Barn Owl (*Tyto alba*) population dynamics on Nantucket, a remote island at the northern limit of the species' range

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Abstract

Global climate change has allowed species' ranges to change and is responsible for unpredictable weather events that affect these species. We used population trends of the Barn Owl, *Tyto alba*, on Nantucket Island, Massachusetts to correlate nesting success with severe winter weather. Of the past twenty five winters, five had colder average temperatures and more snow than the others, and these more severe winters had significantly fewer chicks than the mild ones. Although Nantucket is the northern limit of the species' range, Barn Owls were able to have reproductive success due to the building of nesting boxes in appropriate habitat, but they are still vulnerable to high mortality in years following severe winters.

Introduction

Historical weather trends in certain areas are no longer reliable predictors of future weather events. It is important to know how new trends will affect the world around us. Recent global changes in climate are causing more extreme weather, and these can affect animal populations. Populations that occupy extreme edges of their ranges due to climatic factors are especially vulnerable to unpredictable harsh seasons, making them an appropriate study choice.

The Barn Owl, *Tyto alba,* is widely distributed around the world and Massachusetts represents the northeastern limit of its North American range. These owls are adapted to relatively warm climates. Their feathers do not cover their feet or tarsi, and in general, provide less insulation than the feathers of most other owls. This poor insulation may lead to unusually high metabolic rates that increase in the winter (Massemin and Handrich 1997). Barn Owls store lipids in the autumn and early winter, which are generally gone by the end of winter (Massemin *et al.* 1997). If they enter a starvation period, they deplete most of their lipid reserves before entering diurnal hypothermia to save energy, which could contribute to high mortality during the winter (Thouzeau *et al.* 1999). The shift to lower energy expenditures occurs after about eight days of starvation (Handrich *et al.* 1993). They feed on small rodents and shrews, which can be difficult to capture in deep, crusty snow. Together, these factors make Barn Owls vulnerable to high winter mortality due to starvation during cold, snowy winters (Altwegg *et al.* 2006). Because of this, Barn Owls are dependent on adequate shelter to provide insulation and protection from the wind when they winter in cold areas (Marti 1979).

In North America and Europe, large Barn Owl population declines have been documented during severe winter weather (Altwegg *et al.* 2006, Marti 1994). In the year after a particularly severe Utah winter, Marti and Wagner (1985) found a 40% decline in breeding attempts, but an unusually large breeding population the following year. In years following long-lasting snow cover and low temperatures in

Switzerland, there was a similar decline in survival and a significantly high rate of emigration the following year (Altwegg *et al.* 2003).

Barn owls do not normally migrate, but disperse an average of 50 km from their natal site as juveniles, and have been known to disperse up to 1900 km (Marti 1992). These owls nest in caves and hollow trees, but are adaptable to disturbance and often nest in built structures in close proximity to humans. As adults, they are generally thought to be monogamous and maintain the same nesting site and small home range year after year (Marti *et al* 2005).

Many previous population studies of barn owls have been carried out in areas where the young are able to disperse to or from the study area without flying over large bodies of water. Nests in extremely close proximity to water resulted in lower survival when Barn Owls were fledging since the young birds are not strong fliers and can easily drown (Bendel and Therres 1993). However, Barn Owls are found on many remote islands, so we can infer that they are capable of crossing bodies of water (Marti *et al* 2005).

Over the past 40 years, Barn Owls have established themselves as successful breeders on Nantucket Island, Massachusetts. We studied this population of owls using historic data and current observations. They are currently listed as a species of special concern under the Massachusetts Endangered Species Act. Since Nantucket is at the northern limit of the range of the species, we expected to observe higher mortality during, or lower population growth after, cold winters.

Methods

Study Area

This study took place on Nantucket, an approximately 50 km^2 island separated from the mainland (Cape Cod) by about 40 km of Nantucket Sound. The distance from Great Point (the northernmost part of Nantucket) to the southern tip of Monomoy Island on Cape Cod is about 17 km. Nantucket is separated from Martha's Vineyard by 19 km of ocean, the distance broken by the small islands of Tuckernuck and Muskeget. Barn Owls have been observed on Martha's Vineyard since 1918, and the first breeding pair was found there in 1928 (Keith, 1964). They were not reported on Nantucket until 1963, and the first nest was reported on Nantucket in 1968 (Andrews 1970). Barn Owls are not common on Cape Cod.

