Handa Island Great and Arctic Skua Monitoring Programme

Final Report 2004

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Contents

Cover photo: Displaying great skua by T. Jones

Executive Summary

T. Jones

1. Introduction

Handa Island in Sutherland, North-west Scotland, owned by Dr. Jean Balfour, is an internationally important seabird breeding colony, and a Scottish Wildlife Trust Nature Reserve. The island supports globally significant colonies of breeding guillemots and razorbills (~10% of EC population for each species), whose numbers and breeding success are well monitored each year by successive Wardens of the Reserve. Since the 1990s, Handa has also been home to over 200 breeding pairs of Great skua (3% of EC population), and a smaller colony of 30-40 pairs of Arctic skua (1%). Until recently however, in contrast to the auks, there had been no research carried out on Handa on these ecologically significant predators.

2003 saw the initiation of intensive long-term monitoring and research on the breeding Great and Arctic skua populations of Handa Island (Jones, 2003). Early in 2004, a grant was awarded by Scottish Natural Heritage to facilitate the continuation of this work until 2006. Thus an exciting three-year monitoring programme was begun, a collaboration between the researchers listed above, the Scottish Wildlife Trust, Scottish Natural Heritage, The Seabird Group, and the Highland Ringing Group. Here we report on activities and results from the successful first year of this programme.

2. Objectives

The broad objectives of the three-year programme, as outlined in the original proposal to SNH and SWT, are to investigate the following research topics in the Great and Arctic skua populations of Handa:

1. Numbers of breeding and non-breeding birds attending colony
2. Productivity
3. Factors affecting breeding success (predation; territory size and density)
4. Diet of Great skuas
5. Chick development
6. Territorial attendance of adult birds
7. Winter movements of young reared on Handa
8. Immigration
9. Philopatry
10. Adult survival rate
11. Adult biometrics
12. Pollution levels in Great skuas

In 2004 (Year 1), data were collected relating to research topics 1,2,3,4,5,6,8 and 9. In addition, work was either initiated (e.g. colour ringing) or continued (metal ringing) to facilitate future data collection relating to topics 7, 10 and 11.

3. All-island Survey

The all-island survey of **Great skuas** was conducted this year on the 15th June by C. Smith, following the standard methodology applied in previous years (from Walsh *et al.*, 1995). **208 apparently occupied territories** (AOTs) were recorded (Map: Appendix 1). This represents a 7% decrease from the survey using the same methodology in 2003. However, subsequent thorough monitoring of the whole colony in 2003 gave a reduced total of 209 AOTs, almost the same as the 2004 result.

The Handa Island **Arctic skua** colony in 2004 comprised **30 AOTs** (Map: Appendix 2), compared with 36 AOTs in 2003.

Due to the instability of the club sites in 2004, it was not possible to make an accurate estimate of non-breeding Great and Arctic skuas present on Handa this year.

4. Productivity

In 2003, the entire Great and Arctic skua colonies of Handa were monitored to determine productivity – an unsustainable approach in the long-term. In 2004, it was therefore decided (following Walsh *et al.*, 1995) to set up a long-term monitoring zone containing a minimum of 60 Great skua nests and the entire Arctic skua colony (since the total number of Arctic skua nests is less than the recommended sample size).

Mean Great skua productivity on Handa has been shown to vary significantly in different parts of the island (Jones, 2003). Therefore, in an attempt to better represent the colony as a whole, and for the purpose of research, two distinct areas of the island each containing a minimum of 30 Great skua territories were selected as study sites (Map: Appendix 3). These areas were found in 2003 to support contrasting high and low levels of breeding success among Great skuas.

See research report by C. Smith (p.7) for notes on the methodology used for monitoring productivity, and a detailed comparison of results between the two study sites.

Table 1 below summarises the Great skua breeding statistics for 2004. Defined as mean number of chicks fledged per breeding pair, **Great skua productivity** in 2004 was **0.88** (n=91). The all-island figure for productivity in 2003 was 0.59 (n=202). However, the comparison is not a direct one, due to

Table 1. Summary of Great skua breeding statistics on Handa Island 2004

Laying date (in May)	Clutch volume (ml)	Proportion of addled eggs	Hatching success	Chicks hatched per pair	Fledging success	**Chicks fledged per pair**	Nearest neighbour distance (conspecific)
26.1± 0.9 (77)	144.6 ± 2.3 (69)	9.3%	0.85	1.52 (91)	0.58	**0.88 (91)**	47.5± 2.8 (91)

Values ± SE; sample sizes in parentheses
Hatching success: No. of chicks hatched / no. of eggs laid
Chicks hatched per pair: No. of chicks hatched / no. of pairs
Fledging success: No. of chicks reaching 42 days / no. of chicks hatched
Chicks fledged per pair: No. of chicks reaching 42 days / no. of pairs (=productivity)

subtle differences in methodology, and different sample sizes. A longer-term and more meaningful evaluation of inter-annual variation in results will be carried out at the end of this three-year programme.

The entire **Arctic skua** colony was monitored this year by L. Williams. **Productivity** in 2004 was **1.32** (n=25), a slight increase on the 2003 result of 1.22 (n=32). However, data on post-fledging mortality, which was extremely high in 2003, were not recorded this year.

5. Great skua diet

A 'pellet transect' crossing 14 Great skua territories within Study Site 1 (Appendix 3) was monitored throughout the season by L. Williams. On each occasion, the territories were searched for pellets regurgitated by the holders of the territories, and the contents of the pellets analysed to give an indication of diet. Assuming that each pellet represents one meal, the preliminary results for proportions of prey/carrion items taken by Handa birds in 2004 are as follows: **bird 58.3%** (auk 36.6%), **fish 35.4%** (sandeel 33.9%), other (rabbit, goose barnacle and crustacean) 6.3%. The methodology, results and implications of this study will be discussed in greater detail in a forthcoming scientific publication.

6. Ringing

Ringing effort on Great skuas focused first on chicks from the 2 study sites - aiding identification as chicks aged, as they often wander more than 100m from the nest - and then on the wider population. 50 chicks were colour ringed with white plastic bands with a letter (A-E) and number (0-9), which unlike standard BTO rings can be read with binoculars when birds are in flight or standing. A total of 117 Great skua chicks on the whole island were given BTO metal rings.

Two Great skuas colour ringed in 1992 and 1993 continued to breed this year (although unfortunately both lost their chicks); as they were ringed as adults, this makes them at least 16 years old. A third colour ringed bird was found dead, its age as yet unknown as the rings indicating year of capture were absent. 9 colour ringed individuals were observed in 2003; however more colour ringed birds were probably breeding/present on Handa in 2004 than were recorded, as the study focused only on 91 nests.

29 Arctic skua chicks were given BTO metal rings prior to fledging.

7. Aims for 2005

Monitoring and research on the skuas of Handa will be continued and further developed by the team in 2005, with a particular focus on Great skua diet: see Appendix 4 for a copy of the 2005 workplan. The results will be disseminated to all partners and interested parties in the form of a final report in late 2005/early 2006.

