

## Count of Northern Gannets on the Bass Rock in June 2023

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### Summary

A drone survey of Northern Gannets on the Bass Rock was carried out on 27 June 2023 following a severe outbreak of Highly Pathogenic Avian Influenza in 2022. The survey covered approximately 85% of the colony and provided a high resolution orthomosaic vertical image of the colony. Three independent counts of the number of Apparently Occupied Sites (AOS) and Gannets present were made for 10 of the areas used in previous surveys. Samples of Gannets in the colony and in flight were aged using plumage characteristics.

In the 85% of the colony covered by the survey, the mean counts of the three observers were 47,790 AOS and 51,428 birds respectively. Assuming that the dispersion of AOS in 2023 was the same as during the last survey in 2014, the total Bass Rock population was estimated to be 51,844 AOS.

Comparison of the 2023 count of AOS with the same count areas in 2014 indicated a decrease of 31% associated with a marked reduction in density of AOS throughout the colony.

### Background

In contrast to many seabirds that have shown major population declines in recent years, the Northern Gannet *Morus bassanus* (hereafter Gannet), has shown a sustained increase in breeding numbers for over 100 years (Jeglinski *et al.* 2022). Nowhere has this been demonstrated better than

the population on the Bass Rock, Firth of Forth. Here numbers increased from c.3000 pairs in 1904 to over 75,000 Apparently Occupied Sites (AOS) in 2014 when the Bass Rock overtook St Kilda (Scottish Western Isles) and Bonaventure Island (Canada) to become the world's largest Northern Gannet colony (Nelson 2002, Murray *et al.* 2014). However, the Gannet's fortunes changed abruptly and



Figure 1. The orthomosaic vertical image from a drone survey on 27 June 2023 used to make the count of Northern Gannets on the Bass Rock in 2023. University of Edinburgh/Scottish Seabird Centre image.

dramatically in 2022 when high pathogenicity avian influenza (HPAI) resulted in unprecedented mortality and reduced breeding success in populations throughout the North Atlantic (Lane *et al.* 2023). The disease was confirmed on the Bass Rock on 4 June 2022 and 5035 dead birds were

identified in images taken by a drone on 30 June 2022 (Glen Tyler in Lane *et al.* 2023). The drone images and observations made in the colony throughout the 2022 season indicated that the number of Gannets present in the colony was greatly reduced consistent with a dramatic population decline. Obtaining a robust count of the colony in 2023 was therefore a high priority to assess the impact of the HPAI outbreak. This report documents the methods and results of another detailed, drone survey of the Bass Rock colony in June 2023.

## Methods

The University of Edinburgh's Airborne Research and Innovation Facility undertook a photogrammetry survey of the Bass Rock on 27 June 2023 using a DJI Matrice 300 RTK UAV (drone) (Tyndall 2023). The resulting high resolution orthomosaic vertical image (Figure 1) was viewed on a computer and the boundaries of the 13 counting areas used in previous counts of the colony overlaid (Figure 2: Murray *et al.* 2014). The image covered 9 counting areas (1, 2, 3, 8, 9, 10, 11, 12, 13) and part of one more (7). The missing areas (4, 5, 6) were those where the Gannets nests on sheer cliffs that are not adequately covered by vertical views. In 2014 when coverage of the colony was complete, these missing areas contained 15.4% of the population (Murray *et al.* 2014).

The image was counted independently by MPH, SW and EB. MPH and SW have extensive experience of counting images of gannets from fixed-wing aircraft surveys but had not previously counted drone images. EB was not involved in previous surveys of the Bass Rock gannetry but was more familiar with images from drones than MPH and SW. All three counters used the software DotDotGoose (Ersts 2023) to mark and count the numbers of (a) pairs of Gannets (two birds in close physical contact that were assumed to be members of a pair rather than neighbours) and (b) all other individual Gannets in the colony (Figure 3). Birds were also classified as alive or dead on the basis of their body posture. However, this subjective process proved to be challenging because the criteria used previously (extended neck and outspread wings), corresponded closely to birds that were displaying.

