

Productivity Monitoring of Northern Gannets on the Bass Rock in 2025

Emma Marriott¹, Emily Burton¹, Sarah Wanless², Maggie Sheddan¹, Mal Watson¹, Sue Lewis³

¹ Scottish Seabird Centre, The Harbour, North Berwick, East Lothian, EH39 4SS, UK

² UK Centre for Ecology & Hydrology, Bush Estate, Penicuik, Midlothian EH26 0QB, UK

³ Centre for Conservation and Restoration Science, School of Applied Sciences, Edinburgh Napier University, Edinburgh EH11 4BN, UK

Summary

The Bass Rock's colony of Northern gannets (*Morus bassanus*) is among the world's largest. However, pressures in recent years, notably the outbreak of Highly Pathogenic Avian Influenza in 2022, have resulted in a marked population decline and reduction in the density of breeding sites. These unprecedented changes make monitoring how the population responds crucial for the identification and development of effective conservation measures. Productivity is a key demographic metric but accessibility issues on Bass Rock are a major logistical challenge to recording breeding success directly, especially when the gannet breeding season extends over nearly 6 months.

Remote monitoring techniques potentially offer a more reliable method of monitoring productivity. In early spring 2025, six plots were selected and two remote productivity monitoring techniques (live, controllable video webcams and photo trail cameras) were trialled. Data from the four plots monitored with Scottish Seabird Centre webcams indicated that mean productivity was 0.53 chicks fledged per Apparently Occupied Nest. This value appears broadly similar to the few other gannet colonies that have been monitored in the UK since the Highly Pathogenic Avian Influenza outbreak, suggesting that breeding success for the species may have declined.

Productivity among Bass Rock webcam plots showed relatively little variation. In contrast, productivity in the two plots monitored by the trail cameras was highly variable, with one plot being very successful and the other very unsuccessful. Within-colony variation in breeding success in gannets appears to be unusual. The reasons for the variability in the Bass Rock population are currently obscure but seem more likely to be due to biological rather than methodological factors. Further productivity monitoring using the Scottish Seabird Centre webcams and trail cameras is clearly needed to refine methodologies and to understand to what extent the 2025 results represent the current state of the colony.

Introduction

Britain, Ireland, and the Channel Islands collectively support approximately 70% of the world's breeding population of Northern gannets (*Morus bassanus*; hereafter 'gannets') (Stanbury *et al.*, 2024). In 2022 Highly Pathogenic Avian Influenza (HPAI) resulted in unprecedented mortality and reduced breeding success in gannet populations throughout the Northeast Atlantic, including the Bass Rock (Lane *et al.*, 2023). Prior to the HPAI outbreak, the Bass Rock was the biggest colony in the world, with 75,259 Apparently Occupied Sites (AOS) counted in 2013-2014 (Murray *et al.*, 2015). However, following the HPAI outbreak, the population decreased by 31% in 2023 and there was a further decrease of 11% in 2024 (Harris *et al.* 2023, Burton *et al.*, 2025). As a result of these decreases, the gannetry on St Kilda became the largest colony in the world (Nisbet *et al.*, 2025). Collecting robust, standardised data on the Bass Rock gannet population in the aftermath of the HPAI outbreak is thus of major conservation importance.

Breeding productivity is a key demographic metric, yet annual productivity data are collected at only a handful of Scottish colonies (Harris *et al.*, 2024). Accessibility is a major factor, with many ganneries in Scotland found on islands or in remote regions that can only be accessed by boat during fair weather. Repeat visits are therefore impractical, costly and never guaranteed. The problem is compounded by gannets having one of the longest breeding seasons of any UK seabird (typically March – October). For these reasons, a robust, long-term programme of productivity monitoring on Bass Rock has not been possible. It is thus extremely timely that new studies suggest that these logistical barriers may be overcome using remote monitoring techniques (Tanedo *et al.*, 2021).

In 2025, Scottish Seabird Centre (SSC) and Edinburgh Napier University (ENU) tested two remote monitoring techniques (live video cameras and photo trail cameras) to monitor gannet productivity at six sites on Bass Rock. Live webcams were first installed on Bass Rock by SSC between 1999 and 2000 for public engagement but can also be used as a tool for monitoring and research (e.g. Lewis *et al.*, 2025). Indeed, live video cameras are increasingly used as a practical, efficient means of collecting high quality data with low disturbance impact to augment or replace onsite monitoring (Hentati-Sundberg *et al.*, 2023, Kiat *et al.*, 2025, Tanedo, 2016). Several webcams are required to monitor large colonies such as Bass Rock. However, webcams are expensive and additional installation and maintenance costs limit their use. Trail cameras have been used to monitor other seabird colonies (Lorentzen *et al.*, 2012, Per Huffeldt & Merkel, 2013, Southwell & Emmerson, 2015, Tanedo, 2016) and may prove a more cost-effective alternative to webcams for large colonies since they are cheaper, faster to set up and easier to maintain. However, compared to webcams their field of view is smaller, images may be of poorer

quality, acquiring live feeds can entail high monthly fees and technical faults can result in the loss of timestamps or unreliable rates of image capture (Newey *et al.*, 2015). Crucially with both techniques, if the cameras break or are offline, they can only be fixed if they are located in an area accessible to staff or engineers.

This study aims to address the long-standing gap in consistent productivity monitoring on Bass Rock by 1) obtaining an estimate of breeding success in 2025 and 2) evaluating methods for remote data collection at this colony. Results will be shared with conservation partners, inform public engagement, and provide an evidence base to support research into the impacts of climate change, offshore development and other pressures on gannets. It is further hoped that the findings will form the foundation of a standardised, long-term productivity monitoring programme on Bass Rock. The 2025 data therefore represent both an immediate contribution to understanding the colony's health, and a strategic step toward embedding Bass Rock within a wider, coordinated framework of gannet productivity monitoring.

