Adaptive Flyway Management Programme for the East Greenland/Scotland & Ireland Population of the Barnacle Goose (*Branta leucopsis*)

AEWA European Goose Management Platform

AEWA EGMP Programme No. 2

AEWA European Goose Management Platform

UNEP AEWA

AEWA European Goose Management Platform

Adaptive Flyway Management Programme for the East Greenland/Scotland & Ireland Population of the Barnacle Goose

Branta leucopsis

AEWA EGMP Programme No. 2

December 2021

Lifespan of Plan

6 years (2021 – 2026)

Prepared by

Aarhus University/AEWA European Goose Management Platform Data Centre,

Rubicon Foundation and UNEP/AEWA Secretariat

Adopting Frameworks:
Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) European Goose Management International Working Group (EGM IWG)

Organisations leading on the preparation of the plan:
Aarhus University/AEWA European Goose Management Platform Data Centre, Rubicon Foundation and the UNEP/AEWA Secretariat

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Lifespan and Review of the Plan: The lifespan of this Adaptive Flyway Management Plan (AFMP) is 6 years (2021-2026). It should be reviewed every 6 years (first revision in 2026). An emergency review will be undertaken if there is a significant change to the East Greenland/Scotland and Ireland population of the Barnacle Goose before the next scheduled review.

Milestones in the preparation of the Plan:

A process for the development of the AFMP for the East Greenland/Scotland and Ireland population of the Barnacle Goose was formally adopted by the European Goose Management International Working Group (EGM IWG) at the EGM IWG4 *in June 2019 in Perth, UK.*

The Range States of the East Greenland/Scotland & Ireland population and the Svalbard/South-West Scotland population attended a Meeting of the Barnacle Goose Adaptive Flyway Management Development Process which took place in *Reykjavik, Iceland on 1 October 2019.*

The first draft of this document was presented for consultation to EGM IWG and adopted at the EGM IWG5 held *in June 2020 in an online conference format*.

The second and final draft of the document was circulated for review to the Barnacle Goose Task Force (Greenland and Svalbard Population) and submitted to the EGM IWG6. Including the new sections and updates as well as the amendments requested at the meeting, the final draft was adopted at the EGM IWG6 held *remotely in June 2021*.

AEWA European Goose Management Platform (EGMP):
Please send any additional information or comments regarding this document to the AEWA European Goose Management Platform Coordinator, Eva Meyers (eva.meyers@un.org)

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List of acronyms and abbreviations

AEWA	Agreement on the Conservation of African-Eurasian Migratory Waterbirds
AFMP	Adaptive Flyway Management Programme
CMS	Convention on the Conservation of Migratory Species of Wild Animals
EC	European Commission
EGM IWG	European Goose Management International Working Group
EGM IWG4 / IWG5/ IWG6	The 4th / 5th / 6th meeting of the EGM IWG
EGMP	(AEWA) European Goose Management Platform
FRH	Favourable Reference Habitat (in sense of 'habitat for the species' DG Environment, 2017)
FRP	Favourable Reference Population
FRR	Favourable Reference Range
FRV	Favourable Reference Value
ISSMP	International Single Species Management Plan (Jensen *et al.*, 2018)
IWC	International Waterbird Census
MOP	Meeting of the Parties
MU	Management Unit

Introduction

The International Single Species Management Plan (ISSMP) for the Barnacle Goose *Branta leucopsis* (Jensen et al., 2018) was developed according to Paragraph 4.3.4 of the AEWA Text, Annex 3. This provides for developing ISSMPs for populations which cause significant damage, in particular, to crops and fisheries. In addition, it responds to AEWA Resolution 6.4, which requested the establishment of a multispecies goose management platform and process to address the sustainable use of goose populations and to provide for the resolution of human-goose conflicts, targeting as a matter of priority Barnacle and Greylag Geese.

The ISSMP for the Barnacle Goose was adopted at the 7th Session of the Meeting of the Parties to AEWA (MOP7), 4-8 December 2018 in Durban, South Africa. The ISSMP provides a mandate for developing population-specific Adaptive Flyway Management Programmes (AFMP) for each population of the Barnacle Goose, recognising that there are regional and population-specific differences in migratory behaviour and the human-wildlife conflicts involved. This AFMP shall be formally adopted by the European Goose Management International Working Group (EGM IWG) and then reviewed periodically.

A process for the development of the Barnacle Goose AFMP for the East Greenland/Scotland & Ireland population was formally adopted by the European Goose Management International Working Group (EGM IWG) at the EGM IWG4 in June 2019 in Perth, UK (document AEWA/EGMIWG/4.12/Rev.1).

The Range States of the East Greenland/Scotland & Ireland population and the Svalbard/South-West Scotland population attended a Meeting of the Barnacle Goose Adaptive Flyway Management Development Process which took place in Reykjavik, Iceland on 1 October 2019. The decisions and outcomes of this meeting were provided in document AEWA/EGMIWG/Inf.5.13. and a first draft of the AFMP was submitted to the EGM IWG5 and adopted in June 2020 as document AEWA/EGMIWG/5.20.

In addition, document AEWA/EGMIWG/5.19 was provided as an overview and roadmap for the finalization of the pending BG AFMP sections and for the implementation of the AFMP for the East Greenland/Scotland and Ireland population of the Barnacle Goose in the next 6 years until 2026.

During the intersessional period and ahead of the 6th Meeting of the EGM IWG (EGM IWG6), the EGMP Data Centre, the Secretariat and the Barnacle Goose Task Force (established at EGM IWG5), developed the missing sections of the BG AFMP.

The draft BG AFMP, including the new sections was circulated for consultation within the Barnacle Goose Task Force on 19 April 2021, providing members of the Task Force an opportunity to comment on the newly added sections and initiate a national consultation process.

This is the final version of the document adopted at EGM IWG6 and including all additions/updates agreed on at the meeting.

Table 1 provides an overview of the sections remaining to be developed under this AFMP in the upcoming years.

Table 1. Overview of the AFMP sections remaining to be developed, including the timeline, lead and resources required (and secured).

AFMP sections under development	Timeline	Lead	Resources required
Annex 4: Impact Models	By May 2022 (but pending funding)	Data Centre	EUR 150,000 (shared between Greylag Goose and Russian and East Greenland Barnacle Goose over 2 years)

Table 2. Overview of the next steps and timeline for the finalisation and the implementation of the AFMP

Process	**BG Range State Meeting Oct. 2019**	**EGM IWG5 June 2020**	**EGM IWG6 June 2021**	**EGM IWG7 June 2022**	**EGM IWG8 June 2023**	**EGM IWG9 June 2024**	**EGM IWG10 June 2025**	**EGM IWG11 June 2026**
AFMP development	AFMP process agreed	1st Draft AFMP ready for adoption	Review and adopt complete AFMP, including missing sections					Evaluation and revision of AFMP
	MUs agreed	FRVs agreed	FRVs finalised					
			Population model developed					
			Preliminary impact model developed	Impact model developed				
AFMP implementation		Annual workplans developed	Review annual workplans	Review annual workplans	Review annual workplans	Review annual workplans	Review annual workplans	Review annual workplans
Indicators		Collection of data for indicators starts	Collection of data for indicators	Collection of data for indicators	Collection of data for indicators	Collection of data for indicators	Collection of data for indicators	Collection of data for indicators

							Reporting on all indicators	
Management of offtake / coordination of derogations					Assessment and prediction of the cumulative impact of offtake			Assessment and prediction of the cumulative impact of offtake
		March total count			March total count			March total count
		Nest count in Iceland			Nest count in Iceland			Nest count in Iceland
		Annual monitoring activities	Annual monitoring activities	Annual monitoring activities	Annual monitoring activities	Annual monitoring activities	Annual monitoring activities	Annual monitoring activities
			Reporting offtake for 2020/2021	Reporting offtake For derogation per month	Reporting offtake For derogation per month	Reporting offtake For derogation per month	Reporting offtake For derogation per month	Reporting offtake For derogation per month
			Crippling rate monitoring	Crippling rate monitoring	Crippling rate monitoring	Crippling rate monitoring	Crippling rate monitoring	Crippling rate monitoring

The timeline shown in Table 2 provides an overview of the envisaged process starting from the Barnacle Goose Range State meeting that took place in Reykjavik, Iceland on 1 October 2019 up until 2026, in which various elements of the AFMP can realistically be developed and delivered subject to the availability of resources.

The purpose of this AFMP is to establish an agreement amongst Range States of the East Greenland/Scotland & Ireland population of Barnacle Goose on the implementation of those activities in the Barnacle Goose ISSMP that require coordination at the population and/or Management Unit (MU) level. Specifically, this AFMP addresses the following issues:

1) Definition of MUs (Chapter 1);
2) Definition of Favourable Reference Values (FRVs) for the population and its MUs (Chapter 2);
3) Provide a consolidated assessment of damages and risks caused by this population of Barnacle Goose (Annexes 2 and 4);
4) Establish protocols to assess the cumulative impact of all off-take including both derogations and legal hunting, where allowed (Chapter 3)
5) Establish indicators (Chapter 4 and Annex 5)

The implementation of further activities of the Barnacle Goose ISSMP is to be elaborated in the population-specific workplans. Annex 1 provides guidance on developing such workplans.

It should be noted, however, that Range States remain responsible for national planning and implementation within the framework of the ISSMP including their derogation measures under the provisions of Articles 9 of the Birds Directive and the Bern Convention.

This AFMP covers the period of 2020 – 2026.

1. Definitions of Management Units (MUs)

The ISSMP has mandated the EGM IWG to define the Management Units (MUs) in the AFMP. The Range States of the East Greenland/Scotland & Ireland population agreed to manage this population as one Management Unit, following a Range State Meeting of the Barnacle Goose Adaptive Flyway Management Development Process which took place in Reykjavik, Iceland on 1 October 2019.

2. Definitions of Favourable Reference Values (FRVs)

The ISSMP has mandated the EGM IWG to set the Favourable Reference Values (FRVs) in the AFMP for the breeding and non-breeding seasons. Following EGM IWG4, a revised document setting out the principles of defining FRVs for the Barnacle Goose was circulated on 7 October 2019. This version was revised based on written feedback from Range States and a workshop held with the European Commission (EC) and EU Member States on 31 January 2020 in Brussels. A final version of the document was circulated to the EGM IWG on 24 March 2020 (AEWA/EGMIWG/Inf.5.11[1]).

Favourable Reference Populations (FRPs)

The FRP is proposed to be set at the Agreement Value (i.e. around the year 2000) of **54,000 wintering individuals** and distributed amongst the Range States as in Table 3.

1https://egmp.aewa.info/sites/default/files/meeting_files/information_documents/AEWA_EGM_IWG5_Inf_5_11_FRVs_BG.pdf

Table 3. FRP values for the East Greenland/Scotland & Ireland population

Country	Breeding FRP (in pairs)	Non-breeding FRP (in individuals)	Notes
Greenland	17,400	n.a.	Assuming 2,000 pairs in Iceland.
Iceland	2,000	54,000	Breeding FRP is reported by the government Non-breeding FRP is estimated based on the wintering FRP assuming insignificant mortality after the spring census
Republic of Ireland	n.a.	8,500	Based on distribution of numbers around 2000
United Kingdom	n.a.	45,500	Based on distribution of numbers around 2000
Population total	19,400	54,000	Represents the total of the wintering population

Favourable Reference Range (FRR)

The FRRs for both the breeding and the non-breeding seasons were to be set by the Range States at the level of the 2013-2018 reporting period using the range method (DG Environment, 2017, pp. 125-128). This period is used to establish the FRR because of the CMS definition of the FRR[2] and available EU guidance (DG Environment, 2013, p. 15, 2017, p. 48).

The available range information is summarised in Table 4.

Table 4. FRR values for the East Greenland/Scotland & Ireland population

Country	Breeding FRR (in km^2)	Non-breeding FRR (in km^2)	Notes
Greenland	100,000	n.a	Estimates based on Boertmann & Nielsen (2010)
Iceland	1,000	10,800	The FRRs are provided by the government
Republic of Ireland	n.a.	12,000	
United Kingdom	n.a.	14,156	The FRR is provided by the government
Population Total	**101,000**	**36,956**	

[2] "the range of the migratory species is neither currently being reduced, nor is likely to be reduced" (see Article I.c.(2) of the CMS Convention Text).

Favourable Reference Habitat (FRH)

Assessment of FRH follows the same approach as the habitat for the species under the Article 17 reporting for the Habitats Directive (DG Environment, 2017, pp. 136-141), i.e. Range States were requested to qualitatively assess whether the extent and quality of the habitat is sufficient for the long-term survival of the population.

The UK, the Republic of Ireland and Iceland reported that there is sufficient habitat to support the population at the level of the FRP. Greenland did not report, but the document defining the FRVs for the Barnacle Goose (AEWA/EGM/IWG5/INF/5.8) concluded that based on the fact that the current population is larger than the FRP, there is sufficient habitat to support the population at the FRP level.

3. Cumulative impact of derogation and legal hunting

Action 4.2 of the ISSMP requires Range States to "*asses periodically, and report to the AEWA EGM IWG, the cumulative impact of derogations (as well as hunting in Range States in which derogation is not required) on the development of the population, the likelihood of serious damage to agriculture and risk to air safety and to other flora and fauna (including the Arctic ecosystems), and the non-lethal measures taken to prevent damage/risk, as well as the effectiveness of these. If necessary, coordinate the derogation measures between Range States to avoid risk to the population and to enhance the effectiveness of the measures*".

Consequently, the ISSMP does not define any target size for the population. It remains the sole responsibility of the individual Range States to take or not to take derogation measures in full compliance with the provisions of Articles 9 of the EU Birds Directive and of the Bern Convention.

Based on the above, the role of the Adaptive Flyway Management Programme for East Greenland/Scotland & Ireland population of the Barnacle Goose is not to maintain the population at a certain target level but prevent that the population declines below the FRP. Thus, the FRP represents the lower limit of the legally acceptable population size but not a target for population reduction. Monitoring of the population size and offtake, predictive modelling of the cumulative impact of national derogation measures and hunting (where it is legally allowed) will be used to inform national decision-making to ensure this.

It follows from this logic that monitoring, assessment and, especially, coordination amongst the Range States is less important when the population size is well above the FRP. However, these activities become increasingly important when the actual population size is approaching the FRP. Therefore, a tiered system of coordination[3] is recommended (Table 5). 200% of the FRP of the population is proposed to trigger tighter coordination of offtake amongst the Range States[4].

[3] As agreed at EGM IWG6, "coordination" in this context does not mean that Range States will be expected to de facto coordinate their use of derogations under the EGMP. EU Member States, in particular, maintain their full rights to make use of derogations as provided under the EU Birds Directive. The exact process and its implementation will be further discussed and defined within the Task Force.

[4] 200% of the FRP has been selected as a threshold to trigger coordination of offtake based on the precautionary principle as, everything else being equal, the closer the population is to the FRP the higher the risk that the population drops below the FRP if derogation and/or hunting is excessive or because of other reasons (such as increased predation). Such an ample buffer is also needed because total counts in this population can be carried out only once in every three years. Consequently, the population models need to make predictions for three years ahead, which increases their uncertainty. In addition, everything else being equal, the higher the actual population size is compared to the FRP, the more time is available to diagnose the causes of decline and to take conservation actions, if necessary, to maintain the population above the FRP.

Table 5. Monitoring, assessment and offtake coordination depending on the status of the population

Actual size of the population and its MUs	Measures
> 200% of the FRP	● Monitoring of population size, offtake under derogation and hunting; ● Prediction of population development.
< 200% of the FRP	● Monitoring of population size, offtake under derogation and hunting; ● Prediction of population development; ● Coordination of offtake under derogation and hunting; ● Taking coordinated conservation measures, if necessary.