8. Acknowledgements

We are indebted to Dr. Jean Balfour, Mark Foxwell, the Handa Island Management Committee and Scottish Wildlife Trust for the privilege of being able to work on the skuas of Handa; and to Scottish Natural Heritage and The Seabird Group, without whose financial support this work would not currently be possible. Thanks also to the Highland Ringing Group, to Charles Thomson and Skipper for their unfailing logistical support, and to Nick Cheales at SWT HQ for once again providing background information.

Research Report

The effect of Great Black-backed Gulls on Great Skua behaviour and breeding success on Handa Island, 2004

Claire Smith

INTRODUCTION

Research in 2003 gathered information on the breeding ecology of Handa's skua colonies as a whole and provided strong circumstantial evidence for the negative impact of Great black-backed gulls (*Larus marinus*) on Great skua (*Stercorarius skua*) productivity (Jones, 2003). With the exception of Stronsay in Orkney (R.W. Furness, pers. comm.), Handa represents a novel situation among British Great skua colonies of Great black-backed gulls (GBBs) nesting in their midst. This study aimed to investigate the effect of GBBs on Great Skua productivity and breeding adults' activity patterns.

This year's research focused on 91 territories spread over 2 study areas (map: Appendix 3) of relatively high and low productivity (as identified by Jones, 2003). Detailed observations were conducted on adult behaviour of 27 focal pairs from incubation until chick fledging at 6 weeks. Pairs differed in the number of GBB pairs they had as their nearest neighbours, and in the distance to nesting GBB pairs and other Great skuas. Study site 1 contained 43 Great skua nests and 10 GBB nests and was bordered by an additional 7 GBB territories. Study site 2 comprised 48 pairs of Great skuas and 4 GBB pairs.

Background to behavioural trade-offs

As in many seabirds, Great skuas share parental care of young (Furness, 1987; Hamer, 2001; Phillips, 2001) and as offspring grow are likely to face an increasingly difficult trade-off between foraging and guarding their chicks. Parental foraging effort should increase with chick growth and a strong inverse relationship between growth rate and post-fledgling mortality in Great skuas (Hamer *et al.,* 1991) suggests there is a strong selection pressure to maximize time spent provisioning chicks. However, chicks become more valuable as they age such that the benefits of guarding them increase. Therefore, there exists a trade-off between the need to forage to maximize chick's long-term survival and the need to guard chicks and so maximize their short-term survival. Defence of chicks through pair co-ordination is an important component of successful breeding for Great skuas (Ratcliffe & Furness, 1999).

The major factors affecting foraging trip length and adult attendance at other Great skua colonies have been found to be brood size (Ratcliffe & Furness, 1999), food availability (Hamer et al., 1991), and differences between individuals (age and quality of birds). Bird specialists have also been found to spend less time foraging than fish specialists (Votier *et al*., 2004.) A detailed long-term study on Foula found attendance decreased and brood neglect increased with declining food supply (Hamer *et al.*, 1991.)

Pairs with two chicks exhibit lower attendance and higher incidences of brood neglect than pairs with one, as parents increase foraging effort at the expense of chick guarding (Ratcliffe & Furness, 1999). Younger, inexperienced and poorer quality birds have not only been found to be less efficient foragers, spending more time off-territory, but also co-ordinate their activities less effectively, leaving chicks unattended more frequently than older birds (Ratcliffe & Furness, 1999; Catry & Furness, 1999). Early-laying pairs (lay date is an indicator of quality in Great skuas) had higher attendance than later-laying pairs (Ratcliffe & Furness, 1999).

Unlike Foula, where the majority of skua research in Britain has been conducted, food availability is assumed not to be a problem on Handa due to its large mixed colony of 120,000 Guillemots, 12,000 Razorbills, 16,000 Kittiwakes, 4,000 Fulmars and 1,000 Puffins (Williams, 2004) which breed on the cliffs, and on which Great Skuas feed (pers. obs.; L.Williams, unpubl. data: bird comprising 58% of pellets collected from territories). Sand-eel abundance is known to be high in the area and was confirmed by the high number of sand-eel regurgitates observed by the author and the warden. Handa also contains a large rabbit population which is currently affected by a liver-fluke (L.Williams, pers. comm.) and which skuas take as carrion. As food availability is high the majority of variation in time spent off territory foraging may be expected to be determined by individual foraging effort and predation pressure. In the light of predation pressure, parents nesting in close proximity to one or more pairs of GBBs may be expected to alter individual activity patterns to maintain sufficient foraging effort by making more, shorter foraging trips. Successful pairs may also be expected to coordinate activities better and have higher attendance patterns. Ultimately time spent off territory may be constrained by the need to maximize time spent on territory guarding chicks.

During the breeding season, the role of the larger female is predominantly defence whilst the male forages for the female and chicks. Caldow and Furness (2000) found that in times of food shortage females altered their behaviour to aid the male and maximise foraging. In response to increased predation behaviour male skuas may be expected to alter their foraging behaviour to increase the effectiveness of chick guarding.

METHODS

Productivity

Methods for locating nests and monitoring productivity were consistent with last year's study (Jones, 2003). Territories were visited every 2-3 days during incubation to determine hatching dates and every 5-7 days thereafter until chicks reached 42 days old, after which they were assumed to have fledged (Hamer, 2001). Individuals were found to vary widely in their defence of chicks and response to humans entering their territory, and any nests for which the status of chicks was uncertain were observed from a concealed position which resulted in the discovery of many elusive chicks. Laying dates were assumed to be 29 days prior to hatching of the alpha (or only) egg (Hamer, 2001).

The length and breadth of all eggs were measured to the nearest 0.5mm using callipers and egg volume calculated using 0.00048 x length x breadth^2 (Coulson, 1963). As the majority of nests were discovered over 2 weeks after laying egg volumes were calculated for 2 egg clutches only as it was not always possible to differentiate between alpha and beta eggs (Great skuas lay eggs between 1 and 4 days apart: Hamer, 1991), and it was uncertain whether single egg clutches were 'true' or the result of earlier egg loss.

Behavioural observations

Observations were conducted on 27 pairs between the 12th of June and the 20th of August 2004 from four observation points from which the territories of between 5 and 8 pairs could be viewed simultaneously. Observation points were located at least 150m away from territories and in an unobtrusive position. Observations were conducted between 07:30 and 19:30 BST, the part of the day during which the birds were most active (as determined by observations conducted between 05:00 and 22:00).

Observations were conducted in 4 hour blocks (07:30-11:30, 11:30-15:30 and 15:30-19:30 - each block on a different day), giving a total of 12 hours observation for each 2 week stage of breeding; from the last 2 weeks of incubation to fledging at 6 weeks. Adults in each pair were identified by differences in plumage colour and individual head markings. As mating was not observed, the individual undertaking the majority of incubation was assumed to be the female.

