THE KARLSÖ MURRE LAB METHODOLOGY CAN STIMULATE INNOVATIVE SEABIRD RESEARCH

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SUMMARY

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Studies of seabirds have contributed substantially to theoretical and applied ecology, but practical limitations in the field and lack of knowledge of the life history of studied birds often constitute significant hurdles to progress in research. In the middle of the largest seabird colony in the Baltic Sea, on the island of Stora Karlsö, we have built an artificial breeding site for Common Murres *Uria aalge*. The Karlsö Murre Lab enables high-resolution studies with minimal disturbance of the breeding birds. It became operational, with the first recruitment of breeding murres, in 2009. Building materials and location were chosen to minimize environmental impact. The lab was constructed to allow future outfitting with a range of high-technology devices. Since most of the fledged chicks in the subcolony have been ringed over the last 10 years, this will enable recruitment and studies using advanced technology of birds with known life history. Hence, we will be able to perform seabird studies with a resolution that is impossible in a strictly natural environment. Better knowledge of links between seabirds and their environment facilitates the use of seabirds as indicators, which in turn can improve marine ecosystem-based management.

Key words: Alcidae, Common Guillemot, Baltic Sea, life history, marine management, seabirds, technology

INTRODUCTION

Research on seabirds has generated important insights relevant to theoretical and applied ecology, e.g. from studies of life history (Erikstad *et al.* 1998, Rebke *et al.* 2010), ethology (Birkhead *et al.* 1985, Olsson *et al.* 2001), foraging behavior (Burger & Piatt 1990, Weimerskirch *et al.* 2009), physiology (Bauch *et al*. 2010, Kitaysky *et al.* 2010), demography (Ezard *et al.* 2006, Jenouvrier *et al.* 2008), impacts of climate change (Thompson & Ollason 2001, Jenouvrier *et al.* 2009), fisheries (Melvin *et al.* 1999, Furness 2003), chemical and oil pollution (Holmström *et al.* 2005, Riffaut *et al.* 2005) and colony restoration (Towns 2002). A comprehensive understanding of the linkages between seabirds and their environment requires studies addressing dynamics ranging from short-term (physiology, movement, foraging and behavioral ecology) to long-term (life history and population ecology) and from small (colony) to large (marine ecosystem) scales. The ideal approach should also be multi-species and multi-disciplinary, which would improve the applicability of seabirds as indicators of change in marine ecosystems by improving the understanding of their response to change (Cairns 1987, Furness & Camphuysen 1997, Piatt *et al.* 2007a, Piatt *et al.* 2007b, Parsons *et al.* 2008)

Owing to their high visibility and charisma, colonially breeding seabirds are commonly perceived as having a high conservation value for ethical reasons, and are linked to ecosystem services (e.g. generating income through ecotourism; Boersma 2008). However, performing science on cliff-nesting seabirds breeding on inaccessible exposed ledges is a significant challenge. Major colonies are often protected by legislation, and, to avoid disturbance, performing research in such areas requires careful consideration of the methods used (Carney & Sydeman 1999). Scientific research builds on a foundation of trust (Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2009), and seabird researchers must continuously reflect on and reassess the value of their research. Conducting research in sensitive environments is a privilege with responsibilities. Scientists working in such environments should, as far as possible, use the best available technology for reducing disturbance, produce relevant research to be published in peer-reviewed literature, and widely disseminate their results to stakeholders.

The 2.5 km^2 island of Stora Karlsö (57°17'N, 18°58'E) is the major seabird-breeding site in the Baltic Sea. The breeding population of Common Murres *Uria aalge* consists of approximately 10 000 pairs. The island also holds breeding populations of Razorbill *Alca torda* (10 000 pairs), Great Cormorant *Phalacrocorax carbo* (1 000 pairs), Herring Gull *Larus argentatus* (600 pairs), Lesser Black-backed Gull *Larus fuscus* (500 pairs) and Arctic Tern *Sterna paradisaea* (200 pairs). Since 1913, 58 000 Common Murre chicks have been ringed on the island; together with long-term seabird monitoring and research, the ringing program makes Stora Karlsö the scientific hotspot for seabird studies in the area. The Baltic Sea's species-poor ecosystem has been substantially influenced by human activities during the last century and has a long history of marine data collection and scientific research, which is creating favorable conditions for the study of long-term ecosystem dynamics, including those involving seabirds. Studies using seabird colony data have so far focused on the direct (Österblom *et al.* 2002) and indirect (Österblom *et al.* 2006) effects of fishing, the potential population impacts of oil pollution (Olsson *et al.* 1999), disease

