weddell seal with a head bag, upper right: drugging a southern elephant seals female delivering the drug from a blow tube, lower left: capturing a New Zealand fur seal pup by hand, lower right. Keeping an Australian sea lion (*Neophoca cinerea*) down with isoflurane gas after initial anesthesia with Telazol®. Photo upper left panel: http://nationalzoo.si.edu/SCBI/AquaticEcosystems, remaining panels: Kit Kovacs/Christian Lydersen.

gas (often isoflurane), delivered via a nose-mask (see Geschke and Chilvers 2009, and Figure 9 lower right panel). Adults of smaller species of otariids are often captured using a hoop net and then transferred to a specially designed holding board and physically restrained while being instrumented (see Figure 10). Pups of most of the Antarctic species can just be captured by hand (Figure above).

Figure 10. Holding boards for physical restrainment of Steller sea lion and Antarctic fur seal. Photo left panel: http://www.marinemammal.org/research/models.php, right panels: Kit Kovacs/Christian Lydersen.

As stated above, many Arctic seal species are harder to get close to since they flee when approached by humans. Exceptions occur for some species during the breeding period, such as harp and hooded seals, which stay on the ice to defend their pups or mates. They are normally captured using a hoop or pole net, then weighed and drugged with Telazol® similar to the protocols described above (e.g. Folkow et al. 1996, 2004). Harp seals often enter paralysis when handled (Lydersen and Kovacs 1995) and can be handled for non-invasive procedures without the administration of any drugs (Lydersen and Kovacs 1993). Ringed seals, which are the main prey species for polar bears, are not easily approached by humans. Thus, a lot of more or less sophisticated trapping methods have been developed for this species, including net traps set inside breathing holes that are triggered by the seal itself when it surfaces to breathe (Kelly 1996, see Figure 11). Others include various methods to close the breathing hole when the seal is hauled out on the ice, thus preventing it from re-entering the water (Figure 11). In Baltic Sea seal studies, special traps have been developed for live capturing harbour and grey seals that are floating docks where the seals come to rest. When they haul out on the platform a trapdoor opens and the seal glides down into a holding net under the dock, where the seals can surface to breathe. Seals, especially young individuals, can also be captured directly in the water using a dip net as shown in the figure below. The most common method for capturing most seals in the open water, however, is by setting

Figure 11. Upper left: adult harbour seal caught in net, upper middle: harbour seal pup being caught in the water with a dip net, upper right: darting a walrus, lower left: net trap for ringed seals triggered by the seal itself when it surfaces to breath, lower middle: ringed seal caught by its breathing hole with a pull trap, lower right: hooded seal female being caught with a pole net. Photo: lower left from Kelly 1996, all other pictures: Christian Lydersen/Kit M. Kovacs.

nets and letting the seals entangle themselves. This has been done with great success in ringed and harbour seals in Svalbard for example (Lydersen et al. 2004, Lydersen and Kovacs 2005; Freitas et al. 2008). Many hundreds of harbour seals have been captured in nets in Svalbard. This population is not exposed to any fisheries and thus is very naïve regarding nets. In contrast, harbour seals from mainland Norway are familiar with nets and much harder to capture using this technique. In the Svalbard population of harbour seals, individuals with flipper tags (indicating that they have been captured before) are much harder to re-capture, indicating that the animals learn quickly. In contrast to many of the species mentioned in this chapter adult ringed and bearded seals can easily be handled and instrumented without using drug. They struggle briefly, in the net when caught, but normally calm down quickly and lay quietly while instruments are being attached to them (see Figure 12). Walruses are easily approached but the drugging of this species is more complicated. Telazol® is not effective

Figure 12. Left panel: An adult ringed seal is lying quietly while a satellite tag is glued to the fur on its back, right panel: an adult bearded seal is being released after a satellite tag has been glued to the fur of its back. None of the animals were drugged. Photos: Christian Lydersen/Kit M. Kovacs.

on walruses; they are usually immobilized with an intramuscular injection of etorphine HCl which is reversed with diprenorphine HCl (Griffiths et al. 1993). This drugging technique is associated with a relatively high mortality (of about 5%). The main cause of death connected with opiates such as etorphine HCl, is cessation of respiration. During the most recent walrus research programme in Norway, walruses were intubated as soon as the tag was mounted on the tusk, using an endotracheal tube connected to a Zodiac boat pump. The animals were kept breathing artificially until the diprenorphine HCl took effect and the animal rejected the tube and breathed unsupported. A total of 19 walruses were handled this way with no resulting mortality (Lydersen and Kovacs 2012, also see Figure 13 below.)

Figure 13. Left panel: Finding the trachea in a drugged walrus for intubation of a tracheal tube, right panel: a Zodiac boat pump is used to keep the walrus breathing artificially until it can breathe unsupported. Photos: Kit Kovacs/Christian Lydersen.

Pinnipeds are generally large animals and the weight of the instruments deployed on them (even the larger cameras) is almost negligible when immersed in seawater, so the weight per se is not likely to cause any energetic problems for the animals carrying them. Altered streamlining and increased drag caused by attached instruments on the other hand are issues that could affect various aspects of the behaviour and cost of locomotion for the animals carrying the various instruments. Simulations using computational fluid dynamics calculations to investigate the potential influence of external devices on seal models show that these devices can change the hydrodynamics of the seals which could be expected to affect the seals physiology and behaviour (Hazekamp et al. 2010). Thus, effort should be made to make biologging and telemetric instruments as streamlined as possible.

In a study by Boyd et al. (1997) on Antarctic fur seal females (small seals weighing about 40 kg),drag was increased on free-living Antarctic fur seal females by gluing on a 250 g wood block (with a frontal area of 21.15 cm^2) onto the back of the animals to study potential impacts on foraging effort. The treatment group made shorter and shallower dives than control animals. They also compensated for slower swimming speed with a steeper diving angle. No difference was observed between treatment and control groups in terms of frequency or duration of dive bouts or in the proportion of time spent diving. The time taken to return to the pup was significantly longer for the treatment group, though no difference was measured in growth rates of the pups between the two groups. Since the mothers in the treatment group did not use significantly more body reserves, it was concluded that behavioural adjustments at the scale of individual dives allowed the mothers in the treatment group to compensate for the additional foraging costs. Previous studies on Antarctic fur seal females found conflicting results with regards to effect of carrying instruments (smaller than this wood block). Walker and Boveng (1995) found that individuals carrying TDRs and VHFs had increased foraging trips and nursing-visit durations compared to females that carried only VHFs (Walker and Boveng 1995). This is in contrast to Boyd et al. (1991) who compared the same foraging characteristics on the same seal species between animals with TDR and VHF and animals with no instruments (only painted) and found no significant difference and thus these authors concluded that the instruments did not affect the foraging-attendance cycle of these seals. In a more recent study of effects of carrying instruments in Antarctic fur seal females, individuals carrying cameras were compared to animals carrying just a TDR (Heaslip and Hooker 2008). The cameras weighed 700 g in air and had a cross-section of 46.75 cm^2, while the TDR weighed 50 g and had a cross-section of 3.2 cm^2 (both groups in addition carried VHF transmitters). The seals with cameras had longer dives, spent more time at the bottom of a dive and had slower ascent rates than those with only a TDR. They also found some changes in behaviour when the cameras used a flash, but still dive performance was found to be normal for this seal species and the authors concluded that there were no ethical concerns using these instruments (Heaslip and Hooker 2008).

Short and long term consequences of attachment of external devices on the largest species of seal, the southern elephant seal, were investigated by McMahon et al. (2008). They found no evidence for short-term differences in at-sea mass gain (measured as mass on arrival from foraging trip) or on long-term survival between seals carrying satellite tags or TDRs and VHFs. Additionally, these authors reported that the number of times a seal carried a tracking device (1-8 times) did not affect mass or estimated survival. They concluded that current tracking devices are valuable conservation tools that do not adversely affect the performance of this large marine mammal in terms of mass gain or survival probability on either short or long temporal scales. This study was based on data from 12,251 recently weaned hot-branded southern elephant seals of which 124 carried instruments when they were between 1-9 years of age. Another comprehensive study on effects of handling and instrumentation was carried out on Hawaiian monk seals (*Monachus schauinslandi*) by Baker and Johanos (2002). In their study, each of 549 handled seals was matched to a control seal of the same sex, age, location and year. Handling included instrumentation with satellite tags, TDRs, Crittercams and GPS tags (N=93), blood sampling (N=19) and flipper tagging (N=437). No significant differences were found between handled seals and controls in resighting rates, observed migration rates or condition (one year later). Resighting rates of handled animals and controls were high (80-100%), and it was concluded that these handling techniques had no deleterious effects on Hawaiian monk seals (Baker and Johanos 2002). The data collected in these types of studies are almost impossible to replicate for many of the ice-breeding seal species studied in Norwegian waters. The dynamic ice habitat makes it hard to predict where an individual will be during the next breeding or moulting season. In addition, many of the northern hemisphere ice-breeding species are very hard to capture even once. This in contrast to many of the terrestrial breeding species that use a predictable area for breeding and moulting year after year, facilitating multiple recaptures of individuals.

Capturing techniques themselves can impose a hazard to the animals involved. For example, seals can drown in nets during capture. However, if the nets are continuously guarded this probability is very low. In addition animals can die from reactions to the various drugging agents use, although a “favorite” drug with low associated mortality has been found for most species. An exception is walruses, but the artificial respiration technique described above gives hope for a future reduction in drug-associated mortality for this species. Handling is likely a stressor for captured animals, and some of studies have addressed this issue. In a recent study of handling of grey seal pups neither handling frequency nor cumulative handling time had any effect on plasma cortisol or thyroid hormone levels, increase in cortisol levels over the first five minutes of contact, or mass loss during fasting in either sex (Bennett et al. 2012). The study concluded that routine handling of grey seal pups had no additional impacts on these animals above and beyond the general disturbance created by researchers moving around in the colony. Similarly, no blood chemistry effects were detected in southern elephant seals that could be related to drugging of adult females and physical restraints of pups (Engelhard et al. 2002). No measureable effects in short- or long-term survival were found in southern elephant seal pups that were repeatedly handled during the first six weeks of life (McMahon et al. 2005). However, in a study of plasma enzymes in harp seal pups that were transported and handled for 3 h, plasma creatine kinase was markedly elevated 3 h after capture (St. Aubin et al. 1979). These levels returned to normal after 12 h, and it was suggested that plasma creatine kinase could be used as an indicator of handling stress in seals. Trites (1991) suggested that tagging and handling of northern fur seal (*Callorhinus ursinus*) pups in the Pribilof Islands in Alaska caused weight loss and slower growth rates than for unhandled pups, since the former group consistently weighed less. A re-evaluation of these data suggested that tagged and untagged pups grew at the same rate, but that the tagged pups were born later in the season and thus were more susceptible to being captured than older, bigger pups (Trites 1991). In a study of handling effects on reproductively active adult Weddell seal males, a prolonged elevation in cortisol levels were documented (Harcourt et al. 2010). Administration of a light doze of diazepam significantly improved the cortisol response of handled animals without affecting testosterone levels. This treatment was recommended as an effective method for reducing handling stress in adult male Weddell seals. This finding is in contrast to another study of blood indicators in adult male and female

Weddell seals from McMurdo Sound that has been used as a model species for research for four decades (Mellish et al. 2010). Mellish et al. (2010) detected no variation in blood parameters between low and high disturbance areas. These authors also found no indication of change due to handling in white blood cells, platelets, globulins, haptoglobins or feacal corticosteroids between groups that might indicate stress or inflammation. Responses of Pacific walruses to research capture and handling activities was studied by Jay et al. (1998) in Alaska. These authors reported that walrus handling activities resulted in increased alertness, displacement and dispersal. But, high levels of behavioural change were only noted for a 45 min period post-handling, before the herd returned to normal behaviour. Displacement was moderately and negatively correlated with herd size. Animals continued to use disturbed haul-out sites, and even tagged animals returned rapidly to the sites where they had been tagged.

An assessment of potential effects of various types of epoxy used to attach instrument to the fur of phocid seals was recently published (Field et al. 2012). Possible damage due to exothermic (heat producing) reactions that occur when glue cures, and other possible injuries caused by the tags were explored based on resightings of more than 500 tagged southern elephant seals and Weddell seals. Four out of 508 seals had lesions under the footprint of the instruments that were suspected to be caused by the epoxy getting too hot. These four individuals were resighted in subsequent years fully healed. Small superficial abrasions or lesions at, or toward the edge of, the footprint were observed in 7% of the animals; all of these abrasions were also healed following the first moult after instrumentation. Field et al. (2012) also provide many suggestions for how to minimize the impact of instrument attachments, including a caution not to overheat the epoxy before use (in cold conditions), reducing the amount of epoxy to a minimum and to round the edges of the epoxy upwards and away from the skin.

Flipper tags have been found to have no adverse effect on Hawaiian monk seals pups (Henderson and Johanos 1988). Infrared thermography was used to study the healing process at flipper tag sites in grey seal pups (Paterson et al. 2011). This study showed that a temperature increase associated with the wound healing process around the tag site, but temperature returned to pre-tagging levels before the animals left the study site 2-3 weeks post-tagging. Infrared thermography has also been used to record surface temperature distribution of two juvenile grey seals instrumented with heart rate recorders and mounting straps for attachment of a TDR (McCafferty et al. 2007). When the seals were wet and inactive the surface temperature was unaffected by the instruments. However, as the animals dried out the regions around the edges of the attachment sites had higher temperatures. It was concluded that this localized effect on heat transfer would not significantly change the total heat exchange of the seal on land or at sea, at least not with these relatively small instruments.

Effects of branding with hot or cold- irons have been studied in several seal species. Wound healing was generally completed within a year in hot-iron branded southern elephant seal pups with the moulting process contributing to finalize the healing process (Hoff et al. 2004). In harbour seals, cold-iron brands healed faster than hot-iron brands, however hot-iron brands provided a more permanent mark (Daoust et al. 2006). After 10 weeks 75% of the hot-iron brands showed poor to no healing, while the corresponding figure for the cold-iron brands was 25%. The authors concluded that it was desirable to develop a less intrusive method for identification of seals as an alternative to either of these branding methods. Hot-iron branding of juvenile Steller sea lions produced inflammatory responses that returned to baseline 7-8 weeks post branding (Mellish et al. 2007). Pain-related behaviours were also detected in juvenile Steller sea lions after hot-iron branding (Walker et al. 2010). Specifically, in the first days after branding the animals spent more time grooming the branded area, less time with pressure on the branded side and less time in pools and spent less time moving. The authors suggested that analgesia protocols to ease the pain should be used when branding these animals. No difference in survival was detected among branded versus non-branded southern elephant seals or in New Zealand sea lions (*Phocarctos hookeri*, McMahon et al. 2006, Wilkinson et al. 2011), while Hastings et al. (2009) found a 0.5-0.7% mortality attributed to branding Steller sea lion pups during the first 3 months post branding.

Effects of life history tags (LHX) described above that have been intraperitoneally implanted in California sea lions and Steller sea lions (Horning and Hill 2005) have been investigated in several papers. All sea lions recovered well after surgery with minimal swelling around the incision site (Horning et al. 2008). Physiological effects included increased levels of acute-phase proteins (indicators of infection, inflammation or tissue trauma) 2 weeks post-surgery, with levels returning to baseline after 6 weeks (Mellish et al. 2007). Dive behaviour recorded post-release showed that LHX-implanted sea lions had dive depth, duration, frequency and dispersal distances similar to sea lions without LNX implants (Mellish et al. 2007). In an attempt to address pain associated with these surgeries, changes in behavioural responses before and after were recorded by Walker et al. (2009). These authors recorded changes in back arching, standing, locomotion, time alert, time lying and time spent with pressure on the belly. The sea lions still showed effects 12 days post-surgery, suggesting the need for a more effective analgesic method for this surgical procedure. When implanting VHF tags into harbour seals (Lander et al. 2005) wound healing varied depending on whether the tag was encapsulated in wax or resin, where the latter coating was more likely to develop wound discharge and openings near the incision requiring antibiotic treatment. Wounds were healed at 10 days post-implantation and no effects on post-implantation survival were noted. Neither tissue reactions from the PIT tags implanted in elephant seals nor any differences between survivals in PIT-tagged versus non-PIT-tagged animals was recorded in the study by Galimberti et al. (2000).

Heart rate loggers implanted in California sea lions and northern elephant seals allowed for excellent detection of electrocardiograms, but the elephant seals showed substantial inflammatory responses and the implanted loggers were removed (Green et al. 2009). The sea lions on the other hand had little swellings and no exudates after implantation. The reasons for the different responses between these two species were described as unknown.

Some recently published papers address issues related to tagging of marine mammals in the field (Wilson and McMahon 2006, Gales et al. 2009. McMahon et al. 2011, Walker et al. 2012). These articles propose guidelines for minimizing detrimental effects of tagging and recommend specific monitoring and reporting practices to help standardize future work assessing potential effects of studies involving instrumentation. Further , these articles also address issues related to sample size and justification for why the chosen tag is appropriate for the objective of a particular study and whether there are alternative, less invasive methods available (strongly supporting the consideration of the 3Rs of research: replacement, refinement and reduction).

Cetacean species belonging to both the *Odontoceti* (toothed whales) and the *Mysticeti* (baleen whales)

Marking methods and procedures

Individual identification:

There has been no tradition for marking live whales for individual identification in Norway. An exception was the so-called "discovery tag" programme, which deployed vast numbers of numbered metal cylinders that were shot into the blubber of whales of a variety of species, mainly baleen whales and sperm whales (*Physeter macrocephalus*), with the expectation of recovery during the butchering process of harvested animals. The intention was to determine better estimates of dispersal and range. This tagging method was used from 1932 until the whaling moratorium in started in 1985 (Wells 2002). In other parts of the world several other marking methods have been used for individual identification of various whale species. Many of these are similar to what has been described earlier for pinnipeds, including freeze branding numbers on the dorsal fin or side and attachment of plastic tags

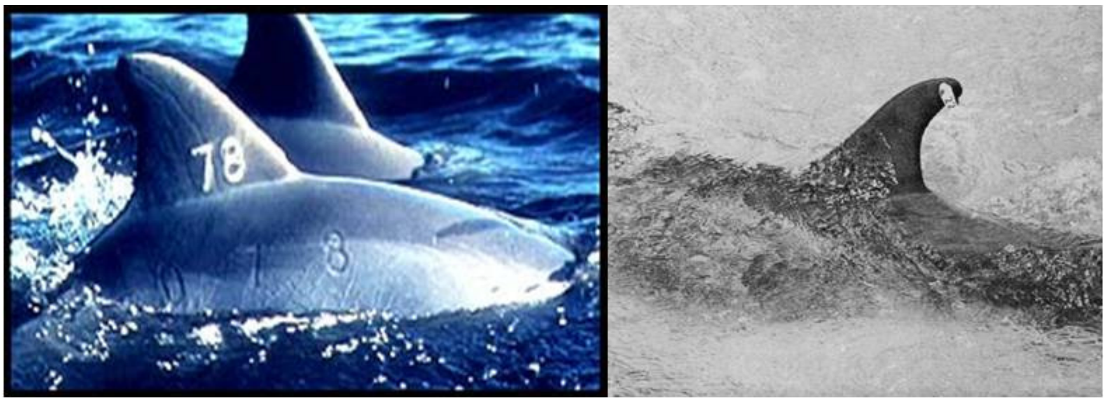


Figure 1. Left panel: Freeze branded numbers on a dolphin, right panel: tag on the dorsal fin of a porpoise Photo: left panel: http://teacher.scholastic.com/dolphin/week2.htm, right panel: Norris and Pryor 1970.

similar to flipper tags used on seals (See Figure 1). More solid number tags have also been used;

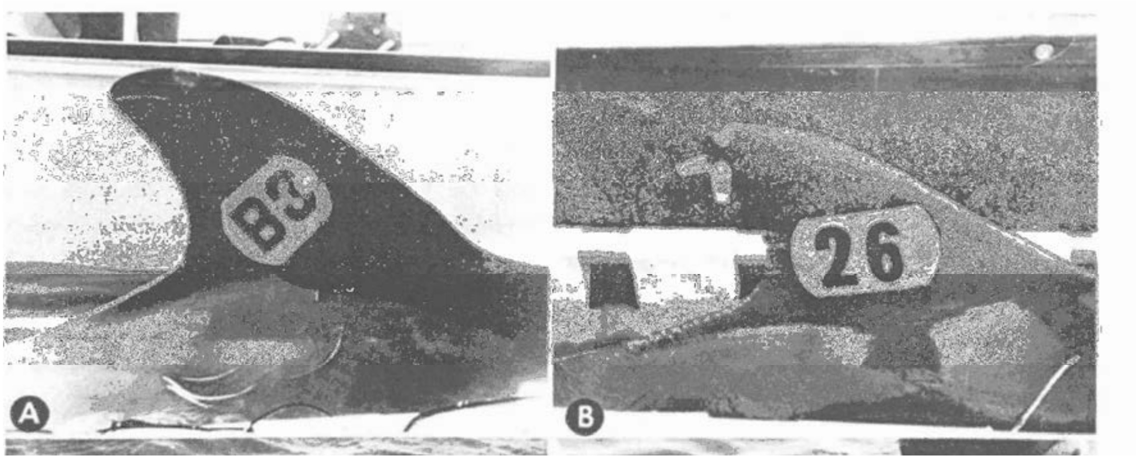


Figure 2. A visual tag with one (left panel) and two (right panel) Teflon bolts attached to the dorsal fin of a dolphin. White "strand" in lower right picture is a spaghetti tag. Photos: Irvine et al. 1982.

this sort of tag has been at were bolted through the dorsal fin with a single or double bolt (see Figure 2). Smaller "button tags", made of coloured fiberglass with a number on them, have also been attached to the dorsal fin of many small cetacean species. Streamers or spaghetti tags, which were originally developed for fish, have been deployed on thousands of dolphins and porpoises. These tags are coloured strands of wire cable of variable length with metal dart tips that are applied using a jab stick or crossbow to anchor the tip between the muscle and blubber layer (see Figure 2). Due to poor retention time and potential animal injuries, use of these tags has been discouraged for many years (Irvine et al. 1982). For a review of many of the studies using these various marking methods see Scott et al. (1990). The most common method employed today for recognizing individual whales is not based on conventional tagging, but rather on other methods such as photo-id of tail flukes or colour patterns or other marks on various parts of a body sometimes in combination with genetics studies (from tissue samples or skin cells passed with fecal material).

<u>Tracking individuals:</u>

VHF- technology has been used in many studies to track various species of whales; generally this gear is remotely deployed on larger species (Mate et al. 2007) and attached to the dorsal fin in smaller species such as harbour porpoises *Phocoena phocoena* (Read and Gaskins 1985). VHF tracking is useful for near-shore tracking, but vessel logistics make this sort of tracking very expensive and labour intensive if animals are offshore, and tracking can only be performed on one individual at the time. Thus other techniques (i.e. satellite tracking) are more commonly used today for tracking individuals. VHF tags normally weigh some few 10s if grams (see figure 3), but the attachment devices may weigh more. For example, the tag used on harbour porpoise by Read and Gaskin (1985) weighed 170 g (in air).

Figure 3. A VHF tag attached to the dorsal fin of a pilot whale *Globicephala melas* (Photo: http://people.oregonstate.edu/~mecks/GIS/Anno_Biblio.html

The most common method for tracking whales today for studies of movement patterns and habitat use is similar to seals - equipping the animals with some sort of satellite transmitter. Depending on the species these are remotely deployed with an extension pole, crossbow, air-pressure gun (Figure 4) or hands-on deployments on captured animals. The various attachments techniques will be dealt with in the next section.

Figure 4. Using an extension pole to attach a satellite tag to a bowhead whale *Balaena mysticetus.* Photo:

http://northwestpassage2012.blogspot.com/2011/09/whales-find-arctic-path-from-atlantic.html

One general problem with remote tagging methods has been that the tags remain on the whales for only a short time. Initially, the anchors of the tags only penetrated the blubber and due to hydrodynamic drag, in combination with the natural process of the whale's tissue rejecting a foreign object, the tags were pulled out after some few days or weeks (see f. inst. Heide-Jørgensen et al. 2001a, b). A lot of experimentation took place to determine how deep the tag should penetrate, how to prevent rejection etc. and in addition miniaturization of tags has taken place which has resulted in much longer tracking periods being achieved (see Mate et al. 2007 for review). Many of the position-only tags today are so small that the tag is implanted in the animal, thus reducing drag almost entirely. Only the antennae and the saltwater switch protrudes out of the whale, and these tags have now produced track durations for several baleen whales species lasting many months (Zerbini et al. 2006, Mate et al. 2007, 2011, Lydersen et al. 2012).

Many odontocete species are instrumented after first being captured, generally in some sort of net arrangement (see section below), and once they are in a controlled situation tags are attached. Most whale species have a dorsal fin and this is the main attachment site for satellite tags. Various types of penetrating bolts are normally used, where the tag is situated on one or both sides of the fin, or in the front of the fin (see Figure 4 and 5 for examples) or in the case of some smaller satellite tags they are attached towards the back of the fin (see Figure 5 for example).

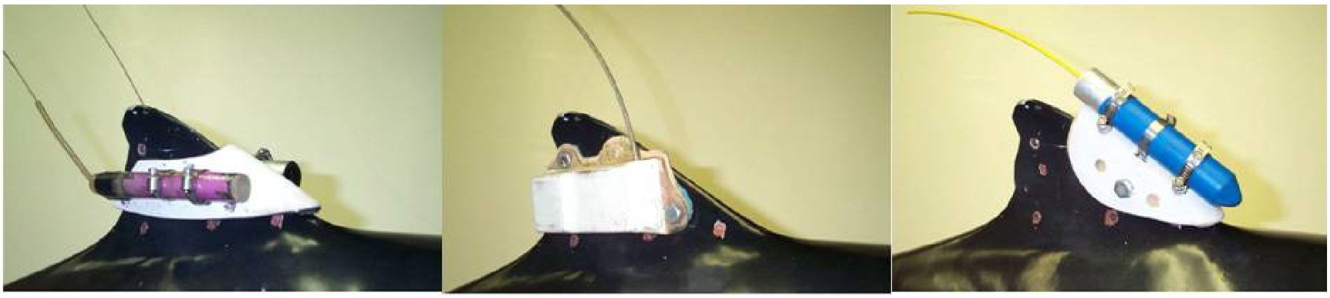


Figure 5. Paired side mounted (left panel), single side-mounted (middle panel) and front-mounted satellite tags on a dorsal fin of harbour porpoises. From Hanson 2001.

Tracking whales using satellite tags attached to the dorsal fin has resulted in many studies of movements and home ranges based on tracking duration of 200+ days (Anon. 2003, Sveegaard et al. 2011, Sonne et al. 2012).

Figure 6. Left panel: A VHF transmitter (top) and a satellite tag (bottom on the dorsal fin of a bottlenose dolphin (*Tursiops truncatus*), right panel: A harbour porpoise with a side mounted satellite tag ready for release. Photo left panel: from Balmer et al. 2011, right panel: http://www.dmu.dk/en/animalsplants/satellite_tracking/harbour_porpoise.

For odontocete species that lack dorsal fins, satellite tags are normally attached via bolts through the dorsal ridge or right in front of it. Saddle mounts were a common method for attaching satellite tags on narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas),* but recently thin wires from the attachment bolts to the tag have proven to be the method providing the longest track durations (Figure 7). These location only SPOT tags (e.g. SPOT5, Wildlife Computers) weigh about 30 g while larger, saddle mouted CTD tags weigh about 650 g (see Figure 7).

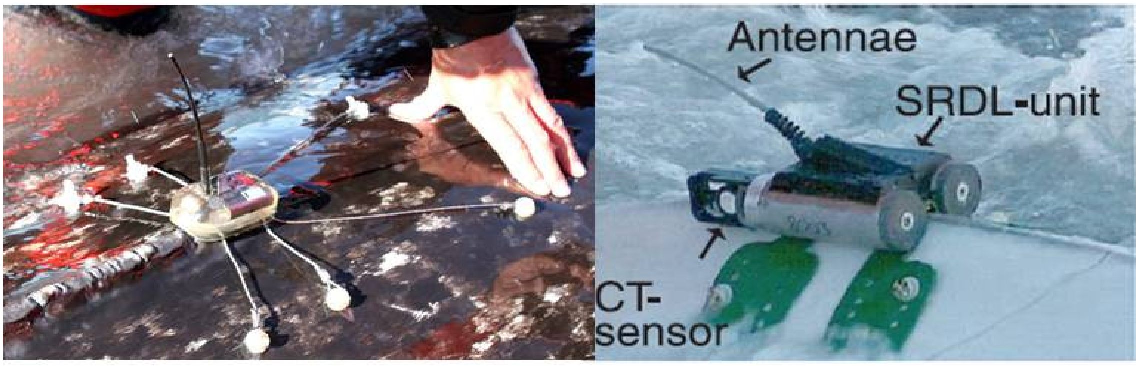


Figure 7. Left panel: satellite tag attached to a narwhal in front of the dorsal ridge using thin wires to attach the tag directly to the attachment pins. Right panel: A satellite tag attached to the dorsal ridge of a white whale using a saddle mount (Photo: left panel: http://oceanexplorer.noaa.gov/explorations/06arctic/background/oceanographers/media/satellite_tag.html), right panel: from Lydersen et al. 2002).

