The use of k values to convert counts of individual Razorbills *Alca torda* to breeding pairs

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Abstract

A 32-year study of Razorbills *Alca torda* on the Isle of May, southeast Scotland, showed that the mean value of k, used to convert counts of individual birds to breeding pairs, averaged 0.795 ± 0.019 SE and increased significantly over the period. This value was much higher than the 0.67 used to convert counts of birds during censuses of colonies for Britain and Ireland in both 1985–88 and 1998–2002. Assuming that the average values recorded at the Isle of May at the time (0.767 and 0.851, respectively) were representative of other colonies, the total British and Irish populations would have been 14% and 27%, respectively higher than the published totals. Given plans for another nationwide survey in the next few years it would be useful to obtain k values from additional colonies to provide better assessment of changes in breeding numbers.

Introduction

Razorbills *Alca torda* breed on sea cliffs and among boulders in the boreal and sub-arctic parts of the North Atlantic and in the Baltic. Although some pairs breed on cliff ledges where they are relatively easy to see, many breed in crevices or under boulders and are very difficult to observe. In Britain and Ireland the recommended counting unit for Razorbills is the presence of an individual bird in the colony, irrespective of whether it is actually breeding (Walsh *et al*. 1995). Sometimes, such as when comparing population estimates of different species or in population modelling, there is a need to convert counts of birds to pairs. In both the 1985–88 *Seabird Colony Register* and 1998–2002 *Seabird 2000* surveys this was done by multiplying the counts of birds by 0.67, a conversion factor k based on studies made on Skokholm, Wales, in the early 1970s and the Isle of May, southeast Scotland, in the 1980s (Lloyd 1973, 1976; Harris 1989). A recent analysis of the value of k used to convert counts of Common Guillemots *Uria aalge* to pairs at two North Sea colonies documented considerable change over the last 15–30 years and showed that the use of published values can give erroneous estimates of breeding populations (Harris *et al*. 2015). Here we report a series of k values collected during a long-term study of Razorbills breeding at a single colony and, given the current interest in making another count of seabirds in Britain and Ireland, stress the need to obtain estimates of k values at other colonies.

Methods

The study was carried out at the Razorbill colony on the Isle of May (56°11'N 02°33'W), Firth of Forth, Scotland. Each breeding season between 1983 and 2014, observations were made from permanent hides of Razorbills breeding 15–30 m away on cliff ledges and cliff tops in five unambiguously defined areas where virtually all incubating or brooding Razorbills were visible and there was room for the colony to expand. All breeding sites in an area were marked on A4 photographic prints and were checked several times a day from before the first pair laid (usually in late April) until all chicks had left the colony in July so that the number of breeding pairs (hereafter pairs) was known each year. It was assumed that when an egg was lost and another egg laid later at the same site that this was a replacement laying and not the laying of another pair. Each year a count of individual Razorbills on the Isle of May was made during the first few days of June when most pairs have small chicks. Counting was carried out between 08.00 and 15.00 BST and complete coverage of the colony took several days. Counts were made using binoculars or a telescope at distances ranging 15–100 m. Birds at this colony are tolerant of people so few if any birds will have been disturbed off cliffs before the count was made. To allow for differences in attendance within and between days, immediately before or after a section of cliff was counted (which typically took 2–3 hours), a count was made of the numbers of individual Razorbills present in one of the study areas. Part of this 'reference area' is shown in Figure 1. The numbers of pairs laying in the reference area increased steadily from 20 in 1983 to 81 in 2014. Counts of

Figure 1. Part of the reference plot used to determine the value of k for Razorbill *Alca torda* on the Isle of May, 13 May 2014. In that year 23 pairs of Razorbills bred in the area covered by this picture. © *Mike P. Harris*

individuals in each section of cliff were converted to pairs using a k value (number of pairs that bred in the reference area that year divided by the count of individuals in the reference area before or after the colony section count). Section totals expressed as pairs were combined to give a total population estimate for that year. An average k value for each year was then obtained by dividing the total number of calculated pairs by the total number of individual birds counted.