The activity of each bird was noted every 6 minutes (after Altman, 1974) providing the following information:

1. Attendance scores (the mean number of birds on territory, a value of 0-2)
2. Total amount of time spent off territory by each adult
3. The number of times each individual left the territory
4. Duration of joint presence/absence.
5. The amount of time spent by each individual in on-territory flapping flight (i.e. flying around the territory as opposed to entering or leaving the territory)
6. Duration of incubation (for 19 nests) N.B. Due to differences in laying date it was not possible to record incubation duration for a full 12 hours for some early laying nests.

Any fights with conspecifics, or with GBBs, were also noted.

Due to variation in the cover of long grass in territories, insufficient 'definite' foraging trip lengths (when the individual was observed regurgitating a meal to the other adult or chicks) were observed for comparative analyses. Duration of 'complete' trips when an individual was observed exiting and re-entering a territory were compared instead.

In addition to normal periodic checking, focal observation territories were searched for chicks following each observation period to determine productivity. Brood size was adjusted in analyses for the following stage if a chick was lost.

The observation data from one pair was excluded from analyses as the male was only seen once on territory and the female later abandoned the eggs. As it was unknown precisely when the male disappeared, records of presence/absence/ trip length and incubation time were unreliable.

One pair's single chick was found predated a few days before fledging but after observations had been completed. This pair was excluded from analyses of behaviour during the 4-6 week stage as all other pairs could be said to be 'successful' in that they raised at least one chick.

Chick growth index

All surviving chicks were weighed and measured once during the linear phase of growth (i.e. when weight and wing length increase at the same rate - 13-34 days, Furness, 1983). Weight was measured to the nearest 10g using a pesola spring balance and maximum wing chord to the nearest 1 mm using a stopped wing ruler (excluding the down on very small chicks).

The focal 14 GBB territories were checked every 5 days to determine hatch dates and productivity. Pellet sweeps of GBB territories, 14 Great skua territories along a transect and the Great skua club site (a congregation of non-breeding birds) were conducted every 10 days to check for evidence of Great skua chick predation.

STATISTICAL ANALYSIS

All productivity analyses are based on double clutches only as all nests were discovered at least 1 week after laying and so data on single egg clutches is meaningless as it is unknown whether they are 'true' single egg clutches or were reduced through predation/addling prior to discovery of the nest.

An index of chick body condition was calculated by taking the residuals from a regression of chick age against weight during the linear phase of growth. Each chick was measured once. These indices were compared between sites using the Mann-Whitney U test (after Voiter *et al.,* 2004)

The GLM (General Linearised Models) procedure of SPSS was used to determine the main effects of the following variables (Table 1) on the aforementioned aspects of adult activity patterns. Factors were removed from the model individually until a combination of factors that significantly explained the majority of variance (in behaviour) remained.

Fixed factors:		*Categories*
	Distance to nearest Great Skua	1 vs 2 – above/below 40.2m (median for 91 nests)
	Distance to nearest GBB	1 = <80m 2 = 80-150m 3 = >300m
	Brood size	1 or 2 adjusted after predation
Covariates:	Lay date	Days after 30th April
	No. GBB's within 150m	Range 0 – 5
Random factors:		
	Area	1 = site 1 2 = site 2

Table 1. Independent variables used in GLM analysis.

N.B. Since there exists a negative Spearman correlation between distance to the nearest GBB nest and number of GBBs within 150m ($r = -.715$, $n = 26$, $P < 0.001$) these variables were incorporated separately into models.

Brood size and laying date were omitted from the model for the incubation period, as the male was only likely to be foraging for himself and the female. For three nests that did not hatch, laying date remained unknown.

Sample sizes differed for each observation stage as observations were terminated at each nest once all chicks had been lost (Table 2). Only 19 nests were included in the incubation stage as insufficient observations were conducted on 7 early hatching nests to obtain 12 hours of data for this stage.

Stage	Incubation	0-2 weeks	2-4 weeks	4-6 weeks
No. of nests	19	23	20	18

Table 2. Sample sizes for each observation stage

RESULTS AND DISCUSSION

Breeding ecology & comparison of study sites

Site	Laying date (in May)	Clutch volume (ml)	Proportion of addled eggs	Hatching success	Chicks hatched per pair	Fledging success	Chicks fledged per pair	Nearest neighbour distance (con-specific)
1	25.2± 1.4 (34)	139.5 ± 3.6 (34)	15%	0.79	1.47 (43)	0.44	0.65 (43)	52.3 ± 4.4 (43)
2	26.8±1.2 (43)	149.4 ± 2.8 (35)	3.6%	0.90	1.56 (48)	0.69	1.08 (48)	43.1 ± 3.5 (48)

Table 3. Summary of breeding parameters for study sites (values ± se with sample size in brackets).

Hatching success: No. of chicks hatched / no. of eggs laid
Chicks hatched per pair: No. of chicks hatched / no. of pairs
Fledging success: No. of chicks reaching 42 days / no. of chicks hatched
Chicks fledged per pair: No. of chicks reaching 42 days / no. of pairs (=productivity)

Hatching success (although lower in Site 1) and lay date did not significantly differ between the 2 sites. Chicks fledged per pair and clutch volume were significantly lower in Site 1 (Mann-Whitney $U = 444.5$, $P<0.05$, $n=72$ and independent t-test, $t = 0.31$, d.f. = 67, $P < 0.05$ respectively).

This was expected for the 'poor site'. The difference in productivity between the sites may be explained by 2 mechanisms; that there is simply more predation of eggs and chicks and increased disturbance due to the proximity of GBBs, or that poorer quality individuals that are simply not as productive and less able to raise chicks nest in this area. Lay date and egg size are indicators of female age and quality. High quality birds tend to lay earlier in the season, as they arrive earlier, obtaining better territories ensuring that hatching coincides with hatching of prey birds, maximising the food available. Breeding success has been found to be four times higher for eggs laid in the first quarter of the laying period than in the last quarter (Furness, 1987). Egg size also increases with female quality and age, although it decreases as females pass their peak breeding age (Hamer, 2001). Clutch volume is notably smaller for Site 1 birds, suggesting lower quality females nest here. However lay date is slightly earlier, suggesting higher quality birds; although due to the higher incidence of addling and egg predation lay date was unknown for 9 pairs in Site 1. [N.B. Two nests with clutch size of 2 were omitted from egg volume analysis, one was discovered after the chicks had hatched and the second was found with both eggs predated.]

Neither hatching success nor lay date differed significantly between nests with 0 and 1 or more GBB within 150m. Neither lay date nor clutch volume (for 2-egg clutches only) were significantly correlated with distance from the nearest GBB nest, thus a tendency for lower quality birds to nest nearer GBBs was not found.

A far greater proportion of eggs were addled in Site 1 than Site 2 (Table 3), and 8 of the 12 nests with addled eggs were within 150m of at least 1 GBB territory. No birds whose eggs addled re-laid a second clutch.