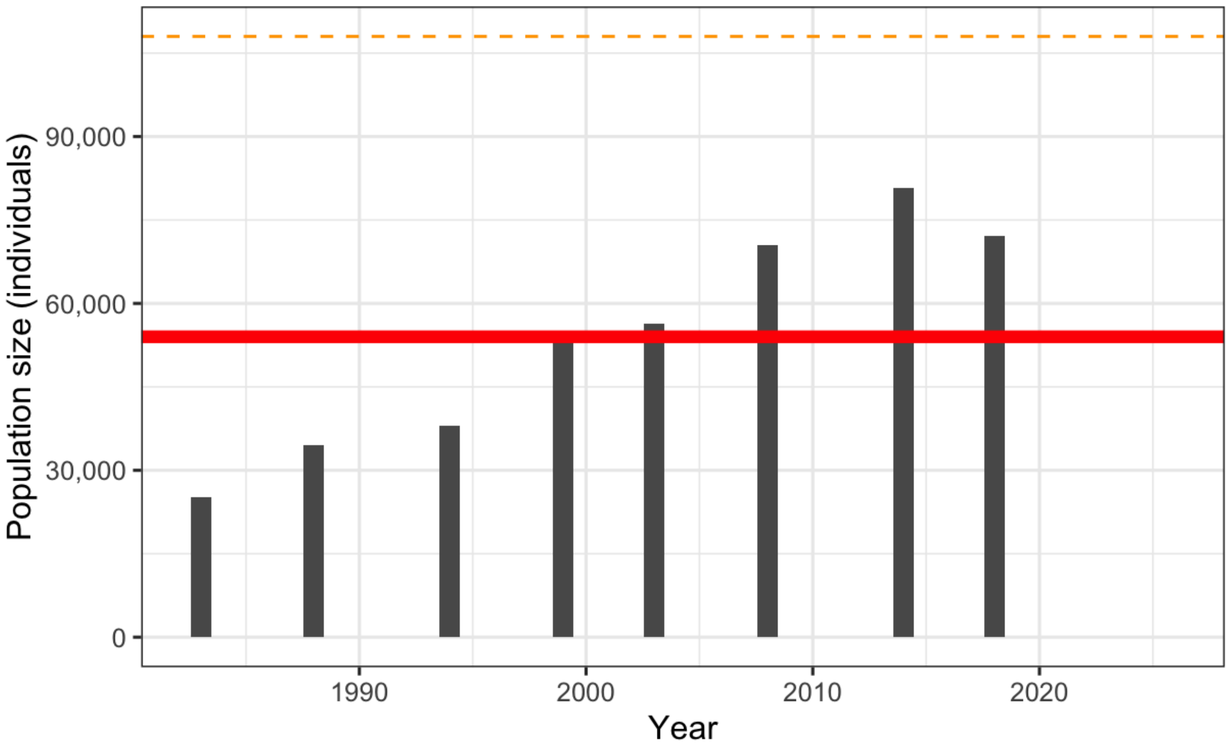

Figure 1. Development of the population size in relation to the FRP (red line) and 200% of the FRP (dashed orange line).

As Figure 1 shows, the current population level is only 34% above the FRP. Therefore, it is recommended that Range States in a coordinated manner:

- Develop a predictive population model;
- Increase the frequency of full population censuses from 5 years to 3 years;
- Agree on the level of allowable offtake (either under derogation or hunting) in order to avoid that the population size drops below the FRP.

4. Monitoring indicators and programmes

Monitoring indicators are designed to measure the progress towards the fundamental objectives of the ISSMP (Jensen et al., 2018, pp. 17-18). Indicators are presented in Table 6 for each Fundamental Objective. For each indicator, the rationale, the definition of the indicator and the indicator protocol is presented in Annex 5.

Table 6. Indicators for fundamental objectives of the ISSMP (Jensen et al., 2018)

Fundamental objective	Related indicators	Deadlines for reporting
I. Maintain the population at a satisfactory level	I.1 Population size compared to the Favourable Reference Population (FRP)	1 Apr. 2021 1 Apr. 2023 1 Apr. 2026
	I.2 Range extent compared to Favourable Reference Range (FRR)	31 Dec. 2025
II. Minimize agricultural damage and conflicts	II.1 Relative change in damage payments	31 Dec. 2025
III. Minimize the risk to public health and air safety	III.1 Risk of zoonotic influenza transmission to the general public	No national reporting is required
	III.2 Number of bird strikes with aircrafts caused by Barnacle Goose	31 Dec. 2025
	III.3 Number of Barnacle Geese passing over commercial airports	31 Dec. 2025
IV. Minimize the risk to other flora and fauna	IV.1 Area of natural habitat or habitat of threatened species negatively affected by Barnacle Goose	31 Dec. 2025
V. Maximise ecosystem services	V.1 Number of people enjoying watching geese	31 Dec. 2025
VI. Minimise costs of goose management	VI.1 Relative change in cost of goose management	31 Dec. 2025

5. Protocols for the iterative phase

Management evaluation and adaptation of the East Greenland/Scotland & Ireland population of the Barnacle Goose follows four iterative phases running in parallel (Figure 2):

1. A 10/12 year cycle of the ISSMP[5];
2. Two 6-year cycles of the AFMP, and within the AFMP:
3. Two 3-year cycles of monitoring of the total population size and assessing if the actual size of the population is below the 200% threshold and approaching the FRP;
4. 1-year cycles of monitoring in Scotland, Iceland and Greenland, as well as update of work plans.

5 The lifespan of the ISSMP is 10 years. However, it might be logical for the EGM IWG to recommend to the AEWA MOP to extend it to 12 years to include two 6-year-long AFMPs.

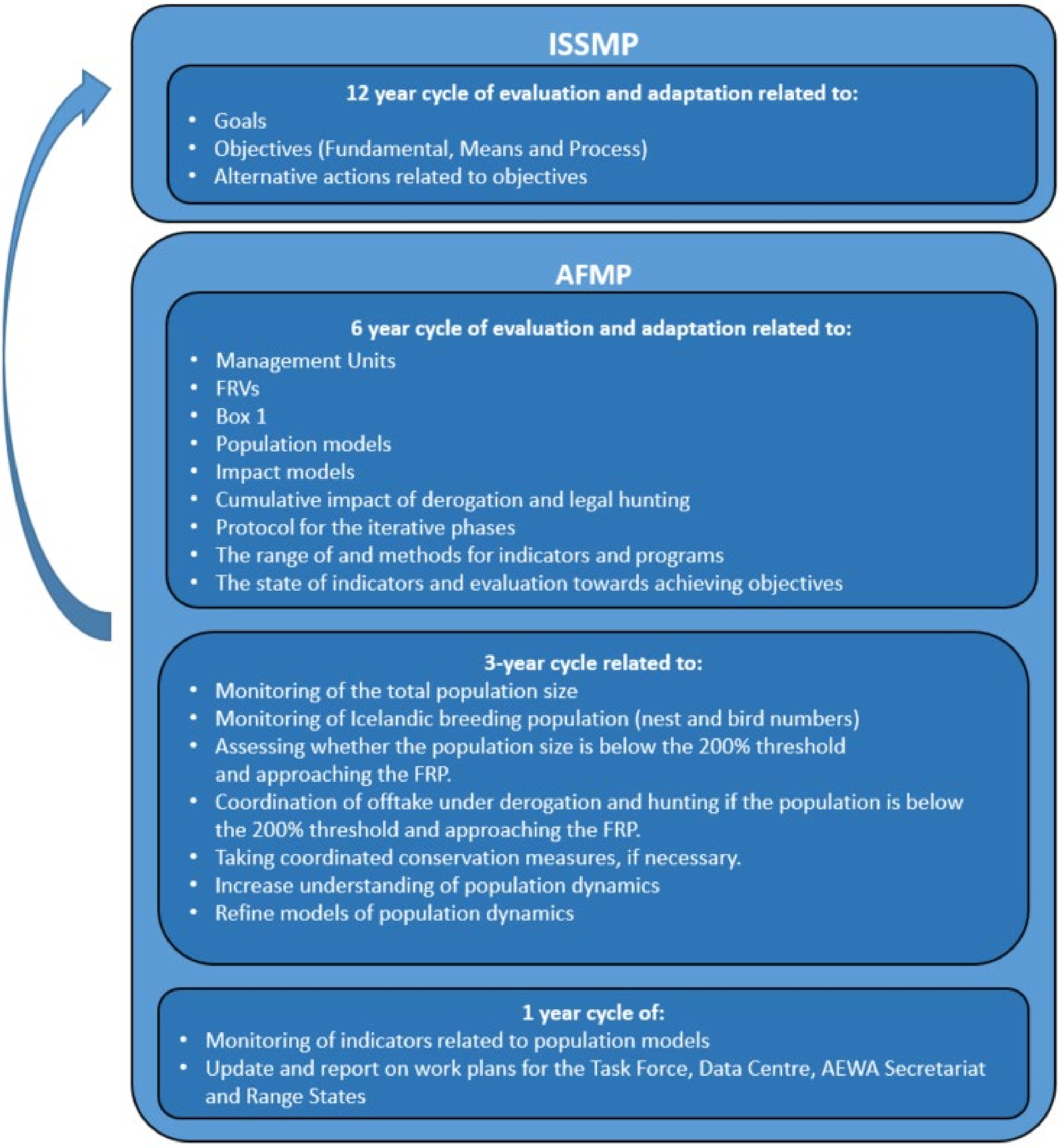

Figure 2. Flow chart of the four iterative phases of the AFMP

10/12 year cycle of the ISSMP

The 10/12 year cycle of the ISSMP encompasses evaluation and adaptation related to

- Goals;
- Objectives (Fundamental, Means and Process);
- Alternative actions related to objectives.

6-year cycle of the AFMP

The 6-year cycle of the AFMP encompasses evaluation and adaptation related to:

- Management Units (Chapter 1);
- FRVs (Chapter 2);
- Box 1 (Annex 2);
- Population models (Annex 3);
- Impact models (Annex 4);
- Cumulative impact of derogation and legal hunting (Chapter 3);
- Protocol for the iterative phases (Chapter 5);
- The range of and methods for indicators and programs (Chapter 4, Annex 5);
- The state of indicators and evaluation towards achieving objectives (Chapter 4, Annex 5);

The AFMP is evaluated and adapted next time in 2026 by the EGM IWG.

Two 3-year cycle within the AFMP

The 3-year cycle within the AFMP encompasses :

- Monitoring of the total population size;
- Monitoring of Icelandic breeding population (nest and bird numbers);
- Assessing whether the population size is below the 200% threshold and approaching the FRP;
- Coordination of offtake under derogation and hunting if the population is below the 200% threshold and approaching the FRP;
- Taking coordinated conservation measures, if necessary;
- Increase understanding of population dynamics;
- Refine models of population dynamics.

1-year cycles within the AFMP of data collection and update of work plans

The annual cycle within the AFMP encompasses:

- Monitoring of indicators related to population models (Action 4.2 in the ISSMP);
- Update and report on work plans for the Task Force, Data Centre, AEWA Secretariat and Range States (Annex 1).

Indicators/monitoring related to objectives and used in population models

The monitoring program and the specific activities are listed below. Monitoring activities take place every year, with the exception of the total population count which is performed every 3 years.

1. Total population counts in Ireland and Scotland (March 2020, 2023 and 2026, ongoing);
2. Population count at key sites in Scotland (ongoing);
3. Age counts on Islay and Tiree in Scotland (October-December, ongoing);
4. Offtake data (harvest and derogation) (ongoing) (derogation per month from 2022-onwards);
5. Crippling rate for the same periods as offtake (season 2020/21-).

Monitoring data is to be submitted to the EGMP Data Centre on an annual basis (every 3-year for the total population count), and no later than 1 April each year.

Progress on monitoring activities are reported in the annual EGMP Population Status and Assessment Report.

References

Boertmann, D. & Nielsen, R.D. (2010). *Geese, seabirds and mammals in North and Northeast Greenland. Aerial surveys in summer 2009.* National Environmental Research Institute, Aarhus University. 66 pp. – NERI Technical Report No. 773. URL: http://www.dmu.dk/Pub/FR773.pdf

DG Environment. (2013). *Great cormorant: Applying derogations under Article 9 of the Birds Directive.* 2009/147/EC(pp. 22).

DG Environment. (2017). *Reporting under Article 17 of the Habitats Directive: Explanatory notes and guidelines for the period 2013-2018*. Pp. 188. Brussels: European Commission.

Jensen, G. H., Madsen, J., Nagy, S., & Lewis, M. (2018). *AEWA International Single Species Management Plan for the Barnacle Goose (Branta leucopsis): Russia/Germany & Netherlands population, East Greenland/Scotland & Ireland population, Svalbard/South-west Scotland population.* AEWA Technical Series No. 70. Bonn, Germany.

Annex 1. MU-specific workplans

According to the ISSMP for the East Greenland/Scotland & Ireland population of the Barnacle Goose, the AFMPs set out annual workplans for the ISSMP actions relevant for the population/management unit. At the current stage, due to the limited data available on the population size and offtake, its harvest cannot be managed at MU-level. As the role of the workplan is to guide the implementation of the ISSMP, the prioritisation and timescale agreed in the ISSMP provides a framework for the work planning process. The ISSMP prioritises actions as Essential, High and Medium priority and assigns time-scales to actions as follows: *Immediate*: launched within the next year, *Short*: launched within the next 3 years*, Medium*: launched within the next 5 years, *Long*: launched within the next >5 years, *Ongoing*: currently being implemented and should continue, *Rolling*: to be implemented perpetually. In essence, this timescale system can be seen as a mechanism to stagger the implementation of actions taking into account both their dependencies and urgencies (Figure 3).

The timescale in combination with the priorities set in the ISSMP can be used to phase the implementation of actions. Thus, the most important would be to implement Essential actions that have an Immediate timing, followed by High priority with Immediate timing, etc.

Implementation of the ISSMP requires work by different entities (Figure 4). Some actions should be done at national level as part of national workplans. To facilitate coordination amongst Range States and to develop these specific workplans, population-specific Task Forces for the Barnacle Goose were established at EGM IWG5 (AEWA/EGMIWG/5.23).

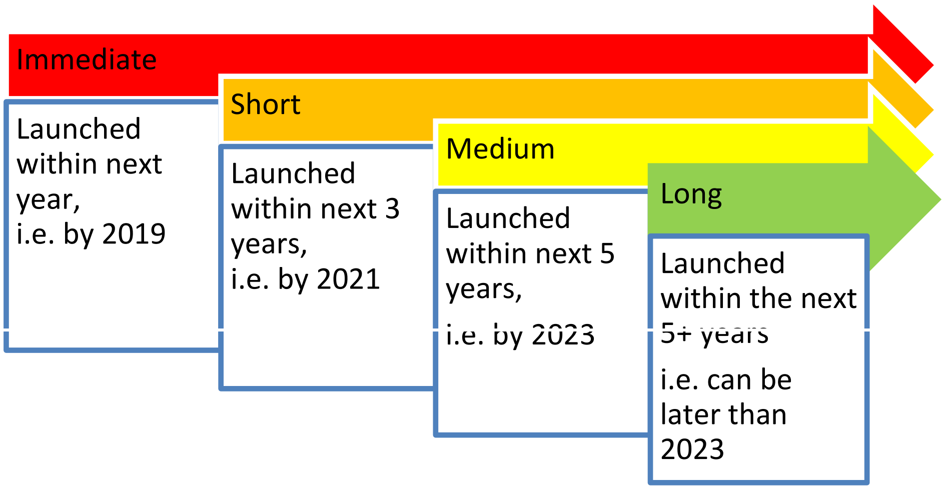

Figure 3*.* Timescale for the implementation of the ISSMP for the East Greenland/Scotland & Ireland population of the Barnacle Goose.

