CHAPTER 1

Priorities for Gyrfalcon research: food, weather, and phenology in a changing climate

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1.1 Introduction

Newton (1979) noted that anyone solely interested in general principles of population regulation should avoid studying diurnal raptors. His logic was sound; raptors nest at low densities, often in remote locations that are difficult to access. The Gyrfalcon (*Falco rusticolus*) epitomizes this description not only during the breeding season, but throughout the year. It is a cold-adapted, diurnal raptor inhabiting Arctic and subarctic regions from approximately 55°N to 82°N (Cade 2011). Extensive study of the natural history, status, and distribution of the species has been conducted in Russia (Dementiev 1960, Mistchenko 1981, Ellis et al. 1992, Ganusevich 2006, Lobkov et al. 2007a, Lobkov et al. 2007b, Mechnikova and Kudryavtsev 2007, Lobkov et al. 2009, Mechnikova et al. 2010, Lobkov et al. 2011, Mechnikova et al. 2011, Mineev and Mineev 2011, Pokrovskaya and Tertitski 2011, Potapov 2011), Fennoscandia (Koskimies 2006, Mela and Koskimies 2006, Koskimies 2011), Iceland (Nielsen and Cade 1990a, b, Nielsen and Petursson 1995, Nielsen 1996, Nielsen 1999, Nielsen 2002, 2003, 2010, 2011), Greenland (Booms and Fuller 2003a, Burnham et al. 2009, Cade and Nielsen 2011), Canada (Poole 1987, Poole and Boag 1988, Poole and Bromley 1988, Mossop and Hayes 1994, Shank and Poole 1994, Barichello and Mossop 2011, Cade and Bird 2011, Mossop 2011) and the United States (Cade 1960, Booms and Fuller 2003b, McIntyre et al. 2009, Booms et al. 2010, Booms et al. 2011, Fuller et al. 2011, McCaffery et al.

2011). Yet despite these research efforts (see Chapter 3), intensive study investigating the mechanisms and life history attributes that influence Gyrfalcon ecology in general remain uncommon (Newton 2011), and studies investigating the effects of climate change on Gyrfalcons and their prey are even more scarce.

It is well established that temperatures in the Arctic have risen at almost twice the rate of temperatures elsewhere (Larsen et al. 2014). However, studying the effects of climate change on wildlife is challenging (Berteaux et al. 2006); unlike physical processes (e.g., permafrost, glacial erosion and oceanic winds, tides and densities) that generally respond to increased temperature in predictable ways, and follow physical laws, animals can respond in surprising ways. It is particularly challenging to predict the manner in which endothermic animals, which must maintain body temperature within a narrow range regardless of the ambient temperature, will respond (Gilg et al. 2012). Shifts in climate can influence phenology (Visser et al. 1998) causing trophic mismatch (Post and Forchhammer 2008), species' distributions (Root et al. 2003, Callaghan et al. 2005) including invasive species (Kutz et al. 2013), loss of habitat (Derocher et al. 2004), demography (Anctil et al. 2014), and food web structure (Legagneux et al. 2012), all of which have the potential to affect Gyrfalcon ecology. In 2011, The Peregrine Fund, Boise State University, and the United States Geological Survey hosted an international conference (*Gyrfalcons and Ptarmigan in a Changing World*) focused on the ecology and conservation of Gyrfalcons and ptarmigan (*Lagopus* spp.) and published a comprehensive compendium of articles describing the state of knowledge of the two species. A main objective of the conference was to identify and describe predicted impacts of climate change on Gyrfalcon distribution and abundance (see Newton 2011).