Nantucket's climate is tempered by the ocean, especially the Gulf Stream, which keeps the island consistently warmer than the mainland, resulting in fewer days of snowy weather. One or two years every decade Nantucket experiences cold, snowy winters.

Much of the Nantucket ecosystem is actively conserved. Approximately 50% is maintained as open grassland or low shrub habitat, but parts of the island have been developed considerably in the last 50 years. Alongside this development, homeowners have built many Barn Owl nesting boxes, the majority of which were put up in the last ten years. Building an owl box is the current fashionable method of rodent control on island.

Data Collection

Since the first Barn Owls were discovered breeding on Nantucket in 1968, the population has been monitored and chicks banded annually. This effort has been fairly consistent from 1987 until 2012, although the number of boxes available changed dramatically between 2001 and 2012, and we may have missed several nests between 2001 and 2004 as more boxes were being built. All boxes that we are aware of have been checked two to four times a year, usually in May and September, which are the common times to find young chicks. Additionally, we have responded to landowner reports in the off-season if there seemed to be particularly high amount of activity in their nesting boxes. There have been nests for several years in a silo, and once in a boat in the harbor. We banded all birds that we found older than an estimated four weeks, but sometimes chose not to catch adults when they were incubating eggs, as this is a sensitive time when disturbance can cause nest abandonment (Marti 1994). We estimate that we checked 80% of available nesting quarters on each survey, including old barns and boxes we didn't find until a few years after they were built.

For recapture and recovery data, we recorded band numbers of any banded birds we encountered, and retrieved data from the North American Bird Banding Program's Bird Banding Laboratory. We added several banded specimens found in the Maria Mitchell Natural Science Museum to the list of recoveries from the Bird Banding Lab.

<u>Data Analysis</u>

Environmental Factors affecting nesting success

To investigate environmental factors that influence nesting choice, two different variables were measured. Distance of nesting sites from houses and paved roads was calculated using Google Earth and these distances correlated with nesting success. Nesting success was based on the percent of nest boxes in use per year, rather than the total number of nesting attempts, because the number of boxes available changed over time. For the second variable, nest sites were categorized as "meadow," "edge," or "forest" and percent box use calculated in each habitat, then a chi-square test was used to determine if boxes in different habitats were utilized in different frequencies. Habitat type were determined by an onsite evaluation and these habitat estimations confirmed with Google Earth imagery, a circle 100 meters in diameter around each nest box was examined; sites that were 80% tree covered were considered "forest", 21-79% treed were "edge", and less than 20% were considered "meadow." Percent box use was calculated by dividing the total number of nests by the number of years the box was available.

Nesting and Success with Weather

Weather data were downloaded from 1986-2012 from WeatherUnderground (website), recorded at the Nantucket Memorial Airport weather station[1]. Winter severity factors included days per year with snowfall, mean winter temperature (1 Dec-31 March), and number of days with the high temperature below 0˚C. These factors were correlated with numbers of nesting attempts and numbers of fledglings using correlations and t-tests in the Microsoft Excel add-on EZAnalyze.

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[1] Weather data is not available for Nantucket from NOAA until 1998.

Survival analysis

Seber's dead-recovery models were used to estimate survival in the program MARK (White and Burnham, 1999). These models calculate survival by considering the number of birds banded each year and the number of dead owls recovered each year, accounting for the age of each bird when recovered, as well as the recovery rate—the probability of a marked individual being found and reported (Altwegg *et al.* 2003). All models in MARK were run, and model selection based on Akaike's Information Criterion (AIC); the model with the lowest AIC is the most parsimonious. Burnham's joint dead-recovery, live-recapture model was also used; this accounts both for birds that lived long but were never recaptured and those which were never found dead (Altwegg *et al* 2006).

Results

Environmental Parameters Affecting Nest Choice

Nesting attempts were not affected by human disturbance factors, but were affected by habitat immediately surrounding the nesting box. Distance to nearest house or road did not correlate with nesting attempts (p=0.812 and 0.970 respectively). However, nesting attempts differed based on surrounding habitat types; Barn Owls were more likely to nest in boxes associated with field or edge habitats (Figure 1). The ratio of the number of nesting attempts to the number of boxes did vary with habitat type (p=0.002) in a test of Chi Square.