In addition, the coordination of cross/cutting tasks have been taken up by a cross/cutting TF (e.g. the Agriculture Task Force) and through coordination amongst the EGMP Task Force coordinators during joint meetings.

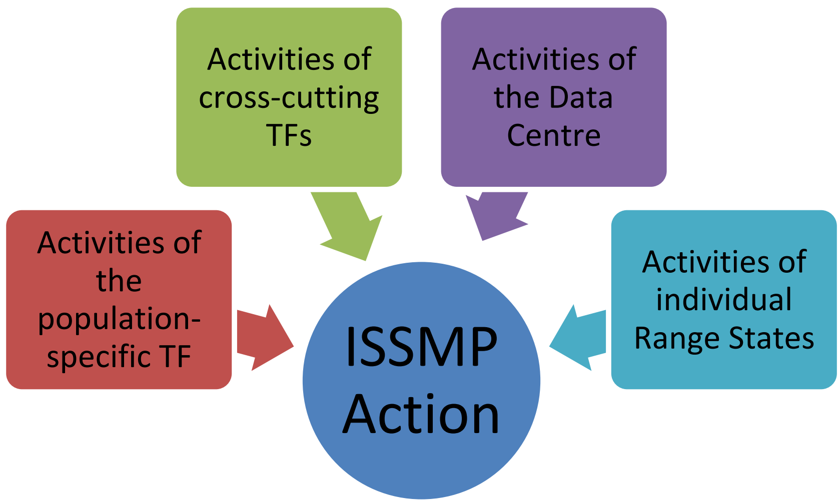

Figure 4. Entities contributing the implementation of the implementation of the East Greenland /Scotland & Ireland population of Barnacle Goose ISSMP and would need to develop annual workplans.

Each EGM IWG entity contributing to the implementation of the ISSMP for the East Greenland/Scotland & Ireland population of the Barnacle Goose uses a common structure to produce its own workplan. This structure includes the ISSMP actions relevant for the time period (i.e. 2020/2021 between the 5th and 6th meetings of the EGM IWG), their priority and timescale as defined in the ISSMP, list of activities to be implemented by the entity (e.g. a Range State, the Goose Task Force, Data Centre and the relevant cross-cutting Task Forces). It is recommended that in the period 2020/2021, the EGM IWG entities focus on implementing the activities that have a timescale of Immediate or Short and focus first on the Essential ones followed by High and then by the Medium priorities as capacity allows.

The online worksplans are periodically updated and the up to date version is available at:
https://docs.google.com/spreadsheets/d/1M64HWxzVagM9W0mG8iMMeVYS3_-M44W6QsHvvUonST8/edit#gid=1472654637

The current version is presented here as at 17 May 2021.

Annex 2. Box 1 of the ISSMP for the East Greenland/Scotland & Ireland population of the Barnacle Goose – Analysis concerning Damage and Site Protection

Summary

- The East Greenland/Scotland & Ireland Barnacle Goose population is significantly increasing on the long-term but stabilizing or declining on short-term.
- There are limited data on the actual costs and applied methods to prevent agricultural damages caused by this population.
- The response from the range states provides an overview of the Barnacle Geese are managed inside and outside the SPAs and how damage prevention is tackled.
- We have received no information from airports along the migratory route for this population.

Aim

The International Single Species Management Plans (ISSMP) for the Barnacle Goose *Branta leucopsis* (Jensen et al. 2018) and Greylag Goose *Anser anser* (Powolny et al. 2018) and the related population-specific Adaptive Flyway Management Programs (AFMP) aim to establish an agreement amongst Range States on the strategic goals and objectives of the conservation and management of the species and more specifically for each of the populations and management units.

The ISSMP require the use of a more detailed analysis concerning damage and site protection, as set out in Box 1 of the ISSMP with the purpose to assist Range States in assessing the need for derogations from the provisions of Article 5 of the Birds Directive and in coordinating the implementation of their derogation schemes.

At the 4th Meeting of the AEWA European Goose Management International Working Group (EGM IWG 4; Perth, Scotland 18-20 June 2019), the EGM IWG agreed on the proposed outline and content of the AFMP and took note of the proposed timelines and steps, as well as data and resources needed.

This text aims at reporting the obtained information in a transparent way, providing a baseline for the future work.

Box 1

The ISSMP envisages the use of more detailed analysis of data on damage to agriculture and risk to air safety and to other flora and fauna as set out in Box 1 (Fig. 5) and the following action to improve consistency in states' decision-making regarding derogations and the consistency of their justifications: "Create a toolbox for decisions in relation to determining significant damage (including metrics, benchmarking, verification, monitoring, various management techniques to prevent damage, compensation)."

Similar processes were described for the two species, Greylag Goose and Barnacle Goose.

Timeline

In September 2019, an agreement between the donor, The Government of the Federal State of Germany and the recipient, The Secretariat of African-Eurasian Migratory Waterbird Agreement (AEWA) was signed and the European Goose Management Platform (EGMP) Data Centre requested to implement the ISSMPs for Barnacle Goose and Greylag Goose. Input on Box 1 of the ISSMPs for the Barnacle Goose and the Greylag Goose is provided for the development of the Adaptive Flyway Management Programs.

During spring 2020, all range states responded to a detailed questionnaire with several sheets in an excel file for each of the two species To our knowledge, possibly as a result of the rather small size and limited range, no conflict between air safety and this population has been reported. Therefore, the issue has not been addressed for this population. The process was reported at the EGMP IWG5 meeting in 2020 and the final results should be reported by spring 2021 and presented for EGMP IWG6 in June 2021.

Box 1. Information needed in each AFMP concerning damage and site protection

Care must be taken to ensure that the management actions recommended by AFMPs are not inconsistent with the legal obligations prescribed by relevant international instruments. The AFMPs have the potential to, *inter alia*, assist Range States in assessing the need for derogations from the provisions of Article 5 of the Birds Directive (and, to the extent that they are relevant, the protections prescribed by the Bern Convention and AEWA) and in coordinating the implementation of their derogation schemes. Each AFMP should therefore contain information that is relevant for assessing the need for derogations at Range State level. This should include:

i. Characterization of the spatial and temporal extent and trends of damage to agriculture and of risks to air safety as well as to other flora and fauna that can be attributed to the population/MU in question, including predicted future changes in these;
ii. Description of the methods applied in the past assessments for each country and recommendations for the development of future guidelines for assessments;
iii. Description of the methods applied or tested to prevent damages and to reduce risks, their effectiveness and sufficiency to tackle the problem;
iv. Understanding of the link between population level and damages or risk.

Each AFMP shall also contain information on habitat conservation measures, including designation of Special Protection Areas (SPAs) under Article 4 of the Birds Directive:

i. List of SPAs and other protected areas designated for the Barnacle Goose;
ii. Management of the species and the damage inside and outside SPAs;
iii. Tackling damage prevention inside and outside SPAs (accommodation areas, derogations, etc.).

Figure 5. Box 1 was included in the International Single Species Management Plans (ISSMP) for the Barnacle Goose *Branta leucopsis* (Jensen et al. 2018).

Agricultural damages

Methods

A questionnaire was developed and sent to each range state of the population (Table 7). These questionnaires were structured to correspond to each of the numbers in Box 1 and the respondents were requested to fill in as detailed information as possible. This resulted in a high variation in the level of new information reflecting the large difference in activities related to the various aspects across countries.

Results and discussion

The results are presented and discussed following the order in Box 1. The reporting rate varied considerably between countries and issues (Table 7).

Table 7. Overview of provided information by each range state. The information in the upper row refers to the numbers in Box 1. ia &iia refer to agricultural damages, ib & iib to damages to other flora and fauna, iv-b to breeding and iv-w to winter.

Country	**ia**	**ib**	**iia**	**iib**	**iii**	**iv-b**	**iv-w**	**SPAii-iii**
IRL	X						X	X
IS			X	X	X	X		
UK	X	X	X		X		X	X

(i) Characterisation of the spatial and temporal extent and trends of damage to agriculture and of risks to human health and air safety as well as to other flora and fauna that can be attributed to the population/MU in question, including predicted future changes in these.

Ireland and Scotland (UK) reported on the agricultural damage caused by the Barnacle geese.

Ireland does not currently produce quantified assessments of agricultural damage as a result of Barnacle geese. Instead, Ireland operates two pro-active measures that financially reward farmers for 'goose-friendly' management and that offsets any loss of yield to the farmers. Thus, the costs associated with these metrics are likely a relevant metric. Participants in these measures create suitable and disturbance-free foraging habitat for geese and other waterbirds during the over-wintering period (primarily October to March). These measures are the Farm Plan Scheme run by the National Parks and Wildlife Service (NPWS), and the GLAS 'Geese and swan' agri-environment measure run by the Department of Agriculture, Food and the Marine (DAFM) under Ireland's Rural Development Programme. However, both of these schemes are targeted at a range of other bird species and not solely targeted at Barnacle geese. Thus, it is not possible to discern the costs associated with these schemes that relate only to Barnacle geese, and this should be considered with regard to the following figures. From 2012-2019, the NPWS Farm Plan Scheme paid c. €274,000 on average to scheme participants, and the DAFM GLAS 'Goose and swan' measure paid c. €3,080,000 annually from 2016-2020.

Scotland reported that Islay costs for GBG were reviewed last time in 2015 with the estimated costs of damage from geese on Islay at c. £1.5m. This included loss of yield, increased reseeding frequency, loss of grazing to sheep and longer in-wintering of cattle. Payments were based on rates for Goose Scheme participants (£/ha/year) at different sites and crops. The total sum paid on Islay for the past 5 years has been c. £900,000 (1.04 m Euro) and the administrative costs (incl. strategy delivery) are around £100,000 (115,000 Euro).

Regarding the effect to other flora and fauna, Scotland reported that derogation shooting of Greenland Barnacle geese caused disturbance and affected the time-energy budgets of Greenland White-fronted geese *Anser albifrons flavirostris* on Islay, and that the effect of shooting disturbance on Greenland White-fronted goose behaviour was much more acute than other causes of disturbance. Because shooting disturbance is rare relative to other causes of disturbance, it did not add substantially to the overall burden of disturbance to Greenland White-fronted geese on the island. It was therefore concluded that there was no evidence that Greenland White-fronted geese switched to suboptimal habitat after being in proximity to shooting disturbance events (Griffin et al. 2020).

Iceland reported that they had no new information on the impact of Barnacle geese to other flora and fauna.

(ii) A description of the methods applied in the past assessments for each country and recommendations for the development of future guidelines for assessments;

Scotland responded to this request: The current payment calculation is based on assumptions made from various studies in 1990s, which are all referenced in the Islay Strategy (McKenzie 2014). Those have been developed and refined over the years but there has been no other work done until the ongoing grass measurements by the use of exclosures was started. The methodology for that is sampling fields and comparing amount of grass in cages with amount outside cages, taking into account other possible herbivores.

Iceland suggested that coordinated guidelines for range states would be useful for the development of future guidelines for assessments of the impact on other flora and fauna.

(iii) Description of the methods applied or tested to prevent damages and to reduce risks, their effectiveness and sufficiency to tackle the problem.

The range states were requested to describe nine different predefined and one 'other' methods applied or tested to prevent damages and asked to score the effect of these (Table 8). However, there is only very limited information on this. Iceland responded on the effect of scaring and Scotland reported that the following methods were applied/tested to prevent damage on agriculture/flora and fauna: Shooting (lethal and non-lethal), limited use of kites, gas guns and scary men, but the effect was not scored (indicated by an X in Table 8). In Scotland, payments made to compensate for damage, happens in Islay, Tiree and Coll, Uist and South Walls. Derogation shooting only takes place on Islay at present.

Table 8. Overview of methods applied or tested to prevent damages by Barnacle Geese and the effect of these in the different range states. Scores are provided for local and national effect (local/national). The scores represent: 1: The measure does not mitigate the problem, 2: The measure could possibly help to mitigate the problem and 3: The measure mitigates the problem.

Agriculture	**Iceland**	**Scotland**	**Ireland**
Control of land use / site protection			
Damage compensation payments		X	
Derogation shooting for scaring		X	
Egg destruction			
Fencing			
Population control			
Sacrificial crops			
Scaring	2/1		
Subsidy schemes to allow geese			
Flora-fauna			
Egg destruction			
Population control			
Scaring			

The paucity of data restricts any discussion and conclusions on the effect of the applied methods.

(iv) Understanding of the link between population level and damages or risk.

The total population winters in sites predominantly on the north and west coasts of Scotland and Ireland. All geese stage in Iceland during c. one month in spring and most geese also stop here during autumn migration. Spring counts in Scotland for approximately every 5 years, provide estimates of the total population size and show that the population has increased significantly since the 1990s but with a recent stabilization or even decline. The 2018 estimate was c. 72,000 birds. In recent de cades, the breeding area has expanded to Iceland with a significant increase in the number of breeding pairs to 2,051 pairs in 2018 (Fig. 6).

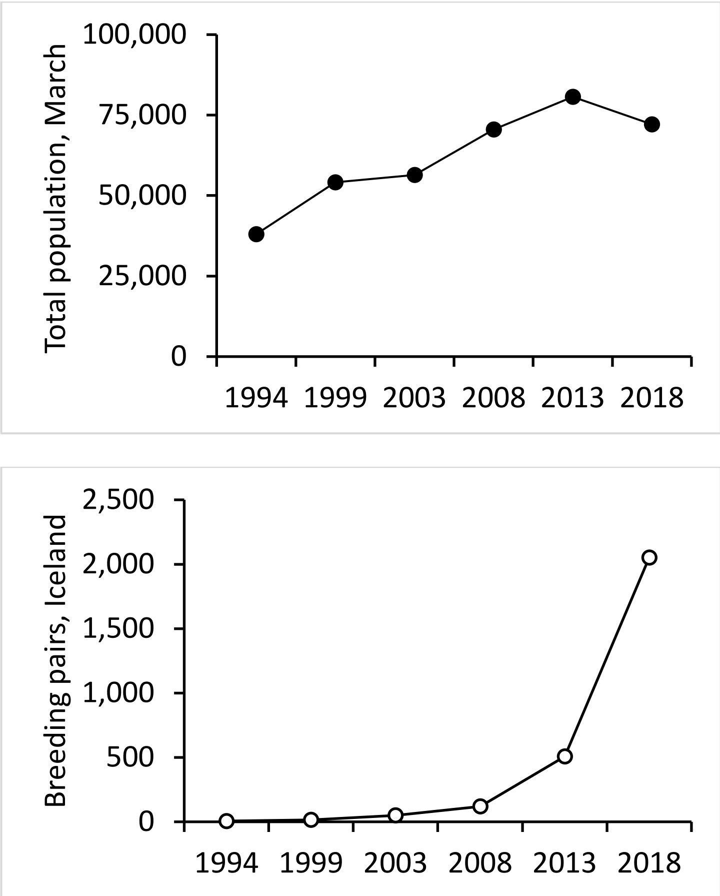

Figure 6. Population changes in the Barnacle Geese population during 1994-2018. The upper graph shows the estimates of the total population on the basis of counts conducted during March in Scotland. The lower graph shows the number of nests in Iceland.

There is a number of important counties in Ireland and sites in Scotland with a high number of wintering Barnacle geese every year (Fig. 7). The most important site is by far the Scottish island, Islay.

