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Estimating chick survival in cliff-nesting seabirds – a hazard made easy with monitoring cameras

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Introduction

To estimate the numbers of cliff-breeding birds and their chick production is a tedious task requiring a large input of expensive hours. In an attempt to make the sampling more efficient, we have developed a system using a durable and easy-to-use camera and modern statistics.

Since 2006 we have explored the use of automatic time-lapse cameras as a means of recording the data necessary to monitor seabird colonies and to study demographic parameters of cliff-nesting seabirds on Spitsbergen and Bjørnøya (Steen & Strøm 2007). The results of the camera testing have been positive, showing that reliable monitoring data for seabirds in terms of numbers of adults present can easily be collected this way. In addition, a study conducted for the Norwegian Polar Institute on Svalbard in 2007-08 (Lorentzen 2008) shows that data from time-lapse photo series can also be used to estimate survival rates of Brünnich's guillemot (*Uria lomvia*) chicks before they leave the breeding ledge. The analytical approach is based on the application of mark-recapture (MR) models. All the necessary data can be extracted from the photo series without physically capturing any birds and thus leaving them undisturbed throughout the breeding season.

Methods

Although the Brünnich's guillemot has been the main focus of our studies, the methods we describe should also be applicable for monitoring other cliff-nesting species such as common guillemot (*U. aalge*) and black-legged kittiwake (*Rissa tridactyla*). For all practical purposes we will here use the Brünnich's guillemot as an example species, but the reader should be aware that some adaptations will be necessary for species that differ from the guillemots on essential aspects described below. It should also be noted that the method we describe was developed to estimate survival to fledging age for the main bulk of the chicks that hatch. To avoid mistaking fledged chicks for failures, the sampling period must be restricted to the time prior to the expected first fledging. Thus, chicks of late breeders or from replacement clutches, which are generally expected to have a relatively low survival rate, will not be included in the dataset.

The method was tested in two Brünnich’s guillemot colonies on Spitsbergen in 2007 (Lorentzen 2008). In the Ossian Sarsfjellet colony (78°56’N, 12°27’E) in Kongsfjorden, we collected photo series in a plot with 62 breeding pairs. The other colony was near Amfifjellet in Krossfjorden. It has no official name, but we call it the Amfifjellet colony (79°10’N, 11°52’E). Here, a plot with 45 breeding pairs was sampled. One camera was used in each colony.

Camera system and operation

The camera system that has been tested is a CamTrakker® automatic time-lapse camera (CamTrak South Inc., Watkinsville, USA). Each system (Figure 1) consists of a water resistant Pelicase® box containing a Sony® Cyber-shot DHC-H5 digital camera (7.2 megapixels and 12x optical zoom) running on two AA batteries. Embedded is also a time-lapse control unit powered by a 6V battery. The system can be programmed to take a picture every 1, 2, 3, 4, 8 or 12 hours, and its capacity depends on both the selected picture frequency and the ambient temperature. By replacing the AA batteries in the Sony® camera with dummy batteries connected to the 6V battery via a voltage regulator (3.3V) one can run the whole system on the 6V battery. Consequently, it can operate for a longer time before battery replacement is needed. With this setup, and taking one image per hour at an ambient temperature of approximately 5°C, the battery normally needs to be replaced with a recharged battery after approximately three weeks. The camera zoom can be adjusted and fixed at the desired factor, and after inserting the 6V battery and memory card the unit can be operated by external switches. Thus, the box does not have to be opened for every adjustment that is required at a later stage, which is yet another important feature when operating in harsh environments.

Figure 1
Monitoring cameras at the southern tip of Bjørnøya (Bear Island), Svalbard. A stone is used as weight to prevent movement of the tripod. (© Sergei N. Cheltsov)

Colony properties and camera positioning

Before deciding on which colony or part of a colony (study plot) to monitor, a few important practical aspects should be considered. The positioning of the camera in relation to the study plot is essential for the quality of the data. As all MR studies rely on a relatively high sample size and recapture (re-sighting) rate to obtain precise survival rate estimates, it is necessary to place the camera in the position from which the chicks have the highest possibility of being detected after hatching.

For Brünnich's guillemot chicks, which are very often concealed between the brooding parent and the vertical rock wall, detection probability is optimized by placing the camera to one side of the colony and as close to the cliff as possible, while still having line of sight to as many breeding-sites (nests) as possible (Figure 2a). An approximate 20° angle relative to the cliff wall is recommended as a guideline. Additionally, to avoid that the birds sitting closest to the camera block the view of birds farther away, the camera should be placed well above the top ledges in the study plot (approx. 30-40° relative to the horizontal plane drawn through the middle of the plot) (Figure 2b).