(Österblom *et al.* 2004), trends in persistent organic pollutants (e.g. Holmström *et al.* 2005) and life-history and demographic ecology (Hedgren 1979, Hedgren & Linnman 1979, Hedgren 1981). But not only researchers have historically benefitted from the unique values of Stora Karlsö. The island received environmental protection in 1880, and today over 9 000 tourists visit the island annually, the seabird colonies being one of the main attractions. Public interest in conservation and the high visibility of researchers working in the colony create incentives for scientists to develop research methods that allow detailed studies while minimizing disturbance. This paper describes recent methodological developments intended to meet this challenge. We present an artificial research laboratory situated in the middle of the Stora Karlsö Common Murre colony, discuss its potential, and relate it to similar existing facilities.

STUDY AREA AND METHODS

Years of brainstorming led to the idea of an artificial construction that would combine "natural settings" from the birds' perspective with improved accessibility and integrated technology from the researchers' perspective. After funding was secured in 2007, an architect, a construction engineer, a geotechnical expert and a construction company were contracted. One year of detailed planning concluded with a construction in steel, oak and limestone (Table 1). The lab consists of two basic entities: an inside room for researchers and equipment (1.5 m deep, see Fig. 1a) and outside ledges covered with limestone at six levels (Table 1), resembling the natural ledges in the colony (Fig. 1b). Two vertical steel pillars (HEA200 profiles) extend through the whole construction. Three steel floor structures (made from HEA120 profiles) are attached to the steel pillars, and vertical U-shaped steel profiles are attached to the floor structures. The wall facing the sea consists of oak boards that slide into the U-profiles (Figs. 1a and 1c). This construction solution is inspired by an ancient local method for mounting fishing huts ("bulhus") and enables full flexibility, as any board can be replaced at any time with sliding doors, a glass, or any other material. The inside room is accessed through a hatch in the top of the lab, and researchers move on ladders among the three floors. Untreated oak (Forest Stewardship Council–certified, www.fsc.org) is used for its combination of durability and low emissions. The oak boards fade naturally to grey, which makes the color of the lab increasingly resemble the surrounding cliff.

TABLE 1
Technical specifications of the Karlsö Murre Lab

Characteristic	Data
Outer dimensions (m)	11 (height), 5 (width), 1.5 (depth)
Total ledge length (m)	36
Weight (kg)	4000 (steel construction), 11 000 (total)
Cost including the planning phase (€)	450 000
Height above sea level (m)	40
Number of breeding pairs supported (maximum)	600
Expected life span of construction (minimum, years)	30

The production of a Digital Terrain Model (DTM) enabled prefabrication of the steel construction with great accuracy. It was brought to the island and mounted using a mobile crane. The only permanent disturbance of the natural environment for mounting the lab is a number of holes drilled in the cliff to secure the concrete foundations that the two vertical steel pillars are attached to, and to anchor the wires, attached to the top of the pillars, that pull the construction towards the cliff, thus holding it in place. A detailed description of the building technique, including original architect sketches, is available on the Baltic Seabird project website (www.balticseabird.com/murrelab.htm).

The planning process included an extensive review of available technological solutions for animal research, but no technological systems were put in place immediately after construction. Instead, we arranged sliding-door-style openings from the inside rooms behind every ledge. The high construction flexibility allows for easy future installation of antennas for Passive Integrated Transponder (PIT) tag readers, scales and cameras for video surveillance.

RESULTS AND DISCUSSION

The Karlsö Murre Lab provides opportunities for novel approaches to research relevant to theoretical and applied ecology while minimizing disturbance. Detailed knowledge about life history is crucial in understanding the links between seabirds and the environment (Furness & Greenwood 1993) and is thus important for establishing the value of seabirds as indicators.