Nest boxes are continually being added by enthusiastic landowners, giving Nantucket's Barn Owls more housing options every year. Availability of additional nesting boxes was strongly correlated with greater numbers of nesting attempts (p=0.000) and more fledglings (p=0.000, Figure 2).

Dispersal

With 486 Nantucket Barn Owls banded in 25 years of consistent banding, only two banded birds have left the population and been reported off island; one was recovered dead, and the other recaptured alive. The dead bird was found on Cape Cod, about 50 km from the banding location and across 17 km of water; it was under 2 years of age. The live bird was caught across 1.5 km of water on Tuckernuck Island and was about 5 months old. The remaining birds were recaptured or recovered an average of 8.7km from their natal site.

Nesting Success by Weather

Between 1987 and 2012 there were five winters that had colder mean temperatures and more days with snow cover than other years (p=0.009, Figure 3a, 1b). Cold winters had more snowy days than warm winters. We ranked 2003, 2004, 1996, 2005, and 1994 as the five most severe winters by mean temperature. When the breeding seasons following these five winters were compared against the remaining mild winters, they had significantly fewer chicks the following year (p=0.015, Figure 3c).

The percent available active nests was negatively correlated with the number of days that it snowed in the preceding winter (p=0.001). Percent available active nests was not correlated with either mean winter temperature (p=0.276), year low (p=0.100), or the number of days the winter high temperature was under 0˚C (p=0.449). The number of fledglings was not correlated with days of snowfall (p=0.896), the mean temperature (p=0.150), or the year low (p=0.42). The number of fledglings was negatively correlated with the number of days that the high temperature was below O˚C (p=0.035). There were fewer fledglings in years with lower maximum low temperatures (p=0.042).

Brood size was not correlated with total snow days (p=0.061), number of days where the high was under 0˚C (p=0.590), or mean winter temperature (p=0.645). The yearly average hatch date for first broods was 9 May, although it ranged from 1 April to 19 June. There was no trend of later nesting attempts during more severe winters (p=0.855).

Survival

The survival of the recovered Barn Owls did not vary over the 26 years of banding. The most parsimonious model in MARK, with an AIC of 344.58, was one with a constant rate of survival but recovery rates that change over time. The estimate of survival from MARK was 0.65 for adults and juveniles combined, but 83% (25 of 30) of recovered individuals were under one year of age when found dead. The average age of birds recovered dead was 1.49 years and ranged from 0.09 to 9.6 years. The recovery rate changed over the years; some years no recoveries were made (a rate of 0.00) while other years many dead owls were found with rates as high as 0.37 in 1996, and 0.31 in 2004. With Burnham's joint live-recapture, dead-recovery model, the most parsimonious model was one where none of the parameters—survival, probability of recapture, probability of recovery, or fidelity—changed over time. This model had an AIC of 427.72 and estimated survival at 61.2%.

Discussion

The Nantucket Barn Owl population was fairly small (1 to 6 pairs nesting) from 1985 until about 2008, but has grown along with an exponential increase in nest boxes. Private landowners have been providing nesting boxes since the 1980s, increasing this number from 5 in 2001 to over 50 in 2012. Most of these boxes are in the northeast and northwest parts of the island, and our monitoring efforts have been focused in these areas. In other parts of the world where there are a scarcity of natural nest sites, providing nesting boxes has been extremely successful, with over 50% of the boxes housing a Barn Owl within a year of being built (Marti 1979). The additional nesting structures available has almost certainly enabled Nantucket's Barn Owl population to grow in recent years, and suggests that Nantucket did not naturally have adequate quality nesting habitat. Nantucket does not have the sort of cliff-side caves that Barn Owls have nested in on Martha's Vineyard, large hollow trees, or even many old barns.