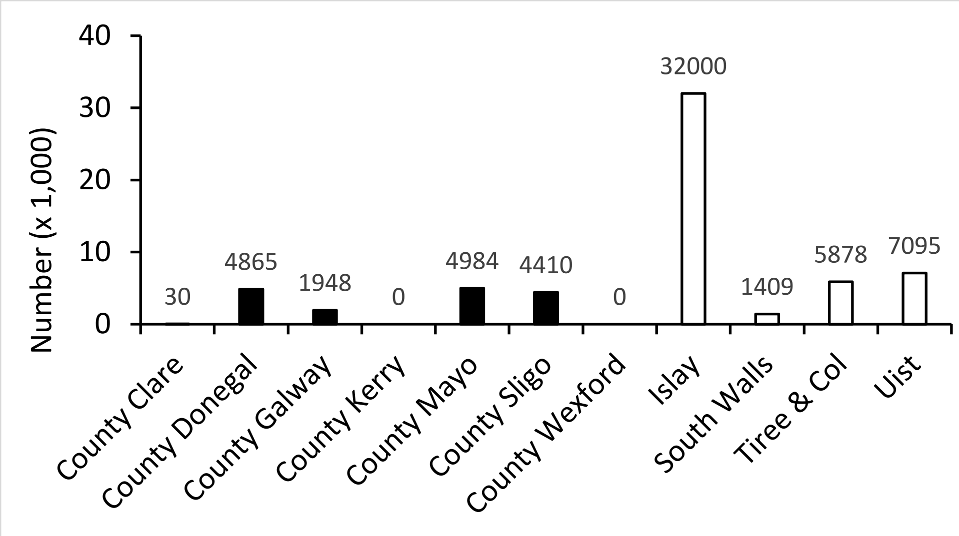

Figure 7. Distribution of Barnacle geese in Irish counties (bold symbols, total 16,237) and at Scottish sites (open symbols, total 46,382) during March 2018.

At Islay, Scotland, they studied relations between Barnacle Geese numbers and grass height by the use of exclosures.

They found that there is a clear statistically significant difference in grass height between the grazed areas and the exclosures in all studied months except January and that there is strongly significant evidence that increasing goose numbers in March are associated with decreased grass height (Ewing in prep).

(i) List of SPAs and other protected areas designated for the Barnacle Goose;

The updated list of the Natura 2000 data - the European network of protected sites is found at https://www.eea.europa.eu/data-and-maps/data/natura-11

(ii) Management of the species and the damage inside and outside SPA;

SPA related (ii) and (iii) are treated together and described below under point (iii).

(iii) Tackling damage prevention inside and outside SPAs (accommodation areas, derogations, etc.)

SPA related (ii) and (iii) were treated together. Replies were received from Ireland and Scotland, UK (Table 9). The replies show that the management of the species is almost identical in the two range states but that damage prevention is somewhat different.

Table 9. Overview on how replying range states manage the Barnacle Goose inside and outside the SPAs and the way in which they tackle the damage prevention inside and outside the SPAs. No/yes refer to whether the measure is applied or not.

Type	**Measure**	**Ireland**	**Scotland**
Management (ii)	Specific habitat restoration activities – roosts	NO	NO
Management (ii)	Specific habitat restoration activities - foraging areas	NO	NO
Management (ii)	Reducing recreational disturbance (non-hunting)	NO[1]	NO
Management (ii)	Hunting-free zones	YES[2]	YES[3]
Management (ii)	Hunting on the species allowed	NO	No hunting, but derogation shooting is carried out on SPAs
Damage prevention (iii)	Population control	NO	Yes to prevent serious agricultural damage (Islay only)
Damage prevention (iii)	Egg destruction	NO	NO
Damage prevention (iii)	Derogation shooting for scaring	NO	YES
Damage prevention (iii)	Scaring	NO with few exceptions to scare birds	YES but not at roosts
Damage prevention (iii)	Control of land use / site protection	NO	YES[4]
Damage prevention (iii)	Damage compensation payments	NO	YES for damage and reseeding
Damage prevention (iii)	Subsidy schemes to allow geese	Yes, via both NPWS Farm Plan Scheme (small scale) and DAFM	YES

		GLAS Geese and Swan measure	
Damage prevention (iii)	Sacrificial crops	NO	NO
Damage prevention (iii)	Fencing	NO	NO

The following comments to the replies are relevant:

Ireland:

[1] Agri-environment measures, with prioritised targeting of SPAs, include requirements to minimise disturbance from agricultural activities.

[2] Ireland has a number of Wildfowl Sanctuaries in which hunting is not-permitted; some are within the SPA network and others are outside the network.

Scotland:

[3] At roosts and undisturbed feeding areas on individual farms.

[4] Certain operations require consents and there are planning and development controls on these.

Air safety

Conclusions

- We have not collected information related to air safety within this flyway.
- Presumably, no current conflict between this population and air safety exists. This is most likely a result of the rather limited size and range of the population.
- This is in contrast to other NW-European regions, where the increasing Baltic/Russian population of barnacle geese has caused growing concern for air safety.

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Annex 3. Population Models

AN INTEGRATED POPULATION MODEL FOR THE FLYWAY POPULATION OF EAST GREENLAND BARNACLE GEESE

Final Project Report

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Executive Summary

In 2020, Nature Scot and the Department of Housing, Local Government and Heritage Ireland, funded the development of an integrated population model (IPM) for the purpose of better understanding the population dynamics of the flyway population of Greenland Barnacle Goose (*Branta leucopsis*) and in order to inform the management of offtake for the species.

Observational data included flyway population counts approximately every five years from throughout the winter range (March), annual Islay specific population counts (March), autumn juvenile counts (November) and offtake totals from Iceland and Islay. Prior distributions of natural (or intrinsic) survival were specified using capture-recapture data from the Svalbard population wintering in Scotland, and that for juvenile differential vulnerability in Iceland was specified using data from Pink-footed Geese in Norway. While we have strived to develop a model representative of this flyway population, our results and conclusions should be regarded in light of the limitations of the available data and methods.

Posterior estimates for all parameters fitted data-based counts well, with the majority of observed counts falling within 95% credible intervals. Posterior estimates for the flyway population show a consistent decline from 80,000 (71,000-89,000) in 2012 to 65,000 (55,000-76,000) in 2019. Similarly, population size in Islay has declined since the early 2000 from a peak of 45,000 (42,000-,48,000) in 2005 to 33,000 (29,000-36,000) in 2019.

Harvest rates in Scotland showed the greatest increase from 2011 to 2017 (2%-7% of the flyway population), whilst Iceland harvest rates have shown little variability (consistently <4%). Declines in the flyway and Islay population size coincide with increased harvest rates in Scotland. Similarly, the importance of alternative wintering sites appears to have increased with the increase in derogation shooting on Islay. This suggests that derogation shooting on Islay may not only be causing declines in the Islay wintering population, but also resulting in distributional shifts in the wintering population to alternative sites.

Estimates of juvenile survival rate were consistently lower than those of adults; this is unsurprising given the greater vulnerability of juveniles to harvest and the resulting greater juvenile harvest rate observed here. Age-specific harvest rate and survival show changes in response to increased harvest rates in Scotland, though this is more pronounced in juveniles.

Our results suggest the decline in the population of Greenland Barnacle Geese since 2012 has been driven by poor productivity and increased harvest rates, predominantly in Scotland. The flyway-specific Adaptive Flyway Management Plan does not provide targets for population sizes but does note that the flyway population should not fall below the Favourable Reference Population of 54,000 individuals, which at present is just below the 95% credible interval of our flyway estimate. Our posterior estimates for Islay population size (mean = 33,000, CI = 29,000-36,000) are close to those set as targets to reduce grazing pressure. Scottish derogation shooting appears to have both reduced flyway population size as well as caused distributional changes in use of wintering sites. The IPM provides a sound framework from which projections under different management scenarios can be assessed. Future work to project how harvest management may influence the flyway population should consider whether derogation shooting will be implemented in wintering sites outside of Islay, as well as future adjustments to harvest rates.

Introduction

The International Single Species Management Plan (ISSMP) for the Barnacle Goose (*Branta leucopsis*) recognised regional differences between the three flyway populations with regards to migratory behaviour and human-wildlife conflict, thereby providing a mandate for the development of population-specific Adaptive Flyway Management Programmes (AFMP) (Jensen *et al.*, 2018; Nagy *et al.*, 2020). This report is concerned with the East Greenland flyway population of Barnacle goose (GBG). Considerable growth in this population since the 1950s, and a shift towards agricultural grazing, particularly pasture, has resulted in increasing conflict with agricultural interests at overwintering sites (McKenzie and Shaw, 2017).

A greater demand for population management and control of GBG is evident across the flyway, driven by a breeding population establishing in Iceland (approximately 16% of the wintering population (Johannesson et al. in prep) and the ongoing conflict on wintering grounds in Islay and emerging in other areas (such as Tiree and North Uist) (Nature Scot, pers. coms). GBG are legal quarry in Iceland during the autumn migration and are killed under licence on Islay as part of the Islay Sustainable Goose Management Strategy (ISGMS). As part of population management for the ISGMS, population viability analyses (PVAs) have been produced for the Islay wintering population (Bunnefeld *et al.*, 2020; Trinder, 2014). However, no population model exists for the entire flyway as previous models often struggled to accommodate incomplete data, making it difficult to estimate many key demographic parameters at a flyway population scale. A key component in the development of an AFMP is understanding population dynamics for this flyway and assessing the cumulative impact of hunting and derogation shooting across the range.

Integrated population models (IPMs) are an increasingly popular advanced modelling approach used to better understand population size and dynamics (Ahrestani *et al.*, 2017; Kéry and Schaub, 2012; Weegman *et al.*, 2016). IPMs are advantageous over traditional modelling techniques as they are capable of integrating multiple types of data, as well as handling missing information (Horne *et al.*, 2019; Layton-Matthews *et al.*, 2019; Schaub and Abadi, 2011). In addition, IPMs offer improved precision of demographic rates and population size, and can estimate latent (unobserved) variables (Kéry and Schaub, 2012; Plard *et al.*, 2019; Schaub and Abadi, 2011). The adaptability of IPMs provides an ideal framework to inform and develop monitoring programs and adaptive management strategies as parameters can be updated over time as new data become available (Fieberg *et al.*, 2010; Gamelon *et al.*, 2019; Johnson *et al.*, 2019; Saunders *et al.*, 2018).

The development of an IPM for GBG, as presented in this report, attempts to address changes in population dynamics and harvest for the entire flyway population. This was challenging due to the sparse nature of the flyway-level population counts (approximately every 5 years). Given the importance of Islay as a wintering site for over half of the flyway population, data collected from this wintering population was key in developing the model. However, the proportion of the flyway population wintering on Islay has declined in recent years, with birds increasingly relying on alternative wintering sites adding additional complexity to the exercise. As more data become available for these sites, the IPM can be developed further. We were also unable to use individual-based data for this population (e.g. for survival estimation). Should these data become available in the future, they can be incorporated into the IPM. In order for our model to be replicated or improved in the future, we have strived to carefully document our reasoning and methods.

Methods

1. Monitoring Data

The data used for this study are comprised of four components: a) population counts, b) productivity data, c) offtake, and d) survival.

1.1. Population counts

The entire GBG population winters in sites predominantly on the north and west coasts of Scotland and Ireland. Whole flyway population counts have been conducted at approximately five-year intervals since 1959 for the international census. These surveys take place in early to mid-March using a combination of air and ground surveys owing to the remote location of many of the wintering sites. We used March flyway count totals from 1987 to 2019 to build the model as they provide the most consistent historical record.

Islay is a key wintering site, with an estimated 78% of the Scottish population and 63% of the flyway population historically wintering on the island. Whole-island counts have been carried out monthly since 1982. Given the potential for movement during the wintering period, we used Islay population totals from counts conducted in March in order to temporally align annual Islay population counts with those for the flyway population.

1.2. Productivity

Age counts based on plumage characteristics conducted on Islay were used to help estimate annual productivity. Age counts are carried out annually on Islay between November and March. However, derogation shooting has been conducted on Islay since 2000 and begins at the start of November. In order to limit the effect of shooting on age ratios, we only used age counts completed in the first two weeks of November (1st – 16th November). Counts were aggregated for adults (birds aged ≥ 1 year) and juveniles each year according to the day of sampling in order to account for variation in observations within the year according to the day and location of the counts (Johnson *et al.*, 2019).

1.3. Offtake

Offtake of GBG takes place in Greenland, Iceland and Scotland. The majority of offtake takes place in Iceland (hunting) and Scotland (derogation shooting); as such we chose not to include data from Greenland owing to the low numbers of individuals harvested annually (<100 individuals).

GBG are subject to an open hunting season in Iceland beginning 1st September and ends with other goose hunting 15th March. However, in order to protect breeding birds which have established since the late 1990s, hunting is banned in the two counties of East Skaftafellssysla and West Skaftafellssysla until 25th September. These counties are the main stopover sites for the Greenland population. As such, the effective hunting period for GBG in Iceland is limited to four weeks from 25th September until the geese depart for the final stage of their autumn migration in mid-late October (Guðmundur Guðmundsson, pers. commun.).

In order to account for the greater vulnerability of juveniles to shooting mortality widely observed in geese (Calvert and Gauthier, 2005; Clausen *et al., 2017;* Madsen*,* 2010; Menu *et al.* 2002), we used wing returns from harvest bags from Scotland and Iceland to estimate differential vulnerability.

In Iceland, age ratios for harvest bags were obtained from wing returns sampled from hunters (1995 to present). When using autumn age ratios from Scotland, differential vulnerability in Iceland appeared to be greater than that observed in Scotland. However, due to the small annual sample size for Icelandic wing data, and a lack of productivity counts from Iceland, we chose to use records from pink-footed geese in Norway to set a prior distribution for higher differential vulnerability of juveniles in the first stage of their autumn migration (Clausen *et al.*, 2017; Madsen, 2010). As both species are Arctic-nesting migrants exposed to shooting at their first stopover sites in their migration, we feel that this was a suitable substitute in the absence of Iceland specific data for GBG (Johnson *et al.*, 2019).

In the UK, prior to 2000, GBG were protected from any shooting under the 1981 Wildlife Countryside Act. Since 2000, they have been subject to licensed derogation shooting exclusively on Islay, controlled by Nature

Scot (formally Scottish Natural Heritage, SNH) (McKenzie and Shaw, 2017). Henceforth, “Scottish harvest” refers to derogation shooting on Islay. Derogation shooting takes place from 1st November and ends 1st April, prior to geese departing on their spring migration.

Wing data for goose harvest on Islay has been recorded by Nature Scot since 2012 and provides annual totals for the number of adults and juveniles in the Scottish harvest bag. Age ratios from wing data were used to specify a prior distribution for differential vulnerability of juveniles in the Scottish harvest bag.

1.4. Survival rates

We were unable to obtain individual-based data for the Greenland population. As such, we used estimates of natural survival obtained using individual-based data from the Svalbard Barnacle Goose flyway. The Svalbard population winters predominantly on the Solway Firth on the border between Scotland and England and is not subject to hunting. Owing to the similarities between these populations we deemed it acceptable to use these estimates to derive priors for natural survival for GBG.

To estimate apparent survival, we modelled winter mark-recapture data with a Cormack-Jolly-Seber framework using the RMark interface (Laake, 2013) for the program MARK (White and Burnham, 1999). We fitted a variety of models which were then evaluated using AICc. Estimates from the best performing model were used to derive priors for survival in the IPM. The best performing model included annual variation in survival and resighting probability. No difference in resighting probability was found between sexes or age classes. Survival was found to be sex-dependent although there were no biologically meaningful differences between males and females. As such, we used survival estimates for females to derive prior distributions for natural survival in the IPM.

