Effects of experimental food supplementation on movements of juvenile northern goshawks (*Accipiter gentilis atricapillus*)

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Abstract Food availability is thought to strongly influence the leaving phase of natal dispersal in animals with condition-dependent dispersal. We conducted a food supplementation experiment to determine the influence of extra food on the onset of dispersal and early dispersal movement patterns of 42 radio-tagged northern goshawks (*Accipiter gentilis atricapillus*) from 28 broods in north-central New Mexico during 1992 and 1993. We randomly assigned half of the broods each year as treatments and the other half as controls. Treatment broods were given supplemental food from hatching (late April) until mid-October. Control broods received the same visitation rate but no food. Birds were located approximately every 2 days from fledging until mid-October in 1992 and 1993. Timing of fledging and independence were not affected by the treatment. However, extra food significantly influenced post-fledging movements of juvenile goshawks. During the late fledgling-dependency period (>65 days of age until independence) control birds were located in the natal area (<2 km from nest tree) more frequently than supplemented birds. This pattern reversed after independence (approximately 82 days of age) when supplemented birds were located more frequently in the natal area than controls. After independence the control birds were never located in the natal area and by the end of September in both years the controls had all left the study area (study area boundaries were approximately 25 km from nest tree). Supplemented birds were never located outside of the study area for the duration of the experiment. We conclude that the control birds dispersed out of the study area and the supplemented birds remained. Since the experimentally fed juveniles remained near a known food source and the controls did not, our study demonstrates that food availability influences at least the first 4 months of post-fledging movement patterns in this population. These results also suggest individuals base dispersal decisions on knowledge of their environment at a local scale, which can influence juvenile recruitment.

Keywords *Accipiter gentilis* · Breeding chronology · Condition-dependent dispersal · Excursions · Food supplementation

Introduction

Natal dispersal is the process by which individuals move from their natal area to where they reproduce or would have reproduced had they survived and mated (Howard 1960; Greenwood 1980; Johnson and Gaines 1990; Stenseth and Lidicker 1992). Because natal dispersal involves a complex series of movements (Walls and Kenward 1995, 1998), the final natal dispersal distance is a function of the cumulative history of movements during the dispersal process (Dufty and Belthoff 2001; Wiens 2001). We agree with Dufty and Belthoff (2001) that natal dispersal refers to events that occur within a distinct ontogenetic stage of development and that, once completed, do not occur again. In altricial birds, natal dispersal would describe the series of events that begin at fledging and end when the bird obtains its first nest area.

Movements of juveniles away from their natal areas can influence the spatial and genetic structure of populations and the evolution of social behaviour (Greenwood 1980; Arcese 1989; Wiens 1996). Dispersal of both juveniles and reproductive adults also links subpopulations in spatially heterogeneous environments and hence is a critical factor in dynamics of metapopulations (Pulliam and Danielson 1991; Bollinger et al. 1993; Wiens 1996).
Despite its importance, natal dispersal is poorly understood. Many factors appear to affect dispersal. One environmental factor thought to strongly influence the onset of natal dispersal in animals with condition-dependent dispersal is food availability (Ims and Hjermann 2001). Variation in timing and distance of natal dispersal in these organisms may be related to differential ability of the young to acquire food in natal areas (Dufty and Belthoff 2001). Animals may move if food resources have been locally depleted or if there is potential for more food resources elsewhere (Bennetts and Kitchens 2000). Alternatively, some animals exhibit exploratory movements (often referred to as excursions) during times of high food availability (Nilsson and Smith 1985; Gonzalez et al. 1989; Ferrer 1993; Walls and Kenward 1995, 1998). Excursions may be a mechanism to identify the location of food or other resources during periods when they are not food stressed. In addition, the information gained during excursions maybe important in the eventual success in foraging and gaining a breeding site (Siders and Kennedy 1996). Our ability to clearly identify causal relationships between environmental factors such as food availability and the onset of natal dispersal is limited because few field experiments have been conducted that simultaneously manipulated food supplies and monitored the fate of dispersing individuals with radio-telemetry. Manipulating food supplies allows us to deconfound naturally correlated variables that could affect natal dispersal such as weather and local food availability. Tracking radio-tagged birds allows movements to be studied in greater detail and over wider areas than can be accomplished by resighting banded birds (a common approach in avian dispersal studies; Koenig et al 1996).