Narwhal males have been instrumented with satellite tags attached to their tusks (Dietz and Heide-Jørgensen 1995), but this practice is no longer in use due to the suspicion that such tags might interfere with the echolocation capabilities of these whales. Both narwhals and white whales in Norwegian waters have been tracked using saddle mount (Lydersen et al. 2001, 2002, 2007) that have provided insight into migration patterns of these animals, mainly during the summer period in Svalbard. The new attachment techniques have provided tracking data for more than 300 days for narwhals (Westdale et al. 2010) and close to that also in white whales (Lewis et al. 2009). Many of the satellite tags also provide diving information that adds insight into the habitat analyses of the tracked whales, and have documented vast amounts of behavioural information, f. inst. that narwhals regularly dive deeper than 1000 meters (Laidre et al. 2003). The prototype for the CTD-satellite tags that (among other things) provide the oceanographic community with vast amounts of CTD-profiles for climate research was developed for use on white whales in Svalbard (Lydersen et al. 2002). These tags are currently mainly used on pinnipeds, especially in the southern ocean as part of the Global Ocean Observation System (see section on pinnipeds).

Another very sophisticated method for tracking whales using acoustic recording tags usually involves a suction cup attachment (and short deployment time). These types of instruments, such as the “D-tag” give an on-animal perspective of its sonic environment and combined with data from various movement sensors relate these sounds to the animal’s activity patterns (Figure 8). The very high data sampling rate that is required to collect information regarding the sound environment experienced by the animal means that the data cannot practically be transmitted, so they have to be stored onboard the tag for later retrieval (a data logger as opposed to a transmitter). Modern tags have a recording capacity of 2 days at a sampling rate of 100 kHz in a volume of 50 cm^3 (Johnson et al. 2009). A variety of low-powered sensors are built into these tags including, pressure, orientation, movement and image sensors. These sensors can be set to sample data synchronously with the sound recordings, avoiding any ambiguity in the precedence of sound and contextual measurements (Johnson et al. 2009). These tags have proven to be a great source of information on eco-physiology, foraging behaviour, biomechanics, bio-sonar, effects of noise, sound production and repertoire and behavioural use of sound for many marine mammals. A vast number of published papers exist based on these types of tags; see Johnson et al. (2009) for a review.

Figure 8. A digital acoustic recording tag (DTAG) attached to a pilot whale (left panel) and a humpback whale (*Megaptera novaeangliae*) (right panel). Photo: left panel: http://www.acousticecology.org/sractivesonars.html, right panel: http://www.sciencedaily.com/releases/2007/09/070901084549.htm.

In Norwegian waters a lot of effort has recently been put into studying the behaviour of various whale species and their reaction(s) to sonar exposure. Acoustic tags, mainly DTAGs, have been deployed on sperm, killer (*Orcinus orca*), pilot, minke and humpback whales and after a period of recording "natural " behaviour the animals have been exposed to various noise sources, such as sonar transmissions and playback of killer whale sounds (Kvadsheim et al. 2007, 2009, 2011). The DTAG was developed by Woods Hole Oceanographic Institute; it records sound at the whale, as well as depth, 3-dimensional acceleration, and 3-dimensional magnetometer information - allowing a fine-scale reconstruction of whale behaviour before, during, and after sonar transmissions. The tag is attached to the whale using a hand-held carbon-fiber pole with suction cups (Figure 8), or a pneumatic remote deployment system. At a pre-set time the vacuum is released from the suction cups and the tag floats to the surface. The tag contains a VHF transmitter so that the whale can be followed during the period of the tag deployment, and to retrieve the tag after release. Since all sensor data are stored onboard the tag must be retrieved. The DTAGs weigh 300 g in air.

Other biologging instruments:

Various other biologging instruments have been attached to many species of whales to study various aspects of their behaviour. Some of the more commonly used instruments are dealt with below.

As for pinnipeds, but to a much smaller degree, Time-Depth-Recorders have been used for detailed diving studies in cetaceans. On smaller species TDRs are either deployed with a suction cup (Baird et al. 2001), or attached with pins to the dorsal fin (Scott and Chivers 2009). These are usually the same small Wildlife Computer tags described in the pinniped section. TDRs with suction cups have also been deployed on large baleen whales such as the North Atlantic right whale (*Eubalaena glacialis*, Baumgartner and Mate 2003), sperm whales (Amano and Yoshioka 2003) and blue whales (*Balaneoptera musculus*, Croll et al. 1998).

More detailed dive behaviour has been studied using accelerometers deployed on various cetacean species (see f. inst. Sato et al. 2007). These instruments weigh about 100 g in air and are attached with a suction cup in most cases. Also as mentioned above, accelerometers are a common sensor that is integrated into acoustic tags in many sophisticated studies of cetacean behaviour.

Cameras have been used a lot for short term behaviour studies of various whale species. The most "famous" are the "Crittercam" sytems developed by National Geographic (Marshall et al. 2007), that have been deployed on many species (Figure 9). The resulting video footage has been analyzed for many scientific articles (e.g. Calambokidis et al. 2007, Herman et al. 2007) in addition to being shown in many nature documentaries.

Figure 9. A pilot whale with a "Crittercam" (left panel) and a "Crittercam" being deployed on a blue whale (right panel) Photo: left panel: Pilot whale with crittercam http://www.nationalgeographic.com/crittercam/pcwhale.html right panel: http://www.cascadiaresearch.org/photo%20gallery/crittercam.htm.

There is a vast amount of scientific literature on instrumentation of cetaceans for studying various aspects of their physiological. However, most of this research has been performed on animals in captivity, or on trained animals brought out into the open ocean for the experiments; such studies are thus beyond the scope of this review. However, some few exceptions are found, like a study by Westgate et al. (2007) where heat flux and skin temperature were measured on free-living bottlenose dolphins in the wild (Figure 10). These thermal loggers were attached to the dorsal fin of the animal either by suction cups

Figure 10. Left panel: (a) a heat flux and skin temperature data logger with suction cup attachment (B) and bolt attachment. Right panel: logger with suction cup attachment on the dorsal fin of an adult bottlenose dolphin. Photo: From Westgate et al. 2007

(for short time deployment) or by bolts (for longer time deployments). The tags are ideally retrieved by re-capturing the dolphin, but in cases where that are unlikely to happen, the long-term package is attached using metals that will corrode and thus release the package.

Capture and handling

Larger whale are not normally captured in order to instrument them; they are usually approached by boat and tags are then deployed either remotely using a crossbow or a pneumatic gun (Figure 11) or by direct contact via a long pole or lance (see Figures 4 and 7 above). Some more sophisticated methods have been tried, such as using small radio-controlled model helicopters to delivery tags, but without much success (Mate et al. 2007 NB: worth reading).

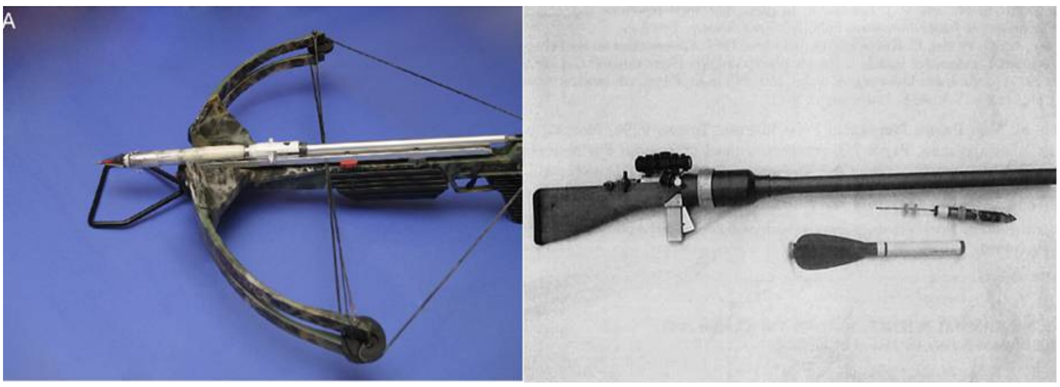


Figure 11. Left panel: a crossbow loaded with an implantable tag and applicator, right panel: Air Rocket Transmitter System (ARTS) consisting of a pneumatic gun, transmitter with steel cutting barbs, and a hollow rocket with tail feathers. Pressure of the compressed air chamber (shown at the base of the barrel of the gun) can be adjusted between 0-50 bar to compensate for distance to target and weight of projectile. Photo: left panel: from Mate et al. 2007, right panel: from Heide-Jørgensen et al. 2001.

As mentioned above the normal manner in which various instruments are attached to larger whales involves either some sort of anchor mechanism penetrating the blubber (and sometimes also the muscle), or by a suction cup at the surface of the whale. Generally, the vacuum inside these suction cups can be released at a preset time so the tag detaches and floats to the surface. For a review of the development of the many types of anchoring techniques, see Mate et al. (2007). These authors review size, configurations, and various materials have been tested; the preferred current tag design is shown in Figure 12 (left panel tag C).

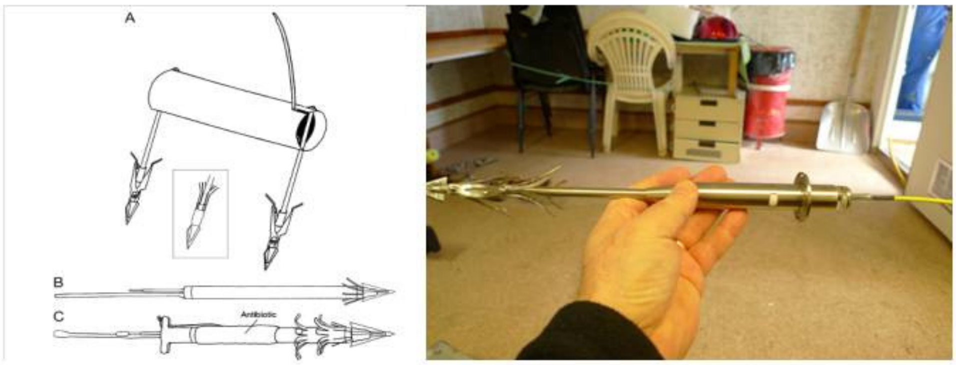


Figure 12. Left panel: A cylindrical surface-mounted projectile tag with two sub-dermal attachments consisting of bladed entry tip and folding barbs (inset show alternative wire rosette). B an early model implantable tag (19 cm long, 1.9 cm diameter housing) showing bladed entry tip in one end and antennae and saltwater switch in the other end. C currently used implantable tag with two rows of stainless steel petals to prevent outward migration. Also an end-cap was added to act as a depth stop and prevent inward migration of the tag. Right panel: same tag design as left panel C, showing a satellite tag used for bowhead whale tracking in Lydersen et al. (2002). Photo: left panel: from Mate et al. 2007, right panel: Kit Kovacs/Christian Lydersen.

Smaller whale species are often caught in nets and handled directly by researchers during instrumentation. Some research has been done with animals that have been accidentally caught in fishing gear, while most experiments involve animals passively swimming into purpose-set nets, or animals being actively chased into set nets. The latter technique is commonly used in Norwegian research programmes on white whales. Whales are guarded with Zodiacs along the shore towards a preset net and when entangled they are pulled into shallow water. Here, they are untangled from the net and restrained with a hoop net held over the head and a cushioned rope tied around the caudal peduncle which is anchored to the shore (see Figure 13). In this controlled situation animals are measured, various samples are collected and the tag is attached to the whale with nylon pins through the dorsal ridge and held in place by nuts and washers (see Figure 6).

Figure 13. Left panel: a white whale being untangled from a net, middle panel: the whale is restrained with a hoop net held around the head and a cushioned rope tied around the caudal peduncle which is anchored to shore, right panel: white whale with satellite tag attached to the dorsal ridge being released. Photos: Kit Kovacs/Christian Lydersen.

Another technique that has been used for live-capturing killer whales for instrumentation in Norwegian waters involved purse-seining the animal, then guiding it onto a stretcher and lifting the whale onboard a vessel with a crane (Figure 14). Tags were then attached to the dorsal fin with bolts.

As for seals, whales are generally speaking large animals and the weight of the instruments described here would be almost negligible when immersed in seawater. So the tags weight is not in itself an issue for the animals carrying them. Some whales are stressed by the close approach of research vessels that conduct the tagging (see discussion in Noren and Mocklin 2012), but these are short-term episodes that likely have only minor effects. Drowning in nets during capturing attempts is a hazard. However, with constant guarding of the nets such episodes should be extremely rare.

Stress levels during handling in connection with satellite tagging have been explored in harbour porpoises (Eskesen et al. 2009). Some animals can experience an overall decrease in respiration rate and a significant change in heart rate during tagging episodes. Eskesen et al. (2009) found no correlation between cortisol concentrations and heart rate or respiration and due to the highly individualistic responses to the tagging, concluded that they could not provide any general advice based on the factors investigated. Pouring water over the animal and keeping it low in the water seemed to stabilize particularly stressed animals. Another study on harbour porpoises detected a significant increase in heart rate when a hole was made in the dorsal fin for attaching a satellite transmitter (Geertsen et al. 2004). This study was conducted on a captive animal that was monitored before during and after attachment of the satellite tag. They also recorded behaviour and found some changes in log-rolling behaviour, roll duration, dive duration, daily food intake and surfacing areas after a radio transmitter was attached through the dorsal fin (Geertsen et al. 2004). Capture and handling white whales was found to produce a marked reduction in circulating levels of thyroid hormones (St. Aubin and Geraci 1988).

In order to assess the suitability of various metallic and plastic substances for tagging cetaceans, small test rods of various materials were implanted through the skin of white whales and bottlenose dolphins in captivity and the cellular responses to these implants were studied (Geraci and Smith 1990). Some plastic compounds were retained during the whole study period (12 weeks) while all other materials were expelled within 39 days. Tags of various configurations were also implanted as part of this study and they were all expelled between 0-44 days. The conclusion was that there is a need to develop a composite implant from material that minimizes the inflammatory reaction and permits rapid formation of a viable biological seal via tissue growth (into a porous material).

Generally speaking recaptures of cetaceans are less frequent compared with what is the case for pinnipeds, so there are not many studies where effects of the tags themselves can be explored. White whales that have been tagged with satellite tags using bolts through the dorsal ridge have been recaptured some years later; the tags had been rejected and the wounds from these tags were completely healed (Orr et al. 1998). Tissue healing following long term satellite transmitter attachments has been reported from harbour porpoises recovered drowned in fishing nets (Figure 14, Sonne et al. 2012). The necropsy of these porpoises revealed that they had full stomachs and that weight and length changes corresponded to natural growth for this species.

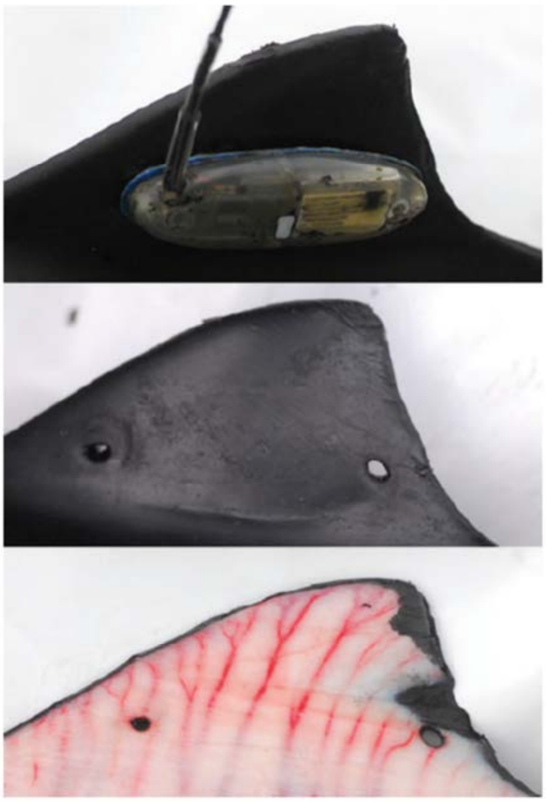


Figure 14. Top panel: Appearance of the satellite tag 48 h after the harbour porpoise drowned in a gill net. The tag was mounted using two 5 mm pins and had been on the animal for 343 days. Middle panel: Appearance of piercing after the tag was detached. Bottom panel: Cross section of the dorsal fin showing the maintenance of capillary blood supply during tag attachment. Photo: from Sonne et al. 2012.

Behavioural responses to attachments of external devises in cetaceans have been reviewed by Walker et al. (2012). Responses include aberrant swimming behaviour when tags are attached through the dorsal fin using bolts (Irvine et al. 1982), changes in frequency of leaps and changes in the speed of swimming following suction-cup attachment (Schneider and Baird

1998), as well as flinching, tail slapping, rapid swimming and surfacing attempts after suction cup attachments (Hanson and Baird 1998, Hooker et al. 2001, Blomqvist and Amundin 2004). External devices deployed by implantation into the skin or blubber of whales have shown minimal behavioural effects. Some animals perform skin-twitches, followed by shallow dives, but other shows no response at all (Mate and Harvey 1983, Watkins and Tyack 1991, Goodyear 1993). One individual whale breached and accelerated rapidly post tagging, which might suggest that it was trying to displace/remove the tag (Goodyear 1993). Some whales reacted to missed tagging attempts by swimming away, raising their heads or backs out of the water, defecating and submerging quickly. These might have been response to the splash the device made when it hit the water (Watkins and Tyack 1991). One study concluded that anchors used to attach tags did not cause severe damage; one whale that lost its tag showed swelling, but no sign of laceration around the tag entry point (Mate and Harvey 1983).

Effects if tagging on survival and reproduction has been explored in Amazon River dolphins (*Inia geoffrensis*, Martin et al. 2006). During this long-term study, 51 adults were fitted with transmitters and an equal number were captured and handled in the same way but released without a transmitter. No significant differences were found in either survival or reproduction between these two groups of animals, indicating that the dorsal fin packages had no measurable impact on these parameters.

Wild Birds

This risk assessment covers the following orders of birds:

Sphenisciformes (Sph) (penguins)
Procellariiformes (Pro) (albatrosses, petrels)
Accipitriformes and Falconiformes (Acc) (birds of prey)
Strigiformes (Str) (owls)
Anseriformes (Ans) (geese, swans and ducks)
Pelecaniformes (Pel) (gannets, cormorants)
Charadriiformes (Cha) (waders, gulls, auks)

On a global scale, these orders comprise a total of around 1200 species, of which approximately 100 breed in Norway and Svalbard and five in Norwegian territories in the southern hemisphere. Because many of the capturing, handling and marking procedures are common for many of these groups, the assessment will be organised as a presentation of the different procedures, each of which will be coded according to which group of birds the procedure is relevant. "All" refers to all groups.

Purpose of marking

The marking of birds involves a wide variety of techniques (see section 4), but by far the commonest is the attachment of a metal ring to a bird's leg (normally the tarsus), so-called bird ringing.

The original purpose of bird ringing was to unravel the mysteries of bird migration. Within Europe, where up to 4 000 000 birds are currently ringed annually (Fig. 1), the broad patterns of migration are now known for most bird species. As elsewhere in Europe, bird ringing in Norway has a long history and since its start in 1914, more than 7 000 000 birds have been ringed in the country.

Data generated by bird ringing activity in Norway are shared internationally with other national ringing centres through The European Union for Bird Ringing (EURING, http://www.euring.org) whose aims are to promote, co-ordinate and encourage

- Scientific and administrative co-operation between national ringing schemes
- Development and maintenance of high standards in bird ringing
- Scientific studies of birds, in particular those based on marked individuals
- The use of data from bird ringing for the management and conservation of birds.

These objectives are achieved mainly through co-operative projects, the organisation of meetings and the collection of data in the EURING Data Bank that today holds in the region of ca. 3 000 000 ring recoveries. These recoveries are available to researchers throughout the world.

In recent decades, member countries of EURING have greatly intensified their efforts in the area of migration research. The computerisation of the archives of recovery data has been a prerequisite for many of the recent recovery analyses and also for producing national recovery atlases. Comprehensive atlases have been published in several member countries, including Norway (Bakken et al. 2003, 2006), Sweden and Great Britain and work has begun on them in a number of others. This is an important step because it will make results from ringing easily accessible. It will also show where knowledge is missing and where efforts in future ringing should be focused. As migration patterns change over time, particularly in relation to factors such as climate change, continued bird ringing is important even for common species.

Birds are excellent tools for monitoring and understanding environmental change, as well as being a charismatic wildlife resource that brings enjoyment to many millions of people. Any record of a ringed bird, either through recapture and subsequent release, or on the occasion of its final recovery as a dead bird, will tell us much about its life. This technique is one of the most effective methods to study the biology, ecology, behaviour, movement, resting/stop-over areas, wintering sites, breeding productivity and population demography of birds. In this context, effort is now being put into change the focus of bird ringing away from migration studies and more into environmental surveillance. EURING and the national ringing centres are, for example, establishing Constant Effort Sites where birds are caught at the same site, using the same methods and over the same time of year, thus generating long-term studies of species composition, sex-ratio, age-structure, body condition, etc., parameters that can tell us a lot about and help determine the causes of any changes in the populations. The birds are ringed, but not so much to document migration patterns but more as a tool to document population structure and estimate changes in survival of different age groups through analyses of recaptured birds at the same sites.

That being said, tracking the journeys of ringed birds does also allow us to define their migratory routes and staging areas, thus providing crucial information for the planning of integrated systems of protected areas for birds.

Figure I. The numbers of birds ringed annually in Europe and the numbers of ringers licensed by each national ringing centre (as of 2007). If several ringing centres operate in one state, summary figures are given. It is estimated that 115 million birds were ringed in Europe during the 20th century. Map from http://www.euring.org.

Beyond ringing of birds, a wide variety of other techniques are currently used to individually mark birds (see below –Marking technology). More details around the purpose of bird ringing can be read on the EURING website at http://www.euring.org/about_euring/brochure2007/index.html. The techniques other than ringing are often used in specific research projects as a means through which individual birds can be recognized at a distance without the need for recapture/recovery.

In recent years there has also been an increase in the use of electronic logging and/or transmitting devices (see below –Marking with electronic devices) by professional researchers to document a wide variety of parameters such as short- or long-term movements of individuals, foraging behaviour, flight dynamics, diving capabilities, physiological responses, etc. Such devices provide essential information on the biology and ecology of birds and their role in the ecosystem(s) plus quantitative data on a wide range of physical parameters that help to understand better what governs their distribution. While often used to answer specific scientific questions posed by the researcher, the data generated are ultimately also important in the management and conservation of the species or groups of species studied.

Who is marking the animal?

As implied above, birds are marked in Norway in two main contexts – ringing by amateurs and marking by professional researchers. In both instances, all marking is carried out under the guidance and control of the Ringing Centre at Stavanger Museum (http://www.museumstavanger.no/museene/stavanger-museum-/ringmerkingssentralen) and the Norwegian Directorate of Nature Management (DN).

Most birds are ringed in Norway by licensed amateur ornithologists whose motivation is the simple privilege of working with birds for the ultimate purpose of conservation. Most ringers are organized in local ringing groups and/or ringing stations under the auspices of the Norwegian Ornithological Society (BirdLife Norway) and catch and ring around 250 000 birds in Norway every year. Of the species that are included in the the Terms of reference the numbers of the marked birds are included in Appendix 1. Before being issued a licence, ringers have to demonstrate their knowledge of bird identification, of sexing and ageing, the practical and administrative details of ringing, and, last but not least, the ethical and conservational aspects of this research method.

In Norway, trainee ringers have to spend a number of years of practice before being allowed to ring birds on their own (Runde 1991, Båtvik et al. 1999). These years of probation and the ringing courses are of great importance in acquiring the methods of safe handling of the birds and the equipment, becoming experienced in the identification of the different, common and uncommon species. Also it takes a few years to master the capturing methods (some of which may be specific and rarely used) and to become skilled in measuring birds. Many ringers are involved in co-ordinated projects, following the welcome general trend of designed projects in bird ringing. Without the help of these volunteers, it would be impossible to work ringing stations and maintain centrally co-ordinated projects, such as Constant Effort Sites (see http://www.bto.org/volunteer-surveys/ringing/surveys/ces) and national and international species-orientated projects.

Only a small proportion of ringers are professional scientists. They are employed mainly by universities or other research institutions, and use bird ringing in special research programs. A very small number of ringers are employees of ringing stations (e.g. Lista fuglestasjon, http://www.listafuglestasjon.no/default.asp?pxside=news&pxnewsid=191) or field assistants of certain conservation projects.

Marking technology

Metal rings (All except Sph)

Figure II.

All birds, except penguins, marked, for whatever reason, should also be ringed with a metal foot ring.

When a bird is caught, a ring of suitable size is attached to the bird's leg. The ring has on it a unique number, as well as a contact address. In Norway the address is Stavanger Museum, Norway. The rings are usually made of aluminium or other lightweight material, but in the case of seabirds and some other species, a stainless steel alloy may be used to reduce corrosion in seawater or to prevent the bird removing the ring with its bill.

Each bird species is assigned a certain size of ring, and this is strictly adhered to so as to avoid adverse effects of e.g. rings slipping over the foot when too large or constricting blood-flow, etc. when too small. Rings are attached using pliers, preferably specially designed ringing pliers, such that the edges meet fully when the ring is closed over the leg. Nestlings should not be ringed until near fully grown and their legs are large enough to hold the rings.

Bird rings are designed to have no adverse effect on the birds - indeed, the whole basis of using ringing to gain data about the birds is that ringed birds should behave in all respects in the same way as the unringed population.

When the correct size is used and the ring is attached properly, the frequency of adverse effects on birds is usually extremely low. There are few documented cases of leg injuries, irritation or entanglement of toes (Calvo and Furness 1992, Fair et al. 2010 and references therein). On the other hand, incorrect ring material or failure to adjust the ring correctly may cause injury to the leg, or, in the case of nestlings, entanglement with nest material. As metal rings wear as a result of abrasion against the leg or through erosion, sharp edges may form but, with the development of new metal alloys this should no longer be a problem.

In some species that “defecate on the legs” such as vultures and storks that live in arid regions, excrement may accumulate between the ring and leg and cause an increase in injuries and annual mortality (Calvo and Furness 1992). In burrow-nesting birds, accumulation of earth around the ring fitted to nestlings has been observed. For example, this occurred in some

Atlantic puffin *Fratercula arctica* burrows that were wetter than normal, but had no obvious negative effects on the chick (pers. obs.). In species breeding in polar areas, some accumulation of ice on the ring may occur, but no negative effects have been documented among the species covered in this report.

Very little research has been done on the long-term effects of metal rings on birds, and the extent to which metal rings may affect survival rates seems to be unknown. It is, however, considered probably slight or trivial (Calvo and Furness 1992).

***Colour rings* (All except Sph)**

Colour-ringing has proved to be a very useful technique in recognizing individual birds without having to recapture them. One or more single-coloured rings are applied to one or both legs in combination with a metal ring. Alternatively, a single multicoloured ring, or a coloured ring in which is engraved a series of letters or digits (or a combination of the two) in a contrasting colour may be used. These rings are usually made of stiff plastic (celluloid, PVC, darvic or suchlike) but sometimes coloured anodized aluminium may be used (e.g. for eagles in Norway where the metal ring may be coloured). All colour-ringers in Norway are obliged to access the European colour-ring web-page (http://www.cr-birding.org/) to coordinate their choice of codes with other projects.

Figure III. Examples of colour rings used on water- and seabirds. Photos: http://training-to-ring-birds.blogspot.com and http://gaviotasyanillas.blogspot.com

Colour-rings are constructed as spiral, wrap-around rings that should be of the same internal diameter as the metal ring such that they do not slip inside (or outside) the lower ring. When put on the bird, the overlapping edges should be glued to ensure that the ring does not unwind and hence slip down around the foot or, as seen in some cases when originally fitted to the tarsus, up over the tibio-tarsal articulation ("ankle") onto the tibia.

Whereas there are some reports of adverse physical effects of colour rings in small birds (often a result of wrong sizes being fitted), neither Calvo and Furness (1992) nor Fair et al. (2010) report any such effects on species covered in this report when the rings were fitted correctly.

There are, however, some reports of behavioural reaction, mainly related to the possible interference of the colour of the ring with individual recognition, status signalling, or mate choice, but again these were most widespread among small species. Among gamebirds, Brodsky (1988) found that male ptarmigans *Lagopus minutus* with red and orange rings gained more mates than those without, but this was later disputed in several subsequent studies of the same or congeneric species (Fair et al. 2010 and refs. therein). Among waders, Cresswell et al. (2007) did not observe increased predation of colour-ringed redshanks *Tringa totanus*.

***Leg flags and strips* (All except Sph)**
Leg flags are widely used in the study of *shorebirds* and provide an easily visible means of identifying a bird from a particular location (plain coloured flags) or an individual bird (engraved leg flag) without having to recatch the bird. The flags can be recorded or their codes read using a telescope.

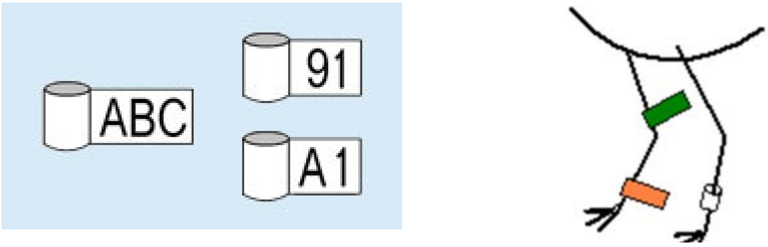


Figure IV. Examples of engraved number/letter types and combinations (left) and typical leg flag and aluminium identification band placement (right). Figs: © 2007 Asian Pacific Shorebird Network.

Figure V. Photo: http://www.hkbws.org.hk/

Leg flags are made from thin plastic and when formed can be opened and fitted to the leg of a wader and the edges of the flag are glued together (Clark et al. 2005). This allows the flag to move freely on the leg without falling off. For many years plain flags have been used to establish migration routes of birds from particular areas. However, increasingly leg flags are engraved with individual codes that allow individual birds to be identified. This has revolutionised our knowledge of migration as records of multiple resightings of individuals throughout the year are possible without the need to recatch the birds.

On large waders, two flags can usually be placed on the tibia, on smaller waders one flag is placed on the tibia and one on the tarsus.

Many types of leg flags have been described but, as for colour rings, no negative effects have been recorded in larger species (Calvo and Furness 1992).