Model estimates of apparent natural survival for Svalbard Barnacle Geese were compared to those for a small subset of GBG wintering in Inishkea (Doyle *et al.,* 2020). Survival estimates for Inishkea were not used to inform priors for the IPM as these estimates are from a small, open population of GBG resulting in a high level of uncertainty.

2. Population Dynamics

The IPM is a pre-breeding census model with an annual time step and an anniversary date in March to align with when the flyway count takes place. We made the following assumptions: 1) natural mortality is distributed evenly throughout the year, 2) harvest takes place sequentially – first in Iceland followed by Scotland, 3) juvenile vulnerability to shooting in Scotland is constant throughout the winter, 4) hunting/derogation mortality is additive to natural mortality. We felt these assumptions were reasonable given the availability of the data and the annual cycle of the model.

Annual change in March population size:
(*Eq.1*)

$$N_{t+1} = N_t\theta\left\{\left(1 - h_t^i\right)\left(\left(1 - p_t^{Islay}\right) + p_t^{Islay}\left(1 - h_t^s\right)\right) + r_t\left(1 - v^i h_t^i\right)\left(\left(1 - p_t^{Islay}\right) + p_t^{Islay}\left(1 - v^s h_t^s\right)\right)\right\}$$

where N_t is the March population size at time t, q is the annual rate of natural survival, p_t^{Islay} is the proportion of the March flyway population on Islay at time t, h_t^i is the annual harvest rate of adults (i.e. >1 year) in Iceland, h_t^s is the annual harvest rate of adult birds in Scotland, v^i is the differential vulnerability of juveniles to harvest in Iceland, v^s is the differential vulnerability of juveniles to harvest in Scotland and r_t is the pre-season age ratio (i.e. ratio of juveniles to adults at the start of the hunting season).

The harvest takes place in Iceland and Scotland; therefore, we predict pre-hunting population size as:
(*Eq.2*)

$$N_t^F = N_{A,t}^S \theta^{6/12} + N_{A,t}^S \theta^{6/12} r_t$$

Here we assume six months of natural mortality where N_t^F is the population size in the autumn at time t and $N_{A,t}^S$ is the population size of adults in the Spring.

We assume harvest takes place sequentially, first in Iceland (H^I) in the early autumn, followed by Scotland (H^S).

Iceland harvest:
(*Eq.3*)

$$H_t^I = \left(N_{A,t}^S \theta^{6/12} h_t^i\right) + \left(N_A^S \theta^{6/12} r_t v^i h_t^i\right)$$
$$H_t^I = N_{A,t}^S \theta^{6/12} h_t^i \left(1 + r_t v^i\right)$$

We assume an additional month of natural mortality as harvest in Scotland is conditional on individuals first surviving harvest in Iceland and spending the winter on Islay.

The number surviving Iceland harvest is thus:
(*Eq.4*)

$$(N_t^F - H_t^I)\theta^{1/12} = N_{A,t}^S \theta^{7/12}\left(1 - h_t^i\right) + N_{A,t}^S \theta^{7/12} r_t \left(1 - v^i h_t^i\right)$$

and Scotland harvest is:
(*Eq.5*)

$$H_t^S = N_{A,t}^S \theta^{7/12} \left(p_t^{Islay}\left(\left(1 - h_t^i\right) h_t^s\right)\right) + N_A^S \theta^{7/12} r_t \left(p_t^{Islay}\left(\left(1 - v^i h_t^i\right) v^s h_t^s\right)\right)$$
$$H_t^S = N_{A,t}^S \theta^{7/12} \left\{\left(p_t^{Islay}\left(\left(1 - h_t^i\right) h_t^s\right)\right) + r_t \left(p_t^{Islay}\left(\left(1 - v^i h_t^i\right) v^s h_t^s\right)\right)\right\}$$

where p_t^{Islay} represents the proportion of the flyway population wintering on Islay. As derogation shooting solely takes place on Islay, only birds wintering on Islay experience shooting mortality.

Annual harvest rates for the flyway population of adults (h_t^A) and juveniles (h_t^J) can be estimated thus:
Adult harvest rate:
(*Eq.6*)

$$h_t^A = \frac{N_{A,t}^S \theta^{6/12} h_t^i + N_{A,t}^S \theta^{7/12} \left(p_t^{Islay}\left(\left(1 - h_t^i\right) h_t^s\right)\right)}{N_{A,t}^S \theta^{6/12}}$$
$$h_t^A = h_t^i + \theta^{1/12} \left(p_t^{Islay}\left(\left(1 - h_t^i\right) h_t^s\right)\right)$$

Juvenile harvest rate:
(*Eq.7*)

$$h_t^J = \frac{N_{A,t}^S \theta^{6/12} r_t v^i h_t^i + N_{A,t}^S \theta^{7/12} r_t \left(p_t^{Islay}\left(\left(1 - v^i h_t^i\right) v^s h_t^s\right)\right)}{N_{A,t}^S \theta^{6/12} r_t}$$

$$h_t^J = v^i h_t^i + \theta^{1/12}\left(p_t^{Islay}\left(\left(1 - v^i h_t^i\right) v^s h_t^s\right)\right)$$

Annual survival rates for adults (s_t^A) and juveniles (s_t^J) can then be derived from natural survival and harvest mortality thus:

Adult survival rate:
(*Eq.8*)

$$s_t^A = \theta(1 - h_t^A)$$

Juvenile survival rate:
(Eq.9)

$$s_t^J = \theta\left(1 - h_t^J\right)$$

3. Prior Distributions of Model Parameters

We had to specify priors for the initial flyway population size in March 1987. We specified a mean that was lower than the 1987 count for the flyway population count (mean = 33,000) and a large variance to account for the uncertainty in the initial population size:

$$N_{1987}^M \sim lognormal(3.39,\ 4.74)$$

The proportion of the total flyway population wintering on Islay has declined in recent years. We used flyway and Islay counts in years where both were available and specified priors for the proportion of birds wintering on Islay (p_t^{Islay}) as an exponential model such that:

$$p_t^{Islay} = \exp\left(\alpha + \beta t\right)$$
$$\alpha \sim normal(0.085{,}136.095)$$
$$\beta \sim normal(-0.012, 56207.160)$$

To account for uncertainty in the precision of population counts, vague priors were assigned for precision in counts with a gamma distribution, assuming counts for the flyway and Islay were in the thousands:

$$\tau^{Flyway} \sim gamma(0.001, 0.001)$$
$$\tau^{Islay} \sim gamma(0.001, 0.001)$$

To account for variability among years we treated pre-season age ratio (*r*) as a random-year effect. This necessitates the specification of priors for the mean and temporal variance. Mean pre-season age ratio (μ_t^r) was specified as an informative prior with a normal distribution according to what we considered a plausible range. We specified a vague prior for the temporal variation in *r* (σ_r) .

Pre-season age ratio (*r*):

$$logit(r)_t = \log\left(\frac{\mu_t^r}{1-\mu_t^r}\right) + \epsilon_t^r$$
$$\mu_t^r \sim uniform(0, 0.4)$$

$$\epsilon_t^r \sim normal(0, \tau_t^r)$$
$$\tau_t^r = 1/\sigma_r^2$$
$$\sigma_r \sim uniform(0,0.5)$$

Due to the low inter-annual variability in estimates in apparent natural survival (θ) and the difficulty in achieving convergence when treating θ as a random year effect, we assigned θ as a fixed (constant) parameter. We used method of moments to specify priors for θ for the mean and variance using a beta distribution for annual survival of Svalbard Barnacle Geese (mean = 0.92 and variance = 0.004).

Apparent natural survival (θ):

$$\theta \sim beta(15.072, 1.309)$$

Due to different management and shooting practices in Iceland and Scotland, combined with changes in practice and monitoring since 1987, we applied different prior distributions for harvest parameters in Iceland and Scotland based on what we considered plausible.

Prior distributions for harvest rates for all years in Iceland (h^i) and post 2000 in Scotland were specified using a beta distribution with a mean harvest rate of 0.02, sd = 0.02. However, before 2000 Barnacle Geese in Scotland were protected and shooting was illegal under all circumstances. We therefore specified a beta distribution to allow for potentially low numbers of illegal shooting on Islay (mean h^s = 0.001, sd = 0.001):

Iceland harvest rate: $h_t^i \sim beta(1,49)$

Scotland harvest rate 1987-1999: $h_{t(1987:99)}^s \sim beta(0.5,499.5)$

Scotland harvest rate 2000-2019: $h_{t(2000:2019)}^s \sim beta(1,49)$

We used the method of moments to specify priors for differential vulnerability in Iceland (v^i) and Scotland (v^s) for the mean and variance using a gamma distribution (Iceland mean = 5.7, variance = 11.4, Scotland mean = 2.4, variance = 1.2):

$$v^i \sim gamma(2.85,0.5)$$
$$v^s \sim gamma(29.50,12.4)$$

4. Observation Models for Monitoring Data

The likelihood for flyway population counts used data from March 1987 and then approximately every five years until 2019, with a likelihood of:

$$C_t^{Flyway} \sim normal\left(\log\left(N_t, \tau^{Flyway}\right)\right)$$

Where N_t is the system prediction for the flyway population.

For counts on Islay, we used data for years with an Islay count in March. As the Islay population is a proportion of the total flyway count, the likelihood for the Islay March count is:

$$C_t^{Islay} \sim normal\left(\log\,(N_t p_t^{Islay}), \tau^{Islay}\right)$$

The likelihood for the number of juveniles observed in the autumn (J_t) was described using a beta-binomial model to account for overdispersion in the juvenile autumn counts (i.e., variation due to date and location):

$$J_t \sim beta - binomial(\omega_t \psi_t, \omega_t(1 - \psi_t), P_t)$$

where ω_t is the parameter for overdispersion, ψ_t is the system prediction for the November juvenile proportion after harvest in Iceland, and P_t is the total number of individuals sampled (juveniles + adults).
Thus:
(*Eq. 10*)

$$\psi_t = \frac{r_t(1 - v^i h_t^i)}{(1 - h_t^i) + r_t(1 - v^i h_t^i)}$$

Prior distributions for ω_t were set using a gamma distribution using the mean (μ_t) and variance (σ_t) of the juvenile proportion each year, such that:

$$\omega_t \sim gamma(\mu_t^2/\sigma_t, \mu_t/\sigma_t)$$

Finally, likelihoods for observed harvest bag in Iceland ($B^{Iceland}$) and Scotland ($B^{Scotland}$) were specified as:

$$B^{Iceland} \sim Poisson(H_t^I)$$
$$B^{Scotland} \sim Poisson(H_t^S)$$

where H_t^I and H_t^S are the system model predictions for Icelandic and Scottish harvest bag respectively. To account for extra-Poisson variability in reported harvests (despite being unmeasured), we expressed harvests in hundreds of birds rounded to the nearest hundred.

5. Computation

We fit the IPM using Bayesian methods using the software JAGS (Plummer, 2003) implemented in the program R (version 4.0.2) (R Core Team, 2020) via the R package JagsUI (version 1.5.1) (Kellner, 2016).

We ran three Markov chain Monte Carlo (MCMC) chains of 60,000 iterations and a burn-in period of 50,000. We assessed parameter convergence by both visually inspecting chains and confirming R-hat ($\hat{R}$) values <1.1 (Gelman and Hill, 2006). We report means and 95% credible intervals (CI) of posterior estimates unless otherwise stated.

R code, data and metadata used to build and run the model is available at:

https://gitlab.com/aewa-egmp/east-greenland-scotland-ireland-population-of-barnacle-goose

Results

Population Size

Posterior estimates for all population sizes (flyway, Islay, other sites) fit well with trends observed through data-based counts for each population (Figure 8). For flyway population size, the majority of counts fall within the 95% credible intervals of posterior estimates. Posterior estimates indicate a continued decline in the total flyway population since 2012 (2012 mean = 80,000 CI = 71,000-89,000, 2019 mean = 65000, CI = 55,000-76,000).

Posterior estimates for Islay annual population size show less variability than data-based counts, this is unsurprising given the random observation errors associated with counts. Since 2004, the Islay population size has been declining whilst the population size in other sites has been increasing such that the two populations have become more similar in recent years (Islay 2019 mean = 33,000, CI = 29,000-36,000, Other 2019 mean = 32,000, CI = 24,000-41,000).

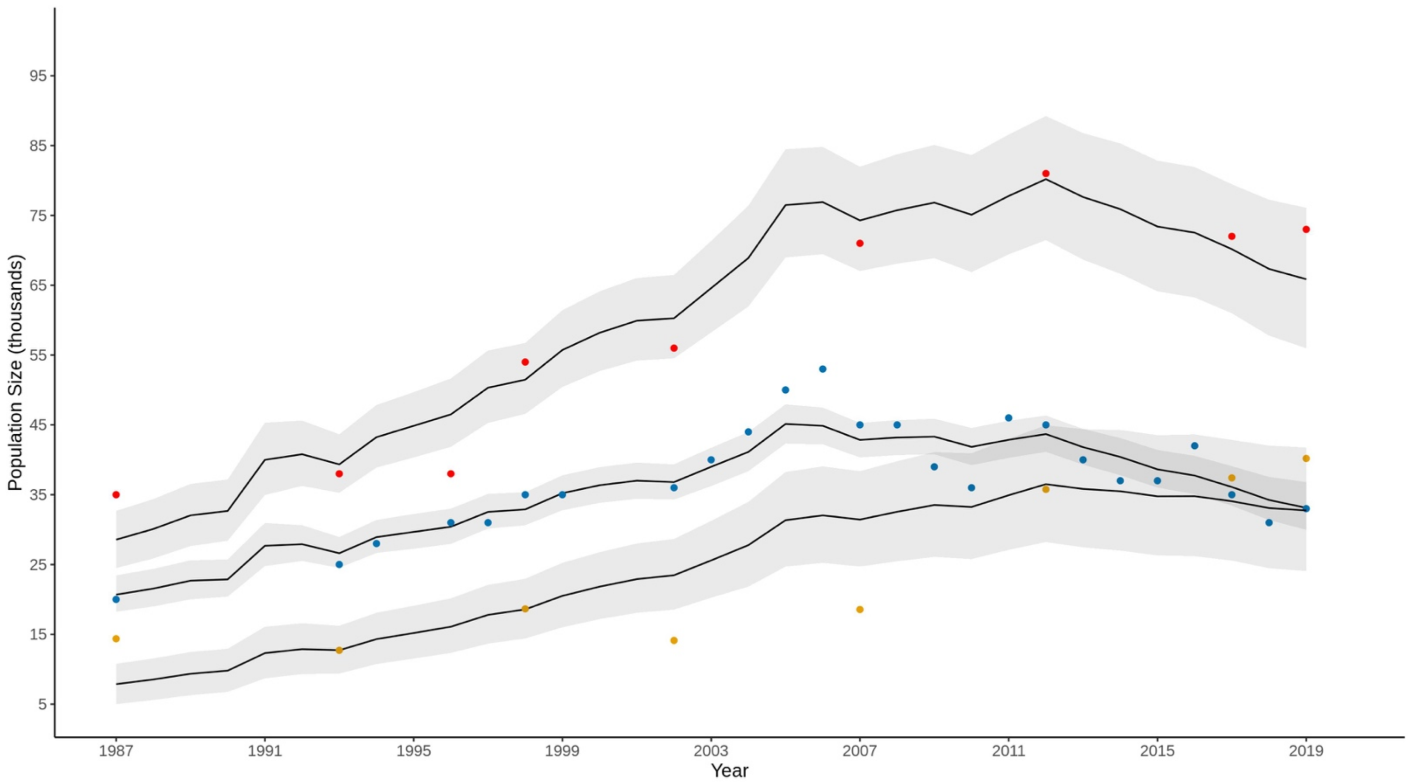

Figure 8. Posterior estimates of Greenland Barnacle Goose population size (in thousands) in black with 95% credible intervals shown in grey. Data-based counts (in thousands) are shown as points for the total flyway (red), Islay (blue), other (yellow).