The Gyrfalcon is one of very few bird species found mostly or entirely in the Arctic (others include the Ivory Gull *Pagophila eburnea*, Thick-billed Murre *Uria lomvia*, and Snowy Owl *Bubo scandiacus*), and although it is likely to be among those species most affected by climate change, it has been identified among other Arctic endemics for which data are deficient (Ganter et al. 2013). For those interested in studying Gyrfalcons, the logistical and financial challenges associated with data collection are immense, and as Newton (1979) indicated "makes for samples that to the statistician seem hopelessly small and hard to evaluate." Consider too, that Krebs (2000) argued strongly that ecologists would be wise to spend the vast majority of their time "getting on with" amongst other things "mouse trapping and bird netting" (i.e., field studies), and he made a strong case for conducting field-related activities within the context of well-thought-out hypotheses that focus on data collection, data analysis, and careful interpretation of data-driven results. Around the same time, Hilborn and Mangel (1997) encouraged ecologists to move beyond the null hypothesis, and consider their data within the context of several competing hypotheses, or models. Burnham and Anderson (2002) introduced ecologists to the use of information-theoretic approaches (Akaike 1974) in data analysis, and provided methods that permitted ecologists to select the "best" model among a set of models that are identified before conducting data analysis. Ideas and philosophical views such as these combined with increased computing power have resulted in a shift away from primarily analyzing ecological data within the traditional frequentist framework towards analysis using likelihood or Bayesian frameworks. Further, there is now widespread recognition that a large number of commonly used statistical methods such as the t-test, analysis of variance, analysis of covariance, and regression can be unified under a single class of general linear models. Even more noteworthy is the explicit acknowledgement that general linear modeling is a subset of an incredibly versatile class of generalized linear models (Nelder and Wedderburn 1972) that include commonly applied techniques such as logistic regression and log-linear modeling. Hence, around the turn of the century a suite of powerful tools (fast computers, unified statistical methodology, and information theoretic approaches) became available to ecologists interested in rising to the challenges identified by practitioners such as Newton (1979), Hilborn and Mangel (1997), Krebs (2000), and Burnham and Anderson (2002). Added to this mix are stand-alone software packages that are freely available such as those used to design and analyze distance sampling surveys (e.g., Program DISTANCE; Thomas et al. 2010) and estimate survival (e.g., Program MARK; White and Burnham 1999).

Given the wide array of powerful and versatile tools that have become increasingly accessible, the potential for analysis of data collected from intensive study of Gyrfalcon populations has become progressively more practical. Notwithstanding the advances in data analysis, rising to the challenge of deploying concentrated field-based research will require reliable long-term funding and a commitment to international collaboration. The objectives of this chapter are to provide context for the chapters that follow, and offer recommendations that could focus research efforts in ways that quickly and as cost effectively as possible place people into the field who are capable of collecting and analyzing data relevant to a species that to date remains enigmatic.

1.1.1 About this book

There are twelve chapters and two appendixes in this book; Chapter 2 points to previous literature that explicitly recognizes the importance of applying standardized definitions to terms that are commonly used when monitoring raptor populations. The chapter provides definitions that describe territory occupancy and nesting activities based on recommendations made by Steenhof and Newton (2007) and Steenhof et al. (2017), and includes definitions for terms that apply to other components of raptor nesting ecology and nesting phenology. The authors argue that use and application of standardized terms facilitates comparisons of data over time and space, reduces confusion, and permits clear communication of results. Chapter 3 describes the relationship between the Gyrfalcon and ptarmigan, examines whether there are any Gyrfalcon populations that do not depend on ptarmigan, and considers periods during the breeding cycle when Gyrfalcons are most reliant on ptarmigan. Chapter 4 argues that wildlife research programs have become increasingly data intensive and can benefit from the principles of data science, particularly when research programs are large or span many years, and when data from multiple projects are compiled. The authors provide a simple relational database (using Microsoft Access) to demonstrate the advantages of applying systematic data management techniques to raptor data. Chapters 5 through 12 are data-driven analyses that offer ideas and field-based research techniques that can be applied to studying Gyrfalcons or any other raptor species. Each data chapter introduces an aspect of raptor ecology and provides a correctly formatted data set, a script written in R code (R Development Core Team 2017), step-wise instructions to implement the analysis, an example of the output, and interpretation of the output. Chapter 5 summarizes techniques using motion sensitive cameras placed at nesting sites to quantify and analyze prey use data (i.e., diet). Chapter 6 describes the use of three-parameter logistic modeling to compare Gyrfalcon nestling growth in years of low and heavy rainfall. Chapter 7 explains how to use generalized linear mixed modeling (GLMM) to gain insight into the influence of hatch date, hatch order, and food supplementation on nestling survival. Chapter 8 presents methods to quantify prey abundance using distance sampling in an effort to encourage studies related to prey supply. Chapter 9 continues the theme of working with prey abundance data, and describes methods to detect temporal trends in ptarmigan abundance. Chapter 10 argues that detection of breeding birds during occupancy surveys is often imperfect and notes that studies that do not account for detection error are prone to underestimating occupancy. Chapter 11 focuses on estimating home range using three approaches: 1) kernel density estimation, 2) local convex hull, and 3) biased random bridge. Using a single data set, the authors show how each estimator produces different renditions of an individual's home range that can affect interpretation and conclusions regarding use of space. The authors of Chapter 12 explain how to incorporate physiological approaches to quantify pre-laying body condition and then link individual body condition to fitness-related breeding decisions such as the timing of reproduction. Appendix 1 provides a guide for aging Gyrfalcon nestlings from hatching to fledging, and Appendix 2 is a guide for using motion sensitive cameras to monitor nesting sites.