Methods

Study Location and Camera Set-up

Six study plots were established on the Bass Rock, Scotland (56.08°N, 2.62°W), in March 2025. Live video observations from the two preexisting SSC webcams were made using remote camera controls via TeamViewer (TeamViewer GmbH, n.d.; Webcams 1 and 2). Webcam 1 was a Hikvision CCTV camera. Webcam 2 was a BOSCH MIC series D/N Camera. Trail camera observations from hourly photographs were made using Spypoint Flex-S cellular solar-powered trail cameras (Trail Cams 1 and 2), which were deployed on March 31 before the breeding birds returned to the colony to avoid disturbance. Images were viewed after the end of the breeding season when the cameras were retrieved, thus data were obtained retrospectively.

The plots were distributed throughout the colony within the constraints of equipment availability and minimising disturbance of the gannets. Four plots (1-4) were observed using SSC webcams and two (5-6) using trail cameras (Figure 1). Plot 4 was an historic plot used by Lewis *et al* (2025) and part of a larger plot monitored by Bryan Nelson during his work in the 1960-70s (Nelson 1965, 1978). Plots 1, 3 and 4 were monitored by SL (ENU). Plots 2, 5 and 6 were monitored by EM (SSC).

The SSC webcams are located on the south side of the island. The ability to pan the cameras 360° allowed for multiple plots to be monitored per webcam. Webcam 1 was accessible throughout the season whereas Webcam 2 was not accessible and thus could not be fixed once the breeding season commenced if the camera failed (Figure 1).



Figure 1. Positions of the two SSC webcams (blue dots, labelled Webcam 1 and Webcam 2) and two trail cameras (red dots, labelled Trail Cam 1 and Trail Cam 2); and the approximate positions of the four productivity plots monitored via the webcams (blue squares; labelled plot 1, 2, 3 and 4) and the two productivity plots viewed through the trail cameras (red squares; labelled plot 5 and 6). The dotted white line denotes the path and railings between the chapel and foghorn. The area within the yellow line shows the approximate accessible area on Bass Rock during the gannet breeding season. Orthomosaic vertical image © University of Edinburgh, 2025.

Trail cameras were positioned in areas out of sight of and inaccessible to humans during the breeding season due to the high density of nests on footpaths, meaning their associated plots (Figure 1) experienced less human disturbance than the webcam plots. They were restricted to areas with

existing infrastructure that was sturdy enough to withstand high winds and potential bird collisions, narrow enough to administer straps to, and high enough to present a clear downward field of view. The only suitable infrastructure were prominent railings along the Bass Rock’s eastern side, which bordered the path between the lighthouse and foghorn (Figure 1). The cameras were secured at knee-height onto these railings using straps, weather-proof tape and wooden wedges to angle the view downwards (Figure 2). As a consequence of the cameras being angled downwards, the solar panels (located on top of each camera) were not always at the optimal angle to catch sunlight. The installation process took roughly 3 hours during one visit to Bass Rock.



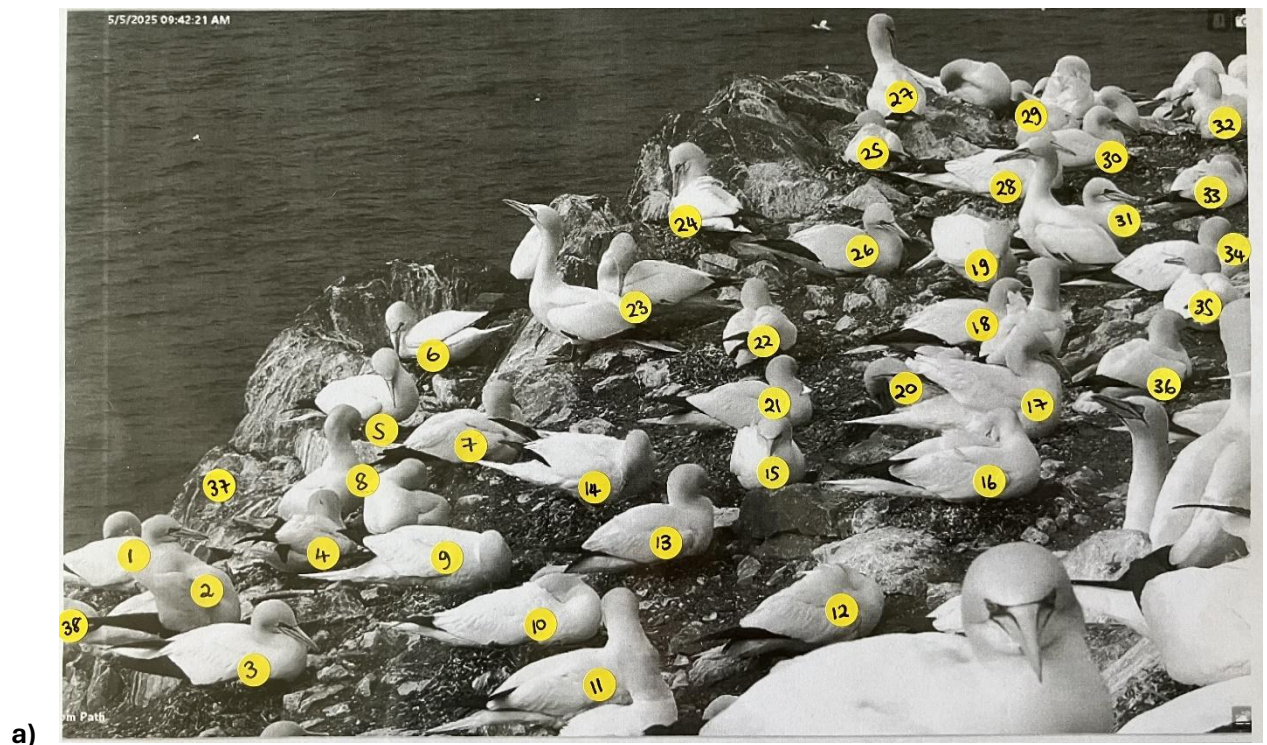
Figure 2. Installation of Trail Cam 2, situated on a railing beside the steps leading down to the foghorn, with the square solar panel visible on top of the camera beside the aerial. This location was in shade for at least half of the day. Photo credit © SSC.