Wing (patagial) tags (All except Sph)

In some studies involving larger birds, brightly-coloured plastic tags are attached to birds' wing feathers. Each tag has a letter or letters (or digits, or both), and the combination of colour and characters uniquely identifies the bird. Because the tags are attached to feathers, they drop off when the bird goes through its annual feather moult. A patagial tag is a permanent tag held onto the wing by a rivet punched through the patagium, the fold of skin extending from the humerus to the carpal joint, making up the leading edge of the wing. These markers are very visible both in flight and on perched birds, although part of the marker may be obscured by feathers when the bird is perching. Cattle and sheep ear tags are sometimes used as patagial tags on large birds.

According to Calvo and Furness (1992) and Fair et al. (2010), some reports indicate that most birds accept such tags readily, with few adverse physical effects. American kestrels *Falco sparverius* even had a higher breeding success than unmarked controls (Smallwood and Natale 1998). Nor did they seem to impair mobility or flight when used on a variety of species

Figure VI. Bald eagle with orange patagialmarker (c). Steve Wagener of Wag

Figure VII. Trumpeter swan with patagial tag,

including ducks and game birds (refs. in Calvo and Furness 1992).

There are, however, other reports of negative effects on the behaviour, survival and breeding success of ring-billed gulls *Larus delawarensis* and herring gulls *L. argentatus,* effects that disappeared when the tags on the former species were replaced by colour-rings (Southern and Southern 1985, Hart 1987, Kinkel 1989). Other signs of discomfort have been also been reported in some species, but not in others (Calvo and Furness 1992).

Again, while Green et al. 2004 and five studies reviewed in Calvo and Furness (1992) reported abrasion of skin, wing callouses and feather wear, six studies reported no such effects. In most of six papers that evaluated or described a new wing marker or attachment technique, no effects on behaviour (apart from initial discomfort in some cases) were noted, although in two others 3.4% of tagged eiders *Somateria mollissima* became solitary and golden eagles *Aquila chrysaetos* tagged as adults could abandon their territories. Similarly, Calvo and Furness' (1992) review of studies of the effects of patagial tags on breeding success and mortality gave conflicting results with some showing negative effects and others none.

Neck collars **(Ans, Cha)**
Neck collars have been used extensively for marking long-necked *waterfowl* since the 1960s. Most collars are, today, expandable cylinders of coloured, hard plastic with a series of 3 or 4 letters, numbers or symbols. Once wrapped round the neck, the overlap is glued.

Figure VIII. Photo: Darren Wheeler, Homerun Taxidermy

As with patagial tags, some studies have reported physical problems whereas other reported no problems. In no cases was food swallowing a problem. Some studies recorded a period during which the birds adjust to carrying the collar and some noted loss of neck feathers when marking, though others didn't (Calvo and Furness 1992). In some very early studies, birds were reported getting their bills stuck in the collar, but this problem seems to have been overcome – probably through an adjustment of collar size. Under severe weather conditions ice can accumulate in the collar, but very rarely causing more than discomfort.

Single instances of behavioural reactions are reported including aggression towards a marked bird (swan and gull), slight delay in nest initiation (goose), interference of courtship behaviour (goose) or more time spent preening on foraging grounds (goose) (refs. in Calvo and Furness 1992, Fair et al. 2010). Similarly isolated effects on reproduction success and adult mortality have been recorded among ducks, geese and waterfowl.

As with all marking techniques, responses differed among species, and systematic evaluations of possible influences of the marker should be considered in all studies (Fair et al. 2010). Because neck collars affected survival, Schmutz and Morse (2000) suggest that collars are useful in studies of movements and distribution but not when studying demography.

Nasal discs and saddles **(Ans)**
There are two types of nasal markers (saddles and discs) commonly used to identify individual *ducks*, as well as to study their local movements and behaviour. Nasal saddles are fitted over the bill and often have codes on them, while nasal disks are simple plastic figures of various shapes and colours that are installed on each side of the bird's bill. Nasal markers are efficient methods to identify ducks at a distance without having to recapture them, although Green et al. (2004) chose not to use them because most fell off within a month. Like neck collars, nasal tags are often used in species where the legs are not normally visible (such as ducks and geese).

Figure IX. Nasal saddle (above) and fitting nasal discs on ducks (right). Photos: http://www.deltawaterfowl.org

Nasal discs and nasal saddles are attached to the culmen with a pin looped through the nostrils in birds with perforate nostrils (i.e. the nostrils are not divided by a septum). They should not, of course, be used if they obstruct breathing.

Although seemingly brutal, there are few reports of physical or behavioural effect on birds marked in this manner. Some discomfort has been reported following attachment, but this was short-lived. Behavioural reactions during pairing among small species have been recorded, but in larger ducks and geese very little apparent effect on breeding behaviour or breeding success (Calvo and Furness 1992, Fair et al. 2010 and refs. therein). As with neck collars, incidences of ice-build up have been seen once under severe winter conditions (Byers 1987), and entanglement with submerged vegetation a couple of times (Sugden and Posten 1968, Evrard 1986).

Compared to other colour-marking techniques, nasal saddles appear to be quite short-lived, with a 50% loss within 13 months from harlequin ducks *Histrionicus histrionicus.* Thus, due to the potential to tangle in underwater vegetation and their short life, nasal discs and saddles are best suited for ducks that do not dive and for short-term projects and (Regehr and Rodway 2003, Fair et al. 2010). Their use should perhaps also be avoided in icy climates, as accumulation of ice on a nasal saddle can plug the nostrils.

Feather dyes **(All)**

Feather dyes can be useful as short-term markers, remembering that they will be replaced by an unmarked plumage at the first body moult. Water-proof, felt-tipped markers are also often used for very short-term marking of feathers, or nail varnish on toenails of nestlings. Among the dyes used are picric acid, Rhodamine B and malachite green, though the use of the picric acid is now strongly discouraged. Dyes and their solvents may cause initial discomfort, present a possibility of harming fumes and possibly also remove oil from the feathers causing wetting (and loss of buoyancy) and subsequent heat loss and should thus be used with care (Calvo and Furness 1992, Fair et al. 2010).

Figure X. Colour-dyed (picric acid) and

Among birds covered in this report, there was evidence of an upset of social behaviour and an increased abandonment of nests among black-headed gulls *Larus ridibundus* whose feathers had been dyed (Neumann 1982, 1985), whereas Raveling (1969) found no such evidence in work on Canada geese *Branta canadensis*.

***Flipper bands* (Sph)**

Figure XI. Metal band on a king penguin. Photo: Benoït Gineste, http://www2.cnrs.fr/en/1818.htm

Owing to anatomical peculiarities of their leg joint, penguins can not be ringed with traditional rings. Instead, flipper bands have been used widely to mark penguins since the 1950s. Flipper bands are durable, cheap, easy to attach and the engraved numbers can be easily read without the need for recapture. The bands are moulded to embrace loosely the axillary part of the flipper. Early flipper bands were made of aluminium, monel, plastic or Teflon, but most researchers today use stainless steel (Culik et al. 1993).

It was long assumed that flipper bands did not compromise penguins and had negligible effects on the behaviour and physiology of penguins. However, as understanding of penguin hydrodynamics, swimming costs, dive profiles, etc. has increased; their use has been increasingly debated by penguin researchers. A review by Jackson and Wilson (2002) showed that whereas there were no apparent effects of flipper bands on chick growth, adult over-winter survival and fledging success of royal penguins *Eudyptes schlegeli*, five studies of four other species revealed negative effects including damage to flippers, increased swimming costs, decreased survival, and reduced return rates to the colony. Subsequent studies (e.g. Gauthier-Clerc et al. 2004, Fallow et al. 2009, Saraux et al. 2011) have shown similar effects, although Boersma and Rebstock (2009) found no effect on foraging-trip duration of Magellanic penguins *Spheniscus magellanicus*.

Figure XII: Traditional metal flipper bands have caused concerns for possible negative impacts, for example on breeding success and for causing drag while swimming, snagging on vegetation and feather wear. A new silicon band, designed by Peter Barham of Bristol University, has been manufactured and tested by Bristol Zoo for the last five years – initially on penguins at the zoo and subsequently on wild birds on Robben Island, South Africa. The silicon bands were found to have successfully addressed these concerns. From: http://www.ufaw.org.uk/wawa.php, 2007.

The use of flipper bands is still controversial. With the exception of the use of microchips that is possible in some situations (see below), it is, however, still the only method by which to individually mark penguins. The biases involved in their use should, however, be taken into consideration when designing a study and interpreting the results (Wilson 2011).

Microchips (transponders) (All)

Figure XIII.

PIT (passive integrated transponder) tags have been used for over twenty-five years to permanently identify individual animals. Beginning with fisheries studies, the use of PIT tags has expanded to include mammals, reptiles, amphibians, birds and many other animals and objects. PIT tags, also known as 'microchips', allow researchers to safely mark animals internally without altering external appearance. In almost all cases the tag will stay with the animal for its entire life cycle. The small size of PIT tags virtually eliminates any negative impact on animals with little or no influence on growth-rate, behaviour, health or predator susceptibility. A PIT tag is encased in glass that protects the electronic components and prevents tissue irritation in the animal. The tag is inserted with a 12-gauge needle or by surgical incision under the animal's skin, and serves as a permanent coded marker that is a reliable form of identification of an individual. The tag is activated by a handheld scanner which generates a close-range, electromagnetic field. The tag is activated and transmits its number to the reader.

One major drawback with the use of PIT tags is that the scanner must be within ca. 0.5 m of the bird for the tag to be read. Automated monitoring systems in e.g. breeding colonies or along pathways (penguins) with a network of antennae on the ground can, however, eliminate the approach of humans carrying the scanner, thereby reducing stress to the animal (e.g. Gendner et al. 2005, Steen et al. 2007). Design engineers' calculations suggest that PIT tags can last as long as 75 years or more. There is no battery to fail and the glass encapsulation is impervious to almost everything.

Through research and testing, PIT technology has been shown to be a reliable and effective method of research and monitoring of individual animals, and has proved to be a useful (and better) alternative to flipper-bands in penguins (Clark and Kerry 1998, Gauthier-Clerc et al. 2004). There is a potential, however, of introducing bacteria through aseptic injection and transponders can migrate around the body and impinge upon vital parts (Clarke and Kerry 1998). Such migration may also make reading them more difficult in large birds. The disadvantage of PIT technology is that it is impossible to detect a marked bird optically.

Discussion

To quote heavily from Calvo and Furness (1992), this review of marking techniques of birds tells of many examples of influences of the various devices on behaviour, breeding success and in some cases survival. It would, however, be wrong to suggest that these examples should be used to argue against marking of birds.

All the techniques described here have been, and still are in extensive use throughout the world and researchers must continue marking birds, despite the inevitable effect on the animal. Instead, one should acknowledge that marks will impair birds, however limited that impairment may be. Once acknowledged, effort should be made to minimize the effects, and to quantify them where possible to put the resulting data into perspective (Wilson 2011).

Of the techniques listed here, the uses of metal rings, colour rings, leg flags and neck collars are those most commonly used and the least invasive. When attached properly, their use is not at all controversial. Like neck collars, nasal tags look brutal but are again widely used and seem to have little effect on the carrier. The use of nasal tags should, of course, be restricted to species with perforate nostrils and, because there are records of some negative effects of these and patagial tags, careful thought should first be put into the possible use of other marking methods before choosing them. Similarly, the use of flipper bands on penguins is controversial in that their effects on hydrodynamics, survival and return rates to the colony are still under debate. Careful consideration should thus be made as to whether the use of microchips (PIT) tags is a suitable alternative, although the impossibility of detecting PIT tags optically limits their use considerably.

Chasing and capture procedures

Figure XIV: Duck catching in China. From Bub (1991)

In contrast to many studies of mammals, catching birds rarely involves a chase, quite simply because birds so easily avoid capture by taking flight. Only flightless birds (penguins) or flying birds in a state of flightlessness (when in complete flight feather moult, or young birds that have not yet grown full flight feathers) can be caught through chasing or herding.

Instead, most flying birds are caught using nets, traps, enclosure in nest boxes or by gentle approach and catching by hand. A plethora of scheming trapping methods has been developed over hundreds of years, even millennia (e.g. Clark 1948, Eastham 2005) and hundreds of techniques are described in Bub (1991). These have been further adopted, adapted and refined by amateur and professional ornithologists to best suit their needs. As such, it is impossible to describe every procedure that is documented, and this review will be limited to those most commonly used in Norway today.

***Corral traps* (Sph, Ans, Cha)**

Penguins are easily walked or herded gently or, when leaving or returning to their breeding site, led by fence lines into enclosures in which they can be processed. If constructed properly and of suitable materials and mesh size, this method should not cause injury of any kind to the bird. Care should be made to ensure that birds can not become entangled as they try to escape and that not too many birds are caught that the researchers can not process them within a reasonable time.

Soon after breeding, geese lose all their flight feathers simultaneously and during this moult are flightless for several weeks. Using a centuries-old technique, moulting geese, whether in flocks of adults or family groups can thus be relatively easily herded together into a temporary enclosure of netting or construction fencing prior to processing. This may also involve herding across water where geese often form large flocks out of reach of four-legged

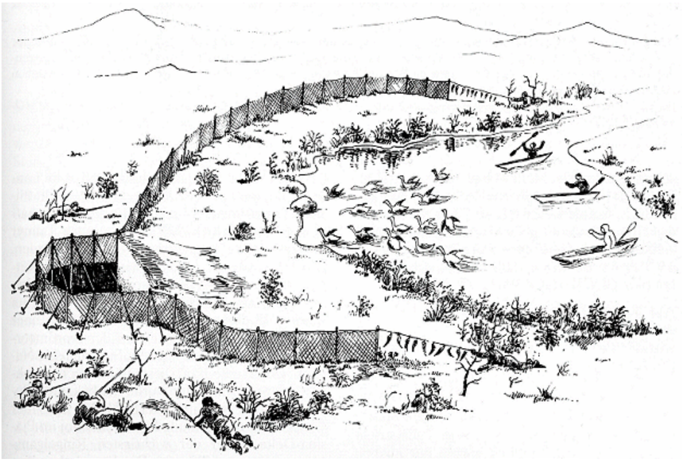


Figure XV: Catching of moulting geese by Siberian Dolgans (Popov, 1937) http://www.geese.org/gsg/indiv_marked_geese.html

Figure XVI: Catching moulting Greater White-fronted Geese in the Pyasina Delta, northern Siberia, July 2005. Photo: http://www.geese.org/geesedocs/uk/geschiedenis.ht

predators. An adequate number of people (and boats) should be involved to ensure that geese are herded without excess stress and chasing. Once contained, geese may be subdued by covering with a light material or, if few, stored in boxes or crates. Care must also be taken to ensure the geese do not get trampled, overheat or suffocate. A modification of this technique has also been used successfully for trapping Atlantic puffin *Fratercula arctica* fledglings as they walked down to the sea from their burrows (Nettleship 1969).

An efficient capture technique using lightweight, portable panels to herd and surround geese into a moveable catch pen is described by Costanzo et al. (1995).

In an early study of barnacle geese *Branta leucopsis*, Owen and Ogilvie (1979) noted a temporary weight loss among 238 birds captured this way, but the weight loss was compensated for within days and "*the overall effect of catching operations was negligible* ..". Another capture of 400 pink-footed geese *Anser brachyrhynchus*, also on Spitsbergen, in 2007 resulted in no loss of either goslings or adults (Jesper Madsen pers. comm.). When carried out correctly, there is a very low mortality associated with the use of corral traps and families, in general, reunite soon after capture (shown in barnacle, pink-footed and brent geese *Branta bernicla*) (Geir W. Gabrielsen, Jesper Madsen pers. comm). A study of the effect of disturbance on same three species showed that attempts to catch pink-footed geese on their nests might easily lead to losing the clutch to avian predators, whereas this probability was lower among barnacle and brent geese because they remain near the nest when caught and released (Madsen et al. 2009).

***Mist-nets* (Pro, Str, Cha, Acc)**

Mist nets are nearly invisible (when deployed properly) nets that are suspended between two upright poles and catch birds as they fly past. They have been used for over 300 years and were originally made of silk by the Chinese. Today they are typically made of nylon and vary in mesh size and length (the usual nets are 6-8 m long and 2.5-3 m high) according to the size of the species targeted for capture. They normally have three to four panels that overlap to form pockets; when the bird strikes the net, it drops into the pocket. Because the bird becomes entangled, the net is checked often and the bird removed promptly. A more-or-less continuous watch is kept when the nest are set also to avoid predation by cats, foxes, etc. that can reach up into the lower parts of the nets. The purchase and use of mist nets in Norway is restricted to those with a special license (Runde 1991).

Figure XVII: Mist net for catching birds. Credit Dawn Balmer/BTO.

Mist nets are mostly used to catch small passerines, but in the context of this report also small petrels (Pro), owls (Str), small to medium-sized (up to e.g. goshawk *Accipiter gentilis*) raptors (Acc), small auks and waders (Cha).

If used by trained personnel, mist netting is an efficient method of capturing flying birds, and the potential for incidental injury is low. Disentangling a bird from a mist net can, however, be difficult and requires a certain amount of training, hence the restrictions applied to their use.

Despite the common usage of mist nets, very little research had been done into their effects or their relative safety. An early study in Australia compared the mortality rate of birds caught at a woodland site and a heathland site and found a disparity between the two - 2.8% at the woodland site and 0.5% at the other (Recher et al. 1985, quoted in Fair et al. 2010). The difference was attributed to more nets and fewer experienced ringers in the woodland site, and the birds being left in the net for too long during the hottest part of the day. A recent comprehensive review by Spotswood et al. (2011) from many ringing organizations in the USA focused on passerines and near-passerines (birds up to 150 g) found a rate of injury of 0.59%, and a mortality of 0.23%. The likelihood of survival of injured birds was, however, similar to uninjured ones. However, most of the species covered in the present report are >150 g (with the exception of the European storm petrel *Hydrobates pelagicus* and Leach's petrel *Oceanodroma leucorhoa*) and much more robust than small passerines such that it is safe to assume that probabilities of injury or death are even lower.

Seabird researchers in Norway use mist nets actively to catch Atlantic puffins *Fratercula arctica* in some colonies, but the rate of injury to this species is negligible. More damage is done to the nets than to the birds! A special case of mist netting is the capture of storm and Leach's petrels. Because these species are nocturnal when on land, birds are not caught until nightfall. This entails an extra degree of vigilance by the catcher to avoid injury both to him- or herself and to the birds when extracting them from the net in torchlight. Also waders are commonly caught in mist nets after nightfall.

Mist nets used for waders and raptors have a larger mesh size in order to entangle the birds. Extracting waders from mist nets can be difficult and only those experienced with the technique use this form of trapping. Some waders species tend to thread their wing joint partly through the mesh requiring a special technique to remove them without damage to the primary feathers. Long-legged waders are also special in that they cannot be stored in constricted compartments/bags as it may cause permanent damage to their ability to stand upright (straighten their feet – see Capture myopathy below). They thus need to be able to stand upright when waiting for processing.

Mist nets are versatile and have even been successfully set underwater to catch grebes, coots and diving ducks with no casualties (Breault and Cheng 1990).

***Dho-gaza* (Acc)**

The dho-gaza net is a tool adapted by ornithologists from a design used by falconers (Zuberogoitia et al. 2008). There are many methods of setting up a dho-gaza. The basic version is a short net, about 1.5-2 m long and 1.5-2.5 m tall, attached to two long poles. The net is a robust mist-net type. Some sort of bait, or lure, usually a prey item like a pigeon or rabbit or an aggression-trigger such as a stuffed eagle-owl, is placed near and below the net. When the raptor sees and attacks the bait they are caught in the net, which wraps around them. The poles, which are set loosely in the ground, fall over, pulling the whole package together. Alternatively, the net is loosely attached to the poles by thin threads that break, and the net folds around the bird like a cornet.

***Cannon/rocket nets* (Ans, Cha)**

Cannon and rocket nest are a very active method used to catch birds. They are nets pulled rapidly by explosively-driven projectiles to cover a pre-determined area of ground and presumptively capture any birds (or other target animals) present before they have time to escape. They are used usually to catch roosting waders but also gulls, ducks, geese and other species of bird that gather in flocks on the ground such as upland gamebirds, corvids, starlings and finches (Bub 1991). In some cases, the ground over which the net is to be fired may be baited to attract the birds from surrounding area. Because the nets are propelled using explosive charges, their use is restricted to skilled workers and subject to strict regulations and licensing. If used incorrectly, birds and/or humans can be injured or even killed (Bub 1991). In Norway, licenses to use cannon nets are issued by the Directorate of Nature Management (DN) and a special handbook outlying their use is nearing completion (Aarvak and Øien in prep.).

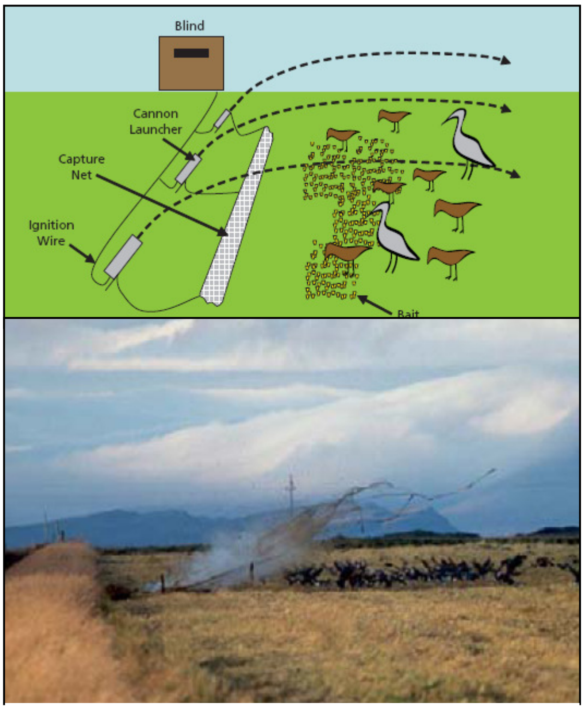


Figure XVIII: Basic set up and launching of a cannon net. From Whitworth *et al*. 2007

The net is fired when it is judged that an appropriate number of birds are catchable, and that none will be endangered during firing. The number of birds caught should not exceed the capacity of the team to deal with them expeditiously. The birds are extracted as speedily as possible from the net and placed in temporary holding cages to await processing in a sheltered environment. Depending on weather conditions, the holding cages may be covered to shade from sun and to minimize stress to the birds.

A canon-net setup has several safe zones in order to avoid injury to people and birds. These are areas within the range of the projectiles and net in which the presence of birds will preclude firing. A safe zone is also established within the potential flight path and range of the projectiles in case of rope attachment failures, etc.

A variation of the cannon net is a so-called *phutt* net that is fired using compressed air, but does not have the range or coverage of a cannon net. Even smaller versions, *zap* nets, may be propelled using elastic rope stretched over the catching area. The advantage of these modifications is that they are quieter and safer.

New models of cannon nets are now available that almost eliminate the possibility of injury to birds and humans. They use light-weight, padded projectiles and small rifle blank shots as propellants. The net is concealed in a case that also holds the firing mechanisms, and can therefore be easily camouflaged; see http://www.trappinginnovations.com for pictures of the "Netlauncher".

There are few papers that address the hazards birds face when trapped using cannon nets, but according to Fair et al. (2010), injuries and mortalities seem to be rare. On condition that there are sufficient numbers of people to help, the holding facilities are adequate and the nets are not fired over water or over the shore on a rising tide (thereby introducing the hazard of drowning), mortality rates recorded in three studies (pelicans, waterfowl and waders) were around 0-1% (Fair et al. 2010 and refs therein). One study of ring-billed gulls showed that the birds held longest under the net were less likely to be resighted on the colony, whereas those that did return resumed breeding as normal (Southern and Southern 1983).

***Walk-in traps* (Ans, Str, Cha)**

The diversity of construction and size of passive walk-in traps is about as great as the diversity of the birds they are designed to catch. Many are simple, passive funnel traps that are usually self-contained wire cages or enclosures of netting material supported by posts. Others have varieties of mechanisms by which the exit is blocked by a door, net or suchlike that is released either manually by the catcher or automatically by the bird. A third variety, the drop trap, is where the cage itself, or part of it is held raised above the ground and then dropped when the bird enters the, often baited, trap site.

Figure XIX: Walk-in trap for waders. Photo: D.M. Harebottle, Univ. Cape Town

Walk-in traps are placed on a site to which a bird or birds are expected to visit or return (e.g. a nest or a rich foraging area). Some may be baited. Once left undisturbed, birds simply walk through the funnel leading into the trap. As the name implies, walk-in traps are invariably used to catch birds that walk or feed on the ground such as *waterfowl*, *waders* and *gulls*. They may also be used to catch ground-nesting birds by deploying them over the nest during the incubation or very early chick-rearing period.

If used properly and with frequent/constant vigilance, the possibilities of injury to birds are minimal. Two studies are reviewed in Fair et al. (2010), one that caught owls and hawks in which there were only minor injuries, and one catching rails (Rallidae) where a mortality of 1.6% was documented. These were, however, mainly due to predation by mammals and drowning by rising tides, i.e. an irresponsible catching protocol!

Clap traps, bow nets, flip nets **(Cha, Ans, Str, Acc)**

Figure XX: Photo: http://www.themodernapprentice.com

A clap trap (or bow net) consists of two halves which, when triggered, close in on each other and trap the bird between them. They are made in a wide variety of shapes and sizes according to the target species (e.g. http://www.bownets.com/product-info.html or https://www.northwoodsfalconry.com/products-page/traps-for-raptors-includes-worlds-best-bownets/) and may be triggered manually or by the bird itself. They are often deployed on nest sites of ground-nesting birds such as *gulls*, *waders* and *owls* or near areas baited to attract birds-of-prey.

A flip net is a larger version of the bow net and was used successfully by Herring et al. (2008) to catch 42 large waterbirds such as great egrets *Ardea alba*, white ibises *Audocimus albus*, roseate spoonbills *Platalea ajaja* and snowy egrets *Egretta thula.* No birds died or were seriously injured. Two suffered minor abrasions (feather loss and mild hematoma), but all birds flew away with no sign of injury. They concluded that the flip net was a "*safe, effective alternative to existing wading bird trapping techniques …*". Another remote-controlled flip net was used to catch 38 great cormorants *Phalacrocorax carbo* that were on the nest with no birds either touched or injured by the frame of the net (Grémillet and Wilson 1998). All but one trapped birds continued to breed successfully. The exception was a bird that lost its chick later in the season, independent of the trapping.

Hoop-, cast- and dip-nets **(Pro, Cha)**

Hoop-nets are used to catch various seabirds, especially Procellariiformes while they are swimming on the sea surface. A typical hoop-net consists of a lightweight hoop with netting attached to the perimeter, creating a bag in the centre of the circular frame. Hoop and mesh size are modified for use with different target species. The net is thrown over the bird(s) from a boat and pulled to the side of the boat to retrieve the bird. Chumming (attracting birds by provisioning) can be used with hoop-nets to increase capture success but may be inappropriate if diet is the focus of research (Ronconi et al. 2010). Over three seasons, Ronconi et al. (2010) caught nearly 300 shearwaters, and the only casualty was a single broken toenail that caused temporary bleeding.

Figure XXI: A modified hoop-net being thrown rapidly, in a swirling motion horizontal to the water. Photo in Ronconi et al. (2010)

Cast nets are similar to hoop-nets, but without the fixed hoop. They resemble nets used by fishermen to catch fish and shrimp in shallow waters. Bugoni et al. (2008) used them very successfully in the SW Atlantic to catch about 500 birds of 13 species, ranging in size from a 30 g Wilson's storm-petrel *Oceanites oceanicus* to the 10 kg wandering albatross *Diomedea exulans*, without causing injury to any birds caught.

Dip-nets may also be used to catch birds that swim close to the side of the vessel. They are also used to catch owls as they fly out of nesting holes.

Bal-chatri **(Acc, Str,)**

This trap consists of a double cage covered in nooses of fine fishing line and containing live bait (illegal in Norway) or lure (stuffed bird, toy mouse, etc.). It is a portable trap and is used to catch *raptors* and a few other species that respond to the bait and become ensnared in the nooses. The size and shape of the trap depend on the size of the raptor targeted, the largest being eagles caught on the roofs of crow traps. If the raptor is removed immediately on capture, there is little likelihood of injury.

Noose mats **(Pro, Str, Cha)**

Noose mats are small areas of e.g. wire meshing covered in nooses of fine fishing line fixed on the ground where the target bird is expected to land or walk. They may for example be placed in the immediate vicinity of, or even mounted above, nests that are built on the ground (e.g. gulls *Larus* spp., snowy owls *Bubo scandiacus*) or in the entrance of the burrows of burrow-nesting birds, e.g. shearwaters of puffins.

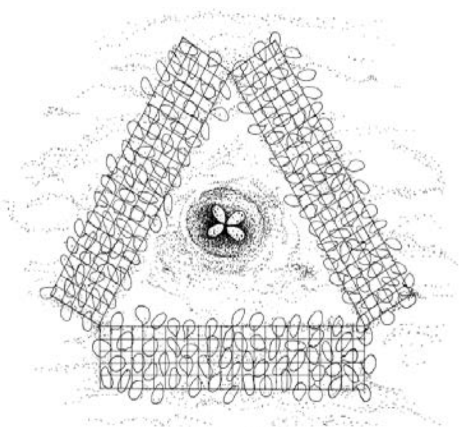


Figure XXII: A noose mat setup. From Mehl *et al*. (2003)

When using noose nets to catch breeding and wintering shorebirds, Mehl et al. (2003) experienced three (0.12%) leg injuries among 2410 birds caught, and one mortality due to predation within seconds of a bird being caught in the nooses. In another study in which 25 American oystercatchers *Haematopus palliatus* were caught, the authors (McGowan and Simmons 2005) write "*Aside from very minor skin abrasions on the tarsus, no birds were injured as a result of our trapping efforts. After birds were trapped, banded, and released, most flew 200 m away, but all birds remained on their territories. On two occasions after banding one member of a resident pair, we left the decoy and trap set up, hoping to catch the second bird of the pair. Both times the birds returned within 5 min and both times we caught the individual we had just released. These observations suggest that birds recover quickly from the stress of trapping and that birds do not become trap-shy once caught.*" Gartshore's (1978) experience of using noose-traps for passerines was equally positive with no nest desertions and no injuries occurring.