The few experiments that have been conducted have had inconsistent results. Food supplementation has delayed the onset of dispersal movements in some organisms (Frumkin 1994; Kenward et al. 1993; Bustamante 1994; Kim 2000), advanced dispersal in others (Willey and van Riper 2000) and had no effect on timing of dispersal in other organisms (Veltmann 1989; Bustamante 1994). Previous supplemental feeding experiments that have had a treatment effect on dispersal timing have only delayed dispersal, not prevented it. The influence of natal area food supplies on distances juveniles move from the natal area is also unclear. Longer post-fledging movements have been reported for better nourished animals (Ferrer 1992, 1993), yet in some studies juveniles from areas with abundant prey moved shorter distances than those from areas of low food availability (Newton 1986; Sonerud et al. 1988).

In this study, we evaluate the influence of food availability on the initiation of natal dispersal and subsequent post-fledging movement patterns of juvenile northern goshawks (Accipiter gentilis atricapillus, hereafter referred to as goshawk). By monitoring the movements of radio-tagged juveniles from supplemented and control nests, we test the hypothesis that juvenile goshawks disperse from natal areas with poor environmental conditions and remain on or close to natal areas when resource conditions are suitable.

### Materials and methods

#### The study species

The goshawk is a large (735–1364 g) forest raptor, occupying boreal and temperate forests throughout the Holarctic (Squires and Reynolds 1997). It often nests and hunts in old-growth or mature forests, which creates potential conflicts in the management of public forest lands for timber production versus goshawk conservation. Although the goshawk currently has no federal protection in Canada, Mexico or the United States, there have been several petitions to list the goshawk as threatened or endangered under the U.S. Endangered Species Act. Its status has been (and still is) the object of considerable litigation in the United States (Kennedy 1997). Management plans developed to reduce the risk of timber harvest to goshawk populations are focused on managing breeding season prey populations (e.g., Reynolds et al. 1992). This approach is based on the assumption that goshawk populations are regulated by breeding season food availability. This study is part of a series of investigations exploring the influence of breeding season food availability on goshawk demographics (Ward and Kennedy 1996; Dewey and Kennedy 2001).

The goshawk’s annual cycle is typical of many temperate raptors. The breeding season begins from mid-February through early April and lasts until the young are independent in late August–early September. Our study was conducted from hatching (April) through the first 2 months of the non-breeding season.

Goshawks are: socially monogamous; territorial, noncolonial, synchronous breeders; and their nests are >1 km apart. They rarely breed as yearlings and most breeding birds are ≥2 years old (Squires and Reynolds 1997). Typical of taxa with similar life histories, they are long-lived (maximum age in the wild is 19 years; Kenward et al. 1999) with high breeding site and mate fidelity (Woodbridge and Detrich 1994).

The degree of philopatry in goshawks, as in most birds, is unknown because resighting rates of banded juveniles is low (1–2%) and other methods, such as satellite telemetry or genetic analyses, have not been used to estimate dispersal rates. However, the fact that female and male goshawks have been documented nesting within 25 km of their natal area in several populations (Squires and Reynolds 1997) including this study population (P.L. Kennedy and J.M. Ward, unpublished data) indicates some level of philopatry. The species is also a partial migrant; some individuals and populations are resident year-round, whereas others migrate seasonally. Local winter food availability and climate likely influence whether or not a bird migrates or resides in the breeding area year-round (Squires and Reynolds 1997; C.W. Boal, D.E. Andersen and P.L. Kennedy, unpublished data). The relationship between natal dispersal and migration movements is unknown in a partial migrant like the goshawk because it is difficult to determine if juveniles are searching for food or breeding areas or both. Since dispersal trajectories are more than just the simple linear pathway between natal area and first breeding area (Wiens 2001), we assume all juvenile movements occurring prior to first breeding are part of the natal dispersal process. We also assume these early life movements influence distances from natal to first breeding site.

#### Food supplementation experiment

From April through October in 1992 and 1993, we conducted a food supplementation experiment using 28 goshawk broods from a population in the Jemez Mountains in north-central New Mexico. The study area is 6,452 km² in size; its boundary was defined as the perimeter of the Jemez Mountains (see Siders and Kennedy 1996...