To facilitate comparisons with previous counts, count data for 2023 were presented in two ways: (a) to compare with the count of live birds during the HPAI outbreak in 2022 (Lane *et al.* 2023), the total number of live birds (birds in pairs plus individuals) was used, and (b) to compare with the pre-avian flu count of apparently occupied sites (AOS normally defined as a site occupied by one or two Gannets irrespective of whether nest material is present) in 2014, the number of sites occupied by a pair or a single bird was used. We attempted to validate whether the classification of AOS used in 2023 corresponded to previous counts by using data from detailed observations of occupancy in a

sample of about 45 sites near the lighthouse (Area 1 in Figure 2), based on daily screenshots (when possible) from the Scottish Seabird Centre webcam obtained between 07:00 and 09:00 from 20/04/2023 to 13/10/2023. Matching up the AOS in this study plot with those in the drone image was tricky because of the very different perspectives in the two methods (Figure 4). However, at face value, there appeared to be remarkably good agreement between the two methods in terms of the number of AOS estimated. Moreover, the webcam data indicated that although only one bird was present at a site on the majority of occasions, pairs were recorded at almost all the sites and breeding attempts were made.

MPH also counted samples of birds in 10 of the 13 areas to assess the proportion of second and third-year birds in the population using aging criteria based on the amount of black feathers in the dorsal plumage (Nelson 2002). The same criteria were used to age the small number of birds flying low over the colony. In this sample it was also possible to identify birds in their fourth year that typically have a few black central tail feathers that are not easy to see except when birds are flying.

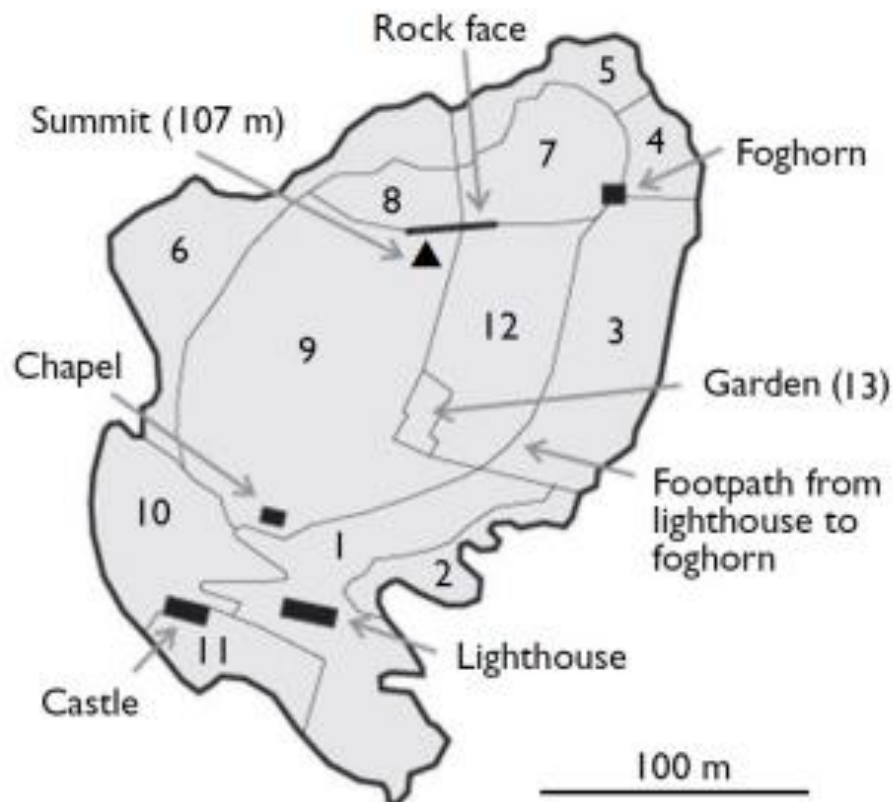


Figure 2. Areas used for counting Northern Gannets on the Bass Rock. Courtesy of Scottish Ornithologists' Club.



Figure 3. Part of the orthomosaic vertical image showing two pairs and 15 single Gannets. The topmost bird is an immature with clearly visible black wing coverts. Image credit University of Edinburgh.