Comparison of Handa egg volume with other colonies

Year	Colony	Alpha egg volume (ml)	Total clutch volume (ml)	Study
2004	Handa	71.9 (69)	144.6 (69)	This study
1989	Foula	82.1 (387)	-	Hamer *et al*, 1991
1996	Foula	82.3 (429)	164.6 (213)	Phillips *et al*., 1997
1995	Foula	83.6 (391)	167.1 (195)	Phillips *et al*., 1997
1994	Foula	83.9 (318)	168.0 (158)	Phillips *et al*., 1997
1996	St Kilda	84.4 (343)	169.4 (153)	Phillips *et al*., 1997 & 1999
1975	Foula,	85.4 (749)	-	Furness, 1977

Table 4. Egg and clutch volume at 3 Great skua colonies (sample size in parentheses).

Also of note is that the clutch volumes of Handa's Great skuas are smaller than those of other colonies. In comparison to Foula this is unsurprising as Great skuas did not start colonising Handa until 1964 and the population increased slowly and steadily until the 1990s (Jones, 2003). However, the same population growth has occurred at St Kilda where the first pair bred in 1963 and numbers rose steadily until 1990, rapidly expanding into a colony of 233 AOTs by 1997 (Phillips *et al*., 1999). Thus the colonies are of the same age. The reason for smaller eggs at Handa is unknown. Although it must be treated with caution as Handa's average egg volume is from a relatively small sample of birds, half of which were chosen as they were nesting in a poor area and so are suspected to be young or of poor quality. This does not reflect the make up of the breeding population as a whole and may not give a true picture of Handa's egg volumes. Egg volumes should continue to be measured to build up a long term data set for comparison with other colonies.

Chick growth index

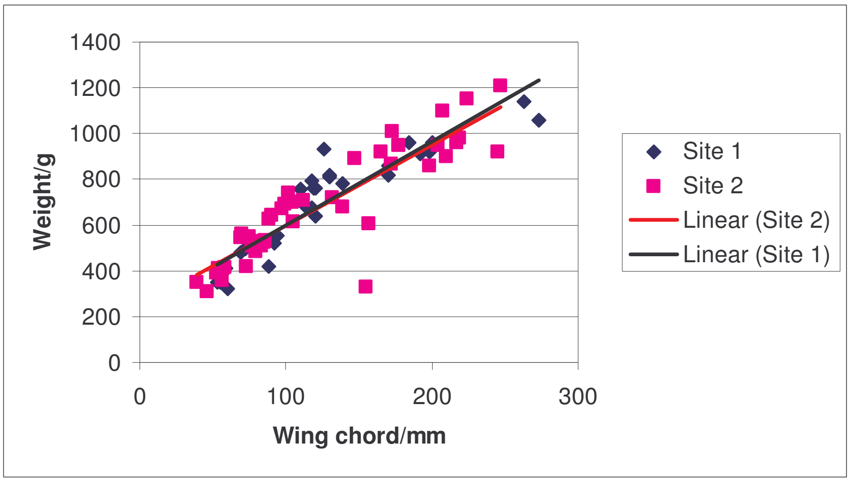

Figure 1. Comparison of chick condition between sites.

Chick growth did not differ significantly between sites, i.e. of those birds whose chicks survived to be weighed, there was no significant difference between provisioning of chicks in site 1 and site 2 by parents. this suggests that adults did not differ in their ability to feed their young and that defence was not at the expense of feeding. N.B the outlying small chick in site 2 starved. However, many chicks died before reaching 12 days old (the linear growth phase) and so were not measured. Some of these chick disappearances may be due to lack of feeding, however this would be extremely difficult to test.

Mortality factors

One 3 day old chick from site 1 was discovered dying during nest checking. It had no external injuries and was of average size for its age; cause of death was unknown. One chick in site 2 was squashed in the nest several days after hatching, the second egg was still being incubated and so was presumably sat on by a parent.

No remains of Great skua chicks were discovered in pellets of territories along a transect nor in pellets of club site birds. The legs of 2 chicks were discovered in two separate GBB territories in site 1. Chicks were un-ringed and so were either from outside the study site or were chicks under 2 weeks old. A month old ringed chick was discovered predated at the boundary between its own and another territory. A 5-week old ringed chick was found predated in a non-study site territory approximately 150m away from its own territory. Both territories from which these predated chicks originated were within 150m of a GBB territory.

At least 2 eggs were predated by hedgehogs as evidenced by a small hole in the top of the egg. A third egg that was already addled was also predated. One chick died hatching.

One chick was extremely underweight when ringed despite having a normal sized sibling that successfully fledged, was only seen once and was later found dead but presumed starved. One chick was found squashed in the nest, another was observed dying by the warden during monitoring without any obvious external abnormalities.

It is worth noting that one GBB chick close to fledging was found predated in a Great Skua territory.

Adult activity patterns – main findings

1. Incubation

Average incubation time was found to be positively correlated with distance from nearest GBB nest (Spearman $r = 0.648$, $P<0.05$, $n = 19$).

2. Attendance

Proximity of Great skuas was found to significantly affect attendance during the incubation stage only ($F=6.786$, $n=19$, $P<0.05$, eta squared = 0.285).

3. Time off territory

Variation in time-off territory for males was determined by the proximity of Great skua nests during the incubation stage ($F= 7.648$, $p<0.05$, observed power = 0.741, $n=19$). During the first chick stage (0-2 weeks old) variation in the amount of time spent off territory by females was determined by lay date and site only when proximity to the nearest GBB and Great Skua nests was included in the model.

4. Observed trip length

The proximity of GBB territories was near significant (0.056) in determining variation in observed trip length by males during the first chick stage only when proximity of Great skua territories was included in the model.

5. Number of times left territory

The number of times the males left territories during the final chick stage (4-6 weeks) was significantly affected by brood size only when proximity of GBB and Great skua territories was included in the model.

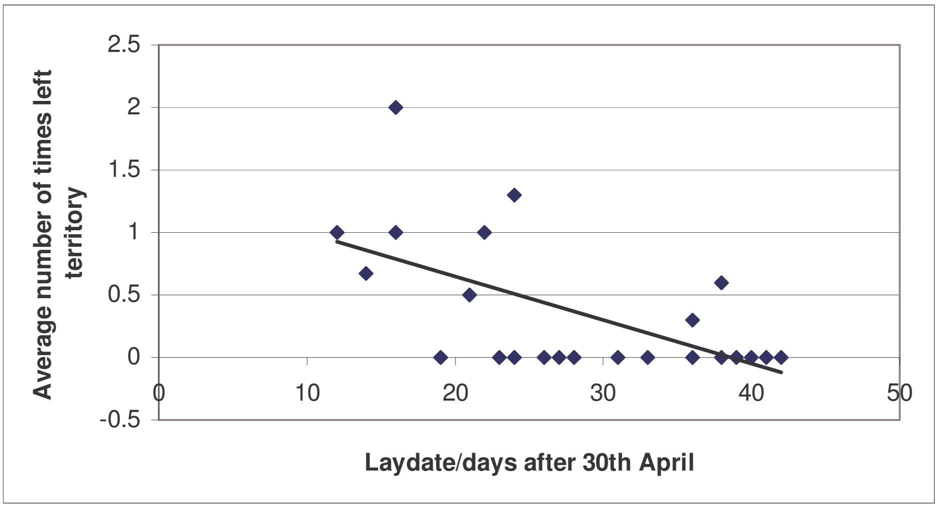

Figure 2. The relationship between lay date and the number of times females left territory during the first chick stage (0-2 weeks)

During the first chick stage whether females left the territory or not was determined by laydate (logistic regression, Wald = 3.818, $P<0.05$, exp(B) = 0.868). Lay date was found to be negatively correlated with the number of times the female left ($r=-0.544$, $P<0.05$, $n=23$.), so that later laying females left territory less frequently.