Harvest

Posterior estimates for adult harvest rates in Iceland and Scotland are provided in Figure 9. Harvest rates in Iceland (h^i) show less variability (consistently less than 4% across all years), than those estimated for Scotland. Scottish harvest rates (h^s) increased with the implementation of the first Islay goose management scheme to include derogation shooting in 2000 and amendments in 2014. Estimates of harvest rates in both Iceland and Scotland show an increase since 2012 corresponding with the peak in population size. The greatest increase in harvest rate is observed in Scotland. With the implementation of the 2014 Islay Sustainable Goose Management Scheme (ISGMS), harvest rates have risen above those observed in Iceland (mean h^s = 3%-7%, 2014-2017).

Juvenile harvest rates were generally higher than those estimated for adults, as was expected given the greater vulnerability of juveniles to harvest (mean v^i = 5.29, v^s = 2.38) (Figure 10). Posterior estimates for harvest bags in both Iceland and Scotland were similar to those in the data (Figure 11).

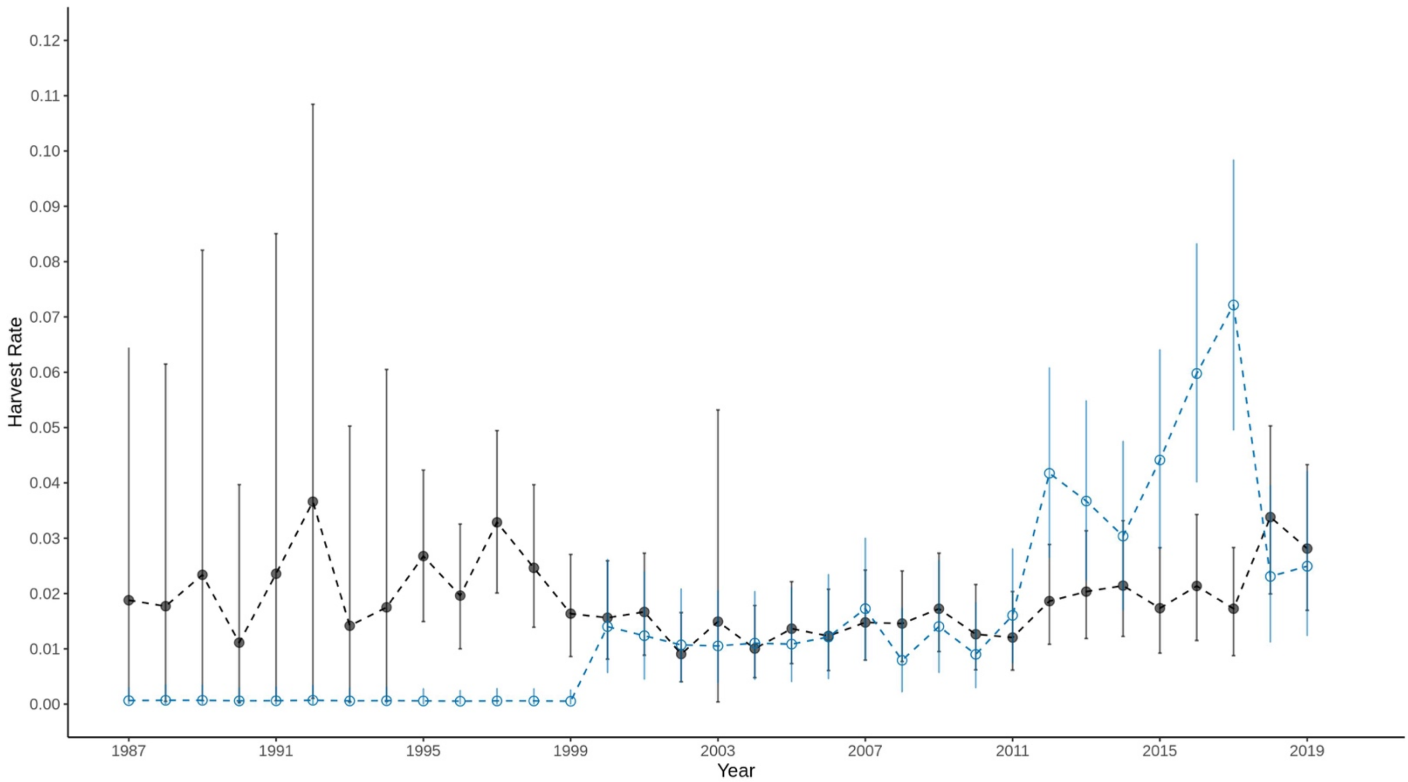

Figure 9. Posterior estimates of adult harvest rates based on an IPM for Greenland Barnacle Geese. Harvest rates and 95% credible intervals for Iceland are in black, and harvest rates with 95% credible intervals for Scotland are in blue.

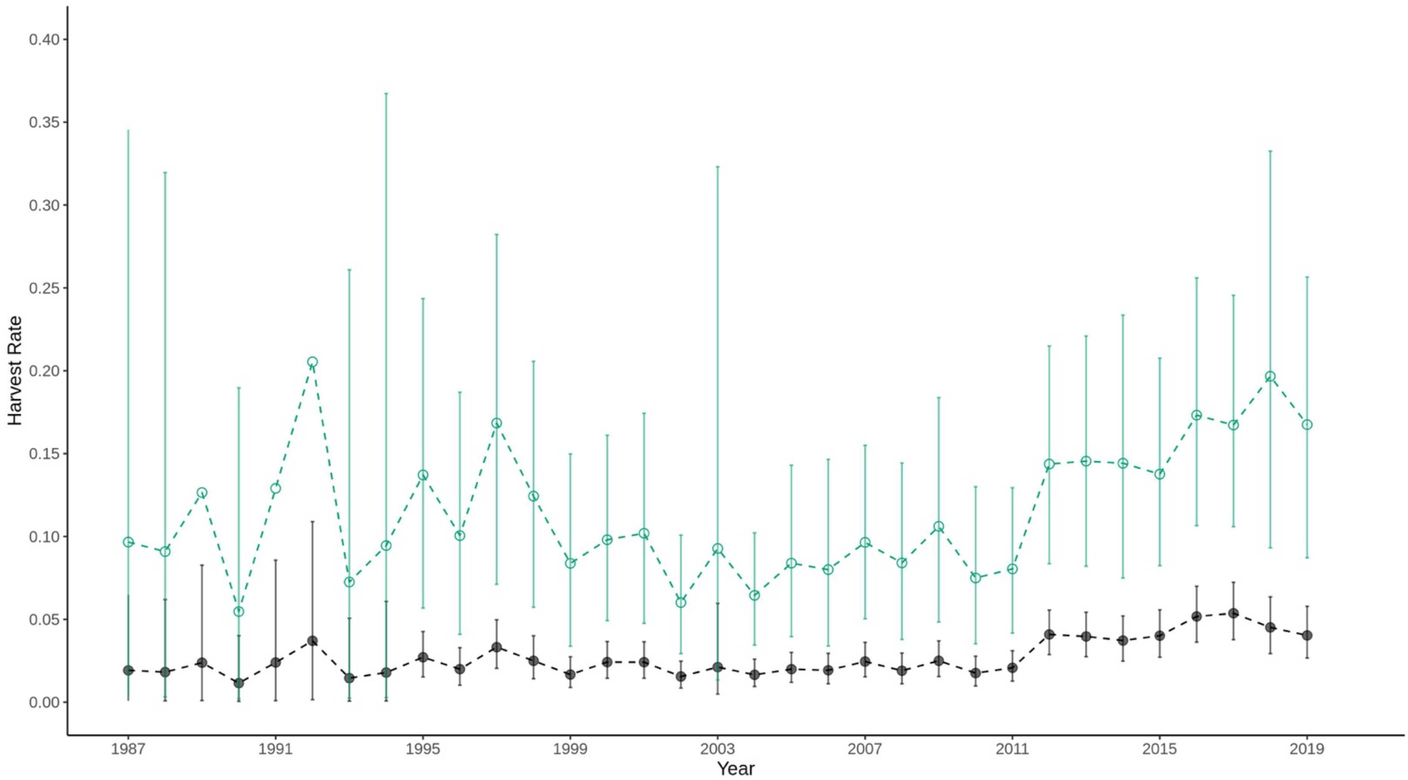

Figure 10. Posterior estimates of age-specific harvest rates in Greenland Barnacle Geese. Adult harvest rates and credible intervals are in black, and juvenile harvest rates and credible intervals are in green.

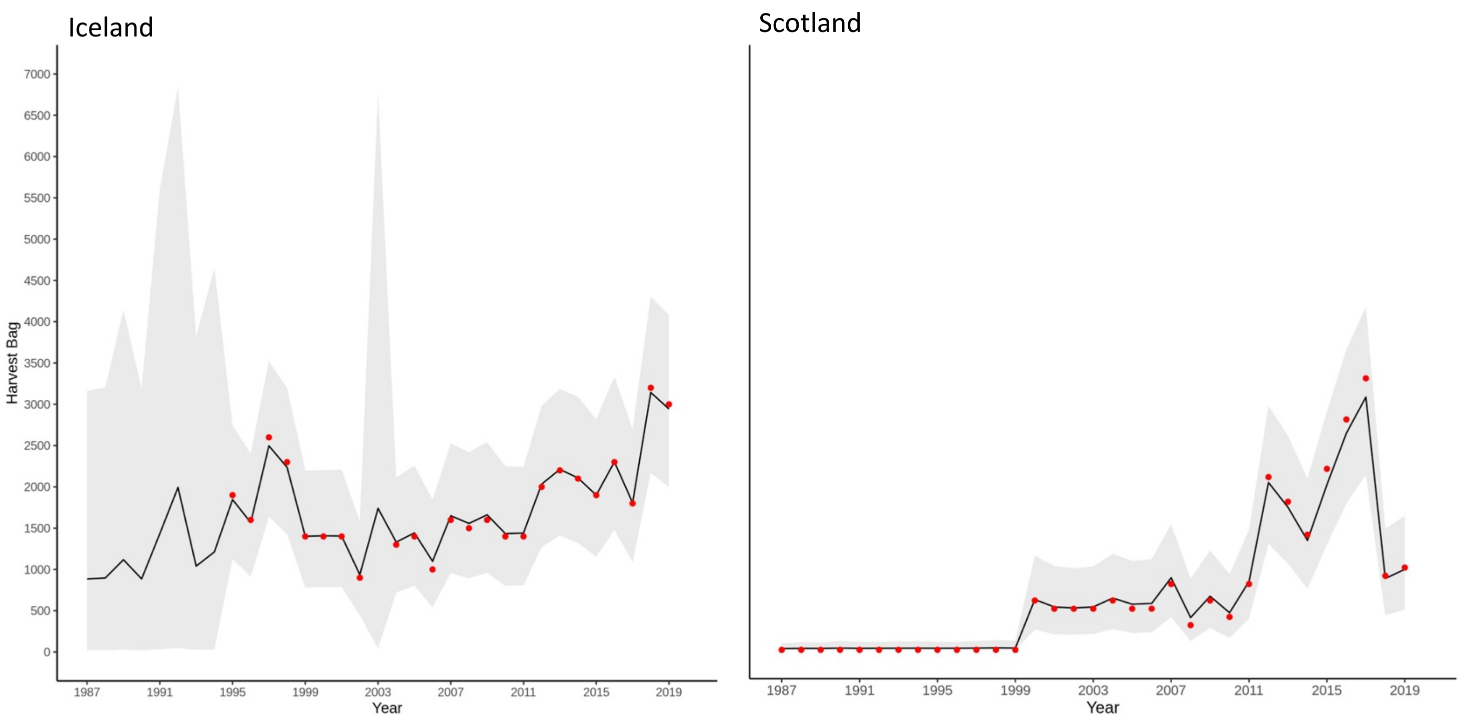

Figure 11. Posterior estimates of annual harvest totals based on an IPM for Greenland Barnacle Geese. Estimates for bag totals are in black with 95% credible intervals in grey. Red points indicate the raw data.

Other Demographic Parameters

Posterior estimates of productivity parameters r_t and ψ_t (pre-season age ratio and November juvenile proportion) show similar variability to that observed in November juvenile counts. Productivity since 2012 shows less variability than previous years and is less in line with data-based juvenile proportions (Figure 12).

The posterior estimate of apparent natural survival (θ) did not differ markedly from the prior (mean = 0.95, CI = 0.93-0.96) and are in line with those observed in previous studies in an absence of harvest (mean θ = 0.95, CI = 0.91-0.98) (Trinder, 2014).

Latent parameters of adult and juvenile survival rate with shooting mortality show a decline in survival rate since 2002, with the greatest declines since 2012. As observed in harvest rates, posterior estimates for survival rate differed between ages classes, with survival rates higher for adults than juveniles for all years (S^A mean = 0.93, CI = 0.90-0.94, S^J mean = 0.84, CI = 0.72-0.91) (Figure 13).

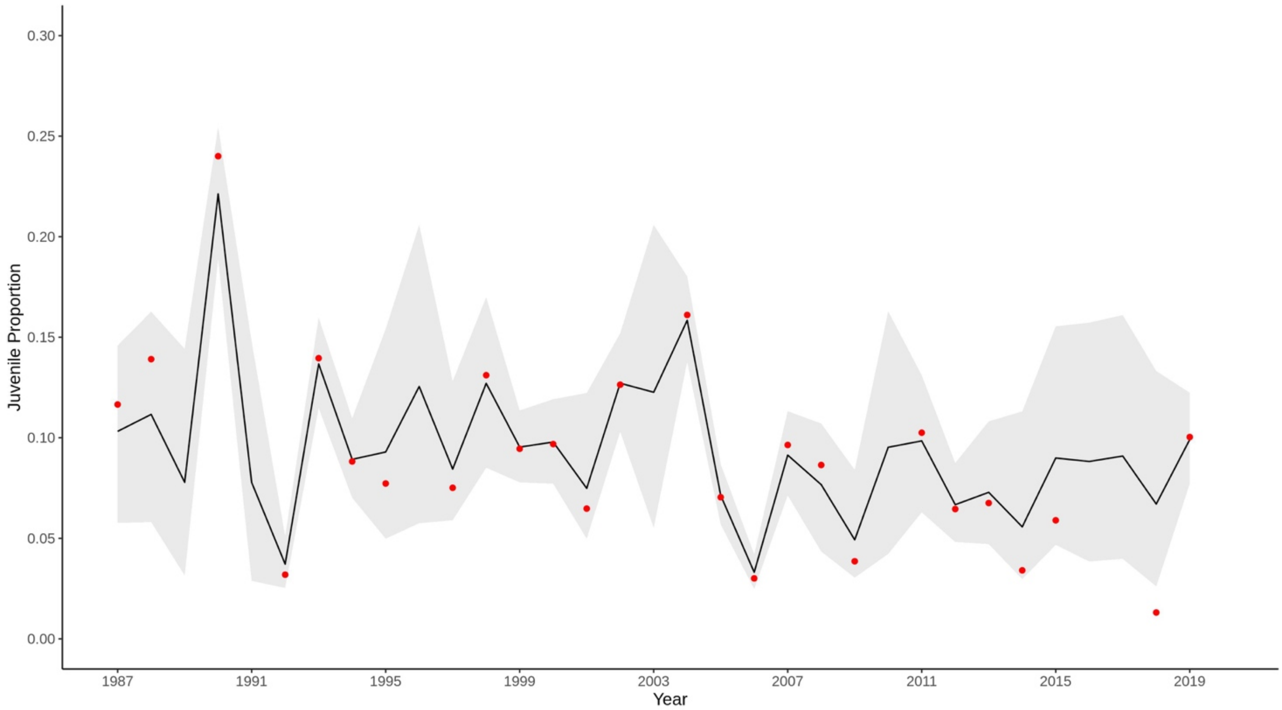

Figure 12. Posterior estimates for the proportion of juveniles in November (ψ) for Greenland Barnacle Geese. Estimates are in black and 95% credible intervals in grey, and data-based proportions are in red.