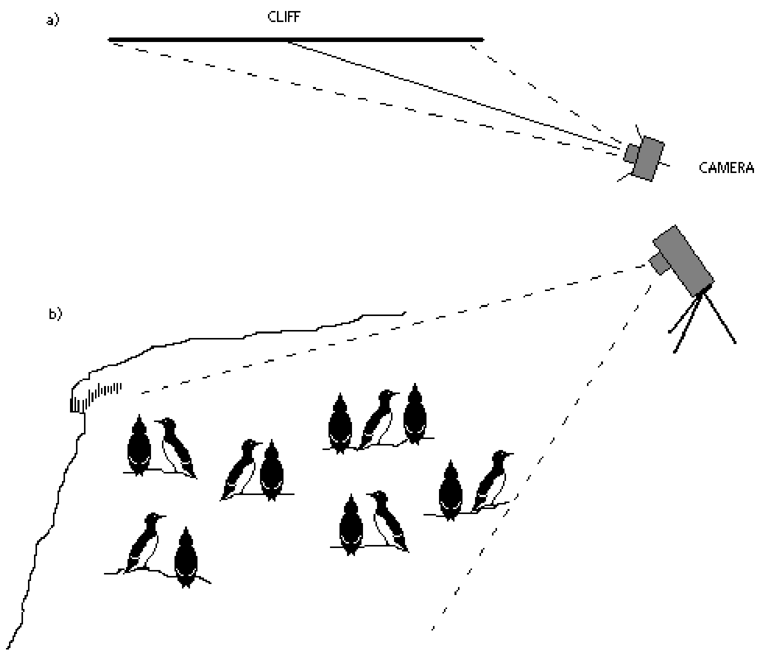

Figure 2
Recommended positioning of cameras for monitoring cliff-nesting Brünnich's guillemots viewed from above (a) and from the side (b).

The ideal study plot consists of many short and narrow ledges, seeing that on wide, long and densely populated ledges the birds closest to the camera may block the view to those in the background, creating unequal detection probability for chicks within the same plot. This heterogeneity in capture and recapture probability will violate one of the assumptions underlying the appropriate modelling designs (see Williams et al. 2002 for a review). In cases where the study plot consists of a mixture of more and less visible breeding-sites, such heterogeneity should be accounted for in the modelling process. Suggestions on how to do this are given below (see Data analysis).

Within the framework of criteria pointed out in the previous section, the study plot should contain as many breeding-sites as possible, making sure that all chicks can be distinguished in the photos. Testing different zoom settings in order to find a compromise between these elements is therefore essential. One should also carefully note the boundaries of the study plot and avoid the use of *digital* zoom, which reduces the quality of the images. No matter the distance between the camera and the plot, the best result is always obtained using the *optical* zoom only.

Photos and photo processing

The cameras should operate from the late incubation and throughout the chick-rearing period, and pictures of the study plot should be taken as often as possible (i.e. the one-hour interval with the camera described above). An estimate of chick survival requires a photo series that runs continuously from a few days before hatching to the date fledging starts. For an estimate of breeding success it is also necessary to know how many eggs were laid. For species that do not build nests, such as the common and Brünnich's guillemots, one approach to find this number is to examine a range of photos taken over e.g. the last five days before hatching and count the number of sites occupied by adult birds that seem to be incubating on all (or most) photos.

Dates of first hatch, last hatch and first fledging should preferably be known for each study plot. From this knowledge one can most precisely determine which photos should be used in the analyses, namely those taken after all or most of the eggs have hatched, and before the first chick leaves the ledge (this interval is here defined as the chick-rearing period). In the sampling process we follow the principles of the robust modelling design (Pollock 1982), in which primary sampling periods are built by secondary sampling sessions. We first choose four-five photos taken consecutively at some point within the first week of the chick-rearing period. These photos constitute the first primary sampling period. We then choose four-five photos at a point later in the chick-rearing period to form the second primary period. A minimum of three discrete primary sampling periods must be created – e.g. one at the start, one close to the middle and one at the end of the chick-rearing period (Figure 3). It is important that the pictures are of good quality. One should therefore avoid photos taken in bright sunlight (creating shadows), fog or other conditions that tend to decrease the visibility.