6. Joint absence

The probability of the chick(s) being left completely unattended was only analysed for the final chick stage when the majority of joint absences occurred (due to the increased food demands of the growing chick/s). Distance to the nearest GBB territory significantly predicted the likelihood of 'brood neglect' when combined with distance to the nearest conspecific.

7. Joint presence

Variation in the amount of time that both adults were present on territory during the 2-4 week stage, was significantly determined by the distance to the nearest GBB territory and study site, only when distance to Great skua territories was included in the model. Variation in the amount of time both adults were present on territory during the last chick stage was significantly affected by proximity of GBB and Great skua territories and brood size (i.e. joint presence was greater for pairs with 1 chick than 2).

8. Flapping flight

Variation in the proportion of individuals engaged in on-territory flapping flight was explained by the following factors:

Stage	Males	Females
Incubation	Proximity of GBB & Great skua territories	None
0-2 wks	Proximity of GBB territories & site	No. of GBBs within 150m & site
2-4 wks	No. of GBBs within 150m & site	No. of GBBs within 150m
4-6 wks	Site & brood size	None

Table 5. Factors determining variation in on-territory flapping flight.

General observations

Attempts at trapping non-breeding Great skuas at the club-site resulted in it moving twice. On one occasion when the club site had moved a GBB parent took one of its fledglings over to the club site, antagonised the adults and attempted to steal food from incoming individuals. One of the breeding, colour-ringed adults was observed on the club site which is unusual as this is defined as an aggregation of non-breeding adults and this behaviour has not previously been documented.

DISCUSSION

The lack of direct evidence for predation of Great skua chicks by conspecifics is unsurprising. Individuals varied widely in the number of pellets found on territory (pers. obs. and L.Williams, unpubl. data.) and are likely to deposit many off territory as has been found in dietary studies (Votier *et al*, 2001; Votier *et al,* 2003). This was confirmed by the variation in the number of pellets found on individual Great skua and GBB territories by the warden and author. However, the discovery of two chicks in GBB pellets conformed that GBBs are predating skua chicks. Great skua egg shell was discovered in a GBB territory in the vicinity of an egg-predated nest in site 1, providing circumstantial evidence for predation of Great skua eggs by GBBs. Great skuas are known to cannibalise chicks, at least in times of food shortage (Furness, 1987) and the lack of direct evidence for conspecific chick predation does not mean it is not occurring. Rather, it is likely to be occurring at a low level in light of the abundance of food on Handa.

Given the density of Great skuas and GBBs, and nest checking intervals, it is not surprising that so few dead chicks were found; indeed 2 of those that were found had already been thoroughly predated. However, due to the opportunistic nature of two species in such close proximity and the fact that the behaviour is so well documented in other studies (Hamer, 2001), it would be highly unlikely that it did not occur. No matter how easy it is for an adult to obtain food from the cliffs a defenceless, flightless chick a few metres from the nest will always be an easier meal.

Although hatching success did not significantly differ between the two sites or between birds with no GBBs or at least 1 GBB within 150m, this result should be treated with caution as a higher incidence of addling occurred in site 1, with the majority of nests with addled eggs being within 150m of a GBB territory. However, far more double clutches were discovered in site 1 thus compensating for this decrease in hatching success. Disturbance during incubation that can lead to egg-chilling was evidenced by the correlation between distance to the nearest GBB territory and incubation time from observational data. Many more fights among GBBs were observed than between Great skuas, that resolve the majority of territory disputes prior to egg-laying (Furness, 1987). Therefore nesting close to GBBs is likely to cause more disturbance during incubation than nesting near a Great skua. As not all addled eggs were fertilised (pers. obs.) it is possible that GBBs may also cause disturbance during mating. It must be noted that occurrence of addling in Great skua eggs is higher than in all other skua and gull species (Furness, 1987) and therefore in absence of GBBs incidence of addling would not be zero. However, if the incidence of addling was simply due to natural variation in adult quality on Handa a similar incidence of addling would be expected at both study sites. Nesting near one or more GBBs was found to decrease the probability of chicks fledging.

Lower quality or younger inexperienced birds would be expected to lay closer to GBBs either because they are unaware of the potential predation pressure or because they arrived later and so are forced to occupy poorer quality territories. It was expected that this would be reflected in later laying dates for such birds as early laying is associated with individual quality (Catry *et al*., 1999). The lack of correlation between distance from the nearest GBB nest and laying date may be due to a bias in the lay date data. Of the 15 nests for which lay date was unknown 10 were within 150m of at least 1 GBB territory, therefore there was a bias towards lay dates of birds nesting further away from GBBs.

Laying near a GBB need not necessarily lead to breeding failure. Several nests that fledged one chick were equidistant from GBBs as those that failed but were at a higher elevation, whereas those that failed were on a plateau below GBB territories. The amount of cover for chicks provided by long grass will also be important in determining fledgling success. Chicks' ability to hide is as important as adults' ability to defend in determining survival.

INDICATORS OF ADULT AGE/QUALITY

The ages of adult skuas on Handa is unknown, although the population as a whole is assumed to be young due to its recent colonisation, and to be comprised of young immigrants from other areas as the doubling of breeding pairs between 1991 and 2002 (Jones, 2003) cannot be accounted for by recruitment alone. Great Skuas do not breed until they are at least 4 years old (Hamer, 2001) and mean productivity between 1989 and 1991 was 1.24 chicks fledged per pair (Jones, 2003). Measures of mean corpuscular volume in females (e.g. Furness, 1987) are not available to provide direct measures of quality. Therefore egg volume and laying date are used as surrogates for age and quality. Egg volumes and laying date have been shown to peak with peak breeding age (14 years) and be highest in high quality birds (Furness, 1983; Hamer & Furness, 1991; Hamer & Furness, 1993; Catry *et al.,* 1999).

The lack of a predictor variable or combination of variables for joint absence is unsurprising given the small number of nests analysed. Additional factors not measured here that may contribute include territory quality: those pairs that neglected chicks on more than one occasion and for more than 6 minutes at a time all occupied high quality territories in terms of chick concealment.

The occurrence of double presence may not directly lead to better brood defence as the propensity of males to assist in defence whilst on territory differed between pairs. At one observation nest, male was rarely seen to assist with defence and the egg was addled then predated.