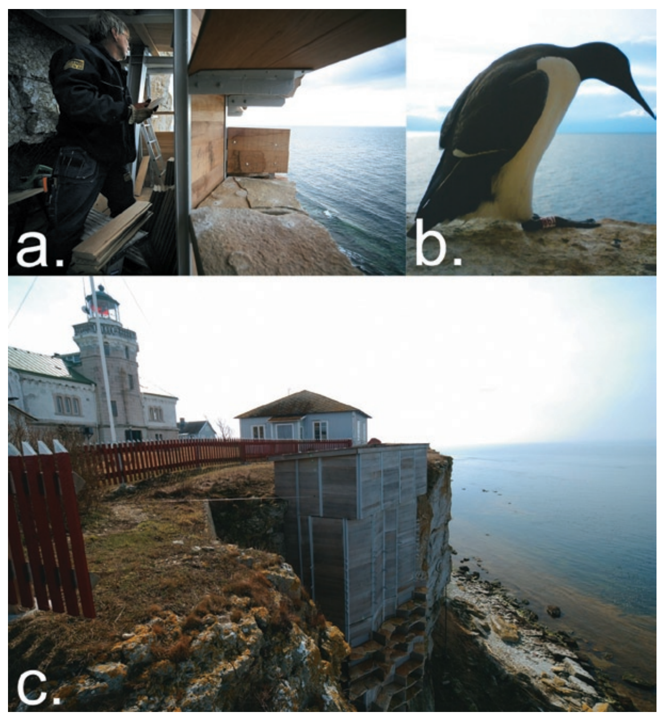

Fig. 1. The Karlsö Murre Lab, showing (a) a cross-section, with the inner room for researchers (on the left) and the bird ledges (on the right), (b) the marked individual T98, ringed as a chick in 2006 and photographed in 2009 with a mobile phone camera at an approximate distance of 30 cm, and (c) the location of the lab, immediately adjacent to the Stora Karlsö lighthouse. Photo credits: (a) Aron Hejdström, (b) Martina Kadin, (c) Magnus Melin.

Since 2000, more than 19 000 chicks have been ringed on the beach after fledging. This constitutes a majority of the chicks in the subcolony surrounding the lab. All chicks have also been weighed, sampled for DNA (enabling molecular sex determination and other studies) and ringed with field-readable, individually coded rings. Standardized studies of returning immature birds have been in place since 2002 and were expanded in 2007. A large proportion of the birds recruiting to the ledges on the lab can thus be expected to be ringed birds of known age with recorded previous visits. One pair recruited and several additional individuals visited regularly in 2009, the first year the lab was operational. In 2010, seven pairs recruited, of which four birds were ringed as chicks in the colony.

There are two main focuses for the research planned at the Karlsö Murre Lab (Table 2). One will relate environmental change to state-dependent responses in breeding Common Murres. The benefit of conducting this research at the Karlsö Murre Lab is that it allows researchers to study demographic change in birds with known life history. The other focus relates local fish abundance to foraging areas and diving behavior. Here, the benefit of using the Karlsö Murre Lab is that it allows researchers to easily attach and detach GPS (Geographical Positioning System), TDR (Time Depth Recorder) and GLS (Global Location Sensor) loggers, to arrange remote data collection from the inside room of the lab, and to collect fish samples from breeding birds.

Beyond our current research priorities for the Karlsö Murre Lab, we envision a number of other potential studies (Table 2) and welcome suggestions for partnerships with leading researchers. All in all, we think the combination of increased accessibility and technology

TABLE 2
Planned and potential studies in the Karlsö Murre Lab.

	Examples of research questions	Constraints in natural habitat	Benefits to using the Karlsö Murre Lab	References
Planned studies				
State-dependent response to environmental change	How does sex and age influence response and trade-ffs?	Sex, age and history unknown	Sex, age and history known	(McNamara and Houston 1996; Lecomte *et al.* 2010)
Foraging area and diving behavior	Where, when and how does foraging interact with fishing?	Difficult to catch birds and deploy and retrieve loggers	Loggers easily attached and detached, remote data collection	(Burger and Piatt 1990; Weimerskirch *et al.* 2009)
Potential studies				
Detailed behavior (ethology)	Sperm competition, extra-pair copulation and paternity, pair switching and mate choice	Observational difficulties, weather sensitive	Observation from distance of 20 cm, integrated videos	(Birkhead *et al.* 1985; Olsson *et al.* 2001; White *et al.* 2010)
Physiology	Hormonal response during the breeding cycle	Sampling difficulties, birds easily disturbed	Novel techniques of blood sampling without disturbance	(Lanctot *et al.* 2003; Becker *et al.* 2006; Kitaysky *et al.* 2010)
Contaminants	Bioaccumulation (fish–bird), bioelimination (parent–chick)	Sampling difficulties, birds easily disturbed	Parallel sampling of prey, eggs, chicks and adults during breeding	(Verreault *et al.* 2005)
Seabird colony restoration	How can ecological engineering contribute to seabird management?	-	Obtaining recruitment data from a new established subcolony	(Collis *et al.* 2002; Parker *et al.* 2007)

