<u>Changes and effects on bodyweight and fuel deposition of passerines during stopover</u>

A Six-Year Analysis at Stopover Site Blåvand

Research Report

Maxim Lisi

HAS Green Academy University of Applied Science ’s-Hertogenbosch

Applied Biology

Research Internship

Blåvand, July 2024

Research Report:

Changes and effects on bodyweight and fuel deposition during stopover

A Six-Year Analysis at Stopover site Blåvand

Author:

Maxim Lisi

540295582

Internship supervisor Blåvand Fuglestation:

Henrik Böhmer

Supervising Teacher HAS Green Academy:

Eline Visser

Pictures Cover Page:

Blåvand Bird Station

Preface

Before you lie the research report "Changes and effects on bodyweight and fuel deposition during stopover: A Six-Year Analysis at Stopover site Blåvand". It has been written during my internship at the Blåvand Bird Station as part of my Bachelor program Applied Biology at the HAS Green Academy, University of Applied Science. The internship took place during the spring season of 2024, where I have been able to learn the craft of bird ringing under the guidance of the Bird Station authorized bird ringers. I want to thank the Copenhagen Bird Ringing Centre for providing me with all the data needed to carry out my research and the Blåvand Bird Station for the opportunity and environment where I have been able to learn and explore my interests and passions. Finally, I want to personally thank Morten Jenrich Hansen and Henrik Böhmer for teaching me the craft of bird ringing, their guidance during my research and for the good company.

I hope you enjoy your reading.

Maxim Lisi

25.07.2024

Abstract

Migratory passerines are one of the many organisms affected by the changing climate. With the decline of many species of passerine birds it is of conservation interest to keep gaining insight in the mechanics of migratory ecology. Stopover strategies during migration are an important factor for rest and fuel deposition during migration. In this research the change in bodyweight, fat- and muscle score of four passerine species has been analysed during their stopover at Blåvand, Denmark over the years 2018 through 2023. A mark and recapture method was used to measure the change in weight and fuel deposition of the birds. The birds were caught using mist nets. The four bird species *Phylloscopus collybita* (Common Chiffchaff); *Regulus regulus* (Goldcrest); *Erithacus rubecula* (European Robin) and *Prunella modularis* (Dunnock) were selected based on their average recapture numbers during the research years. Data analysis showed that all four species gained weight during their stopover but not all showed an increase in either fat or muscle. No clear distinction has been found based on diet and forage behaviours. Local temperature and arrival conditions did not seem to have effect on the stopover conditions of the birds. To gain a better understanding of the difference (or lack thereof) between the fuel deposition of the species, foraging observations could give a better understanding in distinctions in diet which could explain the difference in fuel deposition.

Contents

1 Introduction

Migratory passerines are one of the many organisms affected by the changing climate (Hüppop & Hüppop, 2003; Jenni & Schaub, 2003; Szostek et al., 2015). There are a multitude of factors such as temperature, precipitation, resource abundance and physical condition which influence birds on an inter- and intraspecies level when it comes to behaviour and decision-making regarding migration (Catry et al., 2022; Duijns et al., 2012; Eeva et al., 2000; Gordo & Sanz, 2008). This complexity of migration ecology makes it difficult to draw concise conclusions about all the possible effects of climate change on migratory birds (Bitterlin & Van Buskirk, 2014).

The effects of climate change on the physiology of migratory passerine show that harsher weather conditions during migration can have a negative effect on body mass. (Marra et al., 2005; Yom-Tov, 2001),which lowers migration success for individuals (Schaub & Jenni, 2001a). With the decline of many species of passerine birds, it is of conservation interest to keep gaining insight in the mechanics of migratory ecology. Stopover strategies during migration are an important factor for rest and fuel deposition (fat and muscle increase) during migration (Eikenaar et al., 2014). Choosing the right location and duration for stopover has effect on the arrival time and overall success of migration (Schaub & Jenni, 2000). Migration is a vulnerable and unpredictable annual period for passerines (Moore, 2000; Sillett & Holmes, 2002; Berthold et al., 2003). A better understanding of stopover strategies can inform conservational strategies (Mehlman et al., 2005; Maggini et al., 2020; Martin et al., 2007).

