Consequences of forest management on autumn migrating passerines during stopovers in the Northern Negev

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Each year, millions of birds migrate from their breeding grounds in Europe and Asia, to wintering grounds in Africa. Many of these birds stopover in Israel to rest and refuel. Israel is one of the most important stopover areas in the world, owing to its geographic location at the edge of the Sahara Desert, one of the world's largest ecological barriers for long distance migrants. The fuel for migration is derived from lipids, which are stored subcutaneously in the interfurcular and abdominal regions. Staging at sites with fat-rich food sources might shorten the total migration duration of birds, allowing a safe desert crossing. Atlantic Pistacia (*Pistacia atlantica*) trees planted at En Rimon, a grove located in the Lahav forest, bear fatty fruits during autumn; hence, many migrating passerines are attracted to this grove during autumn. Long-term monitoring and research on bird ecophysiology and behavior has been conducted at En Rimon since the early 1990s. In the past few years, we have examined the effect of diet composition and water availability on fat deposition rate of migratory warbles (Sylvidae) and thrushes (Turdidae). Water supplementation increased both fat accumulation rate and gain in body mass. Additionally, supplementing water with simple carbohydrates (sugars) increased the rate of change in body mass. Similar trends were also observed in a controlled captivity experiment with Blackcaps (*Sylvia atricapilla*). Our results shed light on the role of simple carbohydrates and fatty acids in the fat accumulation processes. Therefore, this study has not only theoretical importance, but also applicative relevance, for the site management of En Rimon, as well as other groves in KKL-JNF forests. Based on our results, the KKL-JNF placed permanent water basins and planted various autumn- and spring-blooming plants as supplemental food sources for migrating birds that include all the diet components necessary for optimal fat accumulation.

Keywords:

migration, En Rimon

Introduction

Bird migration is one of the most fascinating phenomena in the animal world (Rappole, 2013). Intercontinental migration and crossing great geographic barriers such as deserts and oceans requires extensive energy and is a crucial evolutionary force for birds from diverse populations and species (Alerstam and Christie, 1993). Israel, located at the meeting of three continents lies along a major global migration routes (Frumkin et al., 1995), and twice a year, in fall and spring, some 400 million birds fly over the country between their breeding and wintering grounds (Shirihai et al., 1996). A variety of adaptations is required to fulfill the immediate demand for the large amounts of energy needed for migration (Lindström, 1995). The fuel for migration is fat stored in the bird's body, which is accumulated before migration, on stopover and during migration. The bird's digestive system must be ready to absorb large amounts of food over a short period and to excel in rapid metabolism (Karasov and Pinshow, 1998). Individuals in some species may double their body mass in a few days if provided with a sufficient amount of suitable food. At stopover sites, birds have to locate food sources quickly, overcome competition for food sources and avoid predators in unfamiliar areas (Lindström, 1995). Early arrivers to breeding and wintering grounds have an advantage in capturing good plots (Kokko, 1999). En Rimon, a plot with Atlantic Pistacia (*Pistacia atlantica*) trees in the southwestern Lahav Forest, planted in 1981, has become over time a major stopover site for migrating passerines in fall (Sapir, 2002). On their way south to their wintering grounds, the birds stop at the site, feed on the fatty pistacia fruits, and renew their fat stores.

This refueling allows the birds to continue on their fall migration while improving their chances of successfully crossing the Sahara Desert, one of the greatest barriers in the world for birds migrating between their breeding and wintering grounds (Strandberg et al., 2009). The plot, approximately one kilometer northeast of the edge of the settlement of Lehavim is located between route 31 in the south and Nahal Gerar in the north, at the section in which the *wadi* is a narrow channel covered with Prickly Burnet. Monitoring bird migration by trapping and ringing at En Rimon began in the late 1980s. Since the mid-1990s, it functions as an organized long-term project that continues to this day.