Productivity – Breeding Success

The Seabird Monitoring Handbook for Britain and Ireland, henceforth “monitoring handbook”, only provides guidelines for monitoring gannet productivity directly through field observations (Walsh *et al.*, 1995). The ‘*productivity-monitoring method 1 (mapped nests)*’ was adapted for use with data collected remotely.

Each plot aimed to contain at least 20 Apparently Occupied Nests (AONs), usually defined as suitable nesting sites occupied by one or two adult gannets where some nest material was present (Walsh *et al.*, 1995). To investigate how many AONs per plot could be accurately monitored using trail cameras, Trail Cam 2 was installed with a view predicted to contain 50-100 AONs, which is the recommended sample size for plots monitored by direct observations (Walsh *et al.*, 1995, Figure 3c). As trail camera plots were established prior to the breeding season, the number of AONs within each plot was unknown at the time of setup. However, evidence from previous seasons and staff knowledge of typical nesting areas indicated likely breeding use in 2025.

Screenshots of study plots 1-4 were taken using the webcams in late April, when nest sites were visible and occupied by birds attempting to breed. The images were printed, laminated and marked with numbered AONs (Figure 3a). In contrast, AONs for the trail camera study were selected retrospectively, as image analysis was conducted at the end of the breeding season. This allowed photographs from late May and early June, when nest sites were clearly visible during late incubation and early chick rearing, to be used for AON selection. These images were also printed, laminated, and marked with numbered AONs (Figures 3b and c).