Barn Owls are just as likely to choose nest boxes near roads or houses as those more distant from these areas of disturbance. Instead, availability of grassland dictates nest box selection on Nantucket. Much of Nantucket was once grazed by sheep, and parts of the island are maintained as grassland by various conservation organizations and private landowners. Nantucket was well-populated with Short-eared Owls, *Asio flammeus*, through 1989 (Combs-Beattie 1993), but many areas of the island have been developed in the last few decades. Short-eared Owls are quite sensitive to human disturbance and have not nested here consistently since the mid to late-1990s (Beattie, pers.comm.), perhaps opening a niche for the more human-tolerant Barn Owl. Barn Owls are known to decline in areas where grassland habitat has diminished—often agricultural areas that were previously grazed by sheep which have been converted into monoculture farmland or lost to development (Colvin 1985). In a study by Andries *et al.* (1994) in Germany, Barn Owls were more likely to nest in close proximity to open meadow—if these nest sites also had trees or permanent green vegetation nearby. Our study plots were smaller than those in their study, and even the habitat plots considered "meadow" either had a few trees within them or near the margin of the area analyzed; perhaps because of this, the owls did not seem to prefer edge habitat over meadows. Trees provide cover to adults not roosting in the box with chicks, or perching sites for fledglings (personal observation). This preference or even need to be near meadow and grassland edges likely reflects the biotope of small prey mammals.

Although not all tests indicated that more severe winters decreased nesting success, the overall picture supports this trend. There were a few winters that seemed to affect the population of Barn Owls on Nantucket. In years that it snowed more days per winter, fewer of the available nests had chicks. In winters with more days with a high below freezing, there were fewer total nesting attempts. Winters with lower yearly low temperatures had fewer chicks.

This does not seem to be a continuum, but rather a threshold; catastrophic winters may lead to a drastic population decline. For example, during the winters of 2003 and 2004, the population dropped from a minimum of 5 breeding pairs to a single bird found. In 2006, we found a single pair nesting, and by 2008, 11 pairs had nests. Normal small fluctuations in mean temperature or snowfall will not predict population changes because above some threshold the population is not affected (Altwegg *et al.* 2006). That the five most severe winters did display a significant decline in chicks compared with the mild winters is probably more conclusive than correlations between slight fluctuations in mean temperature and chick or nest abundance.

Because Barn Owls are adapted for consistently warm climates, the few severe winters we experienced on Nantucket during the study period resulted in a drop in nesting attempts and chicks. The poor insulating value of Barn Owls' feathers, high metabolic rates (Massemin and Handrich 1997), and delay in entering diurnal hypothermia (Thouzeau *et al.* 1999) makes them vulnerable to these severe winters. The total Nantucket population was likely reduced by the five harsh winters during the study period or was unable to breed due to decreased fitness.

Some of the unbanded adult owls we found might have been reared in our boxes rather than immigrating to Nantucket. Although Barn Owls have been known to disperse thousands of miles, most of our banded birds were found a few miles from the nest box where they hatched. Barn Owls have been reported to breed during the winter, sometimes even in winters that were not unseasonably warm (Poole 1930, Walk *et al.* 1999). It is possible that some pairs of owls would have nested out of the expected breeding months and been missed. Additionally, there could have been nests of which we were unaware.

The U.S. Global Change Research Program predicts an increase in winter temperature—indeed, we have already seen a 2.2˚C increase since 1970—and a decrease in snowfall in the northeast over the next several decades due to climate change (USGCRP 2009). These conditions could be favorable for Barn Owls and other animals that are limited to southern regions by cold, snowy weather. They may be able to expand their range even further north; however, occasional extreme weather will likely result in similar or more widespread population declines.

Acknowledgments:

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APPENDIX:

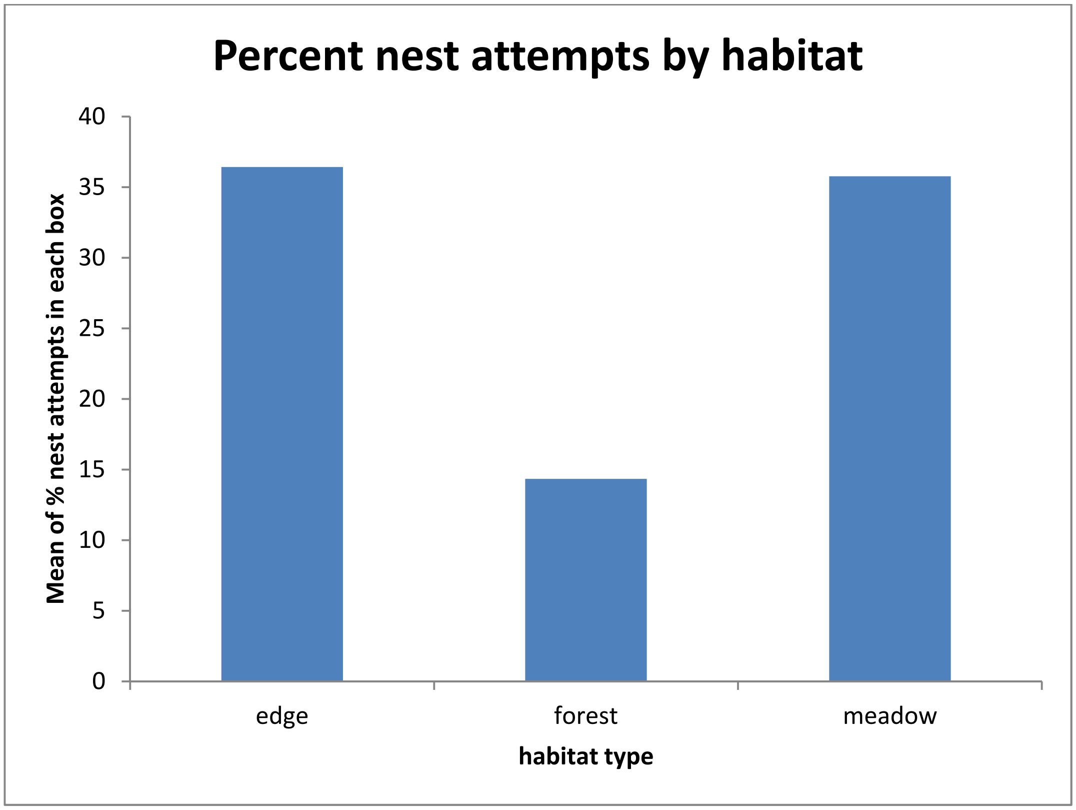

Figure 1: The percentage of nesting attempts varied significantly with habitat type. More owls nested in boxes situated within meadow (<20% tree-covered) or edge (21-80% tree-covered) than forested (>80% tree-covered) habitat.

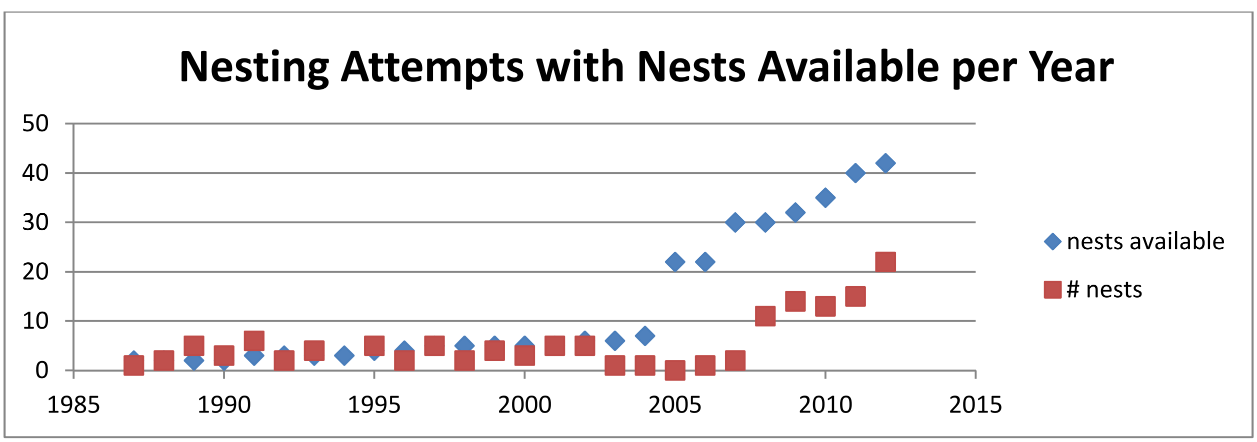

Figure 2: Nesting attempts increased as the number of boxes available increased.