***Noose poles, leg nooses, fleyg nets, hooks, hand (*Pel, Cha)**

A variety of hand-held tools are used to catch seabirds in the colony (e.g. Benson and Suryan 1999). 2-5 m long noose-poles or hooks are used to draw birds off the nest whereas fleyg-nets are used to catch auks, mostly Atlantic puffins, as they fly past the colony. Dip-nets have also been used successfully to catch ground-nesting species (e.g. eider) on the nest. When approached carefully, some seabirds may even be caught by hand while sitting on the nest.

Benson and Suryan (1999) used a leg-noose to catch 75 black-legged kittiwakes *Rissa tridactyla* on the nest and report no injuries, but do warn that incorrect deployment may cause damage to the nest.

Catching some species at the nest or in the colony may result in desertion from the nest, especially if caught early in the egg-laying or incubation period. For example, the Atlantic puffin is very sensitive to being disturbed when incubating eggs and even infrequent checks of the nest may cause considerable reduction in nesting success (Harris 1984). Other species such as northern gannets *Morus bassanus*, shags *Phalacrocorax aristotelis* and cormorants and *P. carbo* incubate their eggs and small chicks on the webs of their feet, and removal of the adult from the nest may result in the nest content being kicked out of the nest (pers. obs.). Similarly, common and Brunnich's guillemots *Uria aalge* and *U. lomvia* lay their eggs directly on the rock shelf, and if the adult is lifted off the shelf, the egg is likely to roll away from the nest site or even off the shelf (pers. obs.). As such, these species should not be handled during the incubation period.

***Net gun* (all)**

A net gun is a hand-held, non-lethal weapon designed to fire a net which entangles the target. Net guns have a long history of being used to capture wildlife, for research purposes. They use compressed air and reloadable cartridges to deploy a long-range net that safely surrounds the animal, eliminating the need for long chases or stressful captures. One manufacturer claims their gun has a 15-20 m range and travels at 7 m per second, making it possible to target and catch even fast moving animals.

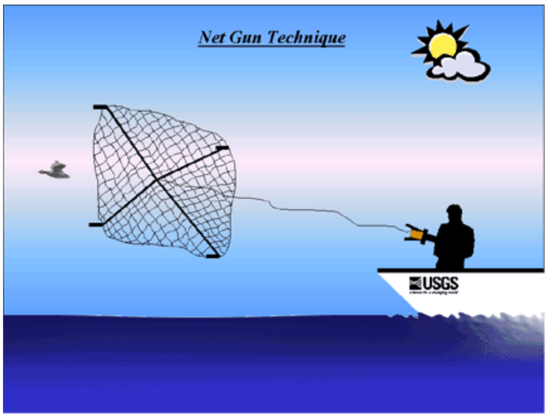


Figure XXIII: http://www.pwrc.usgs.gov/resshow/perry/scoters/capturetechniques.htm

They have been fired from helicopters and boats and used to catch a wide range of birds, from the golden eagle *Aquila chrysaetos*, through shorebirds to seabirds including petrels, albatrosses and eiders (O'Gara and Getz 1986, Milton et al. 2004, Ronconi et al. 2010, Edwards and Gilchrist 2011). To quote Roncini et al. (2010, and references therein, "*They are useful for catching, fast skittish birds otherwise difficult to trap. Limitations include cost and the time required to master firing skills. Because nets come with heavy metal projectiles, there is a possibility of injury or mortality to birds. They appear to be relatively safe for some species however – Milton et al. (2004) netted >1400 common eiders over five years, with 1.4% mortality.*" In another study, Herring et al. (2008) had four direct mortalities representing a mortality rate of 4.5% for great egrets *Ardea alba* and 0.96% for white ibises *Eudocimus alba*. They emphasize the need for a high level of skill for net-gun operators and warn that "*the elevated probability of trapping mortalities associated with capturing large-bodied wading birds may limit its application for capturing endangered species …*"

There are, however, various designs of net gun, and the Norwegian Polar Institute and the Norwegian Institute for Nature Research have used a 'new generation' model to successfully catch rock ptarmigans *Lagopus muta*, glaucous gulls *Larus hyperboreus*, arctic skuas *Stercorarius parasiticus* and long-tailed skuas *S. longicaudus* with no incidents of injury or death (B. Moe pers. comm.). Nor did Edwards and Gilchrist (2011) have any cases of injury in 225 attempts to catch shorebirds and also conclude that the net gun is a safe trapping method.

Discussion

Due to the plethora of target species and consequently trapping techniques and an ever-increasing ingenuity in refining trapping systems shown by scheming amateurs and professionals, a systemic analysis of the hazards involved is impossible. All the techniques listed above are recognized as acceptable among ornithologists on condition necessary vigilance is maintained. Although there exists a protocol in Norway for reporting injuries or mortalities incurred while trapping, this seems to be rarely used thus precluding an analysis of risks. Similarly, few ringers send in dead birds to their local university museums as encouraged in Runde (1991).

Bird catchers should adopt techniques best suited for the bird and the situation under which it is to be caught (at the nest, roosting site, on water, summer, winter, etc.) and work towards an absolute minimum of injuries and mortalities. In a meta-analysis of the effects of capture and restraint based on 9-36 studies of birds, Barron et al. (2010) found that only foraging behaviour was affected after release whereas parameters such as nest success, nest productivity, clutch size, nest initiation date, chick quality, body condition, energy expenditure and survival rate were unaffected.

Nevertheless, all forms of trapping have the potential to injure a bird in one way or another. Before starting a trapping project, the target species' susceptibility to capture myopathy should be investigated and once trapping is in process, it is imperative that the trap should never be left unattended or at least checked at short intervals (in Norway there is a rule that e.g. a mist net should be checked at least once every 30 min). Hand nets, noose poles, net guns etc. should be used by experienced persons. The restrictions applying to the use of cannon nets are already described. This applies especially to shorebirds and waterbirds. Furthermore, to avoid attracting predators or causing shock or injury, the entrapped bird should be removed promptly. Based on so-called 'expert opinion', the US Handbook of Field Methods for Monitoring Landbirds (Ralph et al. 1993, quoted in Spotswood et al. (2011)) provides a guideline of a 1% mortality rate, but it is unclear whether this rate is achievable in practice (Spotswood et al. 2011).

Sedation (and anaesthesia)

Because some bird species can injure themselves or those handling them, some form of restraint is usually necessary. The well-being of the bird is most important, and improper restraint can lead to both physical and physiological disturbances, e.g. hypo- or hyperthermia, stress, shock and capture myopathy. Safe handling is achieved by controlling the bird's feet, head, legs and wings. Darkened enclosures tend to subdue birds and alleviate stress and should be used whenever possible. Large birds can be subdued with a hood, smaller birds by placing in cardboard boxes, weighing bags (ensuring they can breathe, that there is no loss or disruption of the feathers and no danger of hyperthermia). Detailed descriptions of effective restraint techniques can be found in Whitworth et al. (2007).

Chemical sedation of birds is generally unnecessary and is an option only when alleviating pain during invasive marking procedures (see below).

Awakening and release

The awakening and release of anaesthetised birds does not seem to be an issue of concern, and no mention is given in the reviews of Fair et al. (2010), Barron et al. (2010) or Vandenabeele et al. (2011).

When performing 204 surgeries on harlequin ducks *Histrionicus histrionicus* using modifications to anaesthetic procedures, Mulcahy and Esler (1999) experienced 1.5% mortality during surgery. Of two deaths, one was from sudden and irreversible cardiopulmonary arrest during surgery and one from failure to recover fully from anaesthesia. The same authors also mention post-operative deaths after surgery on spectacled eiders *Somateria fischeri*, common and Brünnich's guillemots *Uria aalge* and *U. lomvia* and greater white-fronted geese *Anser albifrons*, but give no data for how many died.

Although implantable PTTs have been used successfully in ducks (but see Fast et al. 2011), a high mortality of guillemots and tufted puffins *Fratercula cirrhata* suggests that "*internal deployment may not be a viable alternative for other taxa*" (Phillips et al. 2003).

Capture myopathy **(all)**

In medicine, myopathy is a muscular disease in which the muscle fibers do not function for any one of many reasons, resulting in muscular weakness. Capture myopathy, also called *exertional myopathy*, is a condition that is characterized by damage to the muscles from an increased myocyte production of lactic acid when oxygen is depleted and anaerobic metabolism occurs. Clinical signs include ataxia, pareses and paralysis. It can result in cramped legs and wings, rendering a bird incapable of standing, walking or flying. The condition is dangerous and potentially lethal. Shorebirds can develop these symptoms during catching operations, and although the condition is generally uncommon or rare, it occurs frequently enough to have prompted several reports on ways to alleviate the problem (Rogers et al. 2004 and refs. therein).

Susceptibility to capture myopathy varies from species to species, condition of the bird and time of year, and although most common in long-legged birds, it may frequently occur in waterbirds (Fair et al. 2010). The probability is increased by several side effects of capture that increase the likelihood of anaerobic respiration in muscles: intense exertion in restrained conditions, cramped postures and heat stress (Rogers et al. 2004 and refs. therein).

Before capturing birds, the symptoms of myopathy should be learnt, and the methods of capture and processing planned to be as short as possible. As struggling is thought to be a cause, this should be reduced by restraining the birds, covering the bird's eyes and/or placing in a dark box or cage. Catching birds in high temperatures also increases the probability of myopathy (Fair et al. 2010 and refs. therein). Numerous forms of treatment are described in Rogers et al. (2004) and Fair et al. (2010).

Marking with electronic devices

"*Fundamental to basic and applied ecology is an understanding of the physiology, behaviour and energetic status of unrestrained organisms in the natural environment*" (Cooke et al. 2004). In recent years, remote measurement of these parameters has become possible through the technological development of a wide variety of electronic devices that enable researchers to document how free-living animals interact with each other and their environment over long periods of time (e.g. Kooyman 2004). Decreases in device size and increased battery life has made the technology especially useful for studying birds and the use of radio-telemetry and datalogging devices have become a rapidly increasing and integral part of nearly all studies of the behaviour, physiology and ecology of all but the smallest species (Barron et al. 2010, McMahon et al. 2011, Sokolov 2011).

There is a multitude of device design in use in the scientific community in accordance with the parameter to be measured and/or the species to be studied. One group of devices has been developed to study the behaviour and physiology of individuals including temperature (internal and external), pressure (altitude and depth) and heartbeat sensors, miniature video recorders, and magnetic sensors attached to appendages to record e.g. beak movement or even defecation (!) (Burger and Shaffer 2008). The other group entails devices that track the movements of birds at a wide variety of spatial and temporal scales (see text box below). For the research in question, the desired location accuracy and longevity of the study are the fundamental parameters to be considered when choosing which device to use. Tracking devices can last from just a few weeks up to 4-5 years and accuracy ranges from 10-15 meters up to 150-200 km. In all cases, device deployment is often hampered by the weight of the unit, most of which is the power source.

Weight limitations

There is a universal acceptance among researchers that birds should not carry a device that weighs more than 5% of the body mass, irrespective of wing-loading. This '5% rule' seems to have originated from early radio telemetry studies (Brander and Cochran 1969, Casper 2009 and refs. therein) and was essentially arbitrary with no aerodynamic justification (Caccamise and Hedin 1985). A more recent '3% rule' that was proposed by Kenward (2001) and/or Phillips et al. (2003) and has been widely adopted by some researchers, and only very recently has been addressed empirically (e.g. Barron et al. 2010, Vandenabeele et al. 2011, 2012) - see also Section 9.

Attachment techniques

Transmitters and bio-loggers may be attached externally in a variety of ways (body harness, glued and/or sutured to the skin, neck collars, taped and/or glued to feathers or attached to leg), or internally by implanted subcutaneously or abdominally. Judgement as to the most appropriate attachment is generally made on a case-by-case basis, necessitating a comprehensive literature search, consultation with experts, and personal experience (Hawkins 2004). Gluing devices to the feather shafts (cut down/trimmed feathers) is often used for short-term projects whereas sutures are generally used for studies on rapidly-growing juvenile birds where the use of glue is impossible or as reinforcements of glued devices (Wheeler 1991, Hawkins 2004). The sutures, however, pull through the skin as the bird grows, and the method is not recommended unless there are no other attachment methods, and there is strong scientific justification for the study (Hawkins 2004).

Figure XXIV: 9.5g Satellite transmitter attached to whimbrel.
Photos: http://www.whimbrel.info/

Body harnesses are small 'rucksacks' that are used to attach devices that are programmed to last for periods of years. The harness may be made of a variety of materials, including wire, plastic-covered wire or elastic, but today most researchers use tubular teflon ribbons that are wrapped around the body and fastened together ventrally. The harness may be sewn together using bio- or UV-degradable cotton such that the unit will fall off the bird's back after some years. For seabirds, links of aluminium/stainless steel or of magnesium components ensure corrosion in the sea. Some types of pre-programmed release mechanisms are now available. Another safety option is to use a 'one break – one release' mechanism such that the harness is not left hanging from the bird when a link is broken. When attached properly, the bird preens its feathers such that the harness and device become more-or-less covered and often only the antenna protrudes through the plumage.

Instead of using harnesses, devices may be *glued* to the bird's feathers using a fast-acting cyanoacrylate "super" glue or other 2-component glues. An alternative is to *tape* (e.g. Tesa™ tape, Beiersdorf WG) the device to the feathers (e.g. Villard et al. 2011). In either case, the deployment of the attachment is often short-term and will last at the maximum until the bird moults its feathers, usually in the autumn. Using various modifications of taping methods, Wilson et al. (1997) attained attachment times to penguins of up to 34 d, though some devices had fallen off already within a few days. Using a combination of tape and epoxy glue, they recovered units from Magellanic penguins *Spheniscus magellanicus* from 30 of 34 birds at intervals of 14-58 days. Large, GPS-tracking devices are usually attached on the back of the bird, the actual position depending on the species, whereas smaller devices are attached either dorsally or ventrally. For very large birds, e.g. condors and eagles, transmitters can be attached to the wing (patagial mount), usually in combination with a wing-tag.

Smaller devices can be attached to leg rings or neck collars using a combination of tape, glue and/or cable-ties, depending on how long the device is to be deployed. Attachment to leg rings has proved a very effective method for deploying e.g. geolocation-loggers to a wide variety of species and small time-depth recorders to diving birds.

Implantation of devices, either subcutaneously or abdominally entails a very different field protocol using anaesthetics and has been successfully used by researchers in Alaska and Norway on e.g. wildfowl (Petersen et al. 2006, Bustnes et al. 2010). Implantation is often used in an attempt to overcome the adverse effects of externally attached devices (Korschgen et al. 1996, Mulcahy and Esler 1999) or in cases where the bird's anatomy is unfit for successful use of harnesses. The surgical procedure is relatively simple, but requires training in both surgery and administration of anaesthetics, either using a vaporizer and oxygen delivery system or intravenously (e.g. Machin and Caulkett 2000).

Short- and long-term effects of marking

While advances in telemetry and bio-logging have given us unique and unparalleled insights into behaviour and provide valuable conservation information for biodiversity managers (McMahon et al. 2011), there are many major potential effects that attached devices may have including behavioural disturbance, physical injuries and compromised energetics (Vandenabeele et al. 2011 and refs. therein). Such perturbations may be enhanced in aquatic species through the potential for greater heat loss to water and increased drag and hence higher rates of energy expenditure underwater (Vandenabeele et al. 2011).

In their meta-analysis of the effects of transmitters and other devices on avian behaviour and ecology (based on 192 studies), Barron et al. (2010) conclude that "*attaching transmitters and similar devices to birds negatively affected most aspects of their behaviour and ecology to some degree. The most substantial effects were increased energy expenditure and decreased likelihood of nesting, whereas six aspects of ecology and behaviour* (offspring quality, body condition, device-induced behaviours, nesting success and foraging behaviours) *were affected to a lesser extent and four others were unaffected*." Surprisingly, flying ability seemed to be unaffected. The authors were, however, unable to assess the aerodynamic effects of devices. They also point out that examining effects of devices on multiple aspects often conclude that some aspects are affected while others are not, and that this may be a result of the relationships that exist between the aspects. For example, when birds maintain normal flying ability, foraging behaviours or reproduction, they may do so at the expense of energy consumption.

What is perhaps more concerning is that many researchers do not measure or report the effects of devices on their bearers, despite the steady increase in the number of published papers based on such devices (Vandenabeele et al. 2011). Of 357 papers that addressed devices on seabirds, only 42 (11.8%) directly focused on the effects of tags or attachment systems and, while 237 (76.5% did discuss instrumentation effects, this accounted for a mean of <2% of the total length of the texts (Vandenabeele *et al*. 2011). They also cite Murray and Fuller (2000) who reported that in 90% (215 of 238) of the papers on vertebrates they surveyed, the marking effects were not considered or at least reported. Similarly, in their review of 836 radio-tracking studies of animals (mammals, fish, birds, other vertebrates and invertebrates), Godfrey and Bryant (2003) found that only 10.4% of the studies (but 19.0% of the 269 bird studies) directly addressed the effect of radio tags on their bearers. The vast majority (83.3%) of the papers were "*classified as "IGNORE", effectively making a tacit assumption that radio-tags had no significant effect on their bearers*." The same proportion was found in Murray and Fuller's (2000) study of marked-animal studies published in major journals in 1995 where only 10% included evidence that tag impact had been considered (cited in Hawkins 2004).

Mass

There is a generally accepted rule that devices should not weigh more than 3% (or 5%) of the bird's body mass. The 3% rule was advocated by Phillips et al. (2003) who reviewed studies made of albatrosses and petrels to which PTTs were attached and found that devices >3% body mass tended to cause extensions in feeding trip durations and, in some cases, high rates of nest desertion. To quote Vandenabeene et al. (2011), "*although a number of studies have detected no negative effects of externally attached devices on birds when they are less than 3% of the body mass, energy expenditure for flight depends critically on bird mass and wing characteristics, a factor which is not built into this recommendation. Thus, larger birds and/or those with higher wing loadings are much less likely to accommodate extra mass with their normal power requirement costs for flight. The difficulties of determining power costs for flight make proper testing of such generalisations problematic.*" Similarly, Barron et al. (2010) found little evidence that negative effects increased as transmitters became proportionally heavier and conclude that "*although adhering to the '3%' or '5%' rule may be reasonable, further research is required to determine a safe maximum proportional mass.*" In their follow up, however, Vandanabeene et al. (2012) found differences in the effects of drag coefficient between seabird lineages, with Alcidae and Phalacrocoracidae experiencing the highest energetic costs of increase in device mass.

An example of studies of the effect of mass is Passos et al. (2010) who found that deployment of devices weighing 30 g (3.8% body mass) and 60 g (7.6% body mass) on Cory's shearwaters *Calonectris diomedea* progressively increased the duration of the birds' foraging trips and decreased their foraging efficiency and mass gained at sea. They underlined the need to quantify the effects of monitoring equipment commonly used to determine pelagic behaviour of seabirds.

Shape

As shown by Culik et al. (1993), even the seemingly innocuous flipper band increased the energy expenditure of Adélie penguins while swimming by 24% as a possible result of drag, physical impairment and/or rudder effects of the band. This may have serious long-term effects and was proposed as the cause of a 39% reduction in breeding success and 16% in survival over 10 years of king penguins *Atenodytes patagonicus* (Saraux et al. 2011), showing that the shape of an external device may have serious consequences.

Device shape is important not only when considering flight aerodynamics but even more so when the hydrodynamics of diving birds is considered. In both cases, drag should be minimised through the reduction of the area of the leading edge, streamlining its shape and attaching to an appropriate part of the body so as to smoothly extend the contours of the birds (Hawkins 2004 and refs. therein). Wind tunnel experiments (using bodies of a bald eagle *Haliaeetus leucocephalus*, tundra swan *Cygnus columbianus*, snow goose *Chen caerulescens* and mallard *Anas platyrhynchos*) found, for example, that by adding a round faring to the front end, the drag of a transmitter could be reduced by about one third as compared with a rectangular box (Obrecht et al. 1988).

Similarly Bannasch et al. (1994) show that, through careful design to reduce device-induced turbulence and optimal matching to the body contour (by placing in the most caudal position), the hydrodynamic resistance of a device attached to penguins could be reduced by 65%. Through field-trails in a water tank using Adélie penguins *Pygoscelis adelie*, Culik et al. (1994) carried this a step further and showed that although the device attached represented 10.5% of the penguin cross-sectional area, swimming speed was reduced by only 8.3% and mean power input by only 5.6% when swimming. Despite its size, the streamlining of the device reduced the effect on swimming energetics by 87%.

Attachment of geologgers on leg bands for smaller species such as thrushes and most waders bears no extra drag costs since they lift and hide their feet within the feathers on the belly.

Attachment

As mentioned previously, the choice of attachment method is made on a case-by-case basis depending on the species studied, the time-scale of the study and what stages of the bird's life-cycle the study covers. Device attachment encompasses two main methods, external attachment using a harness or gluing/taping or internal implantation, and each configuration has its own limitations for durability and duration of use (Fair et al. 2010).

Barron et al. (2010) summarize the risks of the different attachment methods as such – "*Although all observed effects were independent of attributes of the birds, the method of device attachment was important. Nest success and device-induced behaviours differed between attachment types and, although the method of attachment did not affect the frequency of nest abandonment or physical harm, certain attachment methods were more likely to cause death. In particular, anchored and implanted transmitters, which generally require anaesthesia, had the highest reported device-induced mortality rates. Machin and Caulkett (2000) showed that anaesthetizing birds with propofol instead of isoflurane reduced threats to the bird's health and decreased the probability of nest abandonment. Harnesses and collars also had relatively high device-induced mortality rates, sometimes because birds became entangled in vegetation. Researchers can minimize this risk by using adjustable harnesses and collars (Dwyer 1972) to custom fit each bird and by adding a weak link that causes the device to detach if entangled (Karl and Clout 1987). Although glue and tailmount attachments had the lowest reported frequency of mortality, low retention rates of these methods on many species (Woolnough et al. 2004) can limit their value*." This is echoed by Phillips et al. (2003) who suggest that the use of harnesses should be avoided "*particularly for breeding season deployments when tape attachment to feathers is an effective alternative*".

Risk can also be reduced by ensuring that the harness eventually becomes detached, e.g. through the use of bio- or UV-degradable materials when fastening the ribbons (e.g. Kesler 2011). Risk is further reduced by using a 'one break – all release' system or a pre-programmed release mechanism such that the harness is not left hanging from the bird if only one part of it loosens. This applies also as a 'failsafe' to studies in which the intention is to recapture the bird to detach the device and/or download the data, in case the bird avoids recapture. In the case of devices attached using glue or tape, the device will drop off at the latest (but probably before) when the bird moults its feathers.

An attachment method of very small devices used in recent studies (e.g. Frederiksen et al. 2011) involves mounting the device on the leg (either tibia or tarsus) by fastening to e.g. colour-rings. This was used with success on e.g. long-distance migrating godwits *Limosa* sp. (Conklin and Battley 2010). Even after up to 19 months of deployment, they observed no physical or behavioural effects of the method and nor did it preclude normal breeding activity. Over the last three years, geologgers have been mounted on at least 20 different wader species and have also been used with success on small species like the wood thrush *Hylocichla mustelina* (Stutchbury et al. 2009) or northern wheatear *Oenanthe oenanthe* (Bairlein et al. 2012)

As indicated above, implantation of devices, although averting impact on flight, is associated with the highest risk, a risk that may have several origins. Hypothermia and physiological stress is a critical complicating factor during avian surgery, and may be especially a problem in cold conditions (e.g. in the Arctic). It can, however, be overcome using external heat support and preheating of devices to be implanted (Phalen et al. 1996, Sonne et al. 2011). Mulcahy and Esler (1999) and Sonne et al. (2011) successfully used heat blankets, but this method is questioned by Phalen et al. (1996) who advocate the application of radiant-energy source (a heat lamp) instead of a heat blanket.

Tissue damage or infection of the skin does not seem to be a problem when implanting devices and is not mentioned in either Fair et al.'s (2010) review, Barron et al.'s (2010) meta-analysis of 84 studies of birds or Vandenabeele et al's (2011) analysis of 357 seabird studies (all of which addressed all attachment methods – external and internal). Bennett et al. (1997) tested five suture materials when operating rock doves *Columba livia* and found that monofilament nylon and stainless steel caused minimal tissue reaction (but did induce hematomas, seromas and caseogranulomas), and of absorbable material polydiaxan one was recommended for internal sutures.

Discussion

There is no denying that catching, handling and attaching or implanting devices will always have an impact on the bird's physiology or behaviour, and that this can be significant (Hawkins 2004*).* The impact of the devices will, however, differ according to the aim of the study, the species studied and the characteristics of the device. *Furthermore, the reasons underlying adverse impacts of instrumentation are multifactorial and are related not only to the mass, size and shape of the device, but also, for example, to the sensitivity of the animal to disturbance, the capture method, the handling time, the attachment method, food availability and the length of deployment. Consequently, attaching devices to animals may result in combinations of immediate, delayed, short-term, long-term, direct and indirect effects. As such, the magnitude of the effects of instrumentation of animals is case-species- and physiological status-specific* (Casper 2009 and refs therein). That being said, the impact can also be kept to an absolute minimum through careful design of the study and choice and deployment of device. "*The size, weight and configuration of an instrument and attachments* *should be appropriate to the species, class, behaviour and habitat of the animals in question*" (Casper 2009).

A good example is the recent choice of using small (<2 g) geolocators/geologgers (GLS tags) by many research teams instead of larger transmitting devices to track migration patterns despite the lower precision of data and the need to recapture the bird at the end of the study. These small devices are popular because of their small size and, despite the deployment of thousands of GLS tags on a wide range of species, there are no recorded negative effects on diving behaviour, survival, return rate, body condition of birds returning to the site of first capture (e.g.Adams et al. 2009, Ropert-Coudert et al. 2009, Bogdanova et al. 2011, Carey 2011, Bairlein et al. 2012). Also, geolocators are recently being employed in addition to the traditional satellite transmitters to measure the effects of the larger devices.

Similarly, the welfare concequences of the long-term carrying of larger, harness-attached devices and the use of bio- or UV-degradable materials (or a pre-programmed release mechanism) should be carefully considered, especially when addressing rare or threatened species. This is also true for implantation of devices, which should only be considered if external attachment is out of the question.

Irrespective of choice of device or attachment method, no researcher is interested in a methodology that will compromise the behaviour or survival of the target species and hence the results of the study. Peer revision of manuscripts and strict ethical guidelines laid down by scientific journals preclude the publication of a study that is in any way beyond the acceptable norms of field practice. More and more pressure is put on the scientist to document that the methods used are acceptable as a response to e.g. Phillips et al. (2003) who state *"In some studies, researchers may have checked for device effects, found them to be negligible, and omitted the comparison; but in others control data may have been deemed unnecessary or were difficult to collect for logistical reasons. That might reflect a misconception that device effects are uncommon in flying seabirds, possibly influenced by the growing number of studies that use such technology."* A good example of a direct study of the effect of loggers is Kidawa et al. (2011). The problems involved with the use of external instrumentation will hopefully decrease in time parallel to the miniaturization of the devices on the market.

Follow up procedures and needs for recapture

Birds are normally released immediately after external devices have been attached, but for those in which devices have been implanted follow up procedures are relevant before release. Because the health of birds can deteriorate rapidly in captivity if their essential needs are not met, there is always a balance between releasing them before they have lost condition and holding them long enough to ensure they have fully recovered from the operative procedures (Hawkins 2004). Probability of negative welfare concequences is, however, low if a thorough check is made for signs of bleeding, injuries, a full recovery from anaesthesia, sutures, etc. and absence of capture myopathy (see e.g. Hawkins 2004 for details).

Risk Assessment

Method

A semi-quantitative risk assessment is carried out by the Panel of Animal Health and Welfare. The risk identification has been done on information presented by the *ad hoc* group. Risk estimation is based on the probability of the event to occur as well as the magnitude of the consequences judged by the Panel.

Table 2. Definition of terms used for negative welfare consequences

	Consequence	
3	Serious	Death, serious injury, long lasting pain or heavy stress
2	Moderate	Short time stress or pain
1	Limited	Negative welfare consequences are limited or neglible

Table 3. Definition of terms used for probabilities

	Probability	
3	High	Negative welfare consequences would be expected to occur (P = 0.5-1.0)
2	Medium	There is less than an even chance of negative welfare consequences (P = 0.05-0.5)
1	Low	Negative welfare consequences would be unlikely to occur (P < 0.05)

Risk (1,2,3,4,6,9) = Probability (1,2,3) x Consequence (1,2,3)

Green = Risk (1,2) = Low risk of negative welfare
Yellow= Risk (3,4) = Medium risk of negative welfare
Red = Risk (6,9) = High risk of negative welfare

Example: Traditional English fox hunting, risk of negative welfare for the fox:

Consequence = Heavy stress and death = 3

Probability = All foxes that are chased will experience negative welfare = 3

Risk = Probability x Consequence = 3 x 3 = 9 = High risk

PROBABILITY	Limited	Moderate	Serious
High		• Coil spring trap – Otter and Lynx • Darting from helicopter –Terrestrial carnivores	
Medium		• Box trap – Roe deer, Arctic fox, Lynx	
Low		• Approach by boat – Cetaceans	• Darting from helicopter - Moose and Polar bear • Darting from ground – Walrus • Mist net – Wild birds • Net in water – Aquatic birds, Pinnipeds and Cetaceans
		CONSEQUENCE	

Table 4. A summary of the risk assessment concerning risk of negative welfare of wild animals that are exposed to different capture methods

Green = Low risk of negative welfare
Yellow = Medium risk of negative welfare
Red = High risk of negative welfare

PROBABILITY	Limited	Moderate	Serious
High		• Freeze and heat brand – Several species	
Medium	• Neck collar - Waterfowl • Collar – Several mammalian species	• Flipper band -Penguins	• Body harnesses - Wild birds and Otters
Low	• Leg rings – Wild birds • Wing feather tags – Wild birds • Feather dye s– Wild birds • Glue on external device – Large aquatic mammals • Tatoo – Several species	• Glue on external devices – Small aquatic animals • Ear tag -Several species • Anchor tag – Cetaceans • Pit tag – Several species	• Nasal discs and saddles – Waterfowl • Intraperitoneal implants – Mammals
	CONSEQUENCE		

Table 5. A summary of the risk assessment concerning risk of negative welfare of wild animals that are exposed to different marking methods

Green = Low risk of negative welfare
Yellow = Medium risk of negative welfare
Red = High risk of negative welfare

Answers to the questions raised by The Norwegian Food Safety Authority

A. Capture and handling procedures

How do the most commonly used capture and handling methods influence the welfare of free ranging wild terrestrial and marine mammals and birds?