TABLE 3
Other projects that have used construction and innovative technology in studies and conservation of seabirds

Project description	Main objectives	Methodology	References
Wilhelmshaven artificial Common Tern colony	Research (technology use), conservation (establishment of a new colony)	Completely artificial colony; protection against predators; use of transponders and automatic balances	(Becker and Wendeln 1997; Becker *et al*. 2001)
Middleton Island modified radar tower for Kittiwakes	Research (accessibility, supplementary feeding)	Artificial construction with breeding kittiwakes, modified for research purposes	(Gill and Hatch 2002; Jodice *et al*. 2002)
Oregon state Caspian Tern colony restoration project	Conservation (colony restoration), relocation to reduce predation on endangered salmonid stocks	Construction of artificial island; decoys for attraction of birds; predation control	(Collis *et al*. 2002; Roby *et al*. 2002)

will significantly improve the potential for carrying out cutting-edge research. At the same time, the design can contribute to a high ethical standard of the research through minimized disturbance, which will ensure high legitimacy for scientists working in this sensitive environment.

In its design and possible applications, the Karlsö Murre Lab is related to other projects that have used construction and integrated technology to study seabirds. Table 3 summarizes a few examples from North America and Europe in which related methods have been applied. Regarding construction, the most similar example is an artificial colony of Black-legged Kittiwakes *Rissa tridactyla* on Middleton Island, Alaska, US (Gill & Hatch 2002). Detailed studies in the Middleton colony (e.g. Lanctot *et al.* 2003, White *et al.* 2010) became possible as birds started to breed on an abandoned radar tower (Gill & Hatch 2002). The main focus is research, and the handling procedure, with ledge-nesting birds accessible through wall openings, resembles the Karlsö Murre Lab system. The Wilhelmshaven Common Tern *Sterna hirundo* colony in Northwest Germany is another purpose-built facility enabling researchers to carry out high-technology, highly detailed studies (Table 3). In Wilhelmshaven, the construction has enabled the use of innovative technology (transponders, automatic scales and non-invasive blood-sampling), which has lead to significant scientific advances (e.g. Ezard *et al.* 2007, Becker *et al.* 2008, Rebke *et al.* 2010). There are also examples of construction and technology linked to seabirds with a more direct focus on conservation. The movement of a natural Caspian Tern *Sterna caspia* colony around the Columbia River estuary on the border between Oregon and Washington states in the United States is such an example. In this site, concerns about juvenile salmon *Oncorhynchus* spp. mortality due to tern predation triggered a human-assisted relocation of a large colony from one island to another (Roby *et al.* 2002) as well as the establishment of a small, artificial breeding colony on a floating barge (Collis *et al.* 2002). The recruitment of birds to the newly established colonies in the Columbia River estuary was facilitated by extensive use of decoys and audio playback systems.

Marine natural resource policies are increasingly formulated using an ecosystem approach (Murawski 2007). Such a knowledge-intensive approach requires reliable indicators capable of gauging change resulting from human impacts and separating it from natural variation (Niemi & McDonald 2004). A good indicator has scientific significance, policy relevance and public acceptance (Cairns 1987). Thus far, seabirds are actively used as indicators for food-web changes, oiling, plastic debris or contaminants, primarily in the North Sea (Rogers & Greenaway 2005, OSPAR 2007). The use of seabirds as indicators highlights the link between seabird science and public perception of the status of the marine environment. An important aspect of seabird research is therefore its communication. Well-communicated science, especially that involving charismatic species, increases the public's interest in complex issues such as management of natural resources and environmental and global change.

The Karlsö Murre Lab can facilitate this kind of communication. Web cameras, and potentially online visualization of logger data on foraging, can provide an opportunity to follow murres during the breeding cycle in real time. We envision that this would increase understanding of seabirds' strong dependence on a healthy marine ecosystem. Such tools can be combined with education and outreach programs, increasing policy relevance and public engagement with seabirds and their ecosystems (Cairns 1987). We believe the lab can form an important basis for public recognition of linked social-ecological systems and ecosystem-based management.

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