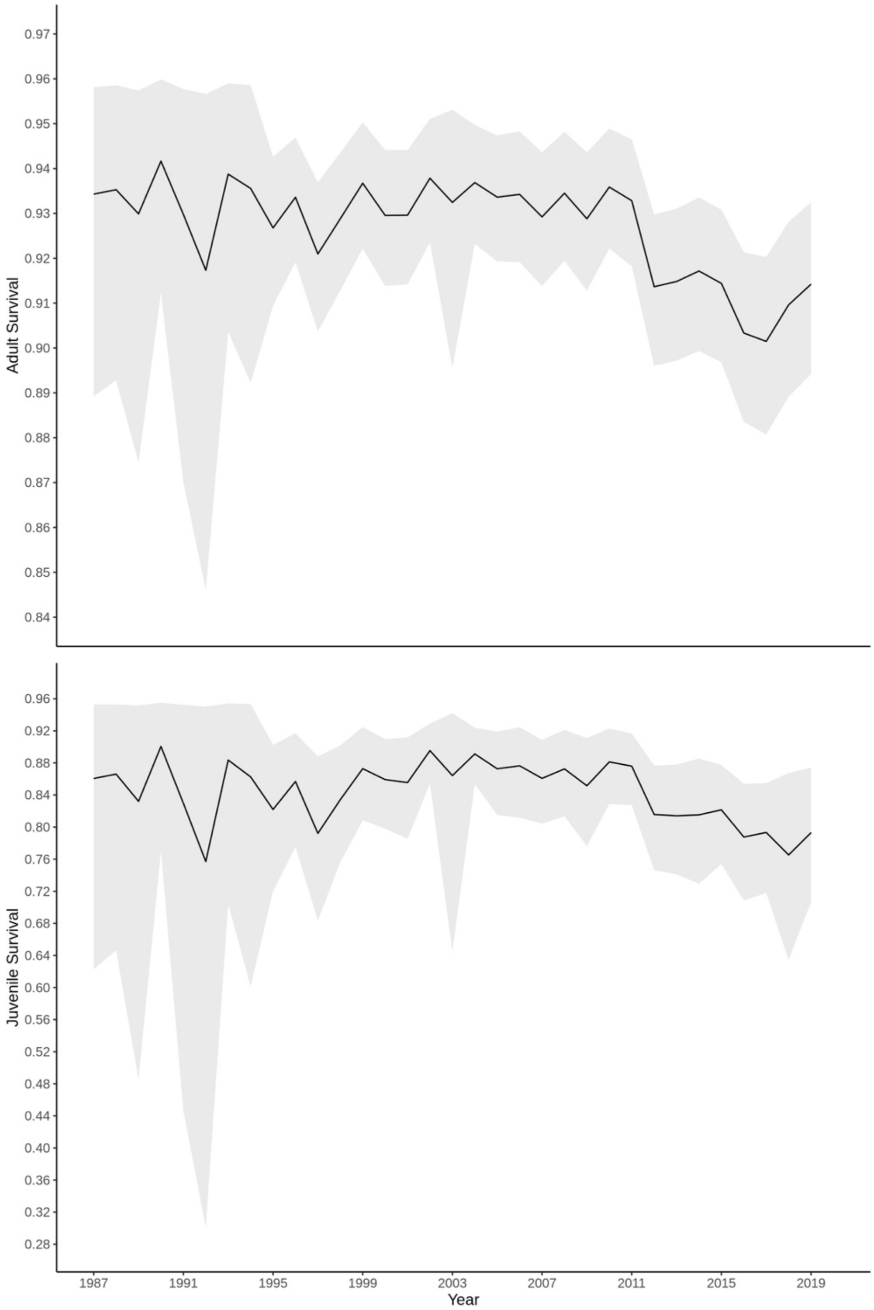

Figure 13. Posterior estimates of adult survival rate (top) and juvenile survival rate (bottom) in Greenland Barnacle Geese. Estimates are in black and 95% credible intervals are in grey.

Discussion

Our results suggest the observed decline since 2012 in the flyway and Islay populations of GBG are associated with increased harvest rates and poor productivity. While harvest since 2012 has increased in Iceland, the increase in Scotland is most pronounced. This coincides with the implementation of the first derogation shooting as part of goose management. Scottish harvest bags showed the greatest increase from 2014 to 2017 with the implementation of the ISGMS, which aims to reduce damage due to goose grazing through the reduction of the local wintering population to between 28,000 and 31,000 individuals (McKenzie and Shaw, 2017).

The population on Islay has also undergone a marked reduction, coinciding with increased populations in alternative wintering sites. These results suggest derogation shooting may be causing distributional changes in use of wintering sites in addition to reducing the size of both the Islay and flyway population.

Due to the intermittent nature of flyway-level population counts for GBG, we found it challenging to estimate the total flyway population size (only 9 data points available since 1987). We recognise that the remote location of many wintering sites makes annual flyway counts challenging. However, given the population decline and apparent distributional shift away from Islay, we suggest greater emphasis on localised annual counts in alternative wintering sites. Nature Scot have already begun annual winter counts in Tiree, South Walls, Coll and Uists, accounting for approximately 16,000 birds (2019, Nature Scot pers. commun.). These data could be used to better estimate annual population size as longer time-series become available. Should wintering sites away from Islay continue to increase in significance (for example, approximately 15,000 geese winter in Ireland), conducting annual localised counts would provide additional monitoring data not only for use in the IPM in the future, but also to identify potential sites of future conflict.

For the development of this IPM, we relied on data from other populations, specifically from pink-footed geese (Clausen *et al.*, 2017) and Svalbard Barnacle Geese in order to set prior distributions for Icelandic differential vulnerability and apparent natural survival respectively. These priors were effective in creating posterior estimates that fit the data; however, it would be preferable to use monitoring data specifically from the GBG. Additional monitoring data for productivity in Iceland would be useful in setting more appropriate priors for annual pre-season age ratio and differential vulnerability in Iceland. Should individual-based data for GBG become available in the future, these data should be incorporated into the IPM in the existing model framework or by incorporating a full survival model into the IPM. The use of this data would provide more appropriate priors for θ and better estimate annual survival for this population. The paucity of existing individual-based data for GBG meant we were unable to estimate all demographic parameters specifically for this population, emphasising the importance of establishing a marking program coordinated across wintering sites. This would improve the robustness of the IPM by allowing population specific estimation of parameters such as natural survival and dispersal.

Posterior estimates for productivity (r and ψ) and data-based counts of juvenile proportion show a great deal of interannual variability as is common in Arctic nesting geese (Cleasby *et al.*, 2017; Dickey *et al.*, 2008; Fondell *et al.*, 2008). Other studies have found winter and spring climate have influenced population sizes in subsequent years (Bunnefeld *et al.*, 2020; Doyle *et al.*, 2020; Mason *et al.*, 2017). While we did consider pre-season age ratio as a random-year effect, we did not include environmental variation in the form of relevant covariates as the addition of Greenland temperature (spring and summer) did not improve model fit (Bunnefeld *et al.*, 2020). Future work may consider the addition of environmental conditions that may influence reproduction and/or survival rates.

The IPM presented here demonstrates how GBG have responded to changes in reproduction and harvest through hunting and derogation shooting. Given the recent decline in flyway population size in response to poor productivity and increased harvest rates since 2012, further work is needed to project how the population may respond to management strategies in the future. Here we provide some recommendations and considerations for the development of these projections.

Firstly, the results from our IPM strongly suggest that increased harvest (particularly in Scotland) has resulted in both declines in the population size of the flyway and Islay population, in addition to changes in the distribution of winter site use (this also likely adds to declines in the Islay population). Our IPM set priors for the Islay wintering proportion of the population based on an exponential model. Projections for Scottish derogation shooting will need to consider whether the decline in the Islay population continues or has begun to stabilize.

Secondly, Barnacle Goose abundance at alternative wintering sites appears to be increasing in response to derogation shooting on Islay and this could lead to growing conflict in new locations. At present, our IPM considers that only birds wintering on Islay are exposed to Scottish harvest. Scenarios for IPM projections will need to consider whether derogation shooting will continue to take place solely on Islay as a means of reducing the total flyway population size, or whether it will be implemented as a management strategy in new locations.

The Adaptive Flyway Management Programme for the GBG has not defined a target population size but does specify that hunting and derogation shooting should not cause the flyway population to fall below the favourable reference population of 54,000 individuals (Nagy *et al.*, 2020). Posterior estimates from our IPM suggest that the current flyway population is declining with a population size in 2019 of approximately 65,000 individuals (CI = 55,000-76,000). Posterior estimates of harvest rates in Iceland have been consistently <4% since 1987. Scottish harvest has undergone a substantial increase since 2000, and this suggests recent declines in abundance at both a flyway and Islay level have been driven by the increase in derogation shooting on Islay rather than changes in harvest pressure in Iceland. The ISGMS aims to reduce the Islay population to between 28,000 and 31,000 individuals to reduce goose grazing damage. According to our IPM, the current Islay population is approximately 33,000. Projections for Scottish harvest should consider if harvest rates on Islay must fall in the future as the target population is reached.

In order to implement an effective adaptive management framework for the GBG, an understanding of population dynamics and how they are influenced by harvest and other factors is crucial. The IPM we present here provides a sound framework from which we can develop projections of how the GBG population will respond to different management scenarios in the future. This can then be used to inform and optimise management strategies across range states. The IPM also provides an ideal framework for adaptation, as model parameters can be updated as additional data become available.

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Annex 4. Impact Models

According to the ISSMPs for the Greylag Goose and the Barnacle Goose, Range States are mandated to quantify the consequences of changes in population size on fundamental objectives, thus investigate if there is a relationship between goose abundances and the amount of damage caused by the species to agricultural crops, risks to air safety or other sensitive flora and fauna.

In order to scale up an assessment of the extent of damage or risks from local to regional, national or even flyway levels, it is necessary to apply either a retrospective time series, statistical analysis or a predictive simulation approach. With regard to agricultural damage, some first indicative examples of national time series analyses were provided in the respective ISSMPs based on compensation payments to farmers in relationship to annual abundances of geese. For Sweden this analysis has been extended and validated (Montràz-Janer et al. 2019). In case of Denmark, where compensation or subsidies are not used to support crop damage management, derogation has been used as a proxy of the intensity of crop loss. At national level, there was a relationship between Barnacle Goose numbers and licenses granted for derogation shooting (Clausen et al. 2020). In the Netherlands, retrospective analyses are also in progress .

Predictive models to assess the relationship have so far been developed at regional levels in Norway (Baveco et al. 2017). Work is in progress in the Netherlands and Denmark (at regional level), using individual-based models and agent-based simulations, respectively. The process of building, parameterisation and testing such models is resource demanding and cannot be rolled out easily to all Range States. Hence, at least for the foreseeable future, such models can realistically only be used for selected regions.

Progress on the Danish regional simulation model

This model is built into the existing ALMaSS system (Animal, Landscape and Man Simulation System), which provides a dynamic and detailed representation of the underlying landscape, including habitat types, farm management, crop rotation etc. as well as changes in weather, vegetation growth and food availability over time. The model includes three species of migratory goose overwintering in Denmark (Pink-footed Goose, Barnacle Goose and Greylag Goose), using pattern-oriented modelling (an iterative framework where different versions are tested against performance criteria in order to assess suitability of the model) to make it behave as closely as possible to the real world. Individual geese interact with the environment and potentially with each other, making foraging choices based on their current memory and energetic state. Population level patterns emerge as a consequence of the behaviour of each of the individuals in the three populations, and the interplay between geese and landscape allows for inference about how and where geese affect the underlying landscape. The model is validated against literature and field data, and may potentially be used for a number of research questions in relation to habitat use, crop damage, foraging decisions and management actions.

The current version aims specifically to address the impact of growing Barnacle Goose numbers on habitat use and crop cultivation, e.g. by identifying the relationship between goose numbers and crop damage. The landscape, weather and simulation of spatial behaviours is fully implemented in the model, while foraging decisions and energetics of individual geese are subject to ongoing development.

Progress on the Dutch regional simulation model

Movements and foraging decisions of Barnacle Geese are simulated with a custom-made, spatially-explicit, individual-based model. The model comprises foraging on grasslands in Friesland (appr. 70x70 km), the Netherlands, with a spatial resolution of 100x100m (1ha) and temporal resolutions of 1 hour for goose behaviour and 1 day for grass growth. Goose movements and foraging decisions depend on a decision tree, which is based on energy expenditure and intake, memory, interactions between flocks, and time of day. The model has been calibrated with GPS data of barnacle geese foraging in Friesland. At present, model validation is ongoing. With this model, we can assess the impacts of different management scenarios and barnacle goose population sizes on goose foraging behaviour and its effects on goose distributions across agricultural grasslands in Friesland. The model can be extended to include other goose species and their interactions.

Retrospective analyses

A thorough analysis was performed on the relation between damage on agricultural grasslands and goose numbers in the province of Friesland, the Netherlands. We linked automatically executed damage reports to estimated goose numbers, using monthly goose counts and an approximation of homogeneous spatial redistributing of these geese that is based on GPS observations. Based on a pilot analysis, three goose species were qualified for use in the final analysis: Barnacle Goose, Greylag Goose, and Greater White-fronted Goose. We expect to publish our findings in 2021.

References

Baveco, H.M. et al. (2017). Combining modelling tools to evaluate a goose management scheme. *Ambio* 46(2): 210-223.

Clausen, K.C., Heldbjerg, H., Balsby, T., Clausen, P., Nielsen, R.D., Skov. F. & Madsen, J. (2020). *Sammenhæng mellem forekomst af bramgæs og reguleringsindsats i Danmark.* Scientific Report, Aarhus University, Denmark (in press).

Montràz-Janer, T., Knape, J., Nilsson, L., Tombre, I., Pärt, T. & Månsson, J. (2019). Relating national levels of crop damage to the abundance of large grazing birds: Implications for management. *Journal of Applied Ecology* 56: 2286-2297.

Annex 5. Indicator factsheets

I.1. Population size compared to the Favourable Reference Population (FRP)

Rationale

This indicator measures the progress towards Fundamental Objective I. Maintain the population at a satisfactory level. The FRPs at national and flyway level are set in Chapter 2 of this AFMP. These FRPs correspond to the ecological requirements part of Article 2 of the Birds Directive.

Indicator definition

The FRP will be monitored on the wintering grounds as the only feasible option to monitor the population size consistently.

Methodology

Data collection

The assessment of the FRP will be based on the 3-yearly coordinated total population counts (see Chapter 5).

Data flow

The dataflow is described in Chapter 5 of this AFMP.

Methodology for indicator calculation

Methodology is described in Chapter 5 of this AFMP.

Methodology for gap filling

Methodology for gap filling is to be agreed before the next total population count in March 2023 and presented in the annual EGMP Population Status and Assessment Report.

Methodology uncertainty

The pre-migration aerial surveys represent a snapshot and some flocks might be easily missed.