## Results

### *Colony counts*

The mean total count of AOS was 47,790 (range 46,930 – 48,671), and the mean total count of birds was 51,428 (range 51,406 – 51,459) (Table 1). There was very close agreement between all three counters in the totals of birds (range of three counts/mean count = 0.1%). Inter-observer differences were slightly greater in terms of counts of pairs and individuals and hence AOS (3.6%), probably because observers used slightly different criteria to distinguish between members of a pair and close neighbours. It was striking that overall, only 7.6% of the sites had a pair present at the time of the

count. Very few apparently dead birds were recorded (mean 23, range 9 – 34), most birds with outstretched necks and spread wings were judged to be displaying.



Figure 4. Close up from the drone image of the area followed during the breeding season using the Scottish Seabird Centre webcam in June 2023. There are three pairs and 47 single birds. Although most birds appear to be incubating, no traces of nests are visible. Image credit University of Edinburgh.

#### *Ages of birds*

Small numbers of immature plumaged birds (predominantly third-year birds i.e., from chicks hatched in 2020), were present throughout the colony, a few apparently paired with adult-plumaged birds. No obvious ‘club’ areas i.e., concentrations of immature birds were identified. Overall, immatures made up 2.1% of the population (Table 2) but values varied greatly between areas, being notably higher in the old lighthouse garden in a small part of Area 13, where some second-year birds (individuals where the back plumage was almost completely black) were also present. This area is liable to flooding and has never had a high density of sites. Of the 557 birds checked in flight, 396 (71.1%) were adults, 65 (11.7%) were fourth-year birds, 82 (14.7%) were third-year birds and 14 (2.5%) were second-year birds.

Table 1. Results of the counts of the image of the Bass Rock obtained from a drone survey on 27 June 2023. Images were counted independently by MPH, SW and EB and the values shown are the means of these raw counts. The counting areas are delimited in Figure 2 and the counting units are defined in the text. The drone survey was estimated to cover 84.6% of the colony so the totals given here are underestimates of the complete colony. The scaled-up total is given in Table 3.

Area	Mean of three counters				
	Single birds	Pairs	AOS	Total birds	Dead
1	3174	207	3381	3588	3
2	115	9	124	133	0
3	4915	327	5242	5568	2
7 (part)	3658	272	3930	4201	4
8	1474	139	1613	1752	1
9	19375	1776	21151	22928	4
10	3199	220	3419	3640	3
11	1595	106	1701	1807	1
12	6411	570	6981	7551	5
13	236	12	248	260	0
Total	44152	3638	47790	51428	23

Table 2. Sample counts of numbers and percentages in the population of immature Gannets (second-year and third-year birds based on plumage characteristics) on the Bass Rock in June 2023. Counts were made by MPH.

Area	Immatures		
	Birds checked	Immature	%
1	1209	23	1.90
2	158	1	0.63
3	990	9	0.91
7	1089	2	0.18
8	876	1	0.11
9	1156	35	3.03
10	1008	36	3.57
11	725	15	2.07
12	1158	27	2.33
13	234	34	14.53
Total	8603	183	2.13

#### *Comparison of the 2023 count with the count in 2022*

The total of 51,428 birds in 2023 indicates an increase of 142% over a count of 21,227 birds on 30 June 2022 during the peak of the HPAI outbreak (Lane *et al.* 2023). However, coverage of the colony

in 2022 appears to have been slightly greater than in 2023, so the actual increase was probably slightly higher. In contrast, the mean total of 23 birds recorded as dead in 2023 was trivial compared to the 5,035 dead birds recorded in June 2022. The quality of images prior to 2022 was poorer than those obtained using drones in 2022 and 2023, so counts of dead birds have not previously been possible but our count of dead birds in 2023 (0.05% of the total of birds) could potentially reflect 'normal' mortality.

#### *Comparison of the 2023 count with the count in 2014*

Comparison of the numbers of AOS in 2023 with those in the same areas during the last survey in 2014, indicates an overall decline of 41% and a marked reduction in the density of AOS throughout the colony (Figure 5), in accordance with observations by Sheddon & Lane (2023). The slight increase in numbers in Area 11 is an artifact since numbers there were increasing rapidly in 2014. A count of an aerial image taken on 14 June 2019 gave 2,360 AOS providing evidence of a decline of c.28% between 2019 and 2023 in line with decreases in the other areas.



Figure 5. Images showing the dramatic differences in the density of AOS between 23 June 2014 (left) and 27 June 2023 (right). In 2014 there were 246 AOS in the delimited area whereas in 2023, there were only 169 – a decrease of 30%. Image credits Stuart Murray (left), University of Edinburgh (right).