Effects of capture and handling

The risk of negative welfare consequences of the most relevant capture and handling methods are considered in a semi-quantitative model (Table 4) on the individual level.

1. Darting from helicopter

Almost all brown bears, polar bears, gray wolves, wolverines, lynx, moose and reindeer that are captured and handled for scientific studies today are located and immobilized (darted with immobilizing agent) using helicopters. The capture is performed using a standardized protocol. The effects of capture have often been reported in terms of mortality, which in reality is the most drastic consequence. Fear, pain, hyperthermia, hypothermia, hypoxemia and respiratory and cardiovascular depression are all potential stressors resulting from tracking and medical restraint. It seems like polar bears and moose are not seriously affected by the helicopter, while other terrestrial carnivores get seriously stressed by being chased by the machine.

The mortality is high compared to sedation and anaestesia in a controlled environment, but the protocol is continuous adjusted to reach "best practise" and through different risk reducing measures the mortality is lowered during the last decade.

Risk assessment sedation and anaesthezia (all species):

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = <u>Medium risk</u>

Risk assessment chasing by helicopter (terrestrial carnivores):

Consequence = Serious = 3

Probability = Low = 2

Probability x Consequence = 6 = <u>High risk</u>

Overall, chasing and medical immobilization from helicopter represent a medium risk of negative welfare for moose and polar bear and a high risk of negative welfare for terrestrial carnivores.

2. Darting from the ground (walrus)

Walrus are immobilized by approaching on foot and darted with immobilizing agent. The capture is performed using a standardized protocol. The mortality in walrus has been very high, but the protocol is continuous adjusted to reach "best practise" and through different risk reducing measures the mortality is lowered.

Risk assessment:

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = Medium risk

3. Box trap

Baited box traps are used for the capture of roe deer, arctic foxes and lynx. Roe deer and arctic foxes are manually restrained before marking, while the lynx of obvious reasons has to be restrained chemically. Capture in a box trap induces fear, but it is difficult to measure the magnitude of the individual stress reaction. It is relevant to estimate that most of the animals experience short time heavy stress and fear when being trapped. During manually restraint and marking the subjective experience of fear is probably even more serious. The probability of impaired welfare (mortality) of a lynx during sedation and anaesthesia is low.

Risk assessment:

Consequence = Moderate = 2

Probability = Medium = 2

Probability x Consequence = 4 = Medium risk

Box trapping followed by manually restraint or medical immobilization represent a medium risk of negative welfare.

4. Coil spring trap (leg-hold trap)

Coil spring traps are used for otters and lynx. The mortality following the use of these traps is low, but the animals are exposed to heavy stress and pain when trapped. In otters it is shown that serious trauma to muscles may occur following the use of coil spring traps, probably because the animal's struggle to be released.

Risk assessment:

Consequence = Moderate = 2

Probability = High = 3

Probability x Consequence = 6 = High risk

Coil spring traps (leg-hold traps) represent a high risk of negative welfare for lynx and otters.

5. Mist net

Mist nets are used for capture of flying birds and are in extensive use by ornithologists. Birds that fly into the net get entangled and are trapped in pockets. Competence is needed to release a bird from the net without hurting feathers, wings or legs and persons who capture and mark birds therefore must be licensed by the authorities. Mortalities of 2.7% have been reported, but usually the mortality is very low because of experienced ringers.

Capture myopathy is a condition that is characterized by damage to the muscles from an increased myocyte production of lactic acid when oxygen is depleted and aerobic metabolism occurs. The condition is dangerous and potentially lethal. Although generally uncommon, it occurs frequently enough to have prompted several reports on ways to alleviate the problem. The susceptibility varies from species to species.

Even though there are no data on stress reaction of wild birds captured in nets or traps, it is obvious that the capturing in general must be stressful to the birds and also is a potential risk of injuries. A meta-analysis of effect of capture and restraint, found, however, minimal effects with that only foraging behaviour was affected immediately after release and that parameters such as breeding success and energy expenditure were unaffected.

Risk assessment:

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = Medium risk

Mist nets represent a medium risk of negative welfare for wild birds.

6. Nets in water

Net traps in water are used to capture pinnipeds, small cetaceans and swimming birds. If not thoroughly looked after, drowning may occur.

Risk assessment:

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = Medium risk

Nets in water represent a medium risk of negative welfare.

7. Approach by boat (Cetaceans)

Whales are approached by boat and marked with different kinds of anchor tags that are stabbed (with a pole) or shot (with a crossbow or air-gun) into the skin. It is reported that whales experience short time stress when boats are approaching them.

Risk assessment:

Consequence = Moderate = 2

Probability = Low = 1

Probability x Consequence = 2 = Low risk

Approach of a boat close to a whale; represent a low risk of negative welfare.

B. Marking methods and procedures

How do the most commonly used marking methods and procedures influence the welfare of free ranging wild terrestrial and marine mammals and birds?

The risk of negative welfare consequences of the most relevant marking methods is considered in a semi-quantitative model (Table 5).

1. Devices placed externally

a) Leg rings (metal rings, colored rings, leg flags)

Leg rings are used for marking birds. They are made of aluminium, stainless steel or colored plastic. Hundreds of thousands of birds of different species are marked each year and very few problems are observed. The use of properly designed foot-rings pose no risk for the birds, but in cases of poorly manufactured rings sharp edges can cause wounds and scratches on the leg. Ducks and geese and other waterfowl may, during the winter, experience an accumulation of ice trapped between the leg and the ring. Color rings can in some rare instances interfere with mating mechanisms and social status.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

Carrying a leg ring appears to present a low risk of impaired welfare.

b) Flipper bands (penguins)

Flipper bands are used for individually marking penguins. They are made of aluminum or stainless steel. There are several reports that show that flipper bands can disturb hydrodynamics, create damage to flippers, cause increased swimming costs and decreased survival or cause reduced return rate to colony. Substituting the metal band with a silicon band seems to create less side effects.

Risk assessment:

Consequence = Moderate = 2

Probability = Medium = 2

Probability x Consequence = 4 = Medium risk

Carrying a flipper band is considered to present a medium risk of impaired welfare for penguins.

c) Wing feather tags

Colored wing feather tags are attached to the wing feathers and the tags drop off when the bird goes through its annual feather moult.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

Carrying a feather tag is considered to present a low risk of impaired welfare.

d) Neck collars in waterfowl

In birds, neck collars are used in long-necked waterfowls. Loss of neck feathers, accumulation of ice under the collar in winter and aggression to marked birds are reported as potential side effects as were slight delay in nest initiation and more time spent on foraging grounds are others.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

Carrying a neck collar is considered to present a low risk of impaired welfare in waterfowls.

e) Neck collars in mammals

Neck collars are the dominating marking technology in wild terrestrial mammals and polar bears, and the collars are combined with different data loggers, VHF-radios or GPS transmitters. The weight must be adapted to the species and the size of the individual animal and the literature suggest that the weight should not exceed 3% of the total body mass. Collars have to be individually fitted around animal's neck so they can be pulled on and off over the head. Drop off mechanisms or weakness zones of woven cotton, ensure that the collar falls off within a reasonable period. Very few side-effects are observed, but those observed include worn fur around the neck, skin abrasions on top of the neck and ice formation between skin and collar.

Risk assessment:

Consequence = Limited = 1

Probability = Medium = 2

Probability x Consequence = 2 = Low risk

Neck collars are considered to present a medium risk of impaired welfare in wild predators and ungulates.

f) Nasal discs and saddles

Nasal saddles can be fitted over the bill of ducks and waterfowl. Nasal discs are plastic figures that are used in ducks with perforate nostrils. The method can cause short-lived discomfort; behavioural reactions during pairing among small species, ice buildup under severe winter conditions and entanglement with submerged vegetation.

Risk assessment:

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = Medium risk

Carrying a nasal disc or a nasal saddle is considered to present a medium risk of impaired welfare in waterfowls.

g) Feather dyes

Feather dyes has a rather short lived value, but coloring feathers is cheap and easy marking method. There is a risk from fumes and initial discomfort because of the solvent used. In birds the solvent can remove oil from feathers causing wetting, heat loss and loss of buoyancy. Upset of social behaviour and abandonment of nests is described among black-headed gulls, but in another study there was no such evidence in Canada geese.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

The use of appropriate feather dyes appears to present a low risk of impaired welfare in wild birds.

2. Devices attached externally by different attachment methods

a) Glue on devices on small animals

Different transmitters (VHF transmitters, satellite transmitters, GPS transmitters), data loggers, cameras etc. can be attached to the hair or feathers using different methods (glue, harness). These methods have different effects on the carrier. For example, when devices are attached to small aquatic animals (penguins, otters, beavers), the devices can disturb diving hydrodynamics, streamlining and dive duration, depth and angle.

Risk assessment:

Consequence = Moderate = 2

Probability = Low = 1

Probability x Consequence = 2 = Low risk

Devices attached externally present a low risk of impaired welfare for aquatic birds and small aquatic mammals.

b) Glue on devices on large animals

Larger aquatic animals are less disturbed because of their body mass. When glue is used to attach devices, it can cause heat-related harm to the skin, but this kind of wounds will usually heal without problem. In whales the use of suction cups is used to connect devices. In walruses tags can be connected to the tusk with hose clamps.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

When the use of glue-on and suction cups devices does not interfere with movement, aerodynamics or hydrodynamics, they appear to present a low risk of impaired welfare in large aquatic animals.

c) Harnesses

Transmitters and other devices can be attached to birds, otters and seals with body harnesses. In otters the harnesses represents a risk of drowning if it becomes entangled in submerged snags. There is also a possibility of abrasion caused by the straps of the harness. The harnesses should not interfere with natural movements and in birds the device should not weigh more than 3% of the body mass. Attaching transmitters and similar devices to birds, has the potential to negatively affect their behaviour and ecology. Increased energy expenditure and decreased likelihood of nesting are some of the negative effects that are observed.

Risk assessment:

Consequence = Serious = 3

Probability = Medium = 2

Probability x Consequence = 6 = High risk

The use of body harnesses represents a high risk of impaired welfare.

3. Devices placed partly internally

a) Patagial, ear, flipper and tail tags

Penetrating bolts are used to attach tags to the wing, ear, tail, flipper, fin and dorsal ridge of animals of concern. The more permanent patagial tags used in birds have also few adverse physical effects, but may affect behaviour, survival and breeding success in some species. Bacterial infection because of non-sterile procedures causes most of the side-effects that can occur.

Risk assessment:

Consequence = Moderate = 2

Probability = Low = 1

Probability x Consequence = 2 = Low risk

If sufficient aseptic procedures are used, the use of patagial, ear, flipper, fin or tail tags present a low risk of impaired welfare.

b) Anchor tags

Anchor tags are used on large marine mammals to fix different transmitters to whales and are attached through the skin and blubber with barbs. They usually are rejected after a while, but the available data show that these tags seem to have minimal behaviour effects on the animals. The inflammatory response following rejection may cause pain that eventually stops when rejection is completed.

Risk assessment:

Consequence = Medium = 2

Probability = Low = 1

Probability x Consequence = 2 = Low risk

Anchor tags represent a low risk of impaired welfare.

c) Tattoo

Bears and polar bears are usually marked with an individual tattoo on the inside of the lip when they are marked with other devices.

Risk assessment:

Consequence = Limited = 1

Probability = Low = 1

Probability x Consequence = 1 = Low risk

The tatoo does not seem to cause any long lasting side-effects, and it presents a low risk of impaired welfare

d) Freeze and heat branding

Freeze and heat branding has been used for individual marking of whales and seals. Studies of the hot branding procedures show 0.5-0.7% mortality in connection to branding, and that the hot-iron wounds in seals were healed in almost a year. Freeze brands heal faster.

Risk assessment:

Consequence = Medium = 2

Probability = High = 3

Probability x Consequence = 6 = High risk

Use of freeze and heat branding seems to present a high risk of negative welfare, because of the pain, discomfort and long recovery times of the tissues.

4) Devices placed internally

a) Pit tags

Pit tags are placed subcutaneous with an injection syringe. The injection of pit tags that are small and non-reactive to the tissues seems to have few side effects. Infection on the site and migration from the injection site are significant issues of concern.

Risk assessment:

Consequence = Medium = 2

Probability = Low = 1

Probability x Consequence = 2 = Low risk

If the right injection site and sufficient aseptic procedures are used, pit tags present a low risk of impaired welfare.

b) Intraperitoneal implants

Intraperitoneal implants have shown to be very useful in many wild species, especially because they do not disturb either the aero- or hydrodynamics of the individual. Nor is their deployment affected by the growth of animal and sometimes makes the recapture of the animal superfluous. Use of intraperitoneal implants demands anesthesia, analgesic protocols and aseptic surgery procedures to prevent infection. The infection risk is significant when the peritoneal cavity is opened in the field. Sutures can be lost or chewed off. There is also risk of intestinal obstruction if the implant is trapped in the inguinal or in the pelvic channel. Implants can cause peritonitis and ingrowth of connective tissue if they are not suitable constructed.

Risk assessment:

Consequence = Serious = 3

Probability = Low = 1

Probability x Consequence = 3 = Medium risk

Intraperitoneal implants represent a medium risk of impaired welfare.

Data gaps

Official data bases have not been sufficiently available to the assessors to conduct a proper quantitative risk assessment. There are also major data gaps in the scientific literature concerning welfare indicators. In general, only rates of mortality have been studied and reported. Negative results are often not published.

More data is needed concerning the effect of handling and marking on long-term survival and reproductive parameters and behaviour (e.g. Cattet et al. 2008, Trefry et al. 2013). Similarly, as tracking devices are proving to be an essential tools in the study of wild animals, rigorous long-term documentation and testing of the effects of logger attachment is also needed (e.g. Fijn et al. 2012).

Conclusions

The Norwegian Food Safety Authority asked the Norwegian Scientific Committee for Food Safety Panel on Animal Health and Welfare (VKM) for a risk assessment concerning the welfare of certain free-ranging wild terrestrial and marine mammals and birds subjected to marking. To prepare scientific background documents necessary to answer the questions, the Norwegian Scientific Committee for Food Safety, Panel on Animal Health and Welfare, established an *ad hoc* group consisting of both VKM members and external experts. The number of species involved and the number of methods that are described was high and, for most species and methods the scientific documentation is incomplete. In the assessment many species, especially birds and pinnipeds, have been treated as groups and not individual species. In addition, data about some of the population sizes are sparse.

Wild animals are adapted for a life in the free, and hazards that can threaten their life, health or welfare are normal parts of their existence. All free-living animals are subjected to natural challenges such as diseases, starvation or predation or man-made hazards such as hunting, traffic, oil (and other) pollution or destruction of habitat. The overall welfare risk of populations from capture and marking are, in comparison, limited or negligible. The focus of this assessment is anyhow on the welfare risks of individual animals created by the need to catch and mark them in a scientific or management context.

In general, any capture or marking of wild animals will interfere with the normal behaviour of the animal and pose a risk to its welfare. The need for science-based national or international regulation of this practice is relevant.

The Norwegian Food Safety Authority asked the following question:

A. How do the most commonly used capture and handling methods influence the welfare of free ranging wild terrestrial and marine mammals and birds?

The capture and handling procedures that are commonly used are thoroughly described and discussed. Some general conclusions are made:

- Capture techniques should be effective and not involve unnecessary periods of chasing or entrapment.

- The immobilization techniques used should not cause unnecessary pain or stress.
- Chemical restraint can be used when it is appropriate and safe.
- Immobilization should only be performed by properly trained personnel.
- Following immobilization, the animals should be monitored until they are able to behave normally.

The following methods are considered to pose a high risk of negative welfare:

- Darting from helicopter of terrestrial carnivores because of the heavy fear and stress reactions during chasing and the following possibility of mortality from chemical immobilization.
- Use of coil spring traps to capture otters and lynx, because of the heavy stress and pain reactions induced by trapping and the relative high frequency of trauma.

The following methods are considered to pose a medium risk of negative welfare:

- Darting from helicopter of moose and polar bears because of the possibility of mortality from chemical immobilization.
- Darting from the ground of walrus because of the possibility of mortality from chemical immobilization.
- Net traps in water to catch aquatic mammals and birds, because of the stress reactions induced by capture and the possibility of drowning.
- Use of mist nets to capture flying birds because of the stress reactions induced by capture and the possibility of serious damages to feathers, muscles and skeleton when trapped and released.
- Use of box traps for roe deer, arctic foxes and lynx because of the stress associated with trapping and the following negative welfare impact of manual handling and chemical restraint.

B. How do the most commonly used marking methods and procedures influence the welfare of free ranging wild terrestrial and marine mammals and birds?

The marking methods that are commonly used for different wild species are thoroughly described and discussed. Some general conclusions are made:

- It is not possible to mark an animal with a device that has no implications to its welfare, either at the time-point of marking or during the period that the mark is being carried by the animal. However, many of the commonly used marking techniques have negligible negative effects on most species.
- The weight, shape and size of the marking device should be adapted to the animal that carries it, and it should not interfere with normal behaviour, health or welfare.
- If the device does interfere to some extent with the normal behaviour, health or welfare of the individual, the device should be removed as soon as possible, either by a drop off mechanism or by recapture and removal of device.

The following methods are considered to pose a high risk of negative welfare:

- Body harnesses in otters and birds, because of the possible entangling in vegetation and problems related to drop off effects.
- Heat and freeze brands, because of the long lasting pain and recovery time.

The following methods are considered to pose a medium risk of negative welfare:

- Nasal discs and saddles in ducks because of ice buildup under severe winter conditions and entanglement with submerged vegetation.
- Flipper bands in penguins, because of documented negative effects on survival.
- Intraperitoneal implants, because of the hazard connected to the surgical procedure and the possible impact of the implant to the physiological functions of the peritoneal cavity.

The conclusions are reached by the Panel of Animal Health and Welfare without reservation of any of its members.

References

Legislative framework

- Act of 16 June 2009 No. 97 Relating to Animal Welfare (Animal Welfare Act) (Dyrevelferdsloven)
    - Regulation on Animal Experimentation (Forskrift om forsøk med dyr), under revision
- Act of 15 June 2001 No. 75 Relating to Veterinarians and Other Animal Health Personnel (Dyrehelsepersonelloven)
    - Regulation on the use of medicines on animals (Forskrift om bruk av legemidler til dyr)
- Act of 4 December 1992 No.132 Relating to Medicines etc. (Lov om legemidler mv)
    - Regulation on Medicines (Forskrift om legemidler)
    - Regulation on Requisition and Deliver of Medicines from Pharmacies (Forskrift om rekvirering og utlevering av legemidler fra apotek)
    - Regulation on Narcotics (Forskrift om narkotika mv)
- Act of 29 May 1981 No. 38 Relating to Wildlife and Wildlife Habitats (The Wildlife Act) (Viltoven)
    - Regulation on Capture and Collecting Wildlife for Scientific or other Special Purposes (Forskrift om innfanging og innsamling av vilt for vitenskapelige eller andre særlige formål)
- European Food Safety Authoriy «Guidance on Risk Assessment for Animal Welfare", 25. January 2012

References to Introduction Part:

Fair, J., Paul, E. and Jones, J. (eds.). 2010. Guidelines to the use of wild bids in research. Washington, D.C.: Ornithological Council.

Ferdowsian, H.R. and Beck, N. 2011. Ethical and scientific considerations regarding animal testing and research. Plos ONE 6: 1-4. E24059.

Gales, N., Bowen, W.D., Johnston, D., Kovacs, K.M., Littman, C., Perrin, W., Reynolds, J. and Thompson, P.M. 2009. Guidelines for the ethical treatment of marine mammals in research. Mar. Mamm. Sci. 25: 725-736.

Sikes, R.S., Gannon, W.L. and the Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. J. Mammal. 92: 235-253.

References for Terrestrial Mammals:

Aguirre, A.A., Rincipe, B., Tannerfeldt, M., Angerbjörn, A., and Mörner, T. 2000. Field anesthesia of wild arctic fox (*Alopex lagopus*) cubs in the Swedish Lapland using medetomidine-ketamine-atipmezole. J. Zoo Wildl. Med. 31:244-246.

Andersen, R., Lund, E., Solberg, E.J. and Sæther, B.-E. 2010. Ungulates and their management in Norway. Sider 14-36 i M. Apollonio, R. Andersen and R. Putman. European ungulates and their management in the 21st century. Cambridge University Press, Cambridge.

Arjo, W.M., Joos, R.E., Kochanny, C.O., Harper, J.L., Nolte, D.L. and Bergman, D.L. 2008. Assessment of transmitter models to monitor beaver *Castor canadensis* and *C. fiber* populations. Wildl. Biol. 14:309-317.

Arnemo, J.M. 1991. Surgical implantation of intraperitoneal radiotelemetry devices in European river otters (*Lutra lutra*). Habitat 6:119-1221.

Arnemo, J.M. 2004. Dødelighet ved medikamentell immobilisering av viltlevende elg i Norge 1976-2004. Norsk Vet. Tidsskr. 116: 531-535.

Arnemo J.M., Negard, T. Søli, N.E. 1994. Chemical capture of free-ranging red deer (*Cervus elaphus*) with medetomidine-ketamine. Rangifer 14: 123-127.

Arnemo, J.M., Linnell, J.D.C., Wedul, S.J., Ranheim, B., Odden, J., and Andersen, R. 1999. Use of intraperitoneal radio-transmitters in lynx *Lynx lynx* kittens: anaesthesia, surgery and behaviour. Wildl. Biol. 5:245-250.

Arnemo, J.M., Ahlqvist, P., Andersen, R., Berntsen, F., Ericsson, G., Odden, J., Brunberg, S., Segerström, P., and Swenson, J.E. 2006. Risk of capture-related mortality in large free-ranging mammals: experiences from Scandinavia. Wildl. Biol. 12:109-113.

Arnemo, J.M. and Caulkett, N.A. 2007. Stress. Pages 103-109 *in* West, G., Heard, D. and Caulkett, N.A. editors. Zoo animal and wildlife anesthesia and immobilization. Blackwell Publications, Ames, Iowa.

Arnemo, J.M. and Aanes, R. 2009. Reversible immobilization of free-ranging Svalbard reindeer (*Rangifer tarandus platyrhynchus*) with medetomidine-ketamine and atipamezole. J. Wildl. Dis. 45:877-880.

Arnemo, J.M., Ranheim, R., Haga, A., Lervik, A., Smith, A.J., and Søli, N.J. 2010. Sedasjon, immobilisering og anestesi av pattedyr og fugler. I: Felleskatalog 2010-11 over preparater i veterinærmedisinen. 21. utg. Oslo: Felleskatalogen AS, 2010: 33e-55e. [Webutgave: Fellekatalogen AS. Oslo: http://www.veterinarkatalogen.no/; http://www.felleskatalogen.no/medisin-vet/sedasjon-pattedyr-fugler/sedasjon-pattedyr-fugler-part-sl6402176 (26.10.2010).

Arnemo, J.M., Evans, A.L., Miller, A.L. and Os, Ø. 2011. Effective immobilizing doses of medetomidine-ketamine in free-ranging, wild Norwegian reindeer (*Rangifer tarandus tarandus*). J. Wildl. Dis. 47:755-758.

Arnemo, J.M., Evans, M.E., and Fahlman, Å., (editors), Ahlqvist, P., Andrén, H., Brunberg, S., Liberg, O., Linnell, J.D.C., Odden, J., Persson, J., Sand, H., Segerström, P., Sköld, K., Strømseth, T.H., Støen, O.-G., Swenson, J.E and Wabakken, P. 2012. Biomedical protocols for free-ranging brown bears, wolves, wolverines and lynx. Report. Hedmark University College, Evenstad. http://www.rovviltportalen.no/content.ap?thisId=500039688 (06.03.2012)

Arnemo, J.M. and Søli, N.E. 2012. Medikamentell immobilisering av dyr. Norsk Vet. Tidsskr. 2012 (5):124.

Austrheim, G., Solberg, E.J., Mysterud, A., Daverdin, M. and Andersen, R. 2008. Hjortedyr og husdyr på beite i norsk utmark i perioden 1949-1999. Norges teknisk-naturvitenskapelige universitet, Vitenskapsmuseet, Rapport zoologisk serie 2008-2.

Baker, B.W. 2006. Efficacy of tail-mounted transmitters for beaver. Wildl. Soc. Bull. 34:218-222.

Blanc, F. and Brelurut, A. 1997. Short-term behavioral effects of equipping red deer hinds with a tracking collar. Z. Saugetierkd. 62, Suppl. 2: 18-26.

Blix, A.S., Lian, H. and Ness, J. 2011. Immobilization of muskoxen (*Ovibos moschatus*) with etorphine and xylazine. Acta Vet. Scand. 53:42.

Brøseth, H. and Tovmo, M. 2012. Antall familiegrupper, bestandsestimat, og bestandsutvikling for gaupe i Norge i 2012. - NINA Rapport 859. 23.

Campbell-Palmer, R. and Rosell, F. 2012. Husbandry guidelines for Eurasian beaver (*Castor fiber*). Royal Zoological Society of Scotland.

Cattet, M. R. L., Christison, K., Caulkett, N.A., and Stenhouse, G.B. 2003. Physiologic responses of grizzly bears to different methods of capture. J. Wildl. Dis. 39:649-654.

Cattet, M., Boulanger, J., Stenhouse, G., Powell, R.A., and Reynolds-Hogland, M.J. 2008. An evaluation of long-term capture effects in ursids: implications for wildlife welfare and research. J. Mammal. 89:973-990.

Chow, B.A., Hamilton, J., Alsop, D., Cattet, M.R.L. and Stenhouse, G. 2010. Grizzly bear corticosteroid binding globulin: cloning and serum protein expression. Gen. Comp. Endocrinol. 167:317-325.

Clausen, B., Hjort, P., Strandgaard, H., and Soerensen, P.L. 1984. Immobilization and tagging of muskoxen (*Ovibos moschatus*) in Jameson Land, northeastern Greenland. J. Wildl. Dis. 20:141-145.

Côté, S.D., Festa-Bianchet, M. and Fournier, F. 1998. Life-history effects of chemical immobilization and radiocollars on mountain goats. J. Wildl. Manage. 62: 745-752.

Evans, A., Salén, V., Støen, O-G., Fahlman, Å., Brunberg, S., Madslien, K., Fröbert, O., Swenson, J.E. and Arnemo, J.M. 2012. Capture, anesthesia, and disturbance of free-ranging brown bears (*Ursus arctos*) during hibernation. PLOS One 7 (7): e40520.

Fahlman, Å., Arnemo, J.M., Persson, J., Segerström, P. and Nyman. G. 2008. Capture and medetomidine-ketamine anesthesia of free-ranging wolverines (*Gulo gulo*). J. Wildl. Dis. 44:133-142.

Fahlman, Å., Pringle, J., Arnemo, J.M., Swenson, J.E., Brunberg, S. and Nyman, G. 2010. Treatment of hypoxemia during anesthesia of brown bears (*Ursus arctos*). J. Zoo Wildl. Med. 41:161-164.

Fahlman, Å., Arnemo, J.M., Swenson, J.E., Brunberg, S., Pringle, J. and Nyman, G. 2011. Physiologic evaluation of capture and anesthesia with medetomidine-zolazepam-tiletamine in brown bears (*Ursus arctos*). J. Zoo Wildl. Med. 42:1-11.

Fahlman, Å., Caulkett, N., Arnemo, J.M., Neuhaus, P. and Ruckstuhl, K.E. 2012. Efficacy of a portable oxygen concentrator with pulsed delivery for treatment of hypoxemia during anesthesia of wildlife. J. Zoo Wildl. Med. 43:67-76.

Flagstad, Ø., Eide, N.E., Ulvund, K.R., Tovmo, M., Andersen, R. and Landa, A. 2011. Fjellrev i Norge 2011, Resultater fra det nasjonale overvåkingsprogrammet for fjellrev. NINA Rapport 767.

Flagstad, Ø., Tovmo, M., Balstad, T., Johansson, M., Syslak, L., Eriksen, L. B., Hagen, M., Søgaard, C. D., Ellegren, H. and Brøseth, H. 2012. DNA-basert overvåking av den skandinaviske jervbestanden 2008-2011 - NINA Rapport 843.

Fuglei, E., Mercer, J.B. and Arnemo, J.M. 2002. Surgical implantation of radio transmitters in arctic foxes (*Alopex lagopus*) on Svalbard, Norway. J. Zoo Wildl. Med. 33:342-349.

Godvik, I.M.R., Loe, L.E., Vik, J.O., Veiberg, V., Langvatn, R. and Mysterud, A. 2009. Temporal scales, trade-offs, and functional responses in red deer habitat selection. Ecology 90:699–710.