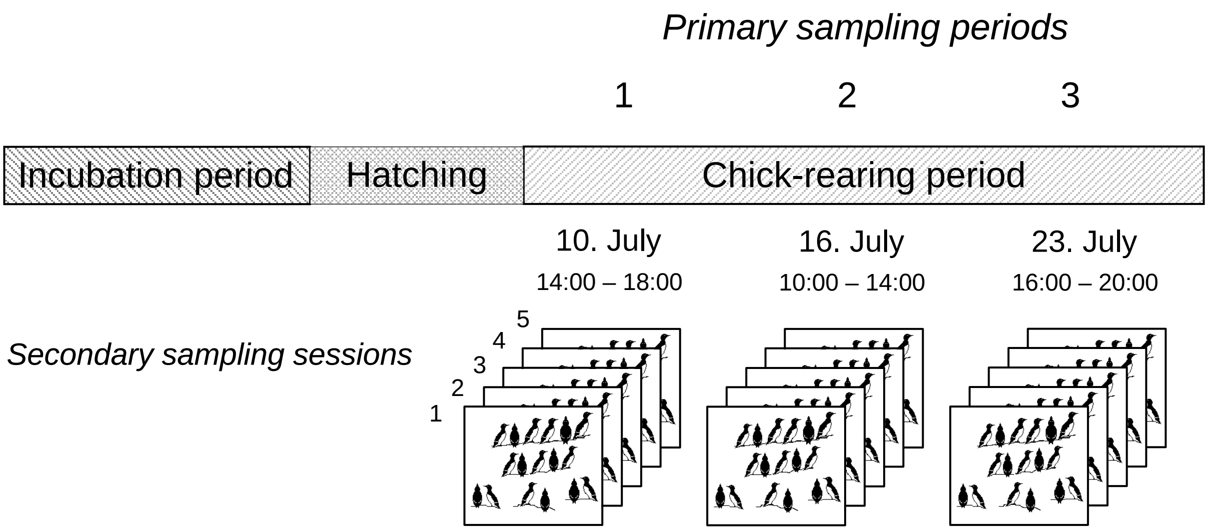

Figure 3
The principle of primary sampling periods and secondary sampling sessions in photo processing. In this example, there are three primary periods within the chick-rearing period, each consisting of five secondary sampling sessions, i.e. photos. With a one-hour interval between each photo, each primary period will cover a time span of four hours.

Once the photos are selected, one should start by examining the last image in the last primary period. Mark the position of every chick that can be seen in the photo, and be sure that each part of the plot is examined thoroughly. Make a numbered list of all the positions (i.e. the breeding-sites or nests). The numbers will now be the “tags” that identify the chicks. By working through all the photos representing the secondary sampling sessions backwards in time, one creates an individual capture-recapture (CR) history (re-sighting record) for each nest-site where a chick has been detected at least once. The CR history consists of ones and zeros, representing for each secondary session that a chick was (1) or was not (0) observed on the site. Both unattended empty sites and sites with an adult bird only are treated as failures to detect the chick, and should be indicated by a 0. Only the certain detection of a chick should yield a 1 in the CR history. It is very important to search the photos carefully and to create a new CR history for every new site where a chick is detected for the first time. However, one should be aware that the chicks might be able to move around slightly on the ledges, and it is important not to register the same chick in different CR histories. Wide, flat ledges where the chicks can easily move far away from where they were hatched caused underestimated survival rates in our test study and should be avoided. Before entering the data file in the software for analysis, each CR history must be sorted in chronological order, starting with the first occasion of the first primary period.

Data analysis

The MR data can be modelled with freely downloadable software such as Program MARK (Cooch & White 2010) (http://www.phidot.org/software/mark/download/index.html) or E-SURGE (Choquet et al. 2008) (http://www.cefe.cnrs.fr/biom/logiciels.htm). Both the Cormack-Jolly-Seber (CJS) model (Cormack 1964, Jolly 1965, Seber 1965) and Pollock’s robust design (Pollock 1982) have proved to give reliable survival rate estimates when the assumptions underlying the models are met. However, the robust design has the advantages of higher precision, ability to model heterogeneity in capture probability, and providing estimates of chick abundance, which in turn can be used to estimate breeding success if the number of breeding attempts are known. Thus, the robust design is the recommended model. If the CJS model is used, the re-sighting data within each primary sampling period (i.e. all the secondary sessions in that period) must be pooled to create a single recording for every period for each nest-site. Ones have priority over zeros in this case, so the capture history “0001 1101 0000” (three primary periods with four secondary occasions in each) would translate into “110” for the CJS modelling design.