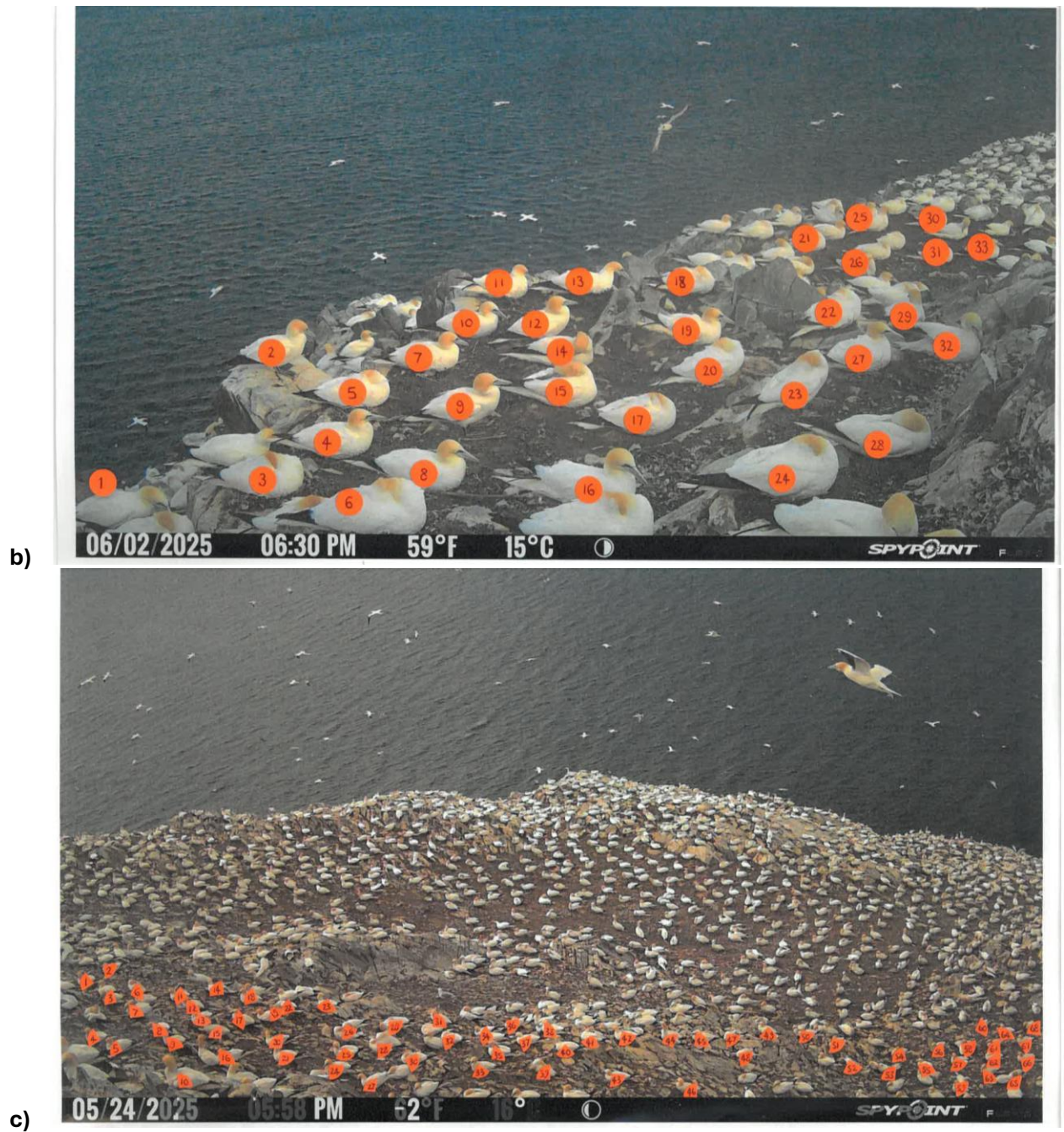


Figure 3. Screenshots of a) plot 1 from Webcam 1 (05/05/2025), b) plot 5 from Trail Cam 1 (02/06/2025) and c) plot 6 from Trail Cam 2 (24/05/2025), marked with numbered AONs. Due to a change in camera angle mid-season, AONs numbered 25, 26 and 28 to 30 at plot 5 were lost to view and thus removed from the study.

During each monitoring session, the presence or absence of adults, eggs, and/or chicks was recorded for each AON. Adults were classified as incubating or brooding based on a combination of behavioural cues and egg or chick sightings. Behavioural cues included continuous sitting, tucking the bill to

reposition an egg or chick and what Nelson (1963) described as ‘nest settling movements’, i.e. rocking and shuffling by a sitting bird.

Successful fledging was defined as a nest where a chick disappeared after reaching an estimated age of 12 weeks (Walsh *et al.*, 1995). Chick age was determined using photographic and descriptive guides from Nelson (1978) and by counting the number of weeks since first observation.

Productivity was calculated as the estimated number of chicks fledged divided by the number of AONs per plot (Walsh *et al.*, 1995). Overall productivity for Bass Rock 2025 was calculated as a mean from webcam plots only, as this method has been used successfully to estimate productivity at the Bass Rock colony in recent years (Lewis *et al.*, 2025). Trail camera footage was used solely to assess the suitability of this technology for future monitoring.

Comparing Remote Observation Technology

Webcams

Observations were made daily, where possible, from 11 April to 11 October 2025 at plots 1, 3 and 4 (number of observation sessions per plot = 169 (Webcam 1), 67 (Webcam 2)) and every 3–10 days between 22 April and 6 October at plot 2 (except on one occasion in early July when there was a 14 day gap due to a lack of staff availability; total number of observation sessions = 35) (Figure 4). The difference in observation frequency between plots (weekly as opposed to daily) was not expected to significantly impact productivity estimates (Tanedo, 2016).

Except for plot 2, each observation session took place between 7-8am GMT. Plot 2 observations occurred within SSC office working hours (9am-5pm), when visitors also had access to the webcam controls. The cameras could only be used for monitoring when no visitors were present, making timings inconsistent.

Webcam 2 experienced a two-month loss of signal, meaning plots 3 and 4 could not be monitored during this time (Figure 4).

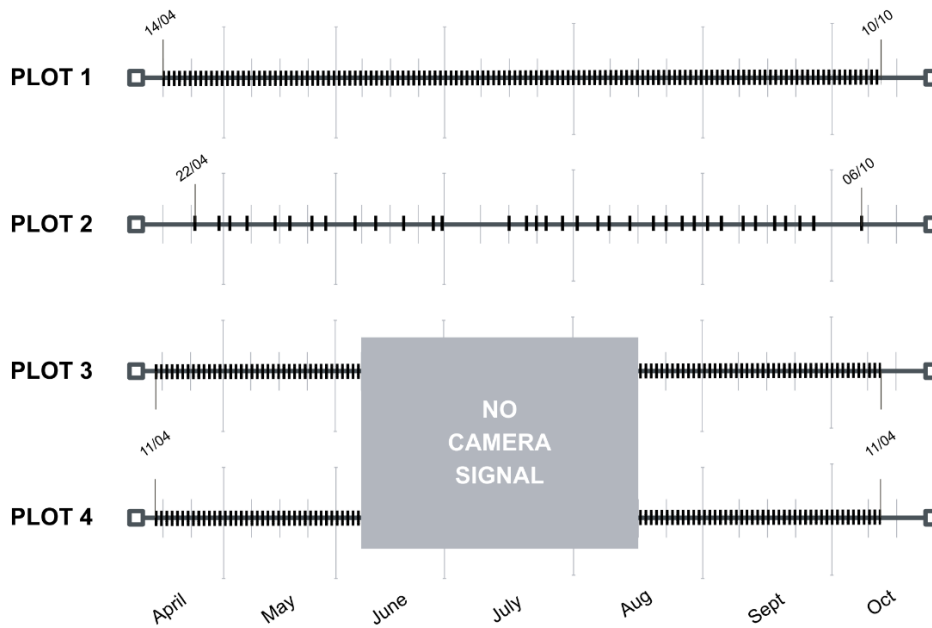


Figure 4. Regularity of monitoring sessions at plots 1 - 4 (webcams), including the timeframe during which no footage was viewable from Webcam 2 due to a loss of signal.

Trail Cameras

Trail cameras captured hourly photos of one plot per camera. Using preview images accessible via the SpyPoint app, we could confirm at the beginning of each month whether the cameras continued to function. However, even if preview images indicated that a malfunction had occurred, these could not be rectified because of the risk of causing disturbance to the gannets. Furthermore, preview images were not of high enough definition to assess breeding status of individual sites through the season. Assessments of breeding success were deferred until high quality images were viewed from SD cards after the trail cameras were retrieved in late October 2025, when the gannets had left the colony. Photos were analysed over autumn and winter 2025.