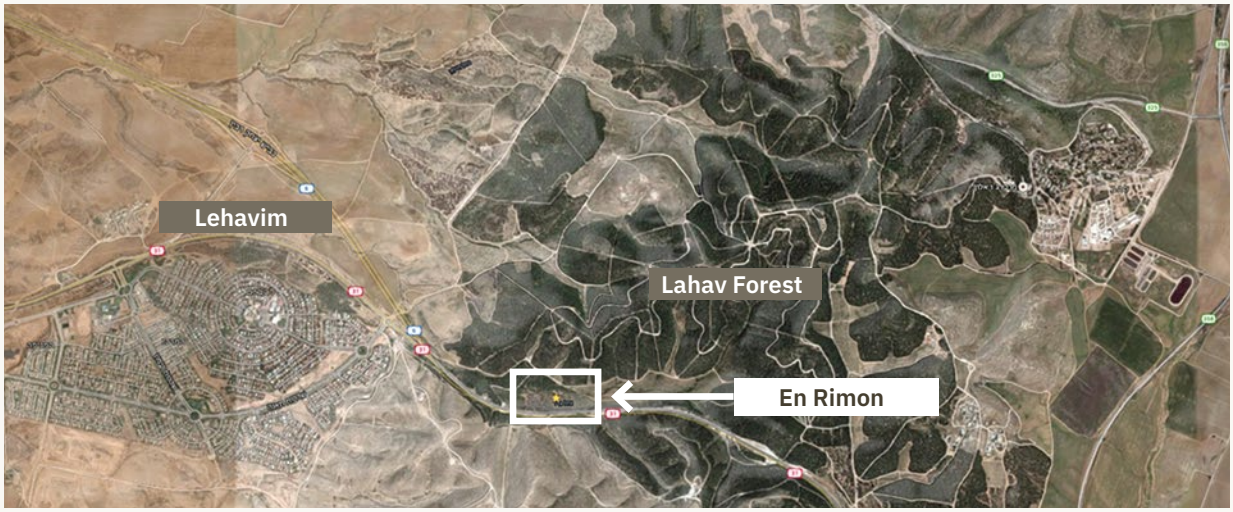

Figure 1

Aerial photography of En Rimon and its surroundings.
The Atlantic Pistacia site (marked with an arrow) is located in the Lahav Forest, between Kibbutz Lahav and Lehavim (31°22'N 34°50'E)

In the last decade, there has been a significant decline in the number of migrating birds stopping at En Rimon. One of the reasons for the decline could be the continuing drought, which caused significant death of trees at the site, and possibly also reduced the water content of the fruit. Moreover, in recent years, when the section of highway 6 between Bet Kama to the Shoket Junction was built, the section of the road between Lehavim and the Shoket Junction, which borders the site on the south, was widened. As part of the work two rows of trees in the southern section of the site were cut. Due to their proximity to the road, these trees benefitted from extensive runoff, and were the largest at the site. The change also damaged the edges of the plot nearest to the road, which was higher than the plot. This slope was populated by various shrubs, mainly Shrubby Saltbush (*Atriplex halimus*) and Leafless Ephedra (*Ephedra foeminea*) that contributed to the diversity of birds.

Previous studies found that the Atlantic Pistacias at En Rimon produced fruit every autumn. These fruit contain manly water and fatty acids, as well as a relatively small percentage of proteins, minerals and sugars, and attract a wide variety of birds between September and November (Sapir, 2002).

In the early 21st century as part of the site management, water was added to troughs in En Rimon. When water was available, the average fat level in Eurasian Blackaps (*Sylvia atricapilla*) stopping over at the site increased (which did not occur in Lesser Whitethroats [*Sylvia curruca*]), and it was suggested that water availability helps fat accumulation. To test this hypothesis Sapir et al. (2004) conducted a study that examined the effect of water supplementation. In this experiment, water troughs at the site were filled from time to time and birds were caught throughout the period. The birds that were caught were marked with numbered aluminum rings, were weighed and their fat was estimated according to the customary scale (Helms and Drury, 1960).

The experiment was conducted in three rounds: a control round, a round with water supplementation in troughs and an additional control round. The rate of fat deposit and the variation in the amount of visible fat was calculated from the values measured during the first and last trapping of the bird. The results showed that water supplementation improves the fat deposit capability of Blackcaps compared to the first control round, and that in the second control round the parameters were low, as they were in the first control round. In Lesser Whitethroats, water supplementation did not affect fat deposit.