Feeding behaviour is a factor in stopover strategies of passerine birds. Depending on their preferred diet, passerine birds might have different migration strategies in order to refuel on stopover sights (Bibby & Green, 1981; Schaub & Jenni, 2001b). Measuring the physiological condition of migratory birds during stopovers can provide information about the quality and use of a stopover site for different species. Most studies focus on similar species with the same food preferences. There is little known about fat- and muscle metabolism at stopover sites based on dietary preferences. One study suggests that there is a difference in fat- and muscle metabolism between populations of thrushes based on the frugivorous availability of their chosen stopover site (Smith & McWilliams, 2010). This shows that the choice between available stopover sites along a migration route can have effect on the physical conditions during migration based on food preferences.

In this research, the change in bodyweight, fat- and muscle score of four passerine species has been analysed during their stopover at Blåvand, Denmark. Since 2018 a standardised method has been used to measure these physical conditions of passerine birds by the Blåvand Bird Station. This research has been conducted to gain insight into the extent weight and fuel deposits change during the stopover of the species; what effects local temperature has on weight changes and what effect arrival weight has on stopover duration. In addition, the effectiveness of the fat- and muscle scoring method has been analysed in order to determine its applicable use.

2 Materials and Methods

The Blåvand Bird Station capture and rings migratory birds during spring and autumn migration. The ringing of spring migration (spring season) starts 1st of March and ends 15th of June. The ringing of autumn migration starts 20th of July and ends 15th of November.

Standardized methods are used at the Blåvand Bird Station for ringing, bird handling and setting up mist nets since 2018. In this research, the data from the spring migrations of the years 2018 until 2023 were analysed.

2.1 Research Location

Research was conducted at the ringing sites of the Blåvand Bird Station located at Blåvand, Denmark. Run by Birdlife Denmark.

The Blåvand Bird Station has two locations where mist nets were placed every ringing season. The positioning of the mist nets was the same every season. The first location is directly around the bird station (station garden). The second location was a five-minute walk from the station garden next to a lighthouse (lighthouse garden). Both locations had 11 nets positioned. The station garden had a total of 128 meters of net. The lighthouse garden had a total of 115 meters of net.

Conifers and different types of shrubs grow in both gardens. All mist nets were placed on pathways between this vegetation. Each garden was equipped with a ringing lab where all ringing was conducted.

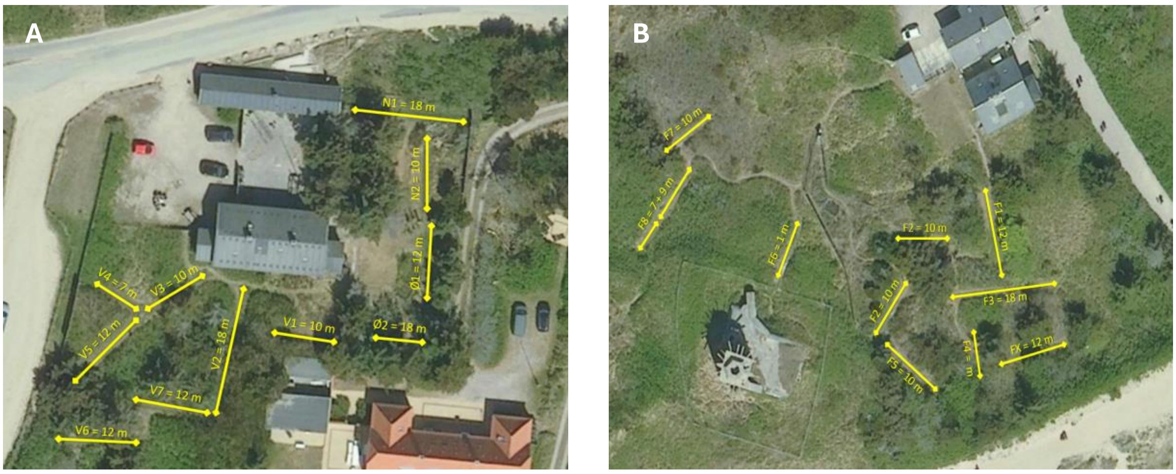

Figure 1 Mist net placement at the two gardens. A: station garden. B: lighthouse garden.