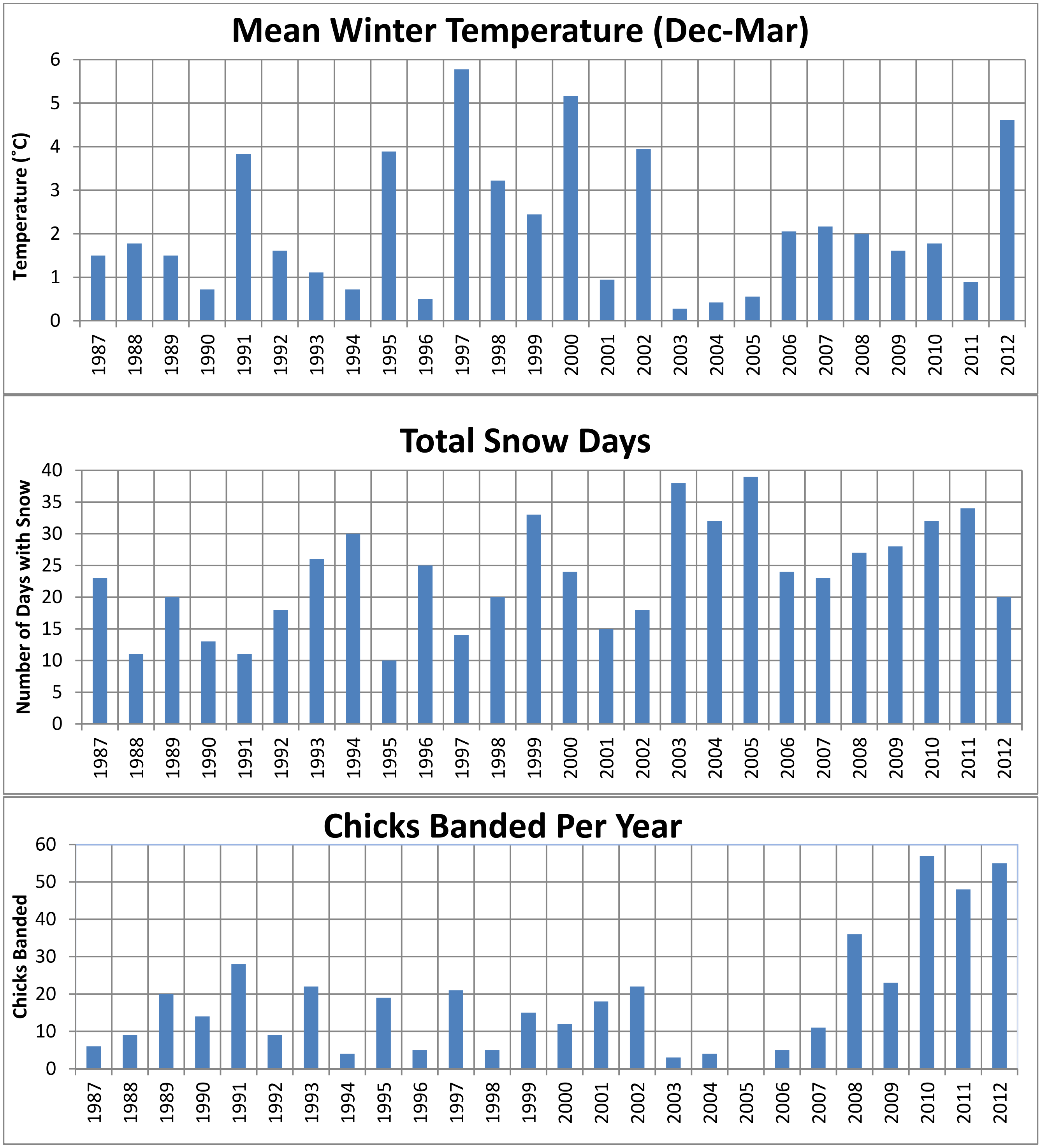

Figure 3: Mean winter temperature, total snow days, and chicks banded per year, 1987-2012. Weather data was recorded at the Nantucket Memorial Airport, and data from 1 December through 31 March were used.