Great skuas suffer far more from GBB attacks than conspecific attacks as GBBs tend to co-operate in attacking Great skuas even when on their own territory, and up to 6 GBBs were witnessed attacking one female Great skua at a time. Therefore as well as GBBs being larger, Great skuas nesting in their vicinity also suffer from their co-operative methods of defence. GBBs became increasingly aggressive toward skuas as their chicks aged and began to wander large distances, often into Great skua territories. One GBB fledging was discovered predated on a Great skua territory but all study pairs raised between 1 and 3 chicks with the majority of losses at the egg stage. It must also be noted that earlier laying GBBs were found to be far more aggressive to other birds and humans than later laying individuals, and Great skuas nesting near early breeding pairs suffered disproportionately.

The effects of brood size and lay date in determining adult activity patterns are conspicuous in their absence and were often the first factors to be removed from GLMs as they were the least significant and accounted for the least variation. Adult attendance has been found to decrease and foraging trip length increase with brood size and lay date (Ratcliffe & Furness, 1999; Catry & Furness, 1999). Their relative unimportance in determining adult activity patterns on Handa suggests that predation pressure by GBBs exerts a larger influence on behaviour. Indeed, duration of joint presence was found to change with brood size in an opposite way than would be expected if parents were maximising chick provisioning. I.e. pairs with 2 chicks had higher joint presence than pairs with 1. If protection of offspring was the primary factor affecting territory attendance by adult skuas then we would expect time on-territory to increase with increase in brood size. The opposite was found on Foula (1987-1989) meaning that the need to increase the time spent foraging in response to nutritional demands of a larger brood was most important at this colony, and overrides any effect due to motivation to protect the brood (Hamer *et al.*, 1991).
This suggests either that these are higher quality individuals that are more efficient foragers, or that behaviour is changed in response to predation pressure. Further evidence for this comes from males' shorter foraging trip lengths when nesting near GBBs; if they

were simply poorer quality males they would be expected to spend more time foraging, and be inefficient.

Flapping flight
The proximity and number of GBBs was found to significantly increase the amount of time spent in on-territory flapping flight during three stages for males and two stages for females Wind tunnel studies of flapping flight have indicated this activity increases the metabolic demand by up to 4 times (Furness, 1978). Thus, increased time engaged in non-facultative flapping flight means such birds use more energy, which could lead to poorer condition.

In the short-term this could decrease condition resulting in decreased foraging ability in males and decreased defending ability in females. Production of large, high quality eggs is determined by protein reserves in females (Hamer *et al*., 1991) and females that engaged in more foraging in Foula during times of food shortage were found to be less likely to maintain protein reserves resulting in smaller, lower quality eggs being produced the subsequent year. Egg size affects breeding success through its influence upon chick growth (larger eggs produce larger chicks) and mortality (Hamer *et al.*, 1991). Clutch volumes were significantly smaller in site 1 which may simply be due to females being of lower phenotypic quality but may also be due to stress from previous seasons. Thus, disturbance by GBBs resulting in increased flapping flight could compound breeding success of lower quality individuals further, decreasing future breeding success.

Conclusions

Evidence suggests that nesting close to GBBs has the potential to adversely affect Great skua breeding success at all stages. Increased disturbance during incubation can reduce hatching success, egg predation and chick predation. Stressed adults that have engaged in far more defence and fights may well end the breeding season in poorer condition, potentially affecting future reproductive success. A longer term study following the behaviour and productivity of focal pairs over several years would be required to confirm this.

It is not evident from this study whether successful Great skua pairs alter their behaviour in response to predation pressure from GBBs or whether they are higher quality individuals with successful behaviour better adapted to it, i.e. more efficient foragers by definition spend less time foraging and are better co-ordinated in their activities, resulting in increased chick guarding. It may be that they are plastic in their behaviour and have adapted to increased predation pressure as lay date (an indicator of individual quality and with high repeatability between years, Catry *et al.,* 1999) did not determine variation in adult activities.

That no one factor explained variation in any of the activities measured across all chick stages suggests an interaction between factors that was not evident due to the low number of nests observed. It is also likely that factors not measured including age and quality of

adults as well as territory quality (i.e. vantage points for adults and cover for chicks) played a role in determining adult activity patterns.
GBB numbers are declining on Handa as part of a nationwide trend (Jones, 2003) and although they are having a severe impact on Great skua productivity this may not be expected to continue indefinitely. However, as levels of immigration decrease due to the halting of expansion from the Shetlands, productivity and the breeding population may be expected to undergo a temporary decline in future as levels of recruitment are low and older breeders nesting near GBBs may be in poorer condition through continual disturbance. However, in light of the poor breeding seasons in the Shetlands due to lack of food, breeding Great skuas may move south and Handa's population may grow further.

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A more detailed version of this report including all statistical analyses is available.