The 2023 survey covered 84.6% of the total extent of the colony. Assuming that the dispersion of sites remained the same in 2023 as in 2014, the raw count of 43,860 AOS scales up to give a corrected total population of 51,844 AOS (Table 3). In 2014 there was very limited room for further colony expansion and, based on comparisons of later photographs and field observations, Wanless *et al.* (2023) estimated that there would have been in the region of 81,000 AOS in 2021. If this value provides a robust estimate of the size of the population on the Bass Rock immediately prior to the outbreak of HPAI in 2022, then the number of AOS could have been reduced by about 36%, and potentially over 50,000 site holding Gannets could have died.

Table 3. Comparison of counts of AOS in 2014 and 2023. In 2014, Areas 8 and 9 were combined and counted as one area. In 2023, they held 1,613 and 21,151 AOS, respectively. n/c: no count was made in these areas in 2023 and only a partial count of Area 7 was made. Allowance for these uncounted areas is made in the corrected total (see text for details).

Area	2014	2023	Change
1	5149	3381	-34%
2	294	124	-58%
3	8134	5242	-36%
4	612	n/c	
5	567	n/c	
6	1433	n/c	
7	9013	n/c	
8 + 9	33321	22764	-32%
10	4714	3419	-27%
11	1643	1701	+4%
12	9932	6981	-30%
13	447	248	-45%
Total	75259	43860	-41%
Corrected count	75259	51844	-31%

## The future

Given the multiple threats currently faced by Gannets including avian flu, rising air and sea temperatures, fisheries and offshore renewables, documenting changes in population sizes of colonies is a top conservation priority. Although the methods used for Gannet surveys are changing with drones replacing fixed wing planes/helicopters and boat and land counts, and sophisticated software is being used to annotate the images, the fundamental aim of obtaining a robust population count remains the same. Central to this is documenting exactly how the count was made including any assumptions and correction factors used. This information is vital to inform how populations have changed and highlight areas of uncertainty and/or bias in counts.

A specific issue associated with the 2023 Bass Rock count was that drone coverage of the colony was incomplete so images of some of the cliff areas were missing. Although these areas represent a relatively small part of the colony (c.15% assuming the same site dispersion as in 2014), obtaining images of these areas should be a priority for future counts. This would remove the need to make assumptions about site dispersion in order to scale up the recorded total to the whole population. It would also facilitate assessing whether population changes on the cliffs show similar patterns to those in sloping areas.