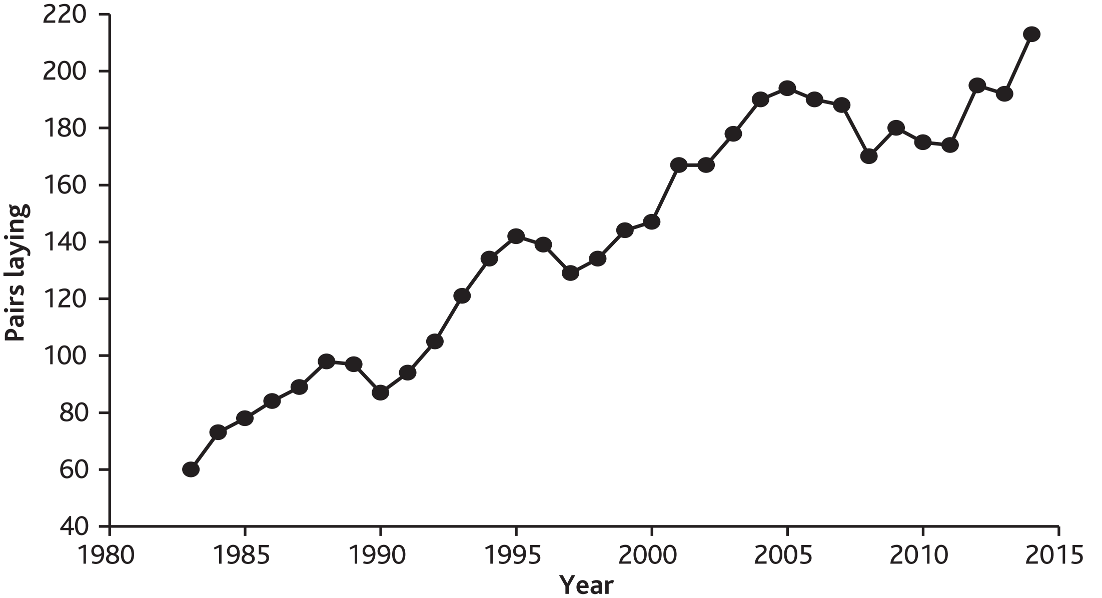

Figure 2. The total numbers of pairs of Razorbills *Alca torda* that bred in five study areas on the Isle of May, 1983–2014.

Results

The number of pairs that laid in the five intensively studied areas increased steadily from 60 pairs in 1983 to 213 in 2014 with the rate of increase gradually slowing down (Figure 2: log pairs = - 1985 + 1.97 year - 0.000490 year^2, R^2 = 95%, n = 32 years, $P < 0.001$). Over the same period the number of individual Razorbills on the Isle of May approximately doubled from c. 2,000 birds during the 1980s to c. 4,000 birds in the late 1990s and early 2000s (Figure 3). Numbers have subsequently been rather variable ranging from c. 3,000 to c. 4,000 individuals. The mean value of k estimated for the reference area over the 32 years was 0.795 ± 0.019 SE (95% CI 0.756–0.834). Values of k varied markedly between years (Figure 4) with the situation in 2005 being particularly extreme (k > 1.0, i.e. fewer birds were counted in the reference area at the time of the whole island survey than the number of pairs known to have bred in the reference area that year). Overall, the annual value of k increased significantly between 1983 and 2014 (k =- 8.89 + 0.00485 year, R^2 = 15%; n = 32 years, P = 0.016). Using year-specific k values to convert annual counts of birds to pairs indicated broadly similar trends over time for the counts of birds and the estimates of the number of pairs in the colony but the magnitude, and in some cases the direction, of year-to-year changes sometimes differed (Figure 3).