2.2 Research Species

The four species were chosen to analyse the physical conditions of had a minimal recapture count of 30 individuals in all years.

Phylloscopus collybita (Chiffchaff) and *Regulus regulus* (Goldcrest) are insectivores (especially during spring migration) feeding on small insects found in the foliage of trees. The *Erithacus rubecula* (Robin) and *Prunella modularis* (Dunnock) are generalist, feeding on seeds, fruits and insects found on the ground.

2.3 Mist Nets

To catch passerines, mist nets were used following the Blåvand ringing guidelines (appendix I). The bird station used a standard setup as describes by Keyes and Grue (1982) where each net was strung up between two poles.

Each day during the migration season the nets were all opened a half hour before sunrise. Before opening the nets, local weather reports were consulted. If there were harsh weather conditions predicted (precipitation or strong winds) some, or all nets would stay closed. With good weather conditions the nets were open for a minimum of five hours a day.

Once the nets were opened, each garden was checked for caught birds every half hour.

2.4 Ringing measurements and data

After removing a bird from a net, the bird was collected in a bag and after the ringing process was completed the physiological measurements were made.

Fat - and muscle score were measured on a visual basis using the methods mentioned in Eck et al., 2012. With the bird lying on its back, the breast feathers was blown aside against the direction of growth. This gave a visual of the flight muscles. The birds were scored on a 4-point class scale (0-3) (appendix II). During the same process the abdominal area was examined to estimate the fat score by looking for visible fat deposits (appendix III). The body weight of the bird was measured in grams, on a scale with a point one decimal accuracy.

When a bird was recaptured on another day during the same season, the same measurements were made as for the first capture date. If an individual was recaptured for a second time on the same day, it would be let go without taking measurements.

2.6 Data Analysis

2.6.1 Change in bodyweight

The mean weight of the total of caught individuals over all the years was calculated for each species. This was done for the measurements during first capture and for the measurements during the last capture. To determine a significant difference between the mean weight over the total years between the first and last capture a t-test was executed ($\alpha = 0.05$).

2.6.2 Change in fat- and muscle score

The relative distribution of fat- and muscle scores were calculated for the first and last capture measurements separately. For each score the percentage of individuals over all the year for the scores were calculated. Dunn's test was used to determine the significance between the relative distribution between the first and last capture measurements ($\alpha = 0.05$).

2.6.3 Correlation between bodyweight and fat- and muscle score

To analyse the correlation between the mean body mass of the research species and the fat- and muscle score, a multiple ordinal regression was utilized. The fat score was used as the dependent variable and body mass and muscle score as the independent variable ($\alpha = 0.05$).

2.6.4 Stopover duration and correlation with arrival weight

For each individual bird, the stopover duration was calculated by counting the days between first and last capture. A multiple pairwise comparison was performed with Dunn's test to determine the significant difference between the mean stopover durations of the species (α = 0.05. For each species, a linear regression test was performed to determine if there was a correlation between mean body mass during first capture and the stopover duration. The data of the body mass was used as the dependent variable, the number of days as independent variable.

2.6.5 Effect of temperature on weight

The local daily temperature data was gathered from the Danish Meteorological Institute. To determine if there was a corelation between change in body mass and local temperature during stopover a linear regression test was performed for each species. The mean change in body mass functioned as the dependent variable and the mean temperature during stopover days as the independent variable (α = 0.05).