1.2 How should we further the study of Gyrfalcon ecology?

If we are to learn more about Gyrfalcon ecology, and the ways in which climate change will affect the species, most would agree that application of the scientific method (data collection, data analysis, and interpretation) will be necessary. Researchers must first decide on which populations to focus, and which data should be collected (i.e., where should we expend hard-won resources)? What types of studies should be done (e.g., diet, home range, prey abundance, food supply, body condition, nestling growth, nestling survival), and how should the data be analyzed and interpreted? Although these areas of study are individually valuable, I suggest that a more comprehensive approach to data collection, focusing on multiple lines of inquiry simultaneously, will be more likely to achieve long-term research goals. For example, although data collected as part of a study of nestling growth and survival can be viewed as a stand-alone study, it should be accompanied by complementary studies that overlap in time and space (e.g., prey abundance; see Chapter 8). Research programs that are able to coordinate multiple complementary studies will yield far greater insights, far more quickly and cost effectively than those that conduct sequential single focus studies. With this general philosophy in mind, I offer eight recommendations intended to focus efforts on building a comprehensive, well-funded Gyrfalcon research program across the Arctic, and then offer three steps that could be taken to immediately further our understanding of Gyrfalcon ecology at broad scales.

1.2.1 Recommendation one: don't forget the goal

The goal is to "further an understanding of the impacts of climate change on Gyrfalcon ecology." Thus, each study must have a component that explicitly includes an evaluation of impacts of shifts in climate or an evaluation of the effects of weather. Notwithstanding the importance of population monitoring, it is not sufficient to simply document trends in time and space (e.g., population-specific rates of occupancy and reproductive success) without placing these trends in the context of long-term variability in annual weather patterns (e.g., shifts in precipitation regime). However, weather and climate are separate phenomena (notwithstanding the obvious relationship that exists); weather is usually associated with atmospheric conditions at any given place and time that reflect temperature, precipitation, wind, cloud cover, and humidity. Climate describes prevailing weather conditions over large spatial extents and long periods of time. Describing the effects of weather is straightforward, but linking effects of weather to changes in climate at spatial scales that are relevant to Gyrfalcons requires up-scaling of local empirically-derived effects to scales at which climate and future climate are modeled. This can be achieved by using one or more Global Climate Models (Flato et al. 2013), or controlling statistically for weather-related effects (e.g., rain, temperature) on reproductive parameters (e.g., occupancy, productivity) using long-term data (Anctil et al. 2014).