A monitoring session involved studying three consecutive hourly images from each trail camera. In cases where the camera failed to capture usable images for three consecutive hours, three clear images were randomly selected from within the same day. Beginning 22 April, three images were selected per plot every 7-10 days and, where possible, the dates on which these were selected were the same for both plots (Figure 5). Monitoring end dates varied between plots depending on when the last chick fledged or was estimated to have reached 12 weeks of age. At plot 5 this was 1 October

(total number of monitoring sessions = 24) and at plot 6 this was 26 October (total number of monitoring sessions = 23).

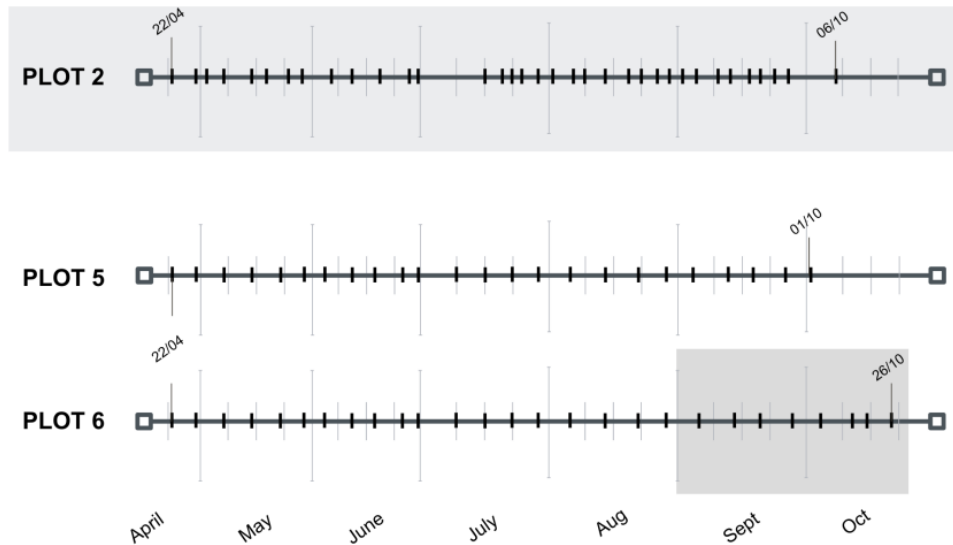


Figure 5. Frequency and consistency of monitoring sessions at plots 5 and 6 (trail cameras) compared to plot 2 (webcam), including the timespan when photo capture became markedly inconsistent (dark grey box).

As the two cameras were facing in different directions relative to the sun, plots 5 and 6 experienced glare at different times. Thus, they could not always be monitored at the same time of day. Plot 5 was most frequently observed using images captured in the early morning (at approximately 7am, 8am and 9am), and plot 6 in the afternoon (at approximately 4pm, 5pm and 6pm).

It was very rare to observe eggs or young chicks directly using hourly images. Adults were identified as ‘sitting’ or ‘standing’. If an adult was observed to be sitting across all three images in a monitoring session, it was assumed to be incubating or brooding. If partly standing (i.e. ‘squatting’) and it was not possible to confirm if an egg or young chick was present, it was assumed to be repositioning or making nest settling movements and could be incubating or brooding. It should be noted that gannets may stand during incubation on very warm days (Nelson, 1963), so under these circumstances a standing gannet may not necessarily mean that there is no egg or young chick if the observer does not have a clear enough view of the nest (due to lighting or distance, for example) to confidently say that no egg was present.

At plot 6 the greater distance at which sites were viewed meant that nest material was not easy to see. AONs were therefore judged to be a suitable nesting site occupied by one or two adult gannets where an apparent incubation attempt was recorded.

Technical faults with Trail Cam 2 resulted in issues with image capture, typically missing hours or sometimes entire days, and/or overexposure of images in strong daylight. There were also errors with the date and time label of images, which would be recorded by the camera as 01-01-2022. However, when images were downloaded onto a hard drive they appeared in the correct chronological order. We therefore assumed that any images dated 01-01-2022 were captured in the timeframe between the previous correctly dated images and those that followed.

The rate of image capture by Trail Cam 2 decreased and became less consistent as the season progressed, particularly from September onwards (Figure 5). Very few clear images were captured during October and the camera failed to capture three images on many days. However, it was not deemed necessary to analyse three images per day from this point in the season, since any adults that were incubating or brooding would be unlikely to raise a very young chick to fledging age so late in the season. Using the images available, it was still possible to determine that all chicks remaining at AONs within the study plot reached 12 weeks and were assumed to have fledged successfully.

Results

Productivity – Breeding Success

Live Webcams

A total of 152 AONs were monitored and 81 chicks were estimated to have fledged successfully giving a mean productivity across the 4 plots of 0.53 (SD \pm 0.50) chicks fledged per AON. There was little variation in productivity among the four plots monitored by the webcams (Table 1).

Table 1. Breeding success (chicks fledged per AON) in Northern gannets on Bass Rock by plot, obtained using live video webcams.

Plot	AONs	Chicks Fledged	Productivity
1	38	20	0.53
2	38	22	0.58
3	30	15	0.50
4	46	24	0.52
Total	152	81	

Trail Cameras

In contrast to the plots monitored by the webcams, where there was little inter-plot variation, breeding success in plots 5 and 6 varied markedly, being high in Plot 5 (0.72 chicks per AON) and low in Plot 6 (0.28 chicks per AON (Table.2)).

Table 2. Breeding success (chicks fledged per AON) in Northern gannets on Bass Rock by plot, obtained using photo trail cameras.