3 Results

The most numerous of the species across the spring migration seasons of the six years (2018 – 2023) was *Erithacus rubecula* (Robin) with 1444 individuals and the *Phylloscopus collybita* (Chiffchaff) with 1426 individuals (table 1). The Robin had the biggest number of total recaptures of 253 individuals. The *Regulus regulus* (Goldcrest) had the highest stopover numbers of 116 individuals and overall highest stopover percentage of 18.2%

Table 1: Comparison of the total amount of captured birds, their recapture and stopover numbers and the overall stopover percentage.

Species	Total captures	Total Recaptures	Stopover	Stopover percentage
Chiffchaff	1426	80	70	4.9
Dunnock	860	145	73	8.5
Goldcrest	639	122	116	18.2
Robin	1444	253	87	6.0

3.1 Change in weight

All species show an increase in mean bodyweight between first and last capture over the six spring seasons (figure 1). Looking at the relative weight increase of the species, the Goldcrest and Robin had the biggest mean increase of 5.6% (0,26 g) and 5.4% (0,82 g) respectively. For all species, the difference in weight between first and last capture was found to be significant ($p < 0.05$). Between the research species no significant difference was found between the relative bodyweight increase.

No correlation has been found between the change body weight and mean temperatures during stopover for any species ($p > 0.05$).

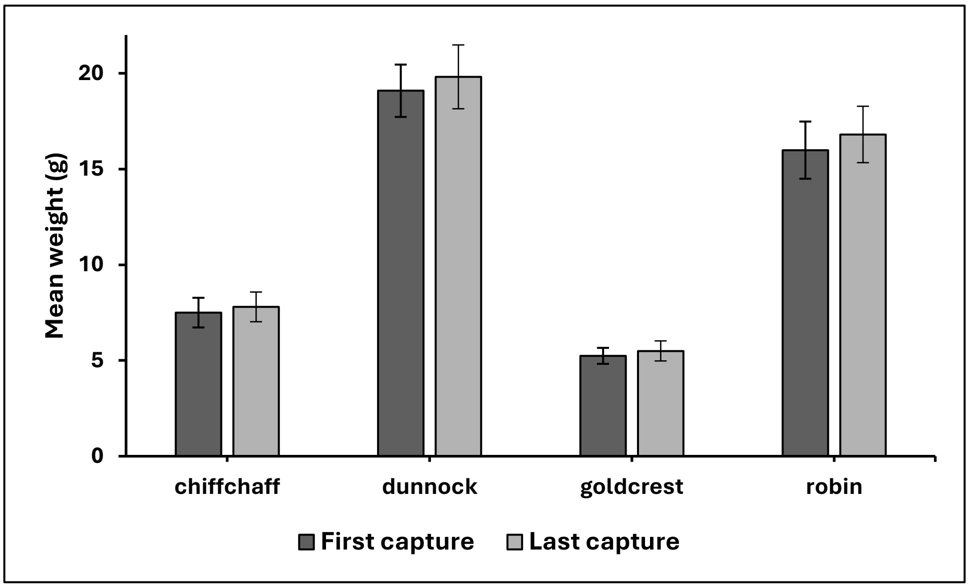

Figure 1: The mean bodyweight of the first and last capture for all four research species. The y-axis shows the mean bodyweight in grams. On the x-axis the left bar of each species shows the mean weight during first capture and the mean bodyweight during last recapture on the right. The error bars show the standard deviation.

3.2 Change in fat score

Fat score 6 was the highest score given during the research period. The Chiffchaff was the only species with a score of 6 during the first capture, which made up 3% of all individuals of the species (figure 2). Between captures, the Robin and Goldcrest showed a decrease and/or no change in scores 0, 1 and 2. For all species, fat scores 5 and 6 increased or stayed the same between captures. For the Goldcrest and Robin, the whole higher half of the scores (3 through 6) increased, with the biggest increase of 28% for the Robin. The increase in overall fat score between first and last capture was found to be significant for both the Robin and Goldcrest ($p<0.05$).