1.2.2 Recommendation two: align priorities with the Circumpolar Biodiversity Monitoring Program

Developing a comprehensive, well-funded Gyrfalcon research program at broad spatial and temporal scales may be best achieved through integration within the existing long-term monitoring framework established by the Circumpolar Biodiversity Monitoring Program (CBMP). The CBMP is the cornerstone program of the Conservation of Arctic Flora and Fauna (CAFF) working group under the Arctic Council; it is comprised of a network of scientists, indigenous organizations, government agencies, and conservation groups collaborating at the scale of the Arctic to detect and report on status and trends of biodiversity. Through efforts to coordinate and standardize monitoring, the CBMP aims to ensure rapid response between management information needs and science or science-based monitoring related to change in Arctic ecosystems. Within the CBMP, Gyrfalcons and ptarmigan have been identified as important Focal Ecosystem Components and are incorporated within the Terrestrial Biodiversity Monitoring Plan (Christensen et al. 2013). The plan outlines the manner in which Terrestrial Expert Networks (groups of scientists and experts) have been tasked with monitoring and assessing the status and trends of taxa-specific Focal Ecosystems Components attributes (e.g., abundance and productivity). The CBMP terrestrial Bird Expert Network communicates with the Terrestrial Steering Group, which in turn organizes and coordinates reporting to national and international stakeholders, including relevant agencies and decision makers within Arctic countries. Thus, despite the fact that the CBMP is not a funding agency, linking proposed Gyrfalcon research activities to international Arctic-based conservation initiatives that include data warehousing and reporting will contribute to leveraging institutional support required to implement a comprehensive research and monitoring program.

1.2.3 Recommendation three: strengthen coordination among Arctic scientists studying raptors

In general, organization of activities among Arctic scientists actively involved in research of large falcons in the Nearctic and Palearctic has been poorly coordinated. However, several scientists have already established an informal working group to compare and discuss research findings, and plan for improved coordination among study sites. Formalizing this network would lend more recognition to the group efforts of Arctic falcon specialists, and aid in promoting research and collaboration among circumpolar countries. In addition, the working group would act as the conduit for information to be shared directly with the CBMP Terrestrial Bird Expert Network, including identification of potential data sources related to Arctic falcon species, development of procedures for data standardization, development of database tools to archive data, identification of knowledge gaps in available data, and development of semi-automated procedures capable of accumulating ongoing summaries of monitoring data. A critical component of the activities conducted by the working group should be to coordinate research and monitoring among existing projects, including submission of joint funding requests, in particular.

1.2.4 Recommendation four: articulate a conceptual view of a system that drives Gyrfalcon ecology

For Gyrfalcon ecologists to gain further insight into factors that affect abundance and distribution of the species, they must first reach agreement on, and articulate, a paradigm that potentially represents the manner in which abundance and distribution are influenced. Having done this, they should follow-up by stating and investigating specific hypotheses that support or challenge the paradigm. This does not mean generating a list of all the factors that may affect the success of individuals, rather it means invoking a conceptual view of the evolutionary constraints that ultimately affect reproductive success within a given environment, and the manner in which changes to that environment will affect distribution and abundance. An example of a paradigm that could potentially be applied to Gyrfalcons is the condition-dependent model proposed by Rowe et al. (1994), and depicted graphically by Bêty et al. (2003). For ecologists studying Gyrfalcons and other Arctic raptors, the condition-dependent model, modified to include the effect of territoriality, and extended to include the laying, incubation, and brood rearing phases (Fig. 1.1), may represent a starting point for articulating a system that summarizes factors governing long-term patterns in occupancy and productivity of Gyrfalcon populations.