Plot	AONs	Chicks Fledged	Productivity
5	25	18	0.72
6	68	19	0.28
Total	93	37	

Comparing Remote Observation Technology

Overall, webcams surpassed trail cameras in terms of practicality and camera functionality, which made the monitoring process more efficient and increased viewer certainty and confidence in the quality of the data captured (Table 3 C & E).

However, trail cameras proved to be the cheaper and more cost-effective option all-round. They were also quick to install and easy to maintain (Table 3 A & B). However, they were less good at monitoring

plots with a high number of AONs and could not be used to reliably identify eggs or young chicks (less than 3 or 4 weeks of age) even at smaller plots.

Both camera types were equally matched regarding their reliability, battery capacity and tendency for footage to blur or pixelate (Table 3 C & D).

Table 3. Summarised comparison of the two remote monitoring techniques (live webcams and photo trail cameras) during productivity monitoring of Gannets on Bass Rock over the 2025 breeding season, with specific reference to A) Time; B) Cost (£); C) Quality/Specifications; D) Reliability; and E) Practicality. All costings were as of 2025 except purchase and installation of webcams.

A) TIME	Webcams	Trail Cameras	Preference
<i>Installation (per camera)</i>	Several days over multiple weeks inc. return boat trips, following many months of planning, liaising with technicians and acquiring permissions.	30 to 60 minutes (including repositioning, fixing in place, checking functionality) plus boat administration and travel.	Trail Cameras
<i>Maintenance (per camera)</i>	Several days throughout season inc. several return boat trips. *See Note	N/A	Trail Cameras
<i>Per Monitoring Session (per plot)</i>	10 - 20 minutes	30 - 60 minutes	Webcams

* Note: Significant logistical challenges and delays are frequently experienced in facilitating repairs due to difficulties lining up engineer availability, boat trips (which have high cancellation rates) and the restrictions posed by the gannet breeding season. This can result in extended periods when the camera is offline.

B) COST (£)

<i>Purchase (per camera)</i>	Approx. £7500 including installation materials	Approx. £250 + Approx. £30 for a 64GB SD Card	Trail Cameras
<i>Installation (per camera)</i>	Approx. £3000 for labour	Approx. £1-10 (camera already comes with some installation equipment) + boat hire/fuel	Trail Cameras
<i>Maintenance (per camera)</i>	Approx. £1000 per year	Approx. £250 to replace a malfunctioning camera; SD cards can be re-used	Trail Cameras

C) QUALITY/SPECIFICATIONS

<i>Resolution</i>	Bosch: 1920x1080P – 30x Zoom Hikvision camera: 1920x1080P – 25x Zoom	(Up to) 40MP photos and 1080p Full HD videos.	Webcams
<i>Photos/Videos</i>	Video and screenshots	Time lapse function allows a delay of up to one hour between photos or videos. 15 second videos.	Webcams
<i>Live Remote Viewing</i>	Yes	No	Webcams
<i>Transmission</i>	Camera digital signals are sent over a copper/fibre network on the island. The digital signal from the camera is converted from Cat 6/Copper cabling to fiber (so it can be transmitted over a longer distance). It is then converted back to copper. The signal is sent from the island to the SSC Visitor Centre via a Microwave Link and links to the visitor centre.	Remote transfer of up to 100 (lower quality) preview photos per month via LTE cellular network signals to the SpyPoint App using SpyPoint's free photo transmission plan. Other plans are available but include a fee. Signal (thus daily transfers) not always reliable.	
<i>Remotely Controllable View</i>	Yes	No	Webcams
<i>Power Source</i>	Supplied by a Photovoltaic system on the island ~5kWpe with ~10kWh of battery storage. Cameras are PoE (Power over Ethernet) with local PoE injectors. 240v supplies from the PVs power local equipment to the cameras (i.e. PoE injectors and ethernet media converters) from local IP rated equipment boxes.	Primary: integrated, solar-charged internal lithium battery. Secondary: 8x AA batteries (lithium recommended for better performance).	Either
<i>Battery Life</i>	May cut out during winter days (shorter daylength) or prolonged overcast weather until direct sunlight returns. Recharges quickly (approx. a few hours).	Varies based on footage type (photo/video) and levels of sunlight. Battery lasted 6 months during the 2025 gannet breeding season capturing hourly timelapse photos.	

<i>Tendency to Buffer, Pixelate, Blur</i>	Only when environmental changes in conditions lead to fluctuations in signal strength.	Tendency for images to suffer from over exposure depending on positioning.	Either
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D) RELIABILITY

<i>Robustness in Harsh Environmental Conditions</i>	High	Medium - High (camera prone to movement, resulting in the loss of some sites from view)	Either
<i>Consistency (timing and quality of footage)</i>	Medium	Medium	Either
<i>Remote Signal</i>	Medium	Low	Webcams
<i>Likelihood of Significant Data Loss</i>	Medium	High	Webcams

E) PRACTICALITY

<i>Ease of Set-Up</i>	Can take a few minutes to locate and pan camera between plots.	<p>Difficult to position in relation to plots during installation; with no screen to ascertain the camera's view, a phone is required with good internet signal (not always possible in remote locations) and the SpyPoint app to receive test images. Alternatively, a laptop to view images from the SD card. Requires much repositioning and thus increased time needed for fieldwork.</p> <p>There is only a short window of time to set up trail cameras between having good weather conditions for boat access and the beginning of breeding.</p>	Webcams
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<i>Ease of Monitoring</i>	High	Low - Medium (photos could only be analysed at end of season; analysis of multiple photos per monitoring session meant time spent monitoring at least tripled, especially when view of nests was unclear; eggs and young chicks not easily identified from photos; large image output, most of which were not required, could be difficult to catalogue, share, prioritise and analyse)	Webcams
<i>Similarity to Field-Based Monitoring</i>	High	Low	Webcams
<i>Plots Visible Per Camera</i>	Multiple	One	Webcams

Discussion

Using remote cameras, we were able to follow six plots for the purpose of monitoring the productivity of gannets on Bass Rock over the course of the 2025 breeding season. The two camera types (live video webcams and photo trail cameras) were used successfully to this end, though our confidence in the results varied. There were advantages and disadvantages associated with both, which will influence how productivity data are gathered at Bass Rock in future and provide useful information for anyone considering using remote camera systems for monitoring seabird productivity.