Guynn. D.C., Davis, J.R. and Von Recum, A.F. 1987. Pathological potential of intraperitoneal transmitter implants in beavers. J. Wildl. Manage. 51:605-606.

Halley, D., Rosell, F. and Saveljev, A. 2012. Population and distribution of Eurasian beaver (Castor fiber). Baltic Forestry 18:168-175.

International Association of Fish and Wildlife Agencies (IAFWA). 2006. Best management practices for trapping in the United States. IAFWA, Furbearer Resources Technical Work Group, Washington, D.C., USA.

Jalanka, H.H. 1990. Medetomidine and medetomidine-ketamine-induced immobilization in blue foxes (*Alopex lagopus*) and its reversal by atipmezole. Acta Vet. Scand. 31:63-71.

Jepsen, J.U., Eide, N.E., Prestrud, P. and Jacobsen, L.B. 2002. The importance of prey distribution in habitat use by arctic foxes (Alopex lagopus). Canad. J. Zool. 80:418-429.

Kreeger, T.J. 2012. Wildlife chemical immobilization. Pages 118-139 *in* Silvy, N. J. ed. The wildlife techniques manual; research, 7th ed., vol. 1. Johns Hopkins University Press, Baltimore, Maryland, USA.

Kreeger, T.J. and Arnemo. J.M. 2012. Handbook of Wildlife Chemical Immobilization. 4th ed. Terry J. Kreeger, Sybille, Wyoming, USA.

Landa, A., Strand, O., Linnell, J.D.C and Skogland, T. 1998. Home-range sizes and altitude selection for arctic foxes and wolverines in an alpine environment. Canad. J. Zool. 76:448.457.

Larsen, D.G. and Gauthier, D.A. 1989. Effects of capturing pregnant moose and calves on calf survivorship. J. Wildl. Manage. 53:564-567.

Léchenne, M.S., Arnemo, J.M., Bröjer, C., Andrén, H. and Ågren, E.O. 2012. Mortalities due to constipation and dystocia caused by intraperitoneal radio-transmitters in Eurasian lynx (*Lynx lynx*). Eur. J. Wildl. Res. 58:503-506.

López-Olivera, J.R., Marco, I., Montané, J., Casas-Díaz, E., Mentaberre, G. and Lavín, S. 2009. Comparative evaluation of effort, capture and handling effects of drive nets to capture roe deer (*Capreolus capreolus*), southern chamois (*Rupicapra pyrenaica*) and Spanish ibex (*Capra pyrenaica*). Eur. J. Wildl. Res. 55:193-202.

Marco, I. and Lavín, S. 1999. Effect of the method of capture on the haematology and blood chemistry of red deer (*Cervus elaphus*). Res. Vet. Sci. 66:81-84.

Macbeth, B.J., Cattet, M.R.L., Stenhouse, G.B., Gibeau, M.L and Janz, D.M. 2010. Hair cortisol concentration as a noninvasive measure of long-term stress in free-ranging grizzly bears (*Ursus arctos*): considerations with implications for other wildlife. Can. J. Zool. 88:935-949.

Mentaberre, G., López-Olivera, J.R., Casas-Díaz, E., Bach-Raich, E., Marco, I. and Lavín, S. 2010. Use of haloperidol and azaperone for stress control in roe deer (*Capreolus capreolus*) captured by means of drive-nets. Res. Vet. Sci. 88:531-535.

Millspaugh, J.J., Kesler, D.C., Kays, R.W., Gitzen, R.A., Schultz, J.H., Rota, C.T., Bodinof, C.M., Belant, J.L. and Keller, B.J. 2012. Techniques for marking wildlife. Pages 258-283 *in* N. J. Silvy, ed. The wildlife techniques manual; research, 7th ed., vol. 1. Johns Hopkins University Press, Baltimore, Maryland, USA.

Moa, P., Negard, A., Overskaug, K. and Kvam, T. 2001. Possible effects of the capture event on subsequent space use of Eurasian lynx. Wildl. Soc. Bull. 29: 86-90.

Moen, G.K., Støen, O.-G., Sahlén, V. and Swenson, J.E. 2012. Behaviour of solitary adult Scandinavian brown bears (*Ursus arctos*) when approached by humans on foot. PLOS One 7(2): e31699.

Moberg, G.P. 2000. Biological responses to stress: implications for animal welfare. Pages 1-21 in Moberg, G.P. and Mench, J. A. Eds. The biology of animal stress: basic principles and implications for animal welfare. CAB International, Wallingford.

Morellet, N., Verheyden, H., Angibault, J.-M., Cargnelutti, B., Lourtet, B. and Hewison, M.A.J. 2009. The effect of capture on ranging behaviour and activity of European roe deer *Capreolus capreolus*. Wildl. Biol. 15:278-287.

Mysterud, A. 1999. Seasonal migration pattern and home range of roe deer (*Capreolus capreolus*) in an altitudinal gradient in southern Norway. J. Zool., London 247: 479-486.

Neumann, W., Ericsson, G., Dettki, H. and Arnemo, J.M. 2011. Effect of immobilizations on the activity and space use of female moose (*Alces alces*). Can. J. Zool. 89:1013-1018.

Nybakk, K., Kjørstad, M., Overskaug, K., Kvam, T., Linnell, J.D.C., Andersen, R. and Berntsen, F. 1996. Experiences with live-capture and radio collaring of lynx *Lynx lynx* in Norway. Fauna norvegica Serie A 17:17-26.

Ó Néill, L., de Jongh, A., Ozoliņš, J., de Jong, T. and Rochford, J. 2007. Minimizing leg-hold trapping trauma for otters with mobile phone technology. J. Wildl. Manage. 71:2776-2780.

Ó Néill, L., Wilson, P., de Jongh, A., de Jong, T. and Rochford, J. 2008. Field techniques for handling, anaesthetising and fitting radio-transmitters to Eurasian otters (*Lutra lutra*). Eur. J. Wildl. Res. 54:681-687.

Odden, J., Linnell, J.D.C., Arnemo, J.M. and Berntsen, F. 2007. Refinement of research capture techniques for Eurasian lynx in Norway (1995-2007). NINA Minirapport 203, Norwegian Institute for Nature Research, Trondheim.

Omsjoe, E.H.; Stien, A. Irvine, J. Albon, S.D., Dahl, E., Thoresen, S.I., Rustad, E. and Ropstad, E. 2009. Evaluating capture stress and its effects on reproductive success in Svalbard reindeer. Can. J. Zool. 87:7385.

Ordiz, A., Støen, O.-G., Sæbø, S., Kindberg, J., Delibes, M. and Swenson, J.E. 2012. Do bears know they are being hunted? Biol. Conserv. 152:21–28.

Ordiz, A., Støen, O.-G., Sæbø, S., Sahlén, V., Pedersen, B.E., Kindberg, J., Swenson, J.E. Daily movement patterns of experimentally disturbed brown bears. Submitted manus.

Painer, J., Zedrosser, A., Arnemo, J.M., Fahlman, Å., Brunberg, S., Segerström, P. and Swenson, J.E. 2012. Effects of different doses of medetomidine and tiletamine - zolazepam on induction time and duration of immobilization of free-ranging yearling brown bears (U*rsus arctos*). Can. J. Zool. 90:753–757.

Panzacchi, M., Linnell, J.D.C., Odden, M., Odden, J. and Andersen, R. 2009. Habitat and roe deer fawn vulnerability to red fox predation. J. Anim. Ecol. 78:1124–1133.

Pelletier, F., Hogg, J.T., and Festa-Bianchet, M. 2004. Effects of chemical immobilization on social status of bighorn rams. Anim. Behav. 67: 1163-1165.

Powell, R. A. 2005. Evaluating welfare of American black bears (*Ursus americanus*) captured in foot snares and in winter dens. J. Mammal. 86:1171-1177.

Quaglietta, L., Martins, B.H., de Jongh, A., Mira, A. and Boitani, L. 2012. A low-cost GPS GSM/GPRS telemetry system: performance in stationary field tests and preliminary data on wild otters (*Lutra lutra*). PLoS One 7(1):e29235.

Ranheim, B., Rosell, F., Haga, H.A. and Arnemo, J.M.. 2004. Field anaesthetic and surgical techniques for implantation of intraperitoneal radio transmitters in Eurasian beavers *Castor fiber*. Wildl. Biol. 10:11-15.

Reid, D.G., Melquist, W.E., Woolington, J.D. and Noll, J.M. 1986. Reproductive effects of intraperitoneal transmitter implants in river otters. J. Wildl. Manage. 50:92-94.

Reynolds, P. 1988. Dynamics and range expansion of a reestablished muskox population. J. Wildl. Manage. 62:734-744.

Rosef, O., Nystøyl, H. L., Solenes, T., Arnemo, J.M. 2004. Haematologic and serum biochemical reference values in free-ranging red deer (*Cervus elaphus atlanticus*). Rangifer 24:79-85.

Rosell, F. and Bjørkøyli, T. 2002. A test of the dear enemy phenomenon in the Eurasian beaver. Anim. Behav. 63:1073-1078.

Rosell, F. and Hovde, B. 2001. Methods of aquatic and terrestrial netting to capture Eurasian beavers. Wildl. Soc. Bull. 29:269-274.

Rosell, F. and Kvinlaug, J.K. 1998. Methods for live-trapping beaver (*Castor* spp.). Fauna Norv., Ser. A. 19:1-28.

Rostal, M. K., Evans, A.L., Solberg, E.J. and Arnemo, J.M. 2012. Hematology and serum chemistry reference ranges of free-ranging moose (*Alces alces*) in Norway. J. Wildl. Dis. 48: in press.

Rothmeyer, S.W., McKinstry, M.C. and Anderson, S.H. 2002. Tail attachment of modified ear-tag transmitters on beavers. Wildl. Soc. Bull. 30:425-429.

Ryeng, K.A., Larsen, S. and Arnemo, J.M. 2002. Medetomidine-ketamine in reindeer (*Rangifer tarandus tarandus*): effective immobilization by hand- and dart-administered injection. J. Zoo Wildl. Med. 33:397-400.

Schemnitz, S.D., Batcheller, G.R., Lovallo, M.J., White, H.B. and Fall, M.W. 2012. Capturing and handling wild animals. Pages 64-117 *in* N. J. Silvy, ed. The wildlife techniques manual; research, 7th ed., vol. 1. Johns Hopkins University Press, Baltimore, Maryland, USA.

Sharpe, F. and Rosell, F. 2003. Time budgets and sex differences in the Eurasian beaver. Anim. Behav. 66:1059-1067.

Silvy, N.J., Lopez, R.R., and Peterson, M.J. 2012. Techniques for marking wildlife. Pages 231-257 *in* Silvy, N.J. ed. The wildlife techniques manual; research, 7th ed., vol. 1. Johns Hopkins University Press, Baltimore, Maryland, USA.

Solberg, E.J., Heim, M., Arnemo, J.M., Sæther, B.-E. and Os, Ø. 2003. Does rectal palpation of pregnant moose cows affect pre- and neo-natal mortality of their calves? Alces 39:65-77.

Solberg, E. J., Grøtan, V., Rolandsen, C.M., Brøseth, H. and Brainerd, S. 2005. Change-in-sex-ratio as an estimator of population size for Norwegian moose. Wildlife Biology 11: 91-100.

Solberg, E.J., Heim, M., Rolandsen, C.M., Sæther, B.-E., and Arnemo, J.M. 2011. Immobilisering og radiomerking av elg på Vega, 1992-2010: konsekvenser for dyrevelferd, kondisjon, reproduksjon og overlevelse. NINA Rapport 658.

Støen, O.-G., Neumann, W., Ericsson, G., Swenson, J.E., Dettki, H., Kindberg, J., and Nellemann, C. 2010. Behavioural response of moose *Alces alces* and brown bears *Ursus arctos* to direct helicopter approach by researchers. Wildl. Biol. 16: 292-300.

Swenson, J.E., Wallin, K., Ericsson, G., Cederlund, G. and Sandegren, F. 1999. Effects of ear tagging on survival of moose calves. J. Wildl. Manage. 63:354-358.

Tobiassen, C., Brøseth, H., Bakke, B. B., Aarnes, S. G., Hagen, S. B. and Eiken, H. G. 2012. Populasjonsovervåking av brunbjørn 2009-2012: DNA-analyse av prøver samlet i Norge i 2011. Bioforsk Rapport Vol. 7, Nr. 57 2012. 54.

Topal, A., Gul, N.Y. and Yanik, K. 2010. Effect of capture method on hematological and serum biochemical values of red deer (*Cervus elaphus*) in Turkey. J.Anim. Vet. Adv. 9:1227-1231.

Tyler, N.J.C. 1991. Short-term behavioural responses of Svalbard reindeer *Rangifer tarandus platyrhynchus* to direct provocation by a snowmobile. Biol. Conserv. 56:179–194.

Valkenburg, P., Boertje, R.D., and Davis, J.L. 1983. Effects of darting and netting on caribou in Alaska. J. Wildl. Manage. 47:1233-1237.

van Dijk, J. 2012. Merking av oter i innlandet i Norge—et pilotstudium. NINA Rapport 799.

Wabakken, P., Svensson, L., Kojola, I., Maartmann, E., Strømseth, T. H., Flagstad, Ø. and Åkesson, M. 2012. Ulv i Skandinavia og Finland: Sluttrapport for bestandsovervåking av ulv vinteren 2011-2012. Høgskolen i Hedmark Oppdragsrapport nr. 5 - 2012. 46.

Øritsland N.A and Alendal, E. 1986. Svalbardreinen. Bestandens størrelse og livshistorie (in Norwegian). In Svalbardreinen og dens livsgrunnlag. Edited by Øritsland NA. Oslo: Universitetsforlaget: 72.

References for Marine Mammals:

Polar Bears:

Aars, J., Andersen, M., Fedak, M. 2007. Studying swimming and diving in female polar bears by satellite tags. 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, South Africa, 29 Nov.-3 Dec. 2007.

Amstrup, S.C. 1993. Human disturbances of denning polar bears in Alaska. Arctic 46: 246-250.

Amstrup, S.C., Durner, G.M., McDonald, T.L., Mulcahy, D.M. and Garner, G.W. 2001. Comparing movement patterns of satellite-tagged male and female polar bears. Can. J. Zool. 79: 2147-2158.

Andersen, M., Derocher, A.E., Wiig, Ø. and Aars, J. 2008. Movements of two Svalbard polar bears recorded using geographical positioning system satellite transmitters. Polar Biol. 31: 905-911.

Argos. 1996. User’s manual. CLS/Service Argos. Toulouse, France.

Born, E.W., Sonne, C. and Dietz, R. 2010. Research on polar bears in Greenland 2005–2009. Pages 135-148 in Obbard, M.E., Thiemann, G.W., Peacock, E., and DeBruyn, T.D. (eds.) Polar Bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, Copenhagen, Denmark, 29 June–3 July 2009. Gland, Switzerland and Cambridge, UK: IUCN

Cattet, M.R.L., Caulkett, N.A., Polischuk, S.C. and Ramsay, M.A. 1997. Reversible immobilization of free-ranging polar bears with medetomidine-zolazepam-tiletamine and atipamezole. J. Wildl. Dis. 33: 611-617.

Derocher, A.E. and Stirling, I. 1995. Temporal variation in reproduction and body mass of polar bears in western Hudson Bay. Can. J. Zool. 73: 1657-1665.

Durner, G.M., Whiteman, J.P., Harlow, H.J., Amstrup, S.C., Regehr, E.V. and Ben-David, M. 2011. Consequences of long-distance swimming and travel over deep-water pack ice for a female bear during a year of extreme ice retreat. Polar Biol. 34: 975-984.

Freitas, C., Kovacs, K.M., Andersen, M., Aars, J., Sandven, S., Skern-Mauritzen, M., Pavlova, O. and Lydersen, C. 2012. Importance of fast ice and glacier fronts for female polar bears and their cubs during spring in Svalbard, Norway. Mar. Ecol. Progr. Ser. 447: 289-304.

Lentfer, J. W. 1968. A technique for immobilizing and marking polar bears. J. Wildl. Manage. 32: 317-321.

Lie, E., Larsen, H.J.S., Larsen, S., Johansen, G.M., Derocher, A.E., Lunn, N.J., Norstrom, R. J., Wiig, Ø. and Skaare, J.U. 2004. Does high organochlorine (OC) exposure impair the restistance to infection in polar bears (*Ursus maritimus*)? Part 1: effect of OCs on the humoral immunity. J. Toxicol. Environ. Health A 67: 555-582.

Lunn, N. Stirling, I., Andriashek, D. and Richardson, E. 2004. Selection of maternity dens by female polar bears in western Hudson Bay Canada, and the effects of human disturbance. Polar Biol. 27: 350-356

Mauritzen, M., Derocher, A.E., Wiig, Ø., Belikov, S.E., Boltunov, A.N., Hansen, E. and Garner, G.W. 2002. Using satellite telemetry to define spatial population structure in polar bears in Norwegian and western Russian Arctic. J. Appl. Ecol. 39: 79-90.

Mauritzen, M., Belikov, S.E., Boltunov, A.N., Derocher, A.E., Hansen, E., Ims, R.A., Wiig, Ø. and Yoccoz, N. 2003. Functional responses in polar bear habitat selection. Oikos 100: 112-124.

Messier, F. 2000. Effects of capturing, tagging and radio-collaring polar bears for research and management purposes in Nunavit and NWT. Unpublished report.

Mulcahy, D.M. and Garner, G. 1999. Subcutaneous implantation of satellite transmitters with percutaneous antennae into male polar bears (*Ursus maritimus*). J. Zoo Wildl. Med. 30: 510-515.

Quakenbush, L.T., Shideler, R. and York, G. 2009. Radio frequency identification tags for grizzly and polar bear research. Final Report OCS study MMS 2009-004. Mineral management Service, Dept. Interior and School of Fish. Ocean Sci., Univ Alaska Fairbanks. 19.

Ramsay, M. and Stirling, I. 1986. Long-term effects of drugging and handling free-ranging polar bears. J. Wildl. Manage. 50: 619-626.

Rode, K., Amstrup, S.C. and Regehr, E.V. 2007. Polar bears in the Southern Beaufort Sea III: stature, mass, and cub recruitment in relationship to time and sea ice extent between 1982 and 2006. USGS Science Strategy to Support U.S. Fish and Wildlife Service Polar Bear Listing Decision, US Department of the Interior, 28.

Stirling, I., Spencer, C. and Andriashek, D. 1989. Immobilization of polar bears (*Ursus maritimus*) with Telazol® in the Canadian Arctic. J. Wildl. Dis. 25: 159-168.

Wiig, Ø. 1995. Distribution of polar bears (*Ursus maritimus*) in the Svalbard area. J. Zool., Lond. 237: 515-429.

Pinnipeds:

Austin, D., Bowen, W.D., McMillan, J. I. and Iverson, S. J. 2006. Linking movement, diving and habitat to foraging success in a large marine predator. Ecology 87: 3095-3108.

Baker, J.D. and Johanos, T.C. 2002. Effects of research handling on the endangered Hawaiian monk seal. Mar. Mammal Sci. 18: 500-512.

Bekkby, T. and Bjørge, A. 1998. Variation in stomach temperature as indicator of meal size in harbor seals, *Phoca vitulina.* Mar. Mammal Sci. 14: 627-637.

Bekkby, T. and Bjørge, A. 2000. Diving behaviour of harbour seal *Phoca vitulina* pups from nursing to independent feeding. J. Sea Res. 44: 267-275.

Bennett, K.A., Moss, S.E.W., Pomeroy, P., Speakman, J.R. and Fedak, M.A. 2012. Effects of handling regime and sex on changes in cortisol, thyroid hormones and body mass in fasting grey seal pups. Comp. Biochem. Physiol. A. 161: 69-76.

Biuw, M., Boehme, L., Guinet, C., Hindell, M., Costa, D., Charrassin, J.-B., Roquet, F., Bailleul, F., Meredith, M., Thorpe, S., Tremblay, Y., McDonald, B., Park, Y.-H., Rintoul, S.R., Bindoff, N., Goebel, M., Crocker, D., Lovell, P., Nicholson, J., Monks, F. and Fedak, M.A. 2007. Variation in behavior and condition of a Southern Ocean top predator in relation to *in situ* oceanographic conditions. PNAS 104: 13705-13710.

Biuw, M., Krafft, B. A., Hofmeyr, G. J. G., Lydersen, C. and Kovacs, K. M. 2009. Time budgets and at-sea behaviour of lactating female fur seals *Arctocephalus gazella* at Bouvetøya. Mar. Ecol. Progr. Ser. 385: 271-284.

Biuw, M., Nøst, O.A., Stien, A., Zhou, Q., Lydersen, C. and Kovacs, K.M. 2010. Effects of hydrographic variability on the spatial, seasonal and diel diving patterns of southern elephant seals in the eastern Weddel Sea. PLoS ONE, e13816. 5.

Bjørge, A., Bekkby, T. and Bryant, E.B. 2002. Summer home range and habitat selection of harbor seal (*Phoca vitulina*) pups. Mar. Mammal Sci. 18: 438-454.

Blix, A.S. and Nordøy, E.S. 2007. Ross seal (*Ommatophoca rossii*) annual distribution, diving behavior, breeding and moulting, off Queen Maud Land, Antarctica. Polar Biol. 31: 1449-1458.

Block, B.A., Jonsen, I.D., Jorgensen, S.J., Winship, A.J., Shaffer, S.A., Bograd, S.J., Hazen, E.L., Foley, D.G., Breed, G.A., Harrison, A.-L., Ganong, J.E., Swithernbank, A., Castleton, M., Dewar, H., Mate, B.R., Shillinger, G.L., Schaefer, K.M., Benson, S.R., Weise, M.J., Henry, R.W. and Costa, D.P. 2011. Tracking apex marine predator movements in a dynamic ocean. Nature 475: 86-90.

Boness, D.J., Bowen, W.D., Buhleier, B.M. and Marshall, G.J. 2006. Mating tactics and mating system of an aquatic-mating pinniped: the harbor seal *Phoca vitulina*. Behav. Ecol. Sociobiol. 61: 119-130.

Bowen, W.D., Tully, D., Boness, D.J., Bulheier, B.M. and Marshall, G.J. 2002. Prey-dependent foraging tactics and prey profitability in a marine mammal. Mar. Ecol. Progr. Ser. 244: 235-245.

Bowen, W.D., Iverson, S.J., McMillan, J.I. and Boness, D.J. 2006. Reproductive performance in grey seals: age-related improvement and senescence in a capital breeder. J. Anim. Ecol. 75: 1340-1351.

Boyd, I.L., Lunn, N.J. and Barton, T. 1991. Time budgets and foraging characteristics of lactating Antarctic fur seals. J. Anim. Ecol. 60: 577-592.

Boyd, I.L., McCafferty, D.J. and Walker, T.R. 1997. Variation in foraging effort by lactating Antarctic fur seals: response to simulated increased foraging costs. Behav. Ecol. Sociobiol. 40: 135-144.

Boyd, I.L., Bevan, R.M., Woakes, A.J. and Butler, P.J. 1999. Heart rate and behavior of fur seals: implications for measurement of field energetics. Am. J. Physiol. 276: H844-H857.

Butler, P.J., Woakes, A.J., Boyd, I.L. and Kanatous, S. 1992. Relationships between heart rate and oxygen consumption during steady-state swimming in California sea lions. J. Exp. Biol. 170: 35-42.

Butler, P.J., Green, J.A., Boyd, I.L. and Speakman, J.R. 2004. Measuring metabolic rate in the field: the pros and cons of the doubly labelled water and heart rate methods. Funct. Ecol. 18: 168-183.

Carlens, H., Lydersen, C., Krafft, B.A. and Kovacs, K.M. 2006. Spring haul-out behavior of ringed seals (*Pusa hispida*) in Kongsfjorden, Svalbard. Mar. Mammal Sci. 22: 379-393.

Charrassin, J.-B., Hindell, M., Rintoul, S. R., Roquet, F., Sokolov, S., Biuw, M., Costa, D., Boehme, L., Lovell, P., Coleman, R., Timmermann, R., Meijers, A., Meredith, M., Park, Y.-H., Bailleul, F., Goebel, M., Tremblay, Y., Bost, C.-A., McMahon, C.R., Field, I.C., Fedak, M.A. and Guinet, C. 2008. Southern Ocean frontal structure and sea-ice formation rates revealed by elephant seals. PNAS 105: 11634-11639.

Costa, D.P., Robinson, P.W., Huckstadt, L.A., Simmons, S.B., MacDonald, B.E., Hassrick, J. L., Goebel, M.E. and Crocker, D.E. 2009. Comparison of the foraging ecology of southern and northern elephant seals. 18th Bien. Conf. Biol. Mar. Mammals, 12-16 Oct. 2009, Quebec City, Canada. p.61.

Daoust, P.-Y., Fowler, G.M. and Stobo, W.T. 2006. Comparison of the healing process in hot and cold brands applied to harbour seal pups (*Phoca vitulina*). Wildl. Res. 33: 361-372.

Davis, R.W., Fuiman, L.A., Williams, T.M., Collier, S.O., Hagey, W.P., Kanatous, S.B., Kohin, S. and Horning, M. 1999. Hunting behavior of a marine mammal beneath the Antarctic fast ice. Science 283: 993-996.

Engelhardt, G.H., Hall, A.J., Brasseur, S.M.J.M. and Reijnders, P.J.H. 2002. Blood chemistry in southern elephant seal mothers and pups during lactation reveals no effect of handling. Comp. Biochem. Physiol. A 133: 367-378.

Falke, K.J., Hill, R.D., Qvist, J., Schneider, R.C., Guppy, M., Liggins, G.C., Hochachka, P. W., Elliott, R.L. and Zapol, W.M. 1985. Seal lungs collapse during free diving: evidence from arterial nitrogen tensions. Science 229: 556-558.

Field, I.C., Harcourt, R.G.; Boehme, L., Bruyin, P.J.N. de; Charrassin, J.-B., McMahon, C. R., Bester, M.N., Fedak, M.A. and Hindell, M.A. 2012. Refining instrument attachment on phocid seals. Mar. Mammal Sci. In press.

Folkow, L.P., Mårtensson, P.E. and Blix, A.S. 1996. Annual distribution of hooded seals *(Cystophora cristata)* in the Greenland and Norwegian Seas., Polar Biol. 16: 179-189.

Folkow, L.P., Nordøy, E.S. and Blix, A.S. 2004. Distribution and diving behaviour of harp seals (*Pagophilus groenlandicus*) from the Greenland Sea stock. Polar Biol. 27: 281-298.

Folkow, L. P., Nordøy, E. S. and Blix, A.S. 2010. Remarkable development of diving performance and migrations of hooded seals (*Cystophora cristata*) during their first year of life. Polar Biol. 33: 433-441.

Freitas, C., Kovacs, K.M., Ims, R.A., Fedak, M.A. and Lydersen, C. 2008. Ringed seal post-moulting movement tactics and habitat selection. Oecologia 155: 193-204.

Freitas, C., Kovacs, K.M., Ims, R.A., Fedak, M.A. and Lydersen, C. 2009. Deep into the ice: over-wintering and habitat selection in male Atlantic walruses. Mar. Ecol. Progr. Ser. 375: 247-261.

Fuiman, L. A., Madden, K. M., Williams, T.M. and Davis, R.W. 2007. Structure of foraging dives by Weddell seals at an offshore isolated hole in the Antarctic fast-ice environment. Deep-Sea Res. II 54: 270-289.

Gales, N. J., Bowen, W. D., Johnston, D. W., Kovacs, K. M., Littnan, C. L., Perrin, W. F., Reynolds, J. E. III and Thompson, P. M. 2009. Guidelines for the treatment of marine mammals in field research. Mar. Mammal Sci. 25: 725-736.

Galimberti, F., Sanvito, S. and Boitani, L. 2000. Marking of southern elephant seals with passive integrated transponders. Mar. Mammal Sci. 16: 500-504.

Geschke, K. and Chilvers, B.L. 2009. Managing big boys: a case study on remote anaesthesia and satellite tracking of adult male New Zealand sea lions (*Phocarctos hookeri*). Wildl. Res. 36: 666-674.

Gjertz, I., Kovacs, K.M., Lydersen, C. and Wiig, Ø. 2000a. Movements and diving of adult ringed seals (*Phoca hispida*) in Svalbard. Polar Biol. 23: 651-656.

Gjertz, I., Kovacs, K.M., Lydersen, C. and Wiig, Ø. 2000b. Movements and diving of bearded seal (*Erignathus barbatus*) mothers and pups during lactation and post-weaning. Polar Biol. 23: 559-566.

Gjertz, I., Lydersen, C. and Wiig, Ø. 2001a. Distribution and diving of harbour seals (*Phoca vitulina*) in Svalbard. Polar Biol. 24: 209-214.

Gjertz, I., Griffiths, D., Krafft, B.A., Lydersen, C. and Wiig, Ø. 2001b. Diving and haul-out patterns of walruses *Odobenus rosmarus* on Svalbard. Polar Biol. 24: 314-319.

Green, J. A., Haulena, M., Boyd, I. L., Calkins, D., Gulland, F., Woakes, A. J. and Butler, P.J. 2009. Trial implantation of heart rate loggers in pinnipeds. J. Wildl. Manage. 73: 115-1221.

Griffiths, D., Wiig, Ø. and Gjertz, I. 1993. Immobilization of walrus with etorphine hydrochloride and zoletil. Mar. Mammal Sci. 9: 250-257.

Guppy, M., Hill, R. D., Schneider, R. C., Qvist, J., Liggins, G. C.and Zapol, W. M., and Hochachka, P. W., 1986. Microcomputer-assisted metabolic studies of voluntary diving of Weddell seals. Am. J. Physiol. 250: R175-R187.

Hall, A., Moss, S. and McConnell, B. 2000. A new tag for identifying seals. Mar. Mammal Sci. 16: 254-257.