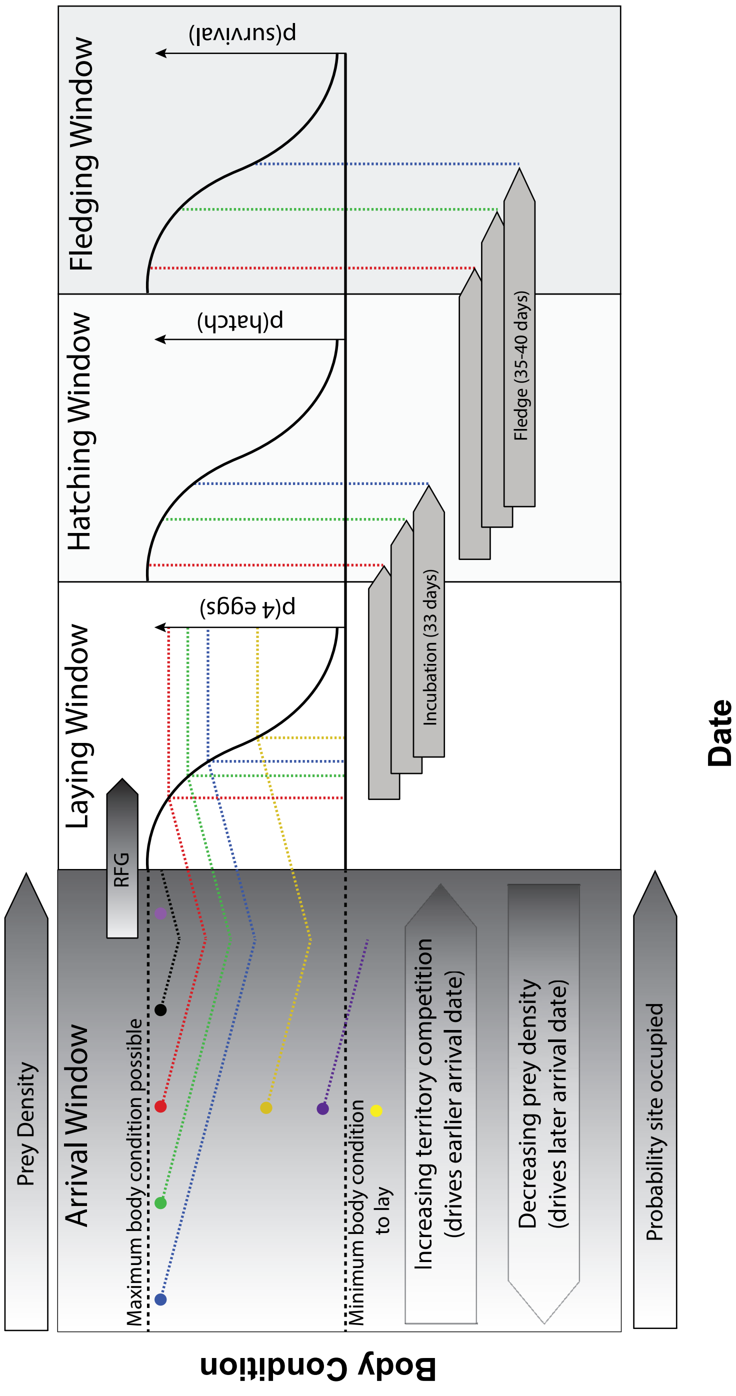
Arrival Window
Laying Window
Hatching Window
Fledging Window
p(4 eggs)
p(hatch)
p(survival)
Prey Density
RFG
Maximum body condition possible
Minimum body condition to lay
Increasing territory competition (drives earlier arrival date)
Decreasing prey density (drives later arrival date)
Probability site occupied
Incubation (33 days)
Fledge (35-40 days)
Date
Body Condition

Figure 1.1 Conceptual modification of the condition dependent-model (Rowe et al. 1994, Bêty et al. 2003) applied to raptorial species to include the effect of territoriality. Each panel represents a discrete period in a breeding cycle beginning with the period that Arctic-breeding raptors arrive (Arrival Window) on territory and culminating in the Fledging Window. The gradient of shading from light to dark within the Arrival Window represents increasing prey density (e.g., due to arrival of avian migrants), and increasing probability that a nesting territory will be occupied. Competition among breeding birds increases as a greater number of nesting territories become occupied, which drives earlier arrival date (i.e., early arriving pairs face reduced competition for nesting territories), whereas low prey density early in the Arrival Window drives later arrival of breeding raptors. At the individual level these two opposing factors result in a strategic trade-off between the advantage of early arrival (no competition) and the advantage of late arrival (abundant prey). A trade-off also exists between the benefit (better reproductive success) and the disbenefit (allocating energy to self-maintenance rather than reproduction) of early arrival. Male provisioning ability is likely a key factor in maintaining good body condition in females. Exposure to relative risks associated with arrival date can be mitigated via body condition of individuals (colored dots). At arrival, each individual can be uniquely characterized in terms of relative body condition (low to high along the y-axis) and arrival date (early to late along the x-axis). Within the Arrival window, the lower horizontal, dashed line represents a body condition threshold for producing and laying eggs; a female (e.g., pale yellow dot) arriving on territory below this threshold will forgo egg-laying in the current breeding season in favor of self-maintenance and future breeding opportunities. The upper horizontal, dashed line represents a physical limitation on body condition. The colored dotted lines represent the changes in individual body condition over time; in general, body condition of individual birds initially declines due to low prey abundance (e.g., migrant prey species have not arrived). As migrant prey arrives on the breeding grounds, body condition of individual raptors improves and egg-laying commences. The Laying Window illustrates predicted clutch size (e.g., the probability of laying four eggs; it is described by a logistic function (Lamarre et al. 2017). The probability of hatch and the probability of nestling survival (Anctil et al. 2014) are illustrated in the Hatching Window and the Fledging Window panels, respectively. Hatching dates and fledging dates are similarly conditional on arrival date and body condition given that each period of the breeding cycle is constrained by a set period of time (i.e., rapid follicle growth (RFG), incubation period, and brood rearing period). In general, breeding activity and phenology follows predictable patterns that are constrained by body condition, date and physical limitations. Two unique outcomes are predicted for late arriving birds: the clutch size of the individual represented by the black dot is predicted to be smaller despite excellent body condition due to the physical constraint associated with egg production per se, and the individual represented by the lavender dot is predicted to forgo egg-laying altogether due to the physical constraint associated with egg production and the absence of unoccupied nesting sites.