In order to understand the significance of the fruit and the water to the process of fat deposition in migrating birds, in 2009 a laboratory experiment was conducted that focused on the differences between diets (Tsurim et al., 2008). Captive Blackcaps in cages were fed different diets. The results of this experiment showed that Atlantic Pistacia fruits without water supplementation were less attractive to birds. Furthermore, a diet composed of Atlantic Pistacia fruit was clearly preferred when water was added, as it allowed the birds to accumulate body mass more rapidly in this regime. Apparently, the Atlantic Pistacia fruit have an advantage during fat deposition in the body, but for some reason it is difficult for the birds to gain the benefit of the fruit without water supplementation, whether due to digestive processes or other physiological reasons.

In order to understand the factors limiting fat deposition in fall migrants, and possibly to connect these processes to the decrease in the number of birds in the plot, we conducted a field experiment in the fall seasons of 2014 and 2015 to test the effect water supplementation has on birds of different species.

Methods

The experiment was extended to two other sites in the northern Negev and replicated three times: twice in the fall of 2014 and once in fall 2015. Each replication consisted of three treatments: (1) water supplementation; (2) water and water with sucrose supplementation (0.5M); (3) control, with no additives. The two additional sites were an Atlantic Pistacia plot at Midreshet Ben-Gurion and at the Yeruham Lake Park. The Pistacia site habitat at the Midreshet Ben-Gurion was similar to the En Rimon habitat regarding vegetation and type of food. The Yeruham Lake Park served as a control for the other two sites, as it has abundant water available and flowering trees to provide sugar. This allowed the two dry Pistacia plots, whose main food source is based on complex carbohydrates (fat), to be compared to a site located in a similar geographic area, which is rich in water and based on simple carbohydrates (sugars).

The experiment was based on capturing and recapturing the largest possible number of birds in order to monitor changes in fat deposition and body mass. During each treatment, four consecutive trapping days were held at the three sites at the same time. Each captured bird was marked with a numbered aluminum ring, weighed and its visible fat was estimated according to the customary scale (Kaiser, 1993). The rate of weight increase and the rate of fat deposition were measured according to the fat estimate and weight at

the first capture and the last capture of the individual bird, in the framework of the same treatment. In the experiment these parameters were measured for a great variety of passerines at En Rimon, mainly from the *Sylvia* family and the *Turdus* family (12 species in all).

Results

Trapping effort produced good results at En Rimon and Yeruham, with about 25% and 11% recaptures, respectively (Figure 2). At Midreshet Ben-Gurion, on the other hand the percent of recaptures was significantly lower and did not permit analysis of the data.

We found that at En Rimon adding water increased the rate of body mass increase, and that addition of sugar water raised the rate even more. At Yeruham the treatments had no effect on the rate of body mass change, and the general rate was equal to the rate of body mass change at En Rimon during the control treatment. Moreover, at Yeruham no changes in the rate of fat deposition were found between treatments, while at En Rimon the rate of fat deposition in the control group was lower than when water or sugar water were added. Adding sugar water affected the rate of mass increase, but was not expressed as an increase in the rate of fat deposition compared to an addition of water only (Figure 3).

In Yeruham, where there are no Pistacia fruits, no difference was found in the rate of fat deposition or the rate of increase of body mass between treatments, while in En Rimon the sugar water supplement increased the rate of increase of bird body mass, but the rate of fat deposition decreased compared to a plain water supplement.

Fruit consumption was assessed by sampling Pistacia seeds in droppings. No difference was found between the three treatments and the only statistically significant difference was found between the trapping sites: fruit consumption at the Midreshet Ben-Gurion site was significantly lower than at En Rimon.