Harcourt, R.G., Hindell, M.A., Bell, D.G. and Waas, J.R. 2000. Three-dimensional dive profiles of free-ranging Weddell seals. Polar Biol. 23: 479-487.

Harcourt, R.G., Turner, E., Hall, A., Waas, J.R. and Hindell, M. 2010. Effects of capture stress on free-ranging, reproductively active male Weddell seals. J. Comp. Physiol. A. 196: 147-154.

Härkönen, T., Hårding, K.C. and Lunneryd, S.G. 1999. Age- and sex-specific behaviour in harbour seals *Phoca vitulina* leads to biased estimates of vital population parameters. J. Appl. Ecol. 36: 825-841.

Härkönen, T. and Harding, K.C. 2001. Spatial structure of harbour seal populations and the implications thereof. Can. J. Zool. 7: 2115-2127.

Hastings, K.K., Gelatt, T.S. and King, J.C. 2009. Postbranding survival of Steller sea lion pups at Lowrie Island in Southeast Alaska. J. Wildl. Manage. 73: 1040-1051.

Hazekamp, A.A.H., Mayer, R. and Osinga, N. 2010. Flow simulation along a seal: the impact of an external device. Eur. J. Wildl. Res. 56: 131-140.

Heaslip, S.G. and Hooker, S.K. 2008. Effect of animal-borne camera and flash on the diving behaviour of the female Antarctic fur seal (*Arctocephalus gazella*). Deep-Sea Res. I 55: 1179-1192.

Hedd, A., Gales, R. and Renouf, D. 1996. Can stomach temperature telemetry be used to quantify prey consumption by seals? Polar Biol. 16: 261-270.

Henderson, J.R. and Johanos, T.C. 1988. Effects of tagging on weaned Hawaiian monk seal pups. Wildl. Soc. Bull. 16: 312-317.

Hill, R.D. 1986. Microcomputer monitor and blood sampler for free-diving Weddell seals. J. Appl. Physiol. 61: 1570-1576.

Hill, R.D., Schneider, R.C., Schuette, A.H. and Zapol, W.M. 1983. Microprocessor-controlled monitoring of bradycardia in free-diving Weddell seals. Antarct. J. 18: 213-214.

Hill, R.D., Schneider, R.C., Liggins, G.C., Schuette, A.H., Elliott, R.L., Guppy, M., Hochachka, P.W., Quist, J., Falke, K.J. and Zapol, W.M. 1987. Heart rate and body temperature during free diving of Weddell seals. Am. J. Physiol. 253: R344-R351.

Hindell, M.A., Bradshaw, C.J.A., Sumner, M.D., Michael, K.J. and Burton, H.R. 2003. Dispersal of female southern elephant seals and their prey consumption during the austral summer: relevance to management and oceanographic zones. J. Appl. Ecol. 40: 703-715.

Hoff, J. van den, Sumner, M.D., Field, I.C., Bradshaw, C.J.A., Burton, H.R., and McMahon, C.R. 2004. Temporal changes in the quality of hot-iron brands on elephant seal (*Mirounga leonina*) pups. Wildl. Res. 31, 619-629.

Hofmeyr, G.J.G., Krafft, B.A., Kirkman, S.P., Bester, M.N., Lydersen, C. and Kovacs, K.M. 2005. Population changes of Antarctic fur seals at Nyrøysa, Bouvetøya. Polar Biol. 28: 725-731.

Horning, M. and Hill, R.D. 2005. Designing an archival satellite transmitter for life-long deployments on oceanic vertebrates: the life history transmitter. IEEE J. Ocean. Engineer. 30: 807-817.

Horning, M., Haulena, M., Tuomi, P.A. and Mellish, J.-A.E. 2008. Intraperitoneal implantation of life-long telemetry transmitters in otariids. BMC Vet. Res. 4: 51: 51-10.

Horning, M. and Mellish, J.-A.E. 2012. Predation on an upper trophic marine predator, the Steller sea lion: evaluating high juvenile mortality in a density dependent conceptual framework. PLoS ONE 7, e30173 10.

Hyvärinen, H., Hämäläinen, E. and Kunnasranta, M. 1995. Diving behaviour of the saimaa ringed seal (*Phoca hispida saimensis* Nordq.). Mar. Mammal Sci. 11: 324-334.

Jay, C.V., Heide-Jørgensen, M.P., Fischbach, A.S., Jensen, M.V., Tessler, D.F. and Jenssen, A.V. 2006. Comparison of remotely deployed satellite radio transmitters on walruses. Mar. Mammal Sci. 22: 226-236.

Jay, C.V., Olson, T.L., Garner, G.W. and Ballachey, B.E. 1998. Response of Pacific walruses to disturbance from capture and handling activities at a haul-out in Bristol Bay, Alaska. Mar. Mammal Sci. 14: 819-828.

Jonker, F.C. and Bester, M.N. 1998. Seasonal movements and foraging areas of adult southern elephant seals, *Mirounga leonina*, from Marion Island. Antarct. Sci. 10. 21-30.

Jørgensen, C., Lydersen, C., Brix, O. and Kovacs, K.M. 2001. Diving development in nursing harbour seals. J. Exp. Biol. 204: 3993-4004.

Kelly, B.P. 1996. Live capture of ringed seals in ice-covered waters. J. Wildl. Manage. 60: 678-684.

Kelly, B.P., Badajos, O.H., Kunnasranta, M., Moran, J.R., Martinez-Bakker, M., Wartzok, D. and Boveng, P. 2010. Seasonal home ranges and fidelity to breeding sites among ringed seals. Polar Biol. 33: 1095-1109.

Kooyman, G.L., Wahrenbrock, E.A., Castellini, M.A., Davis, R.W. and Sinnett, E.E. 1980. Aerobic and anaerobic metabolism during voluntary diving in Weddell seals: evidence of preferred pathways from blood chemistry and behaviour. J. Comp. Physiol. B. 138: 335-346.

Kovacs, K.M. 1987a. Maternal behaviour and early behavioural ontogeny of grey seals (*Halichoerus grypus*) on the Isle of May, UK. J. Zool., Lond, 213: 697-715.

Kovacs, K.M. 1987b. Maternal behaviour and early behavioural ontogeny of harp seals, *Phoca groenlandica.* Anim. Behav. 35: 844-855.

Krafft, B.A., Lydersen, C., Kovacs, K.M., Gjertz, I. and Haug, T. 2000. Diving behaviour of lactating bearded seals (*Erignathus barbatus*) in the Svalbard area. Can. J. Zool. 78: 1408-1418.

Krafft, B., Hofmeyr, G.J.G., Keith, D., Harck, B.I.B. and Kovacs, K.M. 2002a. Studies of seals and seabirds on Bouvetøya 2000/01 - fieldwork and preliminary results. Norsk Polarinst. Rapp. Ser. 120: 62-71.

Krafft, B.A., Lydersen, C., Gjertz, I. and Kovacs, K.M., 2002b. Diving behaviour of sub-adult habour seals (*Phoca vitulina*) at Prins Karls Forland, Svalbard. Polar Biol. 25: 230-234.

Krafft, B.A., Kovacs, K.M., Ergon, T., Andersen, M., Aars, J., Haug, T. and Lydersen, C. 2006. Abundance of ringed seals (*Pusa hispida*) in the fjords of Spitsbergen, Svalbard, during the peak molting period. Mar. Mammal Sci. 22: 394-412.

Kreeger, T.J., Arnemo, J.M. and Raath, J.P. 2002. Handbook of wildlife chemical immobilization. International edition. Wildl. Pharmac. Inc., Forth Collins, Colorado, USA 412.

Kuhn, C.E., Crocker, D.E., Tremblay, Y. and Costa, D.P. 2009. Time to eat: measurements of feeding behaviour in a large marine predator, the northern elephant seal *Mirounga angustirostris*. J. Anim. Ecol. 78: 513-523.

Lander, M.E., Haulena, M., Gulland, F.M.D. and Harvey, J.T. 2005. Implantation of subcutaneous radio transmitters in the harbor seal (*Phoca vitulina*). Mar. Mammal Sci. 21: 154-161.

Lydersen, C. 1991.Monitoring ringed seal (*Phoca hispida*) activity by means of acoustic telemetry. Can. J. Zool. 69: 1178-1182.

Lydersen, C. and Hammill, M.O. 1993. Diving in ringed seal (*Phoca hispida*) pups during the nursing period. Can. J. Zool. 71: 991-996.

Lydersen, C. and Kovacs, K.M. 1993. Diving behaviour of lactating harp seal, *Phoca groenlandica*, females from the Gulf of St. Lawrence, Canada. Anim. Behav. 46: 1213-1221.

Lydersen, C., Hammill, M.O. and Kovacs, K.M. 1994. Diving activity in nursing bearded seal (*Erignathus barbatus*) pups. Can J. Zool. 72: 96-103.

Lydersen, C. and Kovacs, K.M. 1995. Paralysis as a defense response to threatening stimuli in harp seals (*Phoca groenlandica*). Can. J. Zool. 73: 486-492.

Lydersen, C., Nøst, O.A., Lovell, P., McConnell, B.J., Gammelsrød, T., Hunter, C., Fedak, M. A. and Kovacs, K.M. 2002a. Salinity and temperature structure of a freezing Arctic fjord - monitored by white whales (*Delphinapterus leucas*). Geophys. Res. Lett. 29: art. no. 2119. 4.

Lydersen, C., Kovacs, K.M., Ries, S. and Knauth, M. 2002b. Precocial diving and patent foramen ovale in bearded seal (*Erignathus barbatus*) pups. J. Comp. Physiol. B 172: 713-717.

Lydersen, C., Nøst, O.A., Kovacs, K.M. and Fedak, M.A. 2004. Temperature data from Norwegian and Russian waters of the northern Barents Sea collected by free-living ringed seals. J. Mar. Syst. 46: 99-108.

Lydersen, C. and Kovacs, K.M. 2005. Growth and population parameters of the world's northernmost harbour seals *Phoca vitulina* residing in Svalbard, Norway. Polar Biol. 28: 156-163.

Lydersen, C., Aars, J. and Kovacs, K.M. 2008. Estimating the number of walruses in Svalbard based on aerial surveys and behavioural data from satellite telemetry. Arctic 61: 119-128.

Lydersen C. and Kovacs, K.M. 2012. Walrus *Odobenus rosmarus* research in Svalbard, Norway, 2000-2010. NAMMCO Sci. Publ. in press.

Marshall, G., Bakhtiari, M., Shepard, M., Tweedy, J.I., Rasch, D., Abernathy, K., Joliff, B., Carrier, J.C. and Heithaus, M.R. 2007. An advanced solid-state animal-borne video and environmental data-logging device ("crittercam") for marine reseacrh. Mar. Techn. Soc. J. 41: 31-38.

McCafferty, D.J., Currie, J. and Sparling, C.E. 2007. The effect of instrument attachement on the surface temperature of juvenile grey seals (*Halichoerus grypus*) as measured by infrared thermography. Deep-Sea Res. II 54: 424-436.

McConnell, B., Beaton, R., Bryant, E., Hunter, C., Lovell, P. and Hall, A. 2004. Phoning home - a new GSM mobile phone telemetry system to collect mark-recapture data. Mar. Mammal Sci. 20: 274-283.

McMahon, C., Hoff, J. van den and Burton, H. 2005. Handling intensity and the short- and long-term survival of elephant seals: addressing and quantifying research effects on wild animals. Ambio 34: 426-429.

McMahon, C.R., Burton, H.R., Hoff, J. van den, Woods, R. and Bradshaw, C.J.A. 2006. Assessing hot-iron and cryo-branding for permanently marking southern elephant seals. J. Wildl. Manage. 70: 1484-1489.

McMahon, C., Field, I.C., Bradshaw, C.J.A., White, G.C. and Hindell, M.A. 2008. Tracking and data-logging devices attached to elephant seals do not affect individual mass gain or survival. J. Exp. Mar. Biol. Ecol. 360: 71-77.

McMahon, C.R., Collier, N., Northfield, J.K. and Glen, F. 2011. Taking the time to assess the effects of remote sensing and tracking devices on animals. Anim. Welfare 20: 515-521.

Mellish, J.-A., Hennen, D., Thompton, J., Petrauskas, L., Atkinson, S., and Calkins, D. 2007. Permanent marking in an endangered species: physiological response to hot branding in Steller sea lions (*Eumetopias jubatus*). Wildl. Res. 34: 43-47.

Mellish, J.E., Hindle, A.G. and Horning, M. 2010. A preliminary assessment of the impact of disturbance and handling on Weddell seals of McMurddo Sound, Antarctica. Antarct. Sci. 22: 25-29.

Merrick, R.L., Loughlin, T.R. and Calkins, D.G. 1996. Hot branding: a technique for long-term marking of pinnipeds. US Dept. Comm., NOAA Techn. Mem. NMFS-AFSC-68, NOAA.

Mitani, Y., Sato, K., Ito, S., Cameron, M.F., Siniff, D.B. and Naito, Y. 2003. A method for reconstructing three-dimensional dive profiles of marine mammals using geomagnetic intensity data: results from two lactating Weddell seals. Polar Biol. 26: 311-317.

Nordøy, E.S., Folkow, L. and Blix, A.S. 1995. Distribution and diving behaviour of crabeater seals (*Lobodon carcinophagus*) off Queen Maud Land. Polar Biol. 15: 261-268.

Nordøy, E.S., Folkow, L.P., Potelov, V., Prischemikhin, V. and Blix, A.S. 2008. Seasonal distribution and dive behaviour of harp seals (*Pagophilus groenlandicus*) of the White Sea-Barents Sea stock. Polar Biol: 31. 1119-1135.

Nordøy, E.S. and Blix, A.S. 2009. Movement and dive behaviour of two leopard seals (*Hydrurga leptonyx*) off Queen Maud Land, Antarctica. Polar Biol. 32: 263-270.

Nøst, O.A., Biuw, M., Tverberg, V., Lydersen, C., Hattermann, T., Zhou, Q., Smedsrud, L.H. and Kovacs, K.M. 2011. Eddy overturning of the Antarctic Slope Front controls glacial melting in Eastern Weddell Sea. J. Geophys. Res. 116, C11014, doi:10.1029/2011JC006965, 17.

Paterson, W., Pomeroy, P.P., Sparling, C.E., Moss, S., Thompson, D., Currie, J.I. and McCafferty, D.J. 2011. Assessment of flipper tag site healing in gray seal pups using thermography. Mar. Mammal Sci. 27: 295-305.

Qvist, J., Hill, R.D., Schneider, R.C., Falke, K.J., Liggins, G.C., Guppy, M., Elliott, R.L., Hochachka, P.W. and Zapol, W.M. 1986. Hemoglobin concentrations and blood gas tensions of free-diving Weddell seals. J. Appl. Physiol. 61: 1560-1569.

Reder, S., Lydersen, C., Arnold, W. and Kovacs, K.M. 2003. Haul-out behaviour of high Arctic harbour seals (*Phoca vitulina vitulina*) in Svalbard, Norway. Polar Biol. 27: 6-16.

Simpkins, M.A., Kelly, B.P. and Wartzok, D. 2001. Three-dimensional analysis of search behaviour in ringed seals. Anim. Behav. 62: 67-72.

Sisak, M.M. 1998. Animal-bourne GPS and the deployment of a GPS based archiving datalogger on Hawaiian monk seal (*Monachus schauinslandi*). Mar. Techn. J. 32: 30-36.

Staniland, I.J., Robinson, S.L., Silk, J.R.D., Warren, N. and Trathan, P.N. 2012. Winter distribution and haul-out behaviour of female Antarctic fur seals from South Georgia. Mar. Biol. 159: 291-301.

St Aubin, D.J., Austin, T.P. and Geraci, J.R. 1979. Effects of handling stress on plasma enzymes in harp seals, *Phoca groenlandica.* J. Wildl. Dis. 15: 569-572.

Suzuki, I., Naito, Y., Folkow, L.P., Miyazaki, N., Blix, A.S. 2009. Validation of a device for accurate timing of feeding events in marine mammals. Polar Biol. 32: 667-671.

Trites, A.W. 1991. Does tagging and handling affect the growth of northern fur seal pups (*Callorhinus ursinus*)? Can. J. Fish. Aquat. Sci. 48: 2436-2442.

Viviant, M., Trites, A.W., Rosen, D.A.S., Monestiez, P. and Guinet, C. 2010. Prey capture attempts can be detected in Steller sea lions and other marine predators using accelerometers. Polar Biol. 33: 713-719.

Walker, B.G. and Boveng, P.L. 1995. Effects of time-depth recorders on maternal foraging and attendance behavior of Antarctic fur seals (*Arctocephalus gazella*). Can. J. Zool. 73: 1538-1544.

Walker, K.A., Horning, M., Mellish, J.-A.E. and Weary, D.M. 2009. Behavioural responses of juvenile Steller sea lions to abdominal surgery: developing an assessment of post-operative pain. Appl. Anim. Behav. Sci. 120: 201-207.

Walker, K.A., Mellish, J.-A.E. and Weary, D.M. 2010. Behavioural responses of juvenile Steller sea lions to hot-iron branding. Appl. Anim. Behav. Sci. 22: 58-62.

Walker, K.A., Trites, A.W., Haulena, M. and Weary, D.M. 2012. A review of the effects of different marking and tagging techniques on marine mammals. Wildl. Res. 59: 15-30.

Wiig, Ø., Gjertz, I. and Griffiths, D. 1996. Migration of walrus (*Odobenus rosmarus*) in the Svalbard and Franz Josef Land area. J. Zool., Lond. 238: 769-784.

Wartzok, D., Sayegh, S., Stone, H., Barchak, J. and Barnes, W. 1992. Acoustic tracking system for monitoring under-ice movements of polar seals. J. Acoust. Soc. Am. 42: 682-687.

Watanabe, Y., Bornemann, H., Liebsch, N., Plötz, J., Sato, K., Naito, Y. and Miyazaki, N. 2006. Seal-mounted cameras detect invertebrate fauna on the underside of an Antarctic ice shelf. Mar. Ecol. Progr. Ser. 309: 297-300.

Watanabe, Y., Lydersen, C., Sato, K., Naito, Y., Miyazaki, N. and Kovacs, K.M. 2009. Diving behavior and swimming style of nursing bearded seal pups. Mar. Ecol. Progr. 380: 287-294.

Wilkinson, I.S., Chilvers, B.L., Duignan, P.J. and Pistorius, P.A. 2011. An evaluation of hot-iron branding as a permanent marking method for adult New Zealand sea lions *Phocarctos hookeri*. Wildl. Res. 38: 51-60.

Wilson, R.P. and McMahon, C.R. 2006. Measuring devices on wild animals: what constitutes acceptable practice? Front. Ecol. Environ. 4: 147-154.

Whales:

Amano, M, and Yoshioka, M. 2003. Sperm whale behavior monitored using a suction-cup-attached TDR tag. Mar. Ecol. Progr. Ser. 258: 291-295.

Anonymous 2003. Satellittsporing av spekkhoggere. Faktaark. Norges Forskningsråd. http://www.forskningsradet.no/servlet/Satellite?c=Page&cid=1234130557525&pagename=mare%2FHovedsidemal.

Baird, R.W., Ligon, A.D., Hooker, S.K. and Gorgone, A.M. 2001. Subsurface and night-time behaviour of pantropical spotted dolphins in Hawaii. Can. J. Zool. 79: 988-996.

Balmer, B.C., Wells, R.S., Schwacke, L.H., Rowles, T.K., Hunter, C., Zolman, E.S., Townsend, F.I., Danielson, B., Westgate, A.J., McLellan, W.A. and Pabst, D.A. 2011. Evaluation of a single-pin, satellite-linked transmitter deployed on bottlenose dolphins (*Tursiops truncatus*) along the coast of Georgia, USA. Aquat. Mamm. 37: 187-192.

Baumgartner, M.F. and Mate, B.R. 2003. Summertime foraging ecology of North Atlantic right whales. Mar. Ecol. Progr. Ser. 264: 123-135.

Blomqvist, C. and Amundin, M. 2004. An acoustic tag for recording directional pulsed ultrasounds aimed at free-swimming bottlenose dolphins (*Tursiops truncatus*) by conspecifics. Aquat. Mamm. 30: 345-356.

Calambokidis, J., Schorr, G.S., Steiger, G.H., Francis. J., Bakhtiari, M., Marshal, G., Oleson, E.M., Gendron, D. and Robertson, K. 2007. Insight into the underwater diving, feeding, and calling behavior of blue whales from a suction-cup-attached video-imaging tag (CRITTERCAM). Mar. Technol. Soc. J. 41: 19-29.

Croll, D.A., Tershy, B.R., Hewitt, R.P., Demer, D.A., Fiedler, P.C., Smith, S.E., Armstrong, W., Popp, J.M., Kiekhefer, T., Lopez, V.R., Urban, J. and Gendron, D. 1998. An integrated approach to the foraging ecology of marine mammals and birds. Deep Sea Res. II 45: 1353-1371.

Dietz, R. and Heide-Jørgensen, M.P. 1995. Movements and swimming speed of narwhals, *Monodon monoceros,* equipped with satellite transmitters in Melville Bay, northwest Greenland. Can. J. Zool. 73: 2106-2119.

Eskesen, I.G., Teilmann, J., Geertsen, B.M., Desportes, G., Riget, F., Dietz, R., Larsen, F. and Siebert, U. 2009. Stress levels in wild harbour porpoises (*Phocoena phocoena*) during satellite tagging measured by respiration, heart rate and cortisol. J. Mar. Biol. Assoc. UK 89: 885-892.

Geertsen, B.M., Teilmann, J., Kastelein, R.A., Vlemmix, H.N.J. and Miller, L.A. 2004. Behaviour and physiological effects of transmitter attachments on a captive harbour porpoise (*Phocoena phocoena*). J. Cetacean Res. Manage. 6: 139-146.

Geraci, J.R. and Smith, T.G. 1990. Cutanours response to implants, tags, and marks in beluga whales, Delphinapterus leucas, and bottlenose dolphins, Tursiops truncatus. Can. Bull. Fish. Aquat. Sci. 224: 81-95.

Goodyear, J.D. 1993. A sonic/radio tag for monitoring dive depths and underwater movements of whales. J. Wildl. Manage. 57: 503-513.

Hanson, M.B. 2001. An evaluation of the relationship between small cetacean tag design and attachment durations: a bioengineering approach. PhD Thesis, School Aquat. Fish. Sci., Univ. Washington, Seattle, USA. 208.

Hanson, M.B. and Baird, R.W. 1998. Dall's porpoise reactions to tagging attempts using a remotely-deployed suction-cup tag. Mar. Technol. Soc. J. 32: 18-23.

Heide-Jørgensen, M.P., Kleivane, L., Øien, N., Laidre, K.L. and Jensen, M.V. 2001a. A new technique for deploying satellite transmitters on baleen whales: tracking a blue whale (*Balaenoptera musculus*) in the North Atlantic. Mar. Mammal Sci. 17: 949-954.

Heide-Jørgensen, M.P., Nordøy, E.S., Øien, N., Folkow, L.P., Kleivane, L., Blix, A.S., Jensen, M.V. and Laidre, K.L. 2001b. Satellite tracking of minke whales (*Balaenoptera acutorostrata*) off the coast of northern Norway. J. Cetacean Res. Manage. 3: 175-178.

Herman, E.Y.K., Herman, L.M., Pack, A.A., Marshall, G., Shepard, C.M. and Bakhtiara, M. 2007. When whales collide: CRITTERCAM offers insight into the competitive behavior of humpback whales on their Hawaiian wintering grounds. Mar. Technol. Soc. J. 41: 35-43.

Hooker, S.K., Baird, R.W., Al-Omari, S., Gowans, S. and Whitehead, H. 2001. Behavioral reactions of northern bottlenose whales (*Hyperoodon ampullatus*) to biopsy darting and tag attachment procedures. Fish. Bull. 99: 303-308.

Irvine, A.B., Wells, R.S. and Scott, M.D. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fish. Bull. 80: 135-143.

Johnson, M., de Soto, N.A. and Madsen, P.T. 2009. Studying the behaviour and sensory ecology of marine mammals using acoustic recording tags: a review. Mar. Ecol. Progr. Ser. 395: 55-73.

Kvadsheim, P., Benders, F., Miller, P., Doksæter, L., Knudsen, F., Tyack, P., Nordlund, N., Lam, F.-P., Samarra, F., Kleivane, L. and Godø, O.R. 2007. Herring (sild), killer whales (spekkhogger) and sonar – the 3S-2006 cruise report with preliminary results. FFI-rapport 2007/01189, 79.

Kvadsheim, P., Lam, F.-P., Miller, P., Alves, A.C., Antunes, R., Bocconcelli, A., Ijsselmuide, S. van, Kleivane, L., Olivierse, M. and Visser, F. 2009. Cetaceans and naval sonar – the 3S-2009 cruise report. FFI-rapport 2009/01140, 66.

Kvadsheim, P., Lam, F.-P., Miller, P., Doksæter, L., Visser, F., Kleivane, L., Ijsselnuide, S. van, Samarra, F., Wensveen, P., Curem C., Hickmott, L. and Dekeling, R. 2011. Behavioural response studies of cetaceans to naval sonar signals in Norwegian waters – 3S-2011 cruise report. http://rapporter.ffi.no/rapporter/2011/01289.pdf

Laidre, K.L., Heide-Jørgensen, M.P., Dietz, R., Hobbs, R.C. and Jørgensen, O.A. 2003. Deep-diving by narwhals *Monodon monoceros*: differences in foraging behavior between wintering areas? Mar. Ecol. Progr. Ser. 261: 269-281.

Lewis, A.E., Hammill, M.O., Power, M., Doidge, D.W. and Lesage, V. 2009. Movement and aggregation of eastern Hudson Bay beluga whales (*Delphinapterus leucas*): a comparison of patterns found through satellite telemetry and Nunavik traditional ecological knowledge. Arctic 62: 13-24.

Lydersen, C., Freitas, C., Wiig, Ø., Bachmann, L., Heide-Jørgensen, M. P., Swift, R. and Kovacs, K.M. 2012. Lost highway not forgotten: Satellite tracking of a bowhead whale (*Balaena mysticetus*) from the critically endangered Spitsbergen stock. Arctic in press.

Lydersen, C., Martin, A.R., Kovacs, K.M. and Gjertz, I. 2001. Summer and autumn movements of white whales (*Delphinapterus leucas*) in Svalbard, Norway. Mar. Ecol. Prog. Ser. 219: 265-274.

Lydersen, C., Nøst, O.A., Lovell, P., McConnell, B.J., Gammelsrød, T., Hunter, C., Fedak, M. A. and Kovacs, K.M. 2002. Salinity and temperature structure of a freezing Arctic fjord - monitored by white whales (*Delphinapterus leucas*). Geophys. Res. Lett. 29, 2119, doi. 10.1029/2002GL015462.

Lydersen, C., Martin, T., Gjertz, I. and Kovacs, K.M. 2007. Satellite tracking and diving behaviour of sub-adult narwhals (*Monodon monoceros*) in Svalbard, Norway. Polar Biol. 30: 437-442.

Marshall, G., Bakhtiari, M., Shepard, M., Tweedy, J.I., Rasch, D., Abernathy, K., Joliff, B., Carrier, J.C. and Heithaus, M.R. 2007. An advanced solid-state animal-borne video and environmental data-logging device ("crittercam") for marine reseacrh. Mar. Techn. Soc. J. 41: 31-38.

Martin, A.R., da Silva, V.M.F. and Rothery, P.R. 2006. Does radio tagging affect the survival or reproduction in small cetaceans? A test. Mar. Mamm. Sci. 22: 17-24.

Mate, B.R. and Harvey, J.T. 1983. A new attachment device for radiotagging large whales. J. Wildl. Manage. 47: 868-872.

Mate, B., Mesecar, R. and Lagerquist, B. 2007. The evolution of satellite-monitored radio tags for large whales: one laboratory's experience. Deep-Sea Res. II: 54: 224-247.

Mate, B., Best, P.B., Lagerquist, B.A. and Windsor, M.H. 2011. Coastal, offshore, and migratory movements of South African right whales revealed by satellite telemetry. Mar. Mamm. Sci. 27: 455-476.

Noren, D., and Mocklon, J.A. 2012. Review of cetacean biopsy techniques: Factors contributing to successful sample collection and physiological and behavioral impacts. Mar. Mamm. Sci. 28: 154-199.

Norris, K.S. and Pryor, K.W. 1970. A tagging method for small cetaceans. J. Mammal. 51: 609-610.

Orr, J.R., St. Aubin, D.J., Richard, P.R. and Heide-Jørgensen, M.P. 1998. Recapture of belugas, *Delphinapterus leucas,* tagged in the Canadian arctic. Mar. Mamm. Sci. 14: 829-834.

Read, A.J. and Gaskin, D.E. 1985. Radio tracking the movement and activities of harbor porpoises, *Phocoena phocoena* (L.), in the Bay of Fundy, Canada. Fish. Bull. 83: 543-552.

Sato, K., Watanuki, Y., Takahashi, A., Miller, P.J.O., Tanaka, H., Kawabe, R., Ponganis, P. J., Handrich, Y., Akamatsu, T., Watanabe, Y., Mitani, Y., Costa, D.P., Brost, C.-A., Aoki, K., Amano, M., Trathan, P., Shapiro, A. and Naito, Y. 2007. Stroke frequency, but not swimming speed, is related to body size in free-ranging seabirds, pinnipeds and cetaceans. Proc. R. Soc. B 274: 471-477.

Schneider, K. and Baird, R.W. 1998. Reactions of bottlenose dolphins to tagging attempts using a remotely-deployed suction-cup tag. Mar. Mammal Sci. 14: 316-324.

Scott, M.D., Irvine, A.B., Wells, R.S. and Mate, B. 1990. Tagging and marking studies on small cetacenas. Pp. 489-514 In: Leatherwood, S. and Reeves, R.R. (eds.) The bottlenose dolphin. Acad. Press, San Diego, USA.