1.2.5 Recommendation five: design studies that confront the conceptual view

Having agreed upon a conceptual model for Gyrfalcon abundance and distribution, ecologists should design studies that confront the components of the conceptual view by generating hypotheses that are straightforward and can be investigated. For example, assuming that the condition-dependent model is a valid concept under which to investigate Gyrfalcon ecology, a study investigating the relationship between laying date and reproductive success would contribute to the understanding of the underlying mechanism explaining individual reproductive success, particularly in light of the evidence that shows increased nestling survival for Arctic-nesting raptors is associated with early lay dates (Anctil et al. 2014), and that early lay dates are associated with pre-laying body condition (Lamarre et al. 2017).

1.2.6 Recommendation six: identify existing long-term study sites

Newton (2011) noted that several multi-year Gyrfalcon studies have provided good quantitative information against which change could be measured, and argued that a subset of these studies should receive ongoing monitoring effort, with priority given to study areas that can be accessed prior to the egg-laying period, and when ptarmigan can be counted with reasonable accuracy.

There are at least three well-surveyed study areas located from west to east with established Gyrfalcon populations that potentially exhibit unique ecologies that could serve as latitudinal replicates: in the west, Bente (2011) described annual variability in abundance, occupancy, distribution, and nesting success of a population of Gyrfalcons (40–43 nesting territories) on the Seward Peninsula in western Alaska. On average, 73% were successful with mean brood sizes of approximately 2.5 young/successful pair. Mossop (2011) reported on Gyrfalcon monitoring of three distinct populations in the Yukon Territory. The Yukon-Stikine population has received the most consistent monitoring effort over the longest timeframe (1982–2010). Occupancy rate was 78%, with a maximum of 35 nesting territories visited annually. The mean number of nesting territories found to be productive was 7.0, and mean brood size was 2.4 young. In the east, Nielsen (2011) studied a resident population (n=83 territories) of Gyrfalcons in northeast Iceland. This population has been shown to be consistently reproductively successful with mean occupancy of 62%, and mean brood size of 2.7 young per successful pair.

Thus, approximately 160 known nesting territories are distributed among the three study areas of which approximately 75% may be occupied annually producing approximately 2.5 young per successful nesting territory. Without accounting for annual variability, a comprehensive research program involving the three study areas outlined above should expect approximately 120 breeding pairs annually. Coordination among each of the three study sites will require the leadership of an experienced principle investigator capable of supporting a well-trained, field-based research crew.