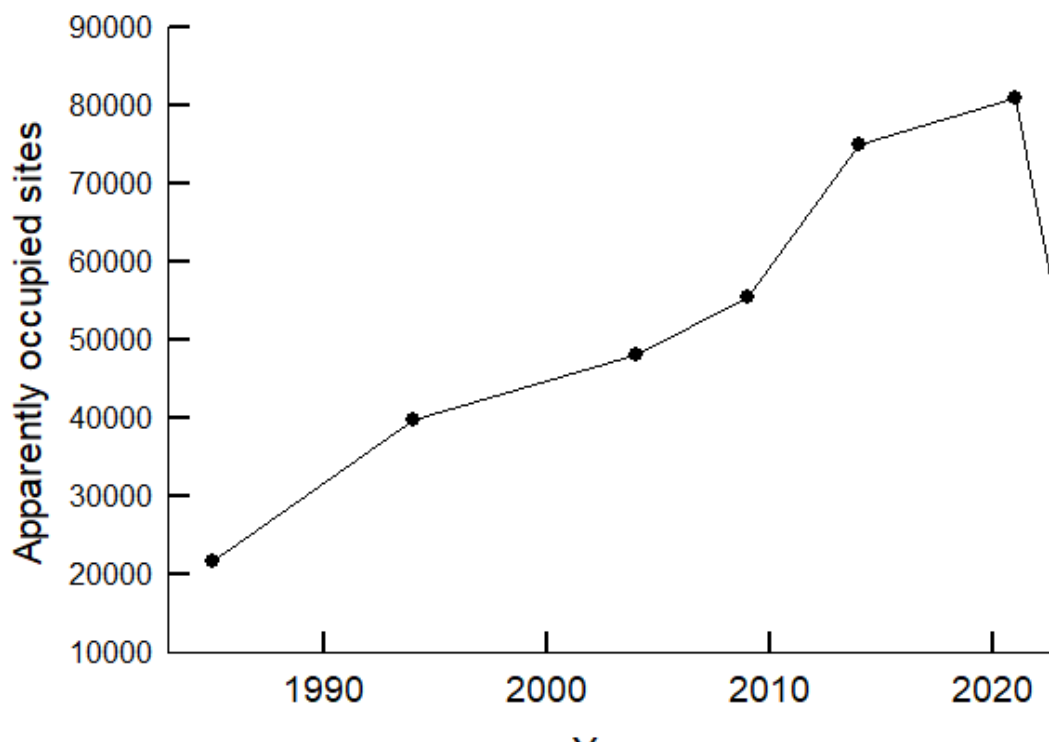


Figure 6. Changes in the numbers of Apparently Occupied Sites on the Bass Rock between 1985 and 2023. Note that the total for 2021 is a derived estimate based on previous population trajectories. Data from Murray & Wanless (1997), Murray *et al.* (2014) and Wanless *et al.* (2023).

Evaluating the impacts of HPAI and other environmental stressors on Gannet populations has also highlighted the need for transparency and consistency in the counting units used to estimate population sizes. Improvements in survey techniques and thus, higher resolution of images used for counting, mean that counts can now potentially be made in more detail. For example, sites with and without nest material can be counted separately. However, the majority of previous counts of most ganneries including the Bass Rock, have used AOS as the count unit and thus, keeping this unit allows the time series to be maintained. Apart from counts of Ailsa Craig in the 1970s (Wanless 1979), there appear to be no correction factors to convert counts of AOS to AON and vice versa.

Thus, obtaining current correction factors for a range of colonies of different sizes would be useful. Identifying AOS on the Bass Rock in 2023 was harder than for previous counts because severe weather following the HPAI outbreak washed away many of the nest mounds. Those birds that returned in 2023 made little attempt to rebuild their nests so many Gannets in the incubating/brooding position in the drone image did not appear to be sitting on nests. Observations from the SSC webcam proved invaluable for confirming these sites did have pairs associated with them and in many cases were bred at.

Assuming that image quality and count methods continue to improve, then additional count units could be incorporated into population assessments to provide detailed information on the structure of the colony, for example, to identify where new sites are being established. Such information is of particular interest in the aftermath of the 2022 HPAI outbreak and potentially for assessing the impacts of future outbreaks. On the Bass Rock, HPAI caused mortality and breeding failure throughout the colony in 2022 (Lane *et al.* 2023). The drone image and direct observations in 2023, indicated that the dispersion of AOS had changed dramatically with the density greatly reduced (Figure 5). This is the first time a major decrease in a UK Gannet population has been recorded. Normally, a gannetry increases by recruits occupying sites around the fringe of the colony, often for a year or so before they breed (Moss *et al.* 2002). Because the Bass Rock population had reached maximum capacity just prior to the HPAI outbreak, there were no longer any fringe areas left to colonise and so presumably recruits will have to fill in the gaps between the sites currently occupied. This situation presents a unique opportunity to follow a previously undocumented process and record how Gannets respond to a major perturbation. Ideally this will include detailed observations in the colony to complement drone surveys with both approaches covering as much of the season as possible. The SSC webcams could potentially play a key role here and build on the approach developed in 2023.

A key aspect of any population recovery will be the number of potential recruits. In theory, there should be large pool of recruits available since the limited information suggests that younger age classes suffered far less from HPAI than adults (e.g., Camphuysen *et al.* 2023). For many years, the Bass Rock gannetry has been producing thousands of young which in the recent past would have had little chance of finding a breeding site at their natal colony and there are no longer any substantial clubs of immature birds on the island (M. Sheddon *pers. comm.*). Presumably these birds have been partly responsible for the faster than anticipated rates of increase at the neighbouring colonies at Troup Head and Bempton and the colonisation of nearby St Abb's Head (Wanless *et al.* 2023). In 2023, immature birds were typically scattered throughout the colony and there were still no obvious

clubs. Documenting future patterns of colony occupation by pre-breeding birds will contribute to a fuller understanding of how populations recover from disease outbreaks and other extreme events.

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