If there is any reason to believe that certain chicks have a lower chance of being detected than others within the same plot (heterogeneous capture probability), the capture histories should be grouped so that low- and high-visibility nests are in separate groups. Pollock’s robust design allows the investigator to model heterogeneity without this kind of grouping in advance. Failure to model heterogeneity in capture probability may bias the survival rate estimates.

If the time intervals between the sampling occasions are not equal (which is very often the case), the length of the time intervals must be specified prior to the analysis. One approach is to specify the number of days between the primary sampling occasions. The estimated survival rate will then represent the daily survival probability. An estimate of the overall survival rate for the chick-rearing period equals the product of the daily survival rates.

Results of a test study

The described success criteria for estimating survival by modelling data from photo series were for a large part revealed in the test study in 2007-08 (Lorentzen 2008). For the Amfifjellet colony study plot, the modelling resulted in an underestimated survival rate (Table 1). This was related to the fact that most breeders in this plot were nesting on a wide, flat ledge where many adults could sit tightly side by side. Thereby, the birds closest to the camera blocked the view of the sites further away. This caused a heterogeneous capture rate, which in turn resulted in a low biased survival rate with both the CJS model and the robust design. The physical properties of the ledge allowed the chicks to move away from their nests. Such temporary emigration also caused underestimated survival rates.

Table 1

Observed rate of survival to fledging age of Brünnich's guillemot (Uria lomvia) chicks in two study plots on Spitsbergen in 2007, compared with the corresponding estimates derived from two approaches for modelling survival with capture-recapture data from photo series (Lorentzen 2008).

Method for estimating overall chick survival rate ϕ	Amfifjellet colony		Ossian Sarsfjellet colony	
	$\hat{\phi}$	$SE(\hat{\phi})$	$\hat{\phi}$	$SE(\hat{\phi})$
Field inspections [a]	0.810		0.750	
Single-state CJS model [a]	0.591	[b]	0.749	[b]
Robust design, heterogeneity [a]	0.586	0.178	0.790	0.103

[a] *Field inspections and capture histories producing the model estimates apply to the same 57 individuals.*
[b] *SE was not calculated due to the complexity of the procedure when time intervals of unequal lengths have different survival estimates.*

The survival rate estimators for the Ossian Sarsfjellet study plot did not suffer under either heterogeneous capture rates or temporary emigration, since the breeders in this colony were more spread apart on short and narrow ledges. The survival rate estimates produced under both the CJS model (0.749) and the robust design (0.790±0.103) were in accordance with the survival rate observed at field inspections in this colony (0.750).

Discussion

We have shown that it is possible to model CR data from photo series of Brünnich's guillemot colonies to produce survival rate estimates for the chicks in the chick-rearing period. For the estimates to be accurate, the study plot must however meet certain demands related to the physical properties of the breeding ledges. In addition, it is favourable to know the exact dates for first hatch, last hatch and first fledging, which can only be determined through repeated nest examinations at an almost daily rate. Indeed, this implies that the method can not be used in all colonies. Neither will the result necessarily be optimal if the colony is not visited at all by field workers during the breeding season. Still, CR by time-lapse photography is a very good supplementary method to physical examination or “manual” around-the-clock monitoring of breeding birds, which can be both dangerous and time-consuming. Photo monitoring is especially useful for parts of a colony that can not be reached physically and for colonies that are located too far away to be visited daily or weekly. Increasing the number of monitored colonies will improve our basis for making a representative assessment of chick survival on a large scale.

Besides the time spent mounting and dismounting the camera, three visits to each colony during the breeding season should be enough. As the cameras monitor the bird colonies, the field workers save up time that would otherwise be spent looking at the birds through binoculars. Processing the photos will demand some work hours, especially the first time a photo series from a new colony is processed. Once the base documentation including an overview of nest sites is established, subsequent analyses will take less time. The cost of work hours versus the value of the data gained will need to be addressed continuously.

Within the field of CR by time-lapse photography, modelling designs that can produce estimates of overall breeding success – not only chick survival – are still in demand. Such a design must implement the estimation of egg survival and hatching success, which are parameters not easily quantified in a bird species with strong site-fidelity almost regardless of the status of the egg. Developing a modelling approach of this kind deserves focus in the time to come.

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Cover photos:
Left: Breeding cliff at Ossian Sarsfjellet, Kongsfjorden, Svalbard, monitored by time-laps cameras. Right: Breeding ledge of Brünnich's guillemot. Red circles indicate occupied breeding sites. (© Erlend Lorentzen)

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