Scott, M.D. and Chivers, S.J. 2009. Movements and diving behavior of pelagic spotted dolphins. Mar. Mammal Sci. 25: 137-160.

Sonne, C., Teilmann, J., Wright, A.J., Dietz, R. and Leifsson, P.S. 2012. Tissue healing in two harbour porpoises (*Phocena phocoena*) following ling-term satellite transmitter attachment. Mar. Mammal Sci. 28: in press.

St. Aubin, D.J. and Geraci, J.R. 1988. Capture and handling stress suppress circulating levels of thyroxine (T4) and triiodothyronine (T3) in beluga whales (*Delphinapterus leucas*). Physiol. Zool. 61: 170-175.

Sveegaard, S., Teilmann, J., Tougaard, J., Dietz, R., Mouritsen, K. N., Desportes, G. and Siebert, U. 2011. High-density areas for harbour porpoises (*Phocoena phocoena*) identified by satellite tracking. Mar. Mammal. Sci. 27: 230-246.

Walker, K.A., Trites, A.W., Haulena, M. and Weary, D.M. 2012. A review of the effects of different marking and tagging techniques on marine mammals. Wildl. Res. in press.

Watkins, W.A. and Tyack, P. 1991. Reaction of sperm whales (*Physether catodon)* to tagging with implanted sonar transponder and radio tags. Mar. Mammal Sci. 7: 409-413.

Wells, R.S. 2002. Identification methods. Pp. 601-608 In: Perrin, W.F., Würsig, B. and Thewissen, J.M. G (eds.). Encyclopedia of marine mammals. Acad. Press, San Diego, USA.

Westdal, K.H., Richard, P.R. and Orr, J.R. 2010. Migration route and seasonal home range of the northern Hudson Bay narwhal (*Monodon monoceros*). Pp. 71-91 In: Ferguson, S.H., Loseto, L.L. and Mallory, M.L. (Eds.) A little less Arctic. Top predators in the world's largest northern inland sea, Hudson Bay. Springer, New York, USA.

Westgate, A.J., McLellan, W.A., Wells, R.S., Scott, M.D., Meagher, E.M. and Pabst, D.A. 2007. A new device to remotely measure heat flux and skin temperature from free-swimming dolphins. J. Exp. Mar. Biol. Ecol. 346: 45-59.

Zerbini, A.N., Andriolo, A., Heide-Jørgensen, M.P., Pizzirno, J.L., Maia, Y.G., VanBlaricom, G.R., DeMAster, D.P., Simoes-Lopes, P.C., Moriera, S. and Bethlem, C. 2006. Satellite-motnored movements of humpback whales *Megaptera novaeangliae* in the southwest Atlantic Ocean. Mar. Ecol. Progr. S.

References for Wild Birds:

Aarvak, T. and Øien, I.J. In prep. Fagnst med kannonnett. Den ultimate guiden til smell, røyk og avansert fuglefangst. Norsk Orn. For. Report x-201x.

Adams, J., Scott, D., McKechnie, S., Blackwell, G., Shaffer, S.A. and Moller, H. 2009. Effects of geolocation archival tags on reproduction and adult body mass of sooty shearwaters (Puffinus griseus). New Zealand J. Zool. 36: 355-366.

Bakken, V., Runde, O. and Tjørve, E. 2003. Norsk Ringmerkingsatlas. Vol. 1. Stavanger Museum, Stavanger.

Bakken, V., Runde, O. and Tjørve, E. 2006. Norsk Ringmerkingsatlas. Vol. 2. Stavanger Museum, Stavanger.

Bairlein, F., Norris, D.R., Nagel, R., Bulte, M., Voigt, C.C., Fox, J.W., Hussel, D.J.T. and Schmaljohann, H. 2012. Cross-hemisphere migration of a 25 g songbird. Biol. Lett. doi:10.1098/rsbl.2011.1223

Bannasch, R., Wilson, R.P. and Culik, B. 1994. Hydrodynamic aspects of design and attachment of a back-mounted device in penguins. J. Exp. Biol. 194: 83-96.

Barron, D.G., Brawn, J.D. and Weatherhead, P.J. 2010. Meta.analysis of transmitter effects on avian behaviour and ecology. Methods in Ecol. and Evol. 1: 180-187.

Bennett, R.A., Yaeger, M.J., Trapp, A. and Cambre, R.C. 1997. Histological evaluation of the tissue reaction to five suture materials in the body wall of rock doves (C*olumba livia*). J. Avian. Med. Surg. 11: 175-182.

Benson, J. and Syryan, R.M. 1999. A leg-noose for capturing adult kittiwakes at the nest. J. Field Ornithol. 70: 393-399.

Boersma, P.D. and Rebstock, G.A. 2009. Flipper bands do not affect foraging-trip duration of Magellanic penguins. J. Field Ornithol. 80: 408-418.

Bogdanova, M.I., Daunt, F., Newell, M., Phillips, R.A., Harris, M.P. and Wanless, S. 2011. Seasonal interactions in the black-legged kittiwake, *Rissa tridactyla*: links between breeding performance and winter distribution. Proc. Roy. Soc. B 278: 2412-2418.

Brander, R.B. and Cochran, W.W. 1969. Radio location telemetry. Pp. 95-103 in Giles, R.H. (ed.) Wildlife Management techniques. The Wildl. Soc., Washington, D.C.

Breault, A.M. and Cheng, K.M. 1990. Use of submerged mist nets to capture diving birds. J. Field Ornothol. 61: 328-330.

Brodsky, L.M. 1988. Ornament size size influences mating success in male rock ptarmigan. Animal Behav. 36: 662-667.

Bub, H. 1991. Bird Trapping and Bird Banding: a Handbook for Trapping Methods all Over the World. Cornell Univ. Press, 330.

Bugoni, L., Neves, T.S., Peppes, F.V. and Furness, R.W. 2008. An effective method for trapping scavenging seabirds at sea. J. Field Ornithol. 79: 308-313.

Burger, A.E. and Schaffer, S.A. 2008. Application of tracking and data-logging technology in research and conservation of seabirds. Auk 125: 253-264.

Bustnes, J.O., Mosbech, A., Sone, C. and Systad, G.H. 2010. Migration patterns, breeding and moulting locations of king eiders wintering in north-eastern Norway. Polar Biol. 33: 1379-1385.

Byers, S.M. 1987. Extent and severity of nasal saddle icing on mallards. J. Wildl. Manage. 45: 498-501.

Båtvik, J.I.I. (Ed.), Bakken, V., Ree, V., Runde, O., Røer, J.E., Røstad, O.W., Sandvik, J., Soot, K.M. and Toft, G.O. 1999. A-kurs i ringmerking – et supplement til Ringmerkerens Håndbok. NOF Rapportserie nr. 3-199.

Caccamise, D.F. and Hedin, R.S. 1985. An aerodynamic basis for selecting transmitter loads in birds. Wilson Bull. 97: 306-318.

Calvo, B. and Furness, R.W. 1992. A review of the use and effects of marks and devices on birds. Ringing and Migration 13: 129-151.

Carey, M.J. 2011. Leg-mounted data-loggers do not affect the reproductive performance of short-tailed shearwaters (*Pufinus tenuirostris*). Wildl. Res. 38: 740-746

Casper, R.M. 2009. Guidelines for the instrumentation of wild birds and mammals. Animal Behav. 78: 1477-1483.

Clark, G. 1948. Fowling in prehistoric Europe. Antiquity 22: 116-130.

Clark, N.A., Gillings, S., Baker, A.J., González, P.M. and Porter, R. 2005. The production and use of permanently inscribed leg flags for waders. Wader Study Gp. Bul.. 108: 38-41.

Clarke, J. and Kerry, K. 1998. Implanted transponders in penguins: implantation, reliability, and long-term effects. J. Field Ornithol. 69: 149-159.

Conklin, J.R. and Battley, P.F. 2010. Attachment of geolocators to bar-tailed godwits: a tibia-mounted method with no survival effects or loss of units. Wader Study Gp. Bull. 117: 56-58.

Cooke, S.J., Hinch, S.G., Wikelski, M., Andrews, R.D., Kuchel, L.J., Wolcott, T.G. and Butler, P.J. 2004. Biotelemetry: a mechanistic approach to ecology. TREE 19: 334-343.

Costanzo, G.R., Williamson, R.A. and Hayes, D.E. 1995. An efficient method for capturing flightless geese. Wildl. Soc. Bull. 23: 201-203.

Creswell, W., Lind, J., Quin, J.L., Minderman, J. and Whitfield, D.P. 2007. Ringing or colour-banding does not increase predation mortality in redshanks *Tringus totanus*. J. Avian Biol. 38: 309-316.

Culik, B.M., Wilson, R.P. and Bannasch, R. 1993. Flipper-bands on penguins: what is he cost of a life-long commitment? Mar. Ecol. Prog. Ser. 98: 209-214.

Culik,, B.M., Bannasch, R. and Wilson, R.P. 1994. External devices on penguins: how important is shape? Mar. Biol. 118: 353-357.

Dwyer, T.J. 1972. An adjustable radio-package for ducks. Bird-Banding. 43: 282-284.

Eastham, A. 2005. Papageno down the ages: a study in fowling methods, with particular reference to the Palaeolithic of Western Europe. Munibe (Anthropologia-Arkeologia) 57: 369-397.

Edwards, D.B. and Gilchrist, H.G. 2011. A new means of catching shorebirds: the Super Talon Net Gun. Wader Study Gp. Bull. 118: 134-136.

Evrard, J.O. 1986. Loss of nasal saddle on Mallard. J. Field ornithol. 57: 170.171.

Fair, J., Paul, E. and Jones, J. (eds.). 2010. Guidelines to the Use of Wild Birds in Research. Washington, D.C.: Ornithological Council.

Fallow, P.M., Chiaradia, A., Ropert-Coudert, Y., Kato, A. and Reina, R.D. 2009. Flipper bands modify the short-term diving behavior of little penguins. J. Wildl. Manage. 73: 1348-1354.

Fast, P.L.F., Fast, M., Mosbech, A., Sonne, C., Gilchrist, H.G. and Desccamps, S. 2011. Effects of implanted satellite transmitters on behavior and survival of female common eiders. J. Wildl. Manage. 75: 1553-1557.

Frederiksen, M., Moe, B., Daunt, F., Phillips, R.A., Barrett, R.T., Bogdanova, M.I., Boulinier, T., Chardine, J.W., Chastel, O., Chivers, L.S., Christensen-Dalsgaard, S., Clément-Chastel, C., Colhoun, K., Freeman, R., Gaston, A.J., Gonzalés-Solis, J., Goutte, A., Grémillet, D., Guilford, T., Jensen, G.H., Krasnov, Y., Lorentsen, S.H., Mallory, M.L., Newell, M., Olsen, B., Shaw, D., Steen, H., Strøm, H., Systad, G.H., Thòrarinsson, T.L., Anker-Nilssen, T. 2011. Multicolony tracking reveals the winter distribution of a pelagic seabird on an ocean basin scale. Diversity Distrib. 2011: 1-13. doi: 10.1111/j.1472-4642.2011.00864.x

Gartshore, M.E. 1978. A noose trap for catching nesting birds. North American Bird Bander 3: 1-2.

Gauthier-Clerc, M., Gender, J.-P., Ribic, C.A., Fraser, W.R., Woehler, E.J., Descamps, S., Gilly, C., Le Bohec, C. and Le Maho, Y. 2004. Long-term effects of flipper bands on penguins. Proc. R. Soc. Lond. BG (Suppl.) 271: 423-426.

Gendner, J.-P., Gauthier-Clerc, M., Le Bohec, C.L., Deschamps, S. and Le Maho, Y. 2005. A new application for transponders in studying penguins. J. Field Ornithol. 76: 138-142.

Godfrey, J.D. and Bryant, D.M. 2003. Effects of radio transmitters: Review of recent radio-tracking studies. Pp. 83-95 in Williams, M. (Comp.) Conservation applications of measuring energy expenditure of New Zealand birds: Assessing habitat quality an costs of carrying radio transmitters. Sci. Conservat. 241, 95.

Green, A.J., Fuentes, C., Vázquez, M., Viedma, C. and Ramón, N. 2004. Use of wing tags and other methods to mark marbled teal (*Marmaronetta angustrirostris*) in Spain. Ardeola 51: 191-202.

Grémillet, D. and Wilson, R.P. 1998. A remote-controlled net trap for ground-nesting cormorants. Seabird 20: 44-47.

Harris, M.P. 1984. The Puffin. T and D Poyser, Calton.

Hart, A.D.M. 1987. Patagial tags for herring gulls: improved durability. Ringing and Migration 8: 19-26.

Hawkins, P. 2004. Bio-logging and animal welfare: practical refinements. Mem. Natl. Inst. Polar Res., Spec. Issue, 58: 58-68.

Herring, G., Gawlik, D.E. and Beerens, J.M. 2008. Evaluating two new methods for capturing large wetland birds. J. Field Ornithol. 79: 102-110.

Jackson, S. and Wilson, R.P. 2002. The potential costs of flipper bands. Functional Ecol. 16: 141-148.

Karl, B.J. and Clout, M.N. 1987. An improved radio transmitter harness with a weak link to prevent snagging. J. Field Ornithol. 58: 73-77.

Kenward, R.E. (ed.) 2001. A Manual for Wildlife Radio Tagging. Academic press, London.

Kesler, D.C. 2011. Non-permanent radiotelemetry leg harness for small birds. J. Wildl. Manage. 75: 467-471.

Kidawa, D., Jakubas, D., Wojczulanis-Jakubas, K., Iliszko, L., Stempniewicz, L. 2011. The effects of loggers on the foraging effort and chick-rearing ability of parent little auks. Polar Biol. DOI: 10.1007/s00300-011-1136-5.

Kinkel, L.K. 1989. Lasting effects of wing tags on ring-billed gulls. Auk 106: 619-624.

Kooyman, G.L. 2004. Genesis and evolution of bio-logging devices: 1963-2002. Mem. Natl. Inst. Polar Res., Spec. Issue 58: 15-22.

Korschgen, C.E., Kenow, K.P., Gendron-Fitspatrick, A., Green, W.L. and Dein, F.J. 1996. Implanting intra-abdominal radio transmitters with external whip antennas in ducks. J. Wildl. Manage. 60: 132-137.

Machin, K.L. and Caulkett, N.A. 2000. Evaluation of isoflurane and propofol anesthesia for intraabdmonal transmitter placement in nesting female canvasback ducks. J. Wildl. Diseases 36: 324-334.

Madsen, J., Tombre, I. and Eide, N.E. 2009. Effects of disturbance on geese in Svalbard: implications for regulating increasing tourism. Polar res. 28: 376-379.

McGowan, C.P. and Simmons, T.R. 2005. A method for trapping breeding adult American oystercatchers. J. Field Ornithol. 76: 46-49.

McMahon, C.R., Collier, N., Northfield, J.K. and Glen, F. 2011. Taking the time to assess the effects of remote sensing and tracking devices on animals. Anim. Welfare 20: 515-521.

Mehl, K.R., Drake, K.L., Page, G.W., Sanzenbacher, P.M., Haig, S.M. and Thompson, J.E. 2003. Capture of breeding and wintering shorebirds with leg-hold noose-mats. J. Field Ornithol. 74: 401-405.

Milton, R., O'Brien, M., Moody, R., Boudreau, M. and Boyd, G.R. 2004. Use of helicopter to capture molting common eider *Somateria mollissima*. Global Flyway Conf. "Waterbirds Around the World," 3-8 April 2004. Edinburgh, UK (Poster) – cited in Ronconi et al. 2010.

Mulcahy, D.M. and Esler, D. 1999. Surgical and immediate post-release mortality of harlequin ducks (*Histrionicus histrionicus*) implanted with abdominal radio transmitters with percutaneous antennae. J. Zoo Wildl. Med. 30: 397-401.

Murray, D.L. and Fuller, M.R. 2000. A critical review of the effects of marking on the biology of vertebrates. Pp. 15-64 in Boitani, L. and Fuller, T.K. (eds.) Research Techniques in Animal Ecology: Controversies and Consequences. Columbia Univ. Press, New York.

Nettleship, D.N. 1969. Trapping common puffin fledglings. Bird-Banding 40: 139-144.

Neumann, G.H. 1982. Normatives verhalten und aggressive aussenseiterreaktionen bei gesellig labenden vögeln. Seevogel 1982 suppl.: 115-124.

Neumann, G.H. 1985. Untersuchungen über nebenwirkungen farblicher Gefiedermarkierungen bei Lachmöen (*Larus ridibundus*) auf einer mülldeponie und unter laborbedingungen und bei brütenden Austernfischern (*Haematopus ostralegus*). Seevogel, 6, Suppl.: 158-170.

Obrecht, H.H., Pennycuick, C.J. and Fuller, M.R. 1988. Wind tunnel experiments to assess the effect of back-mounted radio transmitters on bird body drag. J. Exp. Biol. 135: 265-273.

O'Gara, B.W. and Getz, D.C. 1986. Capturing golden eagles using a helicopter and net gun. Wildl. Soc. Bull. 14: 400-401.

Owen, M. and Ogilvie, M.A. 1979. Wing molt and weights of barnacle geese in Spitsbergen. Condor 81: 42-52.

Passos, C., Navarro, J., Giudici, A. and González-Solís, J. 2010. Effects of extra mass on the pelagic behaviour of a seabird. Auk 127: 100-107.

Petersen, M.R., Bustnes, J.O. and Systad, G.H. 2006. Breeding and moulting locations and migration patterns of the Atlantic population of Steller's eiders *Polysticta stelleri* as determined from satellite telemetry. J. Avian Biol. 37: 58-68.

Phalen, D.N., Mitchell, M.E. and Cavazos-Martinez, M.L. 1996. Evaluation of three heat sources for their ability to maintain body core temperature in the anesthetized avian patient. J. Avian Med. Surg. 10: 174-178.

Phillips, R.A., Xavier, J.C. and Croxall, J.P. 2003. Effects of satellite transmitters on albatrosses and petrels. Auk 120: 1082-1090.

Ralph, C.J., Geupel, G.R., Pyle, P., Martin, T.E. and DeSante, D.F. 1993. Handbook of Field Methods for Monitoring Landbirds. US Dep. Agric. Forest Service, Albany, USA.

Raveling, D.G. 1969. Social classes of Canada geese in winter. J. Wildl. Manage. 33: 304-318.

Recher, H.F., Gowing, G. and Armstrong, T. 1985. Causes and frequency of deaths among birds mist-netted for banding studies at two localities. Austr. Wildl. Res. 12: 321-326.

Regehr, H.M. and Rodway, M.S. 2003. Evaluation of nasal discs and colored leg bands as markers for harlequin ducks. J. Field Ornithol. 74: 129-135.

Rogers, D.I., Battley, P.F., Sparrow, J., Koolhas, A. and Hassell, C.J. 2004. Treatment of capture myopathy in shorebirds: a successful trial in northwestern Australia. J. Field. Ornithol. 75: 157-164.

Ronconi, R.A., Swaim, Z.T., Lane, H.A., Hunnewell, R.W., Westgate, A.J., Koopman, H.N. 2010. Modified hoop-net techniques for capturing birds at sea and comparisons with other capture methods. Mar. Ornithol. 38: 23-29.

Ropert-Coudert, Y., Kato, A., Poulin, N. and Grémillet, D. 2009. Leg-attached data loggers do not modify the diving performances of a foot-propelled seabird. J. Zool. 279: 294-297.

Runde, O. 1991 (Ed.) Ringmerkerens Håndbok. Norsk Ornitologisk Forening, Trondheim.

Saraux, C., Le Bohec, C., Durant, J.M., Viblanc, V.A., Gauthier-Clerc, M., Beaune, D., Park, Y.-H., Yoccoz, N.G., Stenseth, N.C. and Le Maho, Y.L. 2011. Reliability of flipper-banded penguins as indicators of climate change. Nature 469: 203-206.

Schmutz, J.A. and Morse, J.A. 2000. Effects of neck collars and radiotransmitters on survival and reproduction of emporer geese. J. Wildl. Manage. 64: 231-237.

Smallwood, G.A. and Natale, C. 1998. The effect of patagial tags on breeding success in American kestrels. North American Bird Bander 23: 73-78.

Sokolov, L.V. 2011. Modern telemetry: new possibilities in ornithology. Biol. Bull. 38: 885-904.

Sonne, C., Andersen, S., Mosbech, A., Flagstad, A. and Merkel, F. 2011. Monitoring temperature and heart rate during surgical field implantation of PTT-100 satellite transmitters in Greenland sea birds. Vet. Med. Intern. 2011, Article ID 423010, doi:10.4061/2011/423010.

Southern, L.K. and Southern, W.E. 1983. Responses of ring-billed gulls to cannon-netting and wing-tagging. J. Wildl. Manage. 47: 234-237.

Southern, L.K. and Southern, W.E. 1985. Some effects of wing tags on breeding ring-billed gulls. Auk 102: 38-42.

Spotswood, E.N., Goodman, K.R., Carlisle, J., Cormier, R.L., Humple, D.L., Rousseau, J., Guers, S.L. and Barton, G.G. 2011. How safe is mist netting? Evaluating the risk of injury and mortality to birds. Methods in Ecol. and Evol. doi: 10.1111/j.2041-210X.2011.00123.x

Steen, H., Vogedes, D., Broms, F., Falk-Petersen, S. and Berge, J. 2007. Little auks (*Alle alle*) breeding in a High Arctic fjord system: bimodal foraging strategies as a response to poor food quality. Polar Res. 26: 118-125.

Stuchbury, J.M., Tarof, S.A., Done, T., Gow, M., Kramer, P.M., Tautin, J., Fox, J.W. and Afanasyev, V. 2009. Tracking long-distance songbird migration by using geolocators. Science 323: 896.

Sugden, L.G. and Posten, H.J. 1968. A nasal marker for ducks. J. Wildl. Manage. 16: 87-90.

Vandanabeele, S.P., Wilson, R.P. and Grogan, A. 2011. Tags on seabirds: how seriously are instrument-induced behaviours considered? Anim. Welfare 20: 559-571.

Vandanabeele, S.P., Shepard, E.L., Grogan, A. and Wilson, R.P. 2012. When three per cent may not be three per cent; device-equipped seabirds experience variable flight constraints. Mar. Biol. 159: 1-14.

Villard, P., Bonefant, C. and Bretagnolle, V. 2011. Effects of satellite transmitters fitted to breeding Cory's shearwaters. J. Wildl. Manage. 75: 709-714.

Wheeler, W.E. 1991. Suture and glue attachment of radio transmitters on ducks. J. Field Ornithol. 62: 271-278.

Wilson, R.P., Pütz, K., Peters, G., Culik, B. 1997. Long-term attachment of transmitting and recording devices to penguins and other seabirds. Wildl. Soc. Bull. 25: 101-106.

Wilson, R.P. 2011.The price tag. Nature 469: 164-165.

Whitworth, D., Newman, S., Mundkur, T. and Harris, P. 2007. Wild Birds and Avian Influenza. FAO Animal Production and Health Manual No. 5. www://ftp.fao.org/docrep/fao/101/a1521e/a1521e.pdf

Woolnough, A.P., Kirkpatrick, W.E., Lowe, T.J. and Rose, K. 2004. Comparison of three techniques for the attachment of radio transmitters to European starlings. J. Field Ornithol. 75: 330.336.

Zubergogoitia, I., Martínez, J.E., Martínez, J.A., Zabala, J., Calvo, J.F., Azkona, A., Pagan, I. 2008. The Dho-gaza and mist net with Eurasian eagle-owl (*Bubo bubo*) lure: effectiveness in capturing thirteen species of European raptors. J. Raptor Res. 42: 48-51.

References for Data Gaps:

Cattet, M., Boulanger, J., Stenhouse, G., Powell, R.A., and Reynolds-Hogland, M.J. 2008. An evaluation of long-term capture effects in ursids: implications for wildlife welfare and research. J. Mammal. 89:973-990.

Fijn, R.C., Boudewijn, T.J. and Poot, J.M. 2012. Long-term attachment of GPS loggers with tape on great cormorant Phalacrocorax carbo sinensis proved unsuitable from tests on a captive bird. Seabird 25: 54-60.

Trefry, S.A., Diamond, A.W. and Jesson, L.K. 2013. Wing marker woes: a case study and meta-analysis of the impacts of wing and patagial tags. J. Ornithol. 154: 1-11.

Appendix

Number of ringed birds of different species in Norway during the years 2009-2011:

Art	2009	2010	2011	Total
Stokkand	496	707	204	1407
Fiskemåke	493	617	1397	2507
Knoppsvane	71	199	215	485
Toppand	8	8	4	20
Gråmåke	1142	1352	1366	3860
Gråmåke (argentatus)	1	97	5	103
Gråmåke (argenteus)	0	1	0	1
Hettemåke	138	275	414	827
Grønlandsmåke	2	0	2	4
Sothøne	35	35	29	99
Brunnakke	10	13	5	28
Spurvehauk	128	125	166	419
Vannrikse	34	14	4	52
Hønsehauk	87	108	119	314
Spurveugle	24	55	398	477
Kvartbekkasin	13	9	8	30
Kanadagås	20	14	12	46
Kongeørn	33	41	66	140
Kattugle	1084	1310	1161	3555
Lirype	15	3	0	18
Toppdykker	1	0	0	1
Laksand	7	5	0	12
Myrsnipe	813	1988	1546	4347
Musvåk	10	30	34	74
Krykkje	549	579	717	1845
Sildemåke	328	525	452	1305
Sildemåke (intermedius)	1206	172	626	2004
Sildemåke (fuscus)	33	274	14	321
Svartbak	912	925	672	2509
Fjæreplytt	771	1586	1185	3542
Storskarv	323	360	361	1044
Storskarv (sinensis)	482	291	189	962
Storskarv (carbo)	34	6	49	89
Grågås	103	155	172	430
Rugde	30	49	50	129
Perleugle	288	1676	3000	4964
Kortnebbgås	6	3	2	11

Hornugle	21	39	77	137
Sivhøne	6	8	5	19
Enkeltbekkasin	31	36	39	106
Tårnfalk	567	1504	1903	3974
Skogsnipe	9	14	2	25
Krikkand	3	5	8	16
Siland	11	4	4	19
Dvergfalk	19	42	59	120
Kvinand	41	61	18	120
Brushane	38	75	217	330
Storfugl	3	3	5	11
Ærfugl	153	73	107	333
Tjeld	86	86	123	295
Strandsnipe	231	120	80	431
Hvitkinngås	215	224	128	567
Lunde	440	127	205	772
Hubro	25	27	39	91
Sandlo	176	261	245	682
Lappspove	222	146	124	492
Vipe	76	123	173	372
Polarsnipe	673	951	99	1723
Dverggås	4	5	6	15
Fjellvåk	1	29	24	54
Vaktel	2	0	1	3
Åkerrikse	14	7	8	29
Dobbeltbekkasin	146	202	221	569
Makrellterne	379	200	162	741
Toppskarv	197	491	218	906
Havørn	116	99	129	344
Svartehavsmåke	2	0	1	3
Vandrefalk	30	30	22	82
Rødstilk	74	326	92	492
Rødstilk (totanus)	7	0	0	7
Rødstilk (robusta)	1	6	2	9
Dverglo	1	2	0	3
Havsule	118	126	5	249
Havsvale	143	179	269	591
Havsvale (pelagicus)	0	19	0	19
Storspove	15	23	59	97
Jaktfalk	6	16	19	41
Polarmåke	169	120	331	620
Trane	9	6	9	24
Lomvi	565	357	603	1525
Heilo	10	11	7	28
Storjo	115	367	320	802
Grønnstilk	13	7	8	28

Rødnebbterne	379	178	82	639
Polarlomvi	55	77	463	595
Sotsnipe	2	5	1	8
Småspove	8	1	7	16
Fjellmyrløper	5	1	11	17
Tyvjo	19	16	20	55
Alke	71	59	10	140
Fiskeørn	65	66	40	171
Temmincksnipe	13	20	38	71
Teist	99	114	75	288
Gråhegre	2	2	34	38
Alkekonge	544	659	891	2094
Myrhauk	11	9	4	24
Polarsvømmesnipe	5	4	0	9
Lerkefalk	26	10	13	49
Storlom	3	2	3	8
Havhest	15	118	83	216
Boltit	1	1	20	22
Smålom	7	11	14	32
Vepsevåk	6	7	12	25
Stormsvale	5	2	1	8
Gluttsnipe	1	0	5	6
Steinvender	42	253	41	336
Tundrasnipe	16	35	78	129
Sjøorre	2	0	0	2
Dvergsnipe	17	34	138	189
Sandløper	33	93	27	153
Haukugle	5	28	77	110
Tundralo	1	1	9	11
Fasan	3	4	3	10
Islom	1	0	0	1
Stjertand	1	1	1	3
Sangsvane	0	3	4	7
Jordugle	0	22	34	56
Mandarinand	0	1	0	1
Sædgås (fabalis)	0	6	0	6
Sædgås (rossicus)	0	68	0	68
Slagugle	0	12	39	51
Lappugle	0	16	56	72
Svarthalespove (limosa)	0	3	0	3
Svømmesnipe	0	1	0	1
Sivhauk	0	4	0	4
Tårnugle	0	1	0	1
Fjelljo	0	6	7	13
Ismåke	0	14	9	23
Tundragås (albifrons)	0	1	0	1

Jerpe	0	2	0	2
Gravand	0	1	0	1
Gulbeinmåke	0	1	0	1
Myrrikse	0	1	0	1
Rapphøne	0	2	3	5
Ringnebbmåke	0	1	0	1
Snøugle	0	0	36	36
Orrfugl	0	0	1	1
Sabinemåke	0	0	2	2
Grønlandsmåke	0	0	2	2
Sørjo	0	0	22	22
Antarktispetrell	0	0	128	128
Snøpetrell	0	0	6	6
Sum	16376	22141	23370	61887