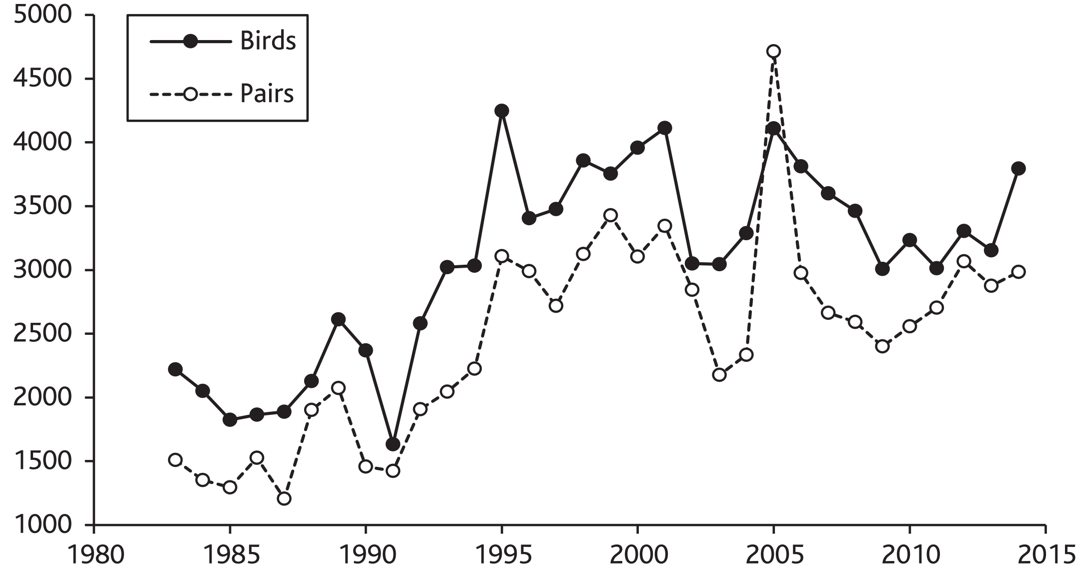

Figure 3. The numbers of individuals and breeding pairs of Razorbills *Alca torda* on the Isle of May, 1983–2014.

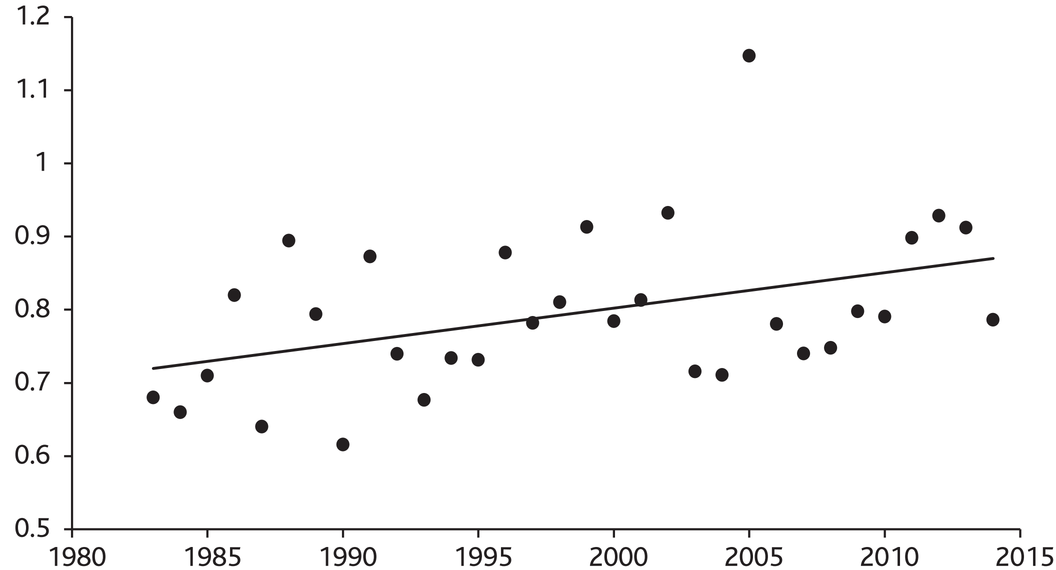

Figure 4. Changes in k values for Razorbill *Alca torda* obtained on the Isle of May, 1983–2014.

Discussion

During the 32 years of our study the Razorbill population on the Isle of May showed an overall increase (Figure 3). Breeding success was generally high (0.64 ± 0.01 SE chicks leaving the colony per pair laying) and Razorbills were not recorded leaving their chicks unattended in the mid 2000s as was the case for

Common Guillemots *Uria aalge* (Ashbrook *et al*. 2008). These trends in abundance and breeding success were broadly consistent with those recorded in other UK colonies bordering the North Sea (Cook *et al*. 2011). Thus the k values presented here likely reflect those at other North Sea colonies but need not apply to other regions where demographic trends have differed. We found considerable annual variation in k values but the estimate for 2005 was quite exceptional. Using it to convert the whole island count of birds to pairs resulted in a doubling in the estimated breeding population size in 2005 compared to 2004 and 2006 (Figure 3). In contrast, the number of pairs of Razorbills recorded laying in the five study areas was only slightly higher in 2005 (Figure 2). The person who made the all-island count that year, although experienced, had no knowledge of where pairs bred, so could conceivably have overlooked birds, but there was nothing exceptional for the k value for Common Guillemot that he measured concurrently in the same plot (Harris *et al*. 2015). Breeding success in the reference plot in 2005 at 0.60 chicks leaving per pair, was slightly lower than normal but not enough to explain the high k value and the feeding frequency of chicks was higher than average (6.7 feeds per day c.f. 3.81 ± 0.20 SE for 31 other years). There seems no justifiable reason to exclude this count but doing so reduces the overall mean value from 0.795 to 0.783 ± 0.016 SE (95% CI 0.751–0.816).