1.2.7 Recommendation seven: invest in multi-year, season-long monitoring

Once priority study sites have been identified, field crews capable of monitoring Gyrfalcons and their prey should be placed at each study site annually for a minimum of five consecutive years. Research should be coordinated to ensure that ecological differences among populations can be identified if they exist. Research activity at each study site should be led by an experienced principal investigator familiar with Arctic field programs. A minimum of two field teams, each comprised of two people (one biologist and one field technician) will be required; one team should focus on monitoring breeding pairs (from pre-laying through fledging), and the other should focus on assessing prey abundance throughout the Gyrfalcon nesting season. The raptor team should be engaged in data collection at the scale of the nesting territory, and at minimum should collect data on occupancy, laying date, hatching date, clutch size, brood size, brood size at fledging, causes of mortality, nestling morphology (e.g., mass to estimate growth rate), precipitation at nesting sites, temperature at nesting sites, and prey deliveries. The prey team should focus on surveys capable of assessing spatially explicit measures of prey density; for example, walking transects and collecting avian prey data that can be analyzed using distance sampling. Given the importance of ground squirrels (*Urocitellus parryii*) in some populations, I further recommend estimating small mammal abundance (ground squirrels, collared lemmings *Lemmus trimucronatus*, brown lemmings *Dicrostonyx groenlandicus*, and voles *Microtus* spp).

1.2.8 Recommendation eight: assessing the effects of weather is as important as assessing the effects of food supply

In the concluding chapter of his book "Complex Population Dynamics," Turchin (2003) indicated that trophic interactions emerged as the most obvious mechanism driving oscillations in populations, and showed that food quantity and quality were as important in six of eight studies among eight species. Newton (1998) indicated that bird populations are limited by food supply, nest sites, predation, parasites and pathogens, and weather. Of these factors, studies involving weather and food supply almost certainly offer the greatest short-term potential for identifying factors most likely to drive changes in abundance and distribution of Gyrfalcons. For

Gyrfalcons, prey abundance and food supply may be particularly important because of the strong link between reproductive success and early season access to ptarmigan (Nielsen 1999, Barichello and Mossop 2011, Mossop 2011, Nielsen 2011). Thus, studies that are able to simultaneously examine the effect of food and weather on survival of nestlings will be of greatest utility.

1.3 Three steps that could be implemented immediately

1.3.1 Step one: source and archive relevant population, weather, and landscape data

Data sourcing and archiving reflect historical research and monitoring effort; however, it is essential that historical data are compiled and archived to ensure they can be updated. Focus should be on three main data types: population trend data (i.e., occupancy and reproductive success), weather data, and landcover data. The main purpose of these summaries would be to serve as a synopsis of the state of knowledge of both Gyrfalcons and ptarmigan, and identify programs that use standardized monitoring protocols, or have potential for application of standardized monitoring protocols, particularly within the context of Recommendation six (identification of existing long-term study sites). Further, these reviews would provide the context and basis for initiatives spearheaded by the working group (Recommendation three), and are consistent with the notion that data from several multi-year Gyrfalcon studies already exist against which change could be measured, with priority given to study areas that can be accessed in late winter around the time of egg laying (Newton 2011).

Summarizing the circum-Arctic status and trends of Gyrfalcons and ptarmigan is consistent with the intent of Recommendation two (assessing the status and trends of taxa-specific Focal Ecosystems Components within the CAFF Terrestrial Biodiversity Monitoring Plan). In addition, effort should be undertaken to describe current monitoring efforts and methods, and identify knowledge and monitoring gaps across as many study areas as possible, but at least among the study sites identified for priority in this chapter (Recommendation six). Similarly, long-term historical weather data (e.g., temperature, precipitation, relative humidity, wind speed and direction) including means (daily and monthly), extreme values, and climate norms are available throughout the Arctic. These data should be obtained for the same periods and geographical regions as those prioritized for status and trend data. In addition, remote sensing data for each priority study should also be acquired with focus on raw or derived data sets that reflect important habitat features for nesting (e.g., terrain ruggedness) and foraging (e.g., land-cover type and amount or normalized difference vegetation index).

1.3.2 Step two: expand the functionality of the Polar Raptor Databank

Systematic data management (see Chapter 4 this volume) is an essential tool for data intensive research programs investigating raptor ecology. Research biologists with access to a relational database undoubtedly benefit from improved data structure, long-term data standardization, and clear metadata. A relational database minimizes errors and allows for efficient manipulation of raw data for analyses in other stand-alone software (e.g., statistics packages), or for calculating derived data, which can make reporting and data sharing straightforward and efficient.