I.2 Range extent compared to the Favourable Reference Range (FRR)

Rationale

This indicator measures the progress towards the Fundamental Objective I. Maintain the population at a satisfactory level. The population is considered to be maintained at a satisfactory level if the range is maintained at or above the level of the Favourable Reference Range, which is set (for most Range States) in Table 2 of this AFMP at the level of the 2003-2018 period.

Indicator definition

This indicator consists of two sub-indicators:

- Actual breeding range in proportion of the breeding FRR;
- Actual non-breeding (staging and wintering) range in proportion of the non-breeding FRR.

The breeding range includes the areas where nesting and brood rearing before fledging takes place.

According to the CMS definition, the non-breeding range includes any areas the migratory species stays in temporarily, crosses or overflies during its normal migration. Hence, the range is not restricted to key sites only, but includes all areas where the species regularly (although not necessarily) occurs annually.

Methodology

Data collection

The entire breeding range and most of the non-breeding range of this population is outside of the European Union. Consequently, there are no reporting obligations under Article 12 of the EU Birds Directive. The AEWA reporting on national population status reporting does not require Range States to report on distribution or range. Therefore, special reporting should be set up to monitor the changes in range extent.

Both the breeding and non-breeding ranges of the population should be monitored following the standards set for the reporting under Article 12 of the EU Birds Directive and use the range method described in DG Environment (2017, pp. 124-128).

Considering the high costs associated with monitoring of the breeding range in Greenland, it is proposed to update the range information only once during the lifespan of the ISSMP in 2027.

Data for the non-breeding range will be collected at the same time as for breeding range data is collected national population status reporting to AEWA (i.e. 2024). Range States are recommended to use the Range Tool[6] developed for the reporting under Article 17 of the Habitats Directive to determine the range. The recommended gap distance for the Barnacle Goose is 140 km based on Box 3.2 in Bijlsma (2019, p. 40) using a body mass value of 1.765 kg. Information on non-breeding distribution can be obtained from the national IWC scheme, International Census of Greenland Barnacle Goose and online observation reporting portals (such as BirdTrack, eBird) active in the Range States.

Data flow

Range States should calculate the range based on their distribution mapping and report to the EGMP Data Centre by 31 December 2025.

Methodology for indicator calculation

For both sub-indicators the actual range will be compared to the national, MU and flyway level FRRs.

Methodology for gap filling

No need for gap filling is foreseen in the Range States.

Methodology uncertainty

The methodology is sensitive to changes on the edges of the range. Currently, the range method was not applied by all Range States.

References

Bijlsma, R., Agrillo, E., Attorre, F., Boitani, L., Brunner, A., Evans, P., . . . van Kleunen, A. (2019). *Defining and applying the concept of Favourable Reference Values for species and habitats under the EU Birds and Habitats Directives*. Retrieved from https://edepot.wur.nl/469035

DG Environment. (2017). *Reporting under Article 17 of the Habitats Directive: Explanatory notes and guidelines for the period 2013-2018*. In (pp. 188). Brussels: European Commission.

6http://cdr.eionet.europa.eu/help/habitats_art17/Reporting2019/Guidelines_for_EEA_range_tool_README_.pdf

II.1. Relative change in damage payments

Rationale

This indicator measures the progress towards the Fundamental Objective II. Minimize agricultural damage and conflicts. The most direct indicator would be the loss of yield of a given crop type caused by Barnacle Geese, aggregated from local to national and international levels. However, such measurements would be extremely costly and models for upscaling do not exist. Therefore, it is necessary to resort to measurable proxy indicators, such as (1) compensation payments or (2) subsidies, or management actions taken to prevent agricultural damage, such as (3) offtake under derogation.

Indicator definition

This indicator includes three sub-indicators (for definition and current use in the EGMP Range States, see Tombre et al. (2019)[7]:

1. Monetary compensation payments for crop damages caused by Barnacle Geese, under which farmers eligible for compensation receive public money to counterbalance for the lost crop.
2. Subsidy payments, i.e. farmers receiving public funds in order to allow goose grazing on their properties. Subsidies are usually paid in advance and may hence not directly reflect the level of damage.
3. Offtake under derogation, referring to the culling of flight-less geese (adults and young), removing of nests or eggs during summer, or geese shot outside the hunting season to protect crops.

Because the three sub-indicators are used slightly differently among Range States and do not all use a monetary currency, they will be used on a relative scale to evaluate trends in damage.

Methodology

Data collection

Data collected for the three sub-indicators at national level, species-specific and annually. Compensation payments, subsidies paid, and numbers of Barnacle Geese killed under derogation will be compiled from the national statutory authorities, who are also responsible for the quality check of the information provided. The authorities will also be asked to report any change in policies, regulations or management practices, which may influence payments or use of derogation.

Data flow

Data for each year from the period of 2020 – 2024 is to be reported to the EGMP Data Centre by 31 December 2025. Data collection shall continue also in 2025 – 2026.

Methodology for indicator calculation

The national payments and derogation information will be entered into a common database. Damage in 2020 will be set at an index of 100 for each country, and subsequent data will be indexed relatively to the starting year, taking into account the national inflation rate. An overview for all range states and the three relative sub-indicators will be updated annually.

Methodology for gap filling

No gap filling.

7https://egmp.aewa.info/sites/default/files/download/population_status_reports/EGMP_010_Management_measures_for_geese.pdf

Methodology uncertainty

The sub-indicators are sensitive to changes in management policies, regulations and practises. A metabase will document all the reported changes. Some countries do not have species-specific reporting of damage and can only give a rough estimate of the damage caused by Barnacle Geese. A system will have to be set up to assess the uncertainties in the reporting.

III.1 Risk of zoonotic influenza transmission to the general public

Rationale

This indicator measures the progress towards the public health component of Fundamental Objective III. Minimise the risk to public health and air safety.

Migratory geese can act as vectors of various diseases harmful to humans and poultry (Buij *et al.*, 2017) although the general risk is considered to be low (see the ISSMP). Risk of zoonotic influenza transmissions has been selected as an indicator because (i) it has high relevance for human health, (ii) there is an ongoing surveillance programme in the EU/EEA with quarterly reports[8]. Hence, monitoring zoonotic influenza does not require additional resources from the EGM Range States. (iii) This indicator represents not only the prevalence of the virus, but also the preparedness to avoid transmissions.

Indicator definition

Number of human cases of zoonotic influenza per year in the flyway that can be attributed to Barnacle Goose.

Methodology

Data collection

No direct reporting is required by the Range States.

Data flow

Data will be obtained by the EGMP Data Centre from the Avian Influenza overview reports published quarterly by the European Food Safety Authority (EFSA), the European Centre for Disease Prevention and Control (ECDC) and the European Union Reference Laboratory for Avian influenza (EURL).

Methodology for indicator calculation

Number of cases per year.

Methodology for gap filling

No need for gap filling is foreseen in the Range States.

Methodology uncertainty

Attribution of the source of infection might be problematic in some cases.

References

Buij, R., Melman, T. C., Loonen, M. J., & Fox, A. D. (2017). Balancing ecosystem function, services and disservices resulting from expanding goose populations. *Ambio, 46*(2), 301-318.

8https://www.ecdc.europa.eu/en/avian-influenza-humans/surveillance-and-disease-data/avian-influenza-overview

III.2. Number of bird strikes with aircrafts caused by Barnacle Goose

Rationale

This indicator measures the progress towards the Fundamental Objective III. Minimize the risk to public health and air safety. The frequency of bird strikes with Barnacle Goose is the direct indicator for the development in incidents, cumulated from local airports to national and international levels. The risk is likely to increase with the number of Barnacle Geese passing over airports (see Indicator III.3).

Indicator definition

The indicator is the number of bird strikes caused by Barnacle Geese at commercial airports in the Range States.

Methodology

Data collection

Data collected at airport and national level, species-specific and annually. This indicator is reported as a standard in all commercial civil airports and the airport authorities attempt to make an identification of the species causing the bird strike. Airports will be asked to report:

a) Date, time of bird strike,
b) Species, flock size, number struck,
c) Aircraft model,
d) Phase of flight (takeoff, landing, descent, climb, en route).

Bird strike data will be compiled from the national statutory authorities. The authorities will also be asked to report any change in reporting practices, which may influence the indicator.

Data flow

Data for each year from the period of 2020 – 2024 is to be reported to the EGMP Data Centre by 31 December 2025. Data collection shall continue also in 2025 – 2026.

Methodology for indicator calculation

Range States will be asked to select at least three high-risk civil commercial airports within the national range of the Barnacle Goose for reporting. The frequency of bird strikes will be listed per airport and per country. An overview for all range states will be updated annually.

Methodology for gap filling

No gap filling is necessary.

Methodology uncertainty

The frequency of bird strikes with Barnacle Goose is low at most airports. Therefore, the indicator has to be combined with III.3 to give a more reliable indication of the risk.

III.3. Number of Barnacle Geese passing over commercial airports

Rationale

This indicator measures the progress towards the Fundamental Objective III. Minimize the risk to public health and air safety. The number of Barnacle Geese passing over an airport indicates the risk of bird strikes in a given airport (Indicator III.2) and can be related to the national and international levels.

Indicator definition

The indicator is the cumulative number of Barnacle Geese passing over civil commercial airports per year in the range of the Barnacle Goose, using the same airports as in III.2.

Methodology

Data collection

Data collected at airport and national level, species-specific and annually. This indicator is reported as a standard in commercial civil airports and the airport authorities attempt to make an identification of the species passing (or landing in the airport). Airports will be asked to report:

a) Date, time of passage,
b) Species, flock size.

Barnacle Goose passage data will be compiled from the national statutory authorities. The authorities will also be asked to report any change in reporting practices, which may influence the indicator.

Data flow

Data for each year from the period of 2020 – 2024 is to be reported to the EGMP Data Centre by 31 December 2025. Data collection shall continue also in 2025 – 2026.

Methodology for indicator calculation

Range States will be asked to select at least three high-risk civil commercial airports within the national range of the Barnacle Goose for reporting. The cumulative number of Barnacle Geese passing per year will be calculated per airport. A national trend index will be calculated. The starting year will be set at an index of 100, and subsequent data will be indexed relatively to the starting year. An overview for all range states (average national indexes and relative change) will be updated annually.

Methodology for gap filling

No gap filling.

Methodology uncertainty

The ability of species identification by bird control employees has to be checked. If some airports use radar for identification, standards for species identifications have to be defined.

IV.1 Area of natural habitat or habitat of threatened species negatively affected by Barnacle Goose

Rationale

This indicator measures the progress towards Fundamental Objective IV. Minimize the risk to other flora and fauna. The risk to other flora and fauna can be induced mainly via (1) grazing of plants, e.g. the Arctic tundra vegetation, with possible knock-on consequences for the whole ecosystem or (2) eutrophication of oligotrophic lake ecosystems by goose droppings transferred from foraging grounds to roosts. However, grazing and nutrient transport is amongst the ecological functions of geese and not necessarily damaging. Therefore, it should be assessed on a case-by-case basis and considered as damage if it conflicts with the conservation objectives of a site.

Indicator definition

Area of natural habitat or habitat of threatened species negatively affected by Barnacle Goose. This indicator considers the natural habitats of conservation interest, which includes natural habitats listed on Annex I of the EU Habitats Directive or any other natural habitats that are of conservation interest at national level. It also includes the habitat for threatened species regardless of whether the habitat is of natural origin or not. In the case of such habitats, the important factor is the presence and dependence of a threatened species on the habitat, and the structure and other characteristics of the habitat. In this context, threatened species include species that are listed on Annex I of the Birds Directive or on Annexes II or IV of the Habitat Directive or listed as threatened on a European or national Red List.

Methodology

Data collection

Range States will need to collect information from the organisations responsible for managing conservation areas on the damage caused by Barnacle Goose two times during the lifespan of this AFMP. As the damage can affect a wide range of species the extent of the habitat damaged will be used as the measurement of the damage. Site management organisations should be asked to report:

a) the threatened species or habitats affected negatively by Barnacle Goose during the reporting period,
b) the location, the nature of the damage and the extent of area affected.

Data flow

Data for each year from the period of 2020 – 2024 is to be reported to the EGMP Data Centre by 31 December 2025. Data collection shall continue also in 2025 – 2026.

Methodology for indicator calculation

The EGMP Data Centre will report the total area affected and also areas by habitat types or species.

Methodology for gap filling

No need for gap filling is foreseen.

Methodology uncertainty

This indicator is dependent on the judgement of the site management organisations.

V.1 Number of people enjoying watching geese

Rationale

This indicator measures the progress towards the cultural/recreational component of Fundamental Objective V. Maximise ecosystem services.

Watching geese represents an important cultural/recreational service for many people (Buij *et al.*, 2017) and the MCDA process (Johnson, 2020) has identified that several stakeholder groups valued this highly. Unfortunately, it is highly difficult to monitor the change in the recreational value of geese. Repeated socio-economic surveys would be rather expensive. Therefore, it is suggested to use the number of people submitting Barnacle Goose observations to online observation recording portals. These portals target the general public and a very high proportion of people interested in watching birds keep records of their observations on these platforms. The main observation portals in the region all contribute to the EuroBirdPortal. This would allow obtaining data at a very low cost. Even if the indicator would probably underestimate the number of people enjoy watching geese, it is assumed it would correlate closely with the total number of people. It is proposed to focus on the number of people rather than the number of man-days because the latter would require a different level of engagement than simple enjoyment.

Indicator definition

Change in the annual number of people submitting Barnacle Goose observations to an online portal that contributes data to the EuroBirdPortal.

Methodology

Data collection

No direct reporting is required by the Range States.

Data flow

Data will be obtained by the EGMP Data Centre from EuroBirdPortal

Methodology for indicator calculation

An annual index of the number of people submitting goose observations to the online portals will be calculated for each country and aggregated at MU and flyway level.

Methodology for gap filling

No need for gap filling is foreseen in the Range States.

Methodology uncertainty

The index might also change if the number of users is changing and it should be tested whether this has any influence on the index.

References

Buij, R., Melman, T. C., Loonen, M. J., & Fox, A. D. (2017). Balancing ecosystem function, services and disservices resulting from expanding goose populations. *Ambio, 46*(2), 301-318.

VI.1 Relative change in cost of goose management

Rationale

This indicator measures the progress towards the Fundamental Objective VI. Minimize costs of goose management. An indicator for the successful fulfilment of this objective is that the measurable administrative costs for dealing with the many facets of goose related management and conflict are reduced with the progressive implementation of the ISSMP for the Barnacle Goose.

Indicator definition

This indicator is defined by the number of administrative man-years spent on the management of Barnacle Goose in the Range States, including program management, communication with users, number of field assessments made, reporting (from local to international levels).

Methodology

Data collection

The EGMP Data Centre will send out a questionnaire to each Range State asking for administrative costs spent on goose management activities at various governance levels (local, regional, national).

Data flow

Data for each year from the period of 2020 – 2024 is to be reported to the EGMP Data Centre by 31 December 2025. Data collection shall continue also in 2025 – 2026.

Methodology for indicator calculation

The number of man-hours divided into different levels of governance and tasks will be amalgamated for each country and be presented in an international overview at 6- year intervals.

Methodology for gap filling

No gap filling.

Methodology uncertainty

It is important to standardize the questionnaires, but due to differences in national organisation of goose management, they will have to be tailored specifically. For some countries it may be difficult to make a quantitative assessment, and it may be necessary to resort to a qualitative assessment (increase, stable, decrease).

Annex 6. Protocols for the iterative phase

Monitoring, assessment and decision-making protocols will be developed by the EGMP Data Centre after the adoption of the AFMP.

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