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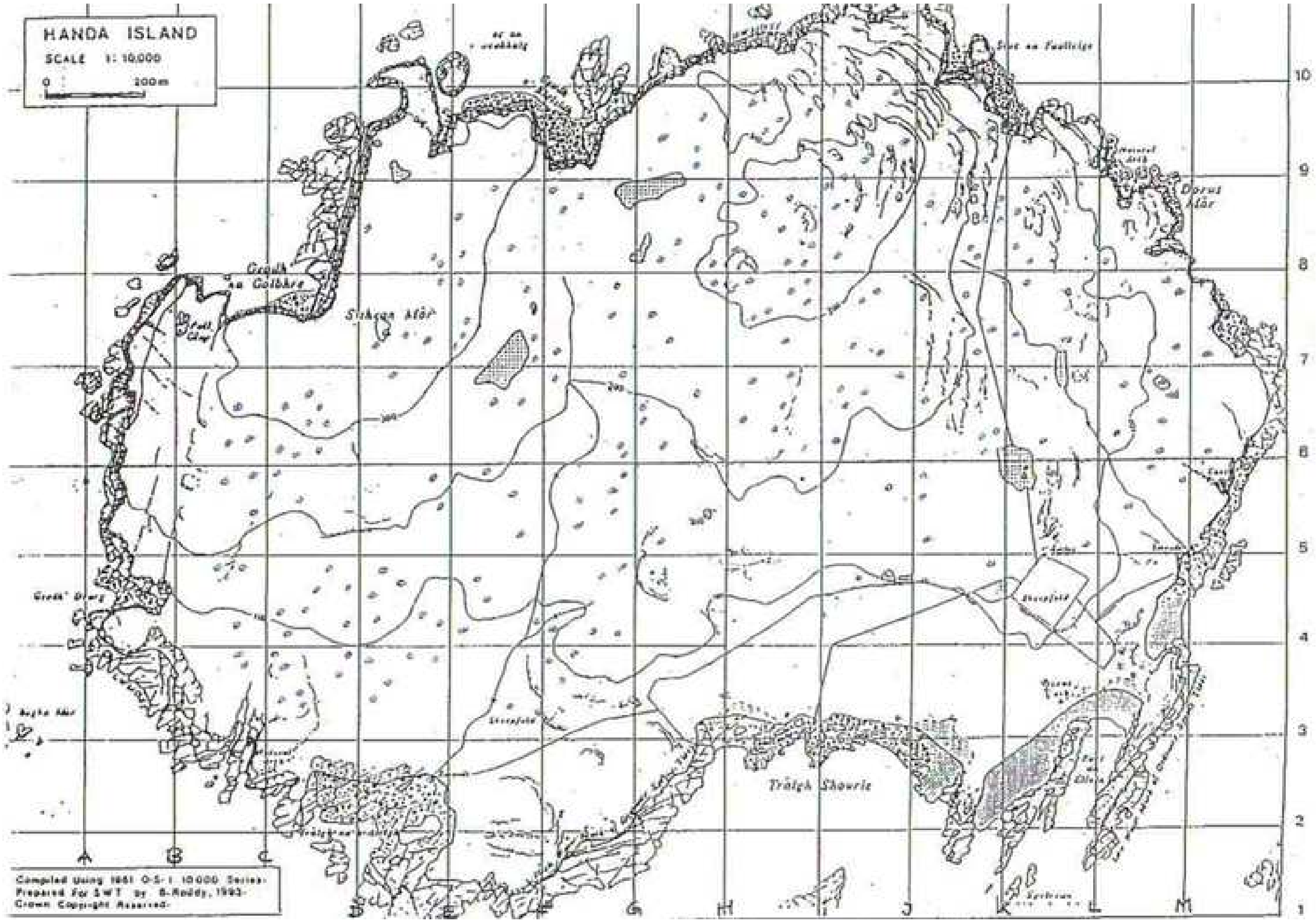
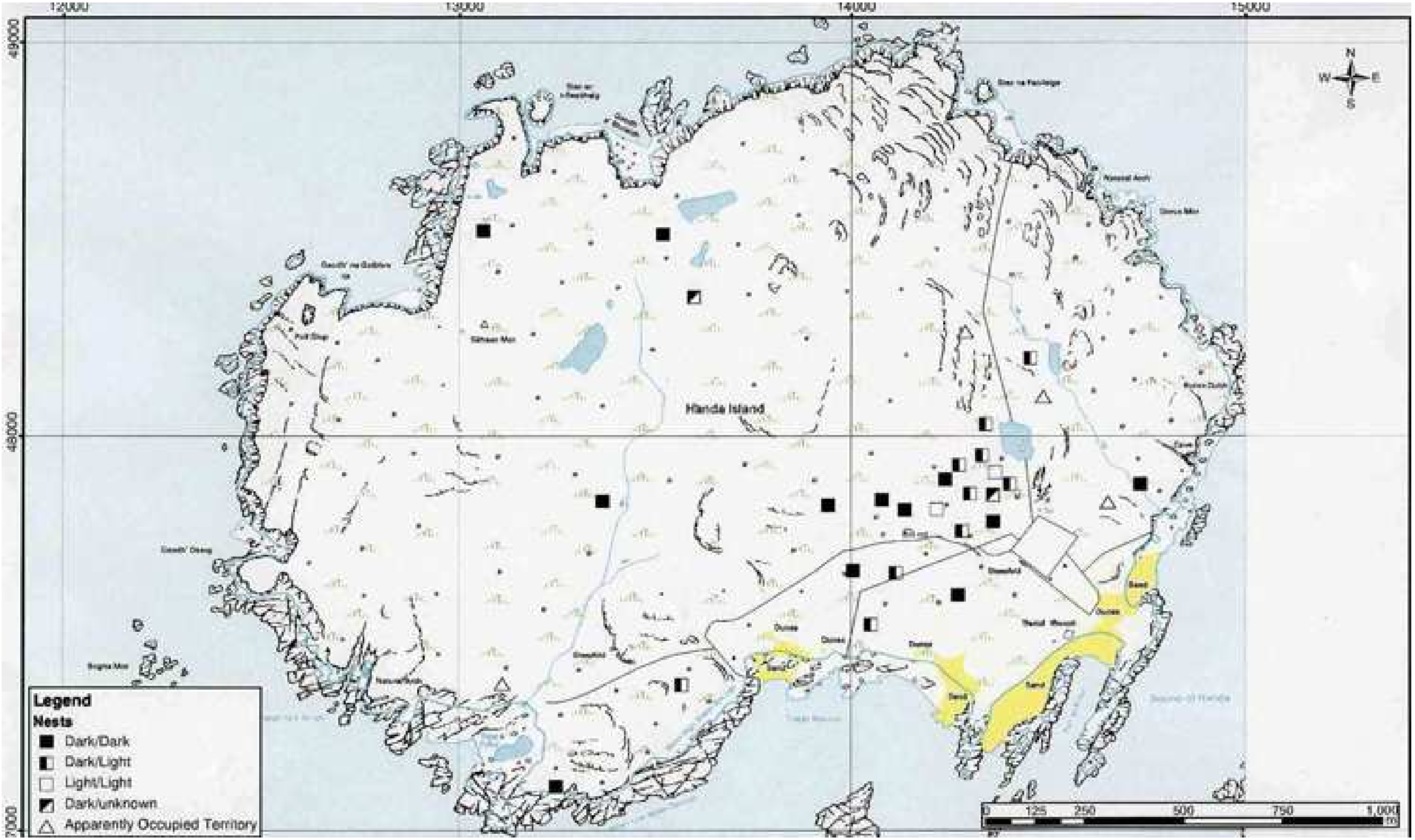
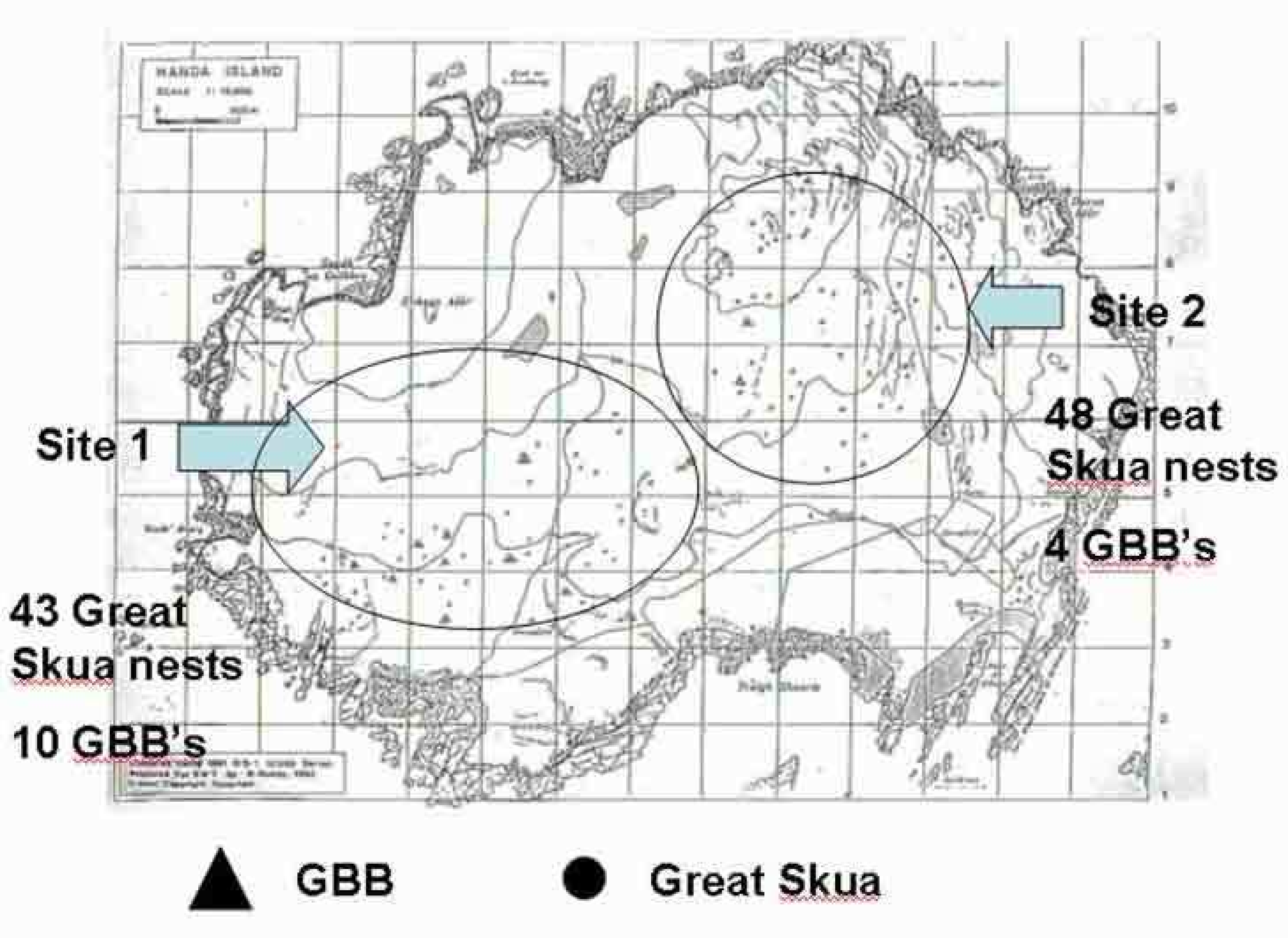
APPENDIX 1: Great skua AOTs on Handa Island, 2004