In the fall of 2015, a controlled cage experiment was conducted that examined the effect of diet composition on Blackcaps. In the experiment, Blackcaps kept in individual cages had free access to Atlantic Pistacia fruit and 18 mealworms daily. After two days of acclimation to captivity, the birds were divided into three diet groups: (1) water supplementation; (2) water and water with sucrose supplementation (0.5 M); (3) control, with no additives. After

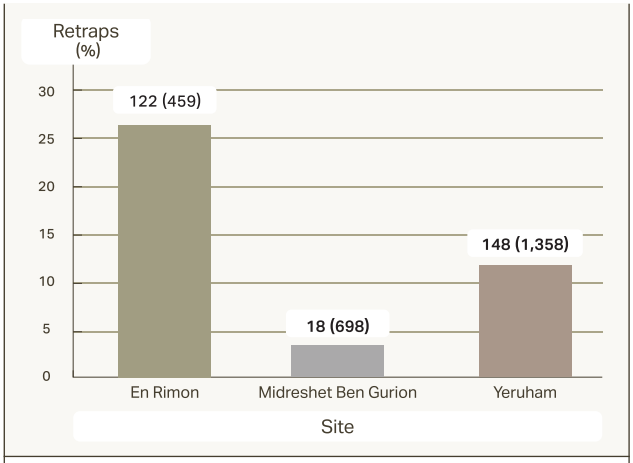

Figure 2

Percent recapture at the study sites during field experiments, 2014. The number above each column denotes the number of birds caught more than once and the number in parenthesis denotes the total number of birds caught in the experiment.

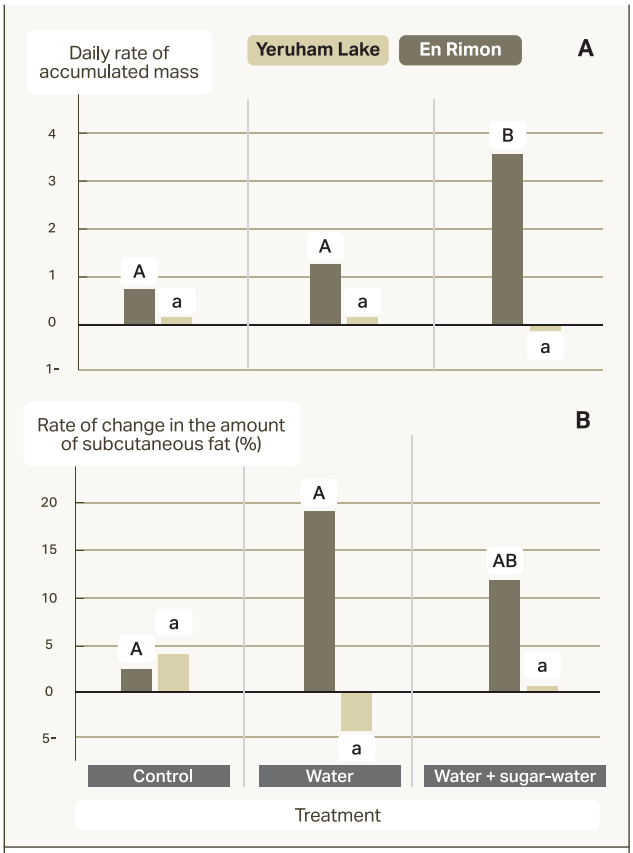

Figure 3

The effect of water and sugar-water supplements on the rate of mass increase (a) and on the rate of change of the amount of subcutaneous fat (b) in migrating passerines, fall 2014-2015. The study sites: En Rimon and Yeruham Park. Different letters represent a significant difference between treatments (for each site separately) in analysis of covariance (ANCOVA).

five days in captivity, the birds were released into nature. This experiment was repeated three times and a total of 51 birds participated in the experiment. We found that the increase in body mass in birds that ingested the sucrose solution was the highest. However, in birds that ingested water alone the rate of change was higher than in the control group (Figure 4). Furthermore, fruit consumption (measured by the number of seeds in the daily droppings) varied between the treatments. Water supplementation increased the fruit consumption compared to the control, but it decreased in birds that received the sugar supplement.