Habitat Info (www.habitatinfo.com), the Mohamed bin Zayed Species Conservation Fund (www.speciesconservation.org), and The Peregrine Fund (www.peregrinefund.org) have partnered to develop the Polar Raptor Databank (PRDB, www.gis.habitatinfo.com/tpf/). The current version of the PRDB is a secure, password-protected system that allows users to upload, store, query, and share data. However, functionality of PRDB should be expanded in ways that permit users to take full advantage of relationships that are inherent within data sets; doing so would allow users to execute queries that permit a specific subset of the entire data set to be accessed or reassembled to conduct the type of analyses that are described in the data chapters that appear in this book (see Chapters 4 and 6 this volume for specific examples). Thus, ongoing development of the PRDB should emphasize data collected on individual birds.

1.3.3 Step three: reinforce current activities of the specialist group by hosting a workshop

Notwithstanding the absolute necessity of broad scale cooperation and participation among established research and monitoring programs, successful implementation of the aforementioned recommendations and steps will require that a core group of people is willing to offer leadership and direction. The primary tasks of this group would be to liaise with CAFF, organize and source funding for meetings and workshops, and begin the process of resourcing field programs accordingly (e.g., student recruitment and asset acquisition). In addition, an important responsibility of this group should be to prepare research proposals that emphasize collaborative and cost-effective efforts to place people into the field who are capable of monitoring multiple breeding populations simultaneously.

1.4 Conclusion

A main objective of this book is to provide introductory material on specific aspects of animal ecology that can be applied to raptors in general and Gyrfalcons in particular. Further, it aims to provide easy access to analytical tools and sample data that users can employ as examples to conduct similar analyses using other data, or to design studies of their own. Additionally, this book explicitly builds on the legacy of the 2011 international conference *Gyrfalcons and Ptarmigan in a Changing World* that focused on the ecology and conservation of Gyrfalcons and ptarmigan.

I recommend a coordinated, broad scale, multi-study area approach using standardized monitoring that focuses specifically on research questions designed to challenge a theoretical system (reasoned in an a priori manner) that potentially drives the breeding ecology of Gyrfalcon populations facing climate change. I further argue that simultaneous assessment of the relative effects of weather and food is a necessity, and that studying one without the other will not provide the level of understanding that is required to achieve the stated goal of the 2011 Gyrfalcon and ptarmigan conference. I suggest that sourcing and archiving relevant population, weather, and landscape data in conjunction with expanding the capability of the Polar Raptor Data Bank are activities that can be achieved immediately. Finally, I argue that a core group of people (the Arctic Falcon Specialist Group) begin to formalize activities such as liaising with CAFF, organizing workshops, and resourcing field programs.

I have presented an approach to studying Gyrfalcons that is consistent with the stated goal, and advocate for this approach based on the call for demographic studies (Newton 2011) such as those realized by the Arctic Raptors Project (www.ArcticRaptors.ca; Franke et al. 2010, Franke et al. 2011, Anctil and Franke 2013, Franke et al. 2013, L'Hérault et al. 2013, Anctil et al. 2014, Robinson et al. 2014, Jaffre et al. 2015, Robinson et al. 2015, Franke et al. 2016, Lamarre et al. 2017, Robinson et al. 2017) in recent years.

Working with Inuit communities, graduate students, field technicians, post-doctoral fellows, and biologists from government, industry, and academia in a coordinated manner, we have learned much about the effects of food, weather, and phenology on Arctic-nesting Peregrine Falcons. I believe the same approach can be applied to Gyrfalcons and their prey. However, Gyrfalcon breeding phenology begins earlier and can end later than that of Peregrine Falcons. Gyrfalcons exist at lower densities in regions that are as, or more remote, logistically demanding, and environmentally challenging. These factors in combination will exclude all but those most intrigued by the species, and I cannot understate that implementing the type of broad scale effort described here will require considerable human and financial resources, as well as commitment to long-term studies and international collaboration. However, executing a common philosophy and promoting study designs that are constrained by a plausible framework will facilitate pooling of data and, ultimately, future meta-analyses.

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