APPENDIX 2: Arctic skua AOTs on Handa Island, 2004



APPENDIX 3: Study sites and focal nests on Handa Island, 2004



APPENDIX 4: Copy of 2005 Monitoring and Research Workplan

Handa Island Skua Monitoring Programme

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22nd March 2005

WORKPLAN 2005

To: Senior Conservation Manager (North), Scottish Wildlife Trust
Dr. Jean Balfour
Cc: Handa Island Management Committee

1. The Context: The 3-year Plan, 2004-2006

The 2005 Workplan described below is designed to fulfil our objectives in Year 2 of a 3-year monitoring plan, the broad objectives of which are outlined in the November 2003 proposal by Jones, Ramsay & Williams, *Monitoring of Great and Arctic Skua Populations, 2004-2006*.

Year 1 of the current monitoring programme, 2004, proved an extremely successful field season. All activities and results are fully documented in the imminent 2004 Final Report.

2. General Objectives for 2005

Two long-term study sites have now been established on the island, and we will continue to focus our work within these areas. Our first priority remains to monitor productivity and post-fledging chick survival in the Great and Arctic skua populations of Handa Island, to continue building up this valuable long-term dataset. The recent poor breeding seasons for skuas and other seabird species in the North Sea, and in particular the well-publicised disastrous 2004 season, serve to reinforce the importance of monitoring Handa's skua populations. In this context, our monitoring of Great skua diet since 2003 may be of importance in the long-term, as we face the prospect of more skuas moving from the Northern Isles to the north-west coastal area of Scotland to breed, exerting more pressure on the local and significant seabird prey populations. In 2005, we therefore plan to increase our focus on the monitoring of skua diet. The number of pellet transects to be monitored weekly will be increased from one to two, and pellets will also be collected weekly from the birds' club sites, in order to strengthen our dataset on diet throughout the season.

One surprising result from 2004, albeit from a relatively small sample size, is the Great skuas' small egg volume relative to other colonies studied. In 2005 we will continue to measure eggs in order to build on this dataset and investigate more thoroughly this phenomenon. We will also measure Arctic skua eggs. We will continue to collect DNA material from chicks, and the monitoring of chick development through the use of biometrics and an index developed in 2004 by Claire Smith, will also be continued.

Also in 2005, a study of Great skua territory quality will be initiated. A number of variables potentially important to productivity (e.g. vegetation type and height, presence of vantage points, distance to water source, etc) will first be identified and quantified. These variables will then be measured in a number of Great skua territories of known productivity. Statistical analyses will then suggest which, if any, of these variables may be important to breeding success, and whether there is any correlation between territory quality and laying date.

The ringing programme will continue, aiming to shed light on a number of key issues including future recruitment, philopatry, and whether Handa is supplying new breeders to other colonies in western Scotland. We again aim to ring all of the Great and Arctic skua chicks on the island with metal BTO rings, and also to continue the colour-ringing study we began in 2004. We will also survey the whole island to bring up to date the records of surviving breeders who were colour-ringed in the late 1980s.

Adult trapping for the purposes of ringing, biometrics, sampling DNA, monitoring heavy metal levels and sampling mean corpuscular volume as an indicator of quality, is another objective of the programme. In 2005 we will continue our efforts, begun in 2004, to successfully begin trapping adults in a way that is humane, effective and appropriate for Handa. Trapping is labour-intensive and we do not anticipate catching more than ten adult birds this season.

3. Workplan for 2005

The 2004-2006 proposal outlined the following research topics which we are investigating:

1. Numbers of breeding and non-breeding birds attending colony
2. Productivity
3. Factors affecting breeding success (predation; territory size and density)
4. Diet of Great skuas
5. Chick development
6. Territorial attendance of adult birds
7. Winter movements of young reared on Handa
8. Immigration
9. Philopatry
10. Adult survival rate
11. Adult biometrics
12. Pollution levels in Great skuas

The table below sketches the workplan for 2005, and indicates which of these research topics each activity relates to. It also indicates the necessary timeframe, and the researchers and fieldworkers participating. All methodologies not outlined above will be the same as those outlined in previous proposals and reports.

WORKPLAN 2005

Activity **(research topics)**	**Timeframe**	**Personnel**
Great and Arctic Skua Monitoring (1,2,3,4,5,6,9,10)	May – August	TJ, CS
Territory Quality Study (3)	July - August	CS
Ringing (3,7,8,9,10)	June - August	AR, TJ, CS, LW, Highland Ringing Group
Trapping and adult biometrics (8,9,10,11)	April - August	AR, TJ, CS

We are extremely grateful to Dr. Jean Balfour, SWT, Mark Foxwell, and all of the members of the Handa Island Management Committee, for your continuing support of our work.