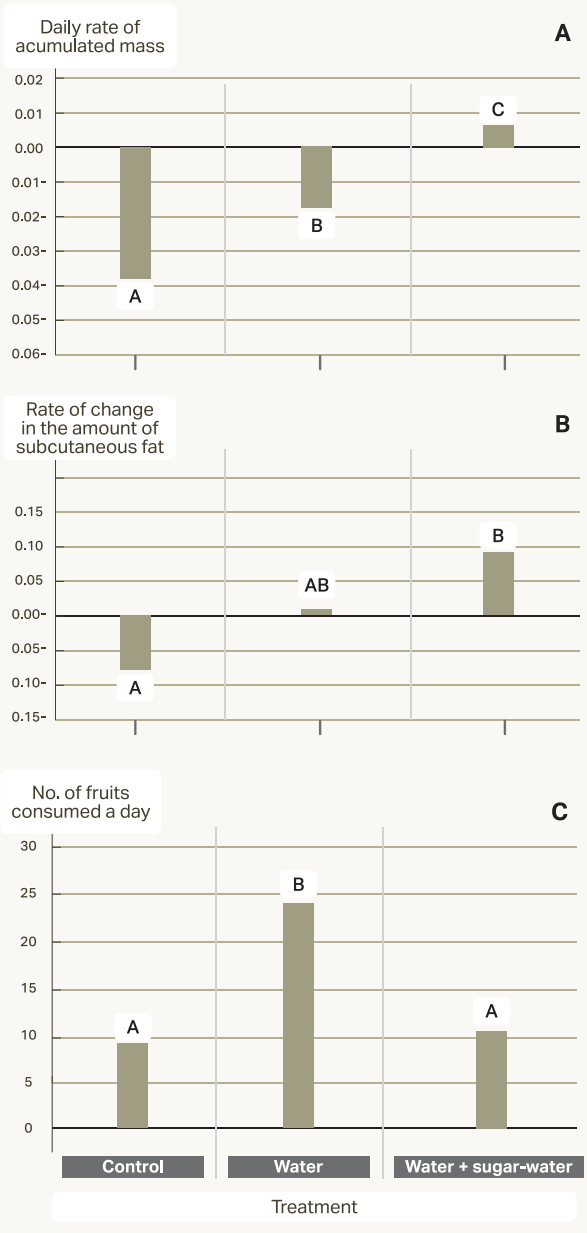

Figure 4

Differences in the rate of body mass change (a), rate of fat deposit (b) and fruit consumption (c) in Blackcaps fed different diets in captivity. Different letters represent a significant difference between treatments (for each site separately) in analysis of covariance (ANCOVA).

Discussion

Bird migration is one of the most fascinating phenomena in the animal world. Understanding the possible mechanisms that allow small birds to fly over extensive, resource-poor areas has theoretical and applied importance. En Rimon is an example of a site suited for the study of the relations between migrating birds and the environment, because of the direct relation between the needs of the birds to the Atlantic Pistacia fruits. Long-term field studies demonstrate the value of the site for ecological research and nature conservation.

One of the objectives of the experiment was to test how previous patterns found in En Rimon can have general implications. We assumed that the Midreshet Ben-Gurion site can be compared to En Rimon, and that the Yeruham Park can serve as a wetland control site. The results show that the Midreshet Ben-Gurion site differs from En Rimon: the percent of recaptures at En Rimon (18.9) is similar to Yeruham (17.7) and almost three times higher than at the Midreshet Ben-Gurion (Figure 2). Furthermore, fruit consumption at En Rimon is significantly greater that at Midreshet Ben-Gurion. For some unknown reason, the Atlantic Pistacia fruit at the Midreshet Ben-Gurion site apparently have less nutritional value, and therefore are consumed less. Birds that stop at this site abandon it rapidly, a phenomenon known from low-quality stopover sites (Sapir, 2002).