The numbers of Common Guillemots on the Isle of May were counted over the same period using the same methods as those described here for Razorbills (Harris *et al*. 2015). The mean value of k for the Common Guillemot was 0.744 ± 0.017 SE, lower than that for the Razorbill (0.795 ± 0.019 SE), although the difference was just not statistically significant ($t = 1.96$, $P = 0.055$). The coefficients of variation were similar (Common Guillemot 13.2%, Razorbill 13.6%) but the annual values were not significantly correlated after data had been detrended ($r = 0.002$ on residuals of linear regression, $n = 32$ years, $P = 0.99$).

The interpretation of differences between counts of individuals, however accurate, is difficult due to at least two factors. First, counts include not only incubating and brooding adults but some of their mates, failed and non-breeders, and immature birds that in species like the Razorbill visit the colonies for 3–4 years before they recruit. Attendance of these birds will likely reflect conditions at the time of the count with attendance being higher when conditions are good. Second, the numbers of immatures present will depend on the breeding success and post-fledging survival several years before, i.e. past conditions. Both these factors have been demonstrated to influence the k value for Common Guillemots on the Isle of May (Harris *et al*. 2015) but detailed data on attendance by Razorbills are not collected so a similar assessment is not possible.

The method described here is the one used in Britain and Ireland. However, in other parts of the range where colonies are very remote and access difficult, a modified version of k has been used to convert counts to pairs by using the number of sites with eggs or chicks that are active at the time of the census rather than the number of pairs that bred that season. In Canada, such k values are extremely variable with means of 40 such estimates for colonies in the Gulf of St Lawrence and 45 values for the Gannet Islands, Labrador being 0.84 ± 0.08 SE and 3.18 ± 0.42 SE, respectively (Chapdelaine *et al*. 2001; Robertson & Elliot 2002; J.-F. Rail & G. Robertson pers. comms.). Although useful as a way of partially standardising counts, as explained above the interpretation of changes from year to year using such k values is problematic since the values will be highly influenced by the breeding success at the colonies at the time. There is also a problem in finding all occupied sites in boulder colonies and in one study using Razorbills fitted with radio-transmitters, 29% of such sites escaped initial detection (Grecian 2004). Where the true numbers of breeding pairs cannot be determined, for instance where birds nest in large boulder fields, or where the birds breed in habitats where they cannot be seen from either land or sea, or birds leave the colonies at the approach of a land- or sea-based counter (so that k values are routinely > 1), comparisons between surveys are probably best restricted to the actual counts of birds and acknowledging that these can give only an approximate indication of what is happening to the breeding population.

The *Seabird Colony Register* in 1985–88 and *Seabird 2000* in 1998–2002 reported 180,900 and 216,087 individual Razorbills in Britain and Ireland that were converted to 122,000 and 145,000 pairs, respectively, using a k value of 0.67 that was the only one available at these times (Lloyd *et al*. 1991; Merne & Mitchell 2004). Assuming that the values recorded at the Isle of May (0.767 and 0.851, respectively) were representative of other colonies over these periods, the total British and Irish populations would have been 139,000 and 184,000 pairs, 14% and 27%, respectively higher than the published figures.

Obtaining even a single k value for cliff-nesting auks is very time consuming, needing at least daily checks of groups of birds for about six weeks covering the entire egg-laying period as well as counts of birds present in the same area when they have chicks (Birkhead & Nettleship 1980). The only published k values for the Razorbill away from the Isle of May are 0.30–0.55 based on a three-year study on Skokholm in the early 1970s (Lloyd 1973, 1976). These figures are outside the range of annual values on the Isle of May and many more data are needed before a general conversion factor can be suggested for the Razorbill. Given plans for another nationwide survey in the next few years it would be useful to obtain k values from additional colonies to provide better assessment of changes in breeding numbers.

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