Productivity

Detailed field-based observations of gannet breeding success on Bass Rock have not been collected since the 1960s, when Bryan and June Nelson undertook their pioneering research on the island (Nelson, 1978). At that time, conditions appeared favourable; the breeding population was increasing at approximately 3% per annum and breeding success was consistently high (78% from 1961-63) across the colony (Nelson, 1978).

In contrast, breeding success in 2025, as estimated using the webcam-based method, was markedly lower (53%), despite monitored plots aligning closely with those studied by Nelson. In particular, plot 4 directly overlaps one of the plots monitored during the 1960s–1970s. It is not possible to determine conclusively whether this reduction reflects the substantial social disruption caused by the 2022 outbreak of HPAI or whether other factors have also contributed.

The HPAI outbreak is, however, likely to have resulted in a higher proportion of breeding attempts involving newly formed pairs or younger birds with fewer than three years' breeding experience. Both circumstances are associated with reduced hatching success and chick survival (Nelson, 1978). Nelson (1978) also reported lower breeding success in disturbed areas, which may further contribute to the observed disparity between productivity in the 1960s and that recorded in 2025. However, if this was true we might have expected to see lower productivity in plots 3 and 4, as they were located in less accessible areas, and this was not the case. Directly comparing productivity in areas known to experience high levels of disturbance with those where we are confident there is no human disturbance would help overcome uncertainties. This would necessitate increasing the spatial coverage of plots and would also help determine whether the current results are representative of the colony.

The lack of robust, standardised productivity data prior to 2022 limits the extent to which the 2025 results can be placed in a longer-term context. Opportunistic monitoring undertaken between 2007 and 2020 using SSC webcams (see Appendices, Table 4) typically consisted of a single annual count per plot, usually conducted in August or September. Productivity was calculated as the number of visible chicks divided by the number of AONs, irrespective of chick age. As monitoring was dependent on volunteer availability and camera functionality, both methods and timing varied considerably between seasons and did not align with the monitoring handbook guidelines or those used in the present study. Nevertheless, annual estimates during this period mainly ranged from 0.41 to 0.64 chicks assumed to have fledged per AON, values broadly comparable to the 2025 estimate but generally lower than the productivity estimates from the Seabird Monitoring Programme (SMP) for Scottish gannetries during this time period, which seem to have generally varied around an average of 0.7 chicks fledged per AON (Harris *et al.*, 2024). Although these earlier estimates for Bass Rock must be treated with caution, they suggest that breeding conditions may have been less favourable even prior to the HPAI outbreak.

Observations from the SSC webcam further indicate that individuals which appear to have been exposed to and recovered from HPAI show no significant difference in breeding success compared with birds assumed not to have contracted the virus (Lewis *et al.*, 2025). It is also notable that breeding success has remained broadly stable since the 2022 outbreak, with estimates from 2025 closely

matching those recorded in 2023 (56% in 2023 versus 53% in 2025 (Lewis *et al.*, 2025)). The 2023 results also appear consistent with productivity estimates from the SMP, which recorded an average of 0.59 chicks assumed to have fledged per AON across Scottish colonies in 2023 (Harris *et al.*, 2024).

Continued, comprehensive annual monitoring of gannet breeding success on Bass Rock is therefore essential to document how and whether the colony recovers, and over what timescale. This need is further emphasised by ongoing climate change and impacts of potential offshore windfarm developments within important foraging areas and flight paths of Bass Rock gannets.

Comparing Remote Observation Technology

Our findings support previous studies showing that trail cameras and live webcams provide practical and efficient methods for collecting data at remote seabird colonies, either supplementing or replacing onsite monitoring (Lorentzen *et al.*, 2012; Per Huffeldt & Merkel, 2013; Southwell & Emmerson, 2015; Tanedo, 2016; Tanedo *et al.*, 2021).

The monitoring handbook recommends repeated visits to representative plots throughout the breeding season to assess gannet productivity. On Bass Rock, this approach is largely impractical. The island is accessible only by boat, requiring suitable weather, lengthy organisation and funding, and much of the colony is inaccessible during breeding due to extremely high nesting densities and the risk of disturbance. As a result, monitoring is currently restricted to a small section of the colony, which may introduce bias.

Remote camera-based monitoring overcomes these limitations by allowing multiple plots to be observed across the colony throughout the season without disturbance. In this study we trialled two approaches: live video webcams and time-lapse trail cameras.

The live webcams made effective use of existing infrastructure on Bass Rock and allowed high-frequency data collection with relatively low effort. Pan, tilt and zoom functions enabled observers to locate plots and examine individual nests in detail, closely replicating field observations made with binoculars. Monitoring a plot of 30–46 AONs typically required around 10 minutes when camera signal was good. However, because the webcams were also used for the Scottish Seabird Centre visitor experience, research access could not always be guaranteed during opening hours, which limited flexibility in scheduling monitoring sessions. Furthermore, the potential loss of data from poor camera signals could add uncertainty to productivity estimates. The 5-week loss of signal from Webcam 2

coincided with the early to mid chick rearing period, which was less crucial than if it had occurred during peak laying or fledging. Given the lengthy breeding season of this species, the monitoring handbook indicates that it is appropriate to conduct monitoring once in May during late incubation/early nestling time and once in August shortly following fledging of the first chicks (Walsh *et al.*, 1995). However, any loss of signal during these key periods could have major implications for productivity monitoring at the relevant plots.

More webcams, installed specifically for research, distributed more widely across the colony and programmable for automated monitoring, would significantly improve efficiency and data quality. Although installation and maintenance costs are high, such systems can operate for many years, support multiple research and outreach purposes, and reduce the logistical challenges and risks associated with boat access. They also provide detailed information on breeding phenology, such as egg-laying and hatching timing, and allow more reliable identification of breeding failures.

In the absence of funding for additional webcams, trail cameras may provide a useful supplementary method for monitoring wider areas. However, our results indicate that they are suitable only for small plots and primarily for estimating overall breeding success. Identifying eggs and young chicks from time-lapse photographs proved extremely difficult, limiting their usefulness for monitoring breeding phenology.

Given the risk of camera movement, technical faults, and the small number of AONs visible per trail camera, increasing the number of cameras and reducing plot size would improve data reliability. Multiple trail cameras monitoring plots of 20–40 AONs are preferable to fewer cameras covering larger plots. At greater viewing distances, as with Trail Cam 2 (68 AONs viewed from over 15 m), it was difficult to identify nest material or distinguish between standing and incubating birds, and impossible to detect eggs or small chicks. Because most breeding failures occur during incubation or early chick rearing (Nelson, 1978), this limits trail cameras largely to identifying chicks that survive to fledging. Image analysis was also considerably more time-consuming than webcam observations.

Technical performance also varied between cameras. Trail Cam 2 experienced issues with exposure, time recording and photo capture, particularly later in the season, whereas Trail Cam 1 was consistently reliable. Such variability has been noted in other trail camera trials for wildlife monitoring (Newey *et al.*, 2015) and suggests that several cameras should be deployed where trail cameras are the primary monitoring tool. We recommend using approximately 5-10 cameras to

mitigate potential equipment failure. Solar charging may also affect performance, so cameras should be positioned so panels receive at least six hours of direct sunlight per day.

A key component of productivity monitoring is determining whether birds are incubating or brooding. This behaviour was difficult to interpret from still photographs but could be observed much more reliably in webcam video footage. Future trials using trail cameras capable of recording short video clips may improve accuracy, efficiency and allow monitoring methodology to be standardised across webcams and trail cameras.

Despite these limitations, trail cameras provided valuable observations from previously unmonitored areas of Bass Rock. Estimated productivity differed substantially between the two plots monitored (0.72 chicks fledged per AON at one plot and 0.28 at the other), suggesting possible spatial variation within the colony. This contrasts with earlier work by Nelson (1978), who reported consistently high breeding success across the colony in the 1960s. The variation observed here may reflect recent disruption associated with HPAI or other currently unknown factors. However, differences in camera placement and image quality may also have influenced estimates, particularly where image quality was poor.

Further methodological refinement is therefore required before trail camera productivity estimates can be incorporated into the annual productivity assessment for Bass Rock.

Seabird Monitoring Programme

Remote monitoring technology is increasingly being used within the field of seabird monitoring. However, protocols for monitoring productivity using video or photo cameras are not currently included in the monitoring handbook, meaning that results from different colonies are not standardised.

Our experience on Bass Rock suggests that for sites where cameras are used for productivity monitoring of gannets, plots should consist of 20 – 50 AONs. This sample size is smaller than that recommended for plots monitored by onsite observations. Accordingly, we suggest that in camera-based monitoring programmes a greater number of plots should be monitored to compensate for the reduction in nests monitored per plot. We also recommend developing two separate methods: (1) for monitoring using video footage, and (2) for monitoring via timelapse photography.

Conclusions

Breeding success of gannets on Bass Rock in 2025 was low and as yet there is no evidence of an improvement in productivity since the HPAI outbreak in 2022. To varying degrees, both live video webcams and static photo trail cameras proved effective for productivity monitoring. At locations where birds nest at high density, thus allowing one camera to view multiple nest sites at close-range, and where onsite visits by staff can be expensive, infrequent, time-consuming, of high disturbance risk and reliant on stable weather conditions, the remote monitoring techniques explored in this report can provide a cost effective and efficient alternative to traditional observational methods.

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Appendices

Table 4. A summary of gannet productivity monitoring by John Hunt in some years during the period 2007 to 2021 using one or more of the Bass Rock webcams in the SSC. Sample counts were done of randomly selected AONs. Most monitoring was carried out between August and September only. 'Young Assumed Fledged' was a count of the total number of chicks seen at AONs during the monitoring session(s) in August and/or September.

Year	Number of AONs	Young Assumed Fledged	Estimated Productivity (%)
2007	135	56	41%
2008	180	95	53%
2009	74	42	57%
2010	672	430	64%
2011	572	311	54%
2013	115	62	54%
2014	906	444	49%
2015	751	447	60%
2017	187	90	48%
2018	460	96	21% *See Note
2019	<i>Camera Issues – No Monitoring Possible</i>		
2020	504	237	47%
2021	<i>Camera Issues – No Monitoring Possible</i>		

* Note: Birds were late arriving and down in numbers, apparently due to poor Spring weather.

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