As in previous finds, water supplementation improved fat deposition and mass gain rate of birds at En Rimon. Adding sugar contributed to an additional mass gain, but did not affect the rate of fat deposition (Figure 3). The importance of sugars and fat as fuel for migration is still unknown, and the results of this study could suggest that these are two interchangeable energy sources that are dependent on the energetic requirements of the birds. The sugar may enable an immediate rise in energy and in the fluid volume in the body, but is less effective as a source for long-term fat deposition. Therefore, sugar has immediate importance for depleted birds that arrive in poor condition to stopover sites, but fat reserves for longer terms are created mainly with fat. The results thus testify to the importance of Atlantic Pistacia fruit as a source of fat as fuel for migration, but also indicate

a problem when they serve as the sole energy source with no available water.

The results of the captivity experiments suggest that given available sugar, the birds prefer it to the Atlantic Pistacia fruit. In the cage experiments, the rapid rise in body mass on the sugar diet is backed up by fat deposition (Figure 4), unlike the field experiments. Nevertheless, in order to monitor weight gain we selected birds weighing less than average for the controlled cage experiment. The inferior body state of these birds may have influenced their dietary choice, a phenomenon found in stressed birds (Cecere et al., 2011).

Significance of the results for management

The En Rimon site underwent significant changes in recent years, which included area reduction due to building, decline in habitat diversity for the same reason, and a decline in the health of the trees and mortality of some trees. All these contributed to the decline in biodiversity and in the number of birds stopping over at the site every fall (Figure 2). Birds stop at sites along their migration route to rest and accumulate fat that serves as fuel for migration. Therefore, understanding the interaction between the characteristics of the stopover site and weight gain processes, is important and extremely significant for non-natural sites, and will allow development of management plans adapted to other sites throughout Israel.

The En Rimon restoration plan was implemented on two planes. The first stage included laying a drip-irrigation system for all the living trees. This system, which became functional in winter 2020, will prevent further drying up and death of living trees. Dead trees were removed and replaced with new trees. The second stage included planting trees and shrubs from a variety of species that flower and produce fruit, some of them in spring. An irrigation system that allows rapid growth and resistance to difficult summer conditions was installed for all the plants. In addition to these actions, that are directly related to the vegetation, large plastic troughs were installed that could be filled with water for drinking.

In the future, we also plan to add raised seed trays that will provide food for the many Chaffinches that overwinter in the Lahav Forest. The addition of these trays will allow us to diversify the food sources, mainly for birds in the finch family. One of phenomena in En Rimon due to the continuing drought, is the reduction of the fruiting season, from a season that continues to early spring, to a shortened season that ends in mid-winter or even in the beginning of winter. The number of finches of different species that overwintered at the site declined correspondingly. As the En Rimon site is also used for environmental education and interpretation, it is very important to attract the birds to the troughs and the feeding trays, in particular small songbirds that are usually difficult to see.

The results of the study stress the importance of the Atlantic Pistacias and their fruit as a source to replenish the depleted fat deposits in migrating birds, but also the limitations of fruit consumption at a dry site in fall. Therefore, management using controlled irrigation has a double significance. It will prevent the trees from becoming stressed, which will improve fruit yields and contribute to creating a slightly more humid environment, which will allow the birds to digest the fruit more effectively and increase the rate of weight gain. At the same time planting plants that flower in fall, will allow the stressed birds that just arrived at the site to leave more rapidly, will shorten the process of renewed adaptation to feeding (a process that takes one-two days) and will eventually provide a more balanced diet. There are currently a few eucalyptus trees that bloom in fall at En Rimon, and it is possible that increasing their number will attract more birds and improve the foraging conditions of all the birds stopping over at the site, despite the possible increase of the potential competition for food (Shochat et al., 2002).

Preserving stopover sites for migrating birds is no less important than preserving their breeding and wintering sites, and is of major importance for the general fitness of birds from diverse species and populations. This is particularly true for En Rimon, which has been proven to be a major stopover site in Israel, and probably in the entire Middle East. Suitable management of the site can contribute to preserving the populations that gather at En Rimon from extensive areas in Western Asia and Eastern Europe. On a local scale, this management can be harnessed to promote educational and community programs focusing on sustainability and nature conservation in the Northern Negev.

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En Rimon, 2021
Photo: Bonny Sheinman, KKL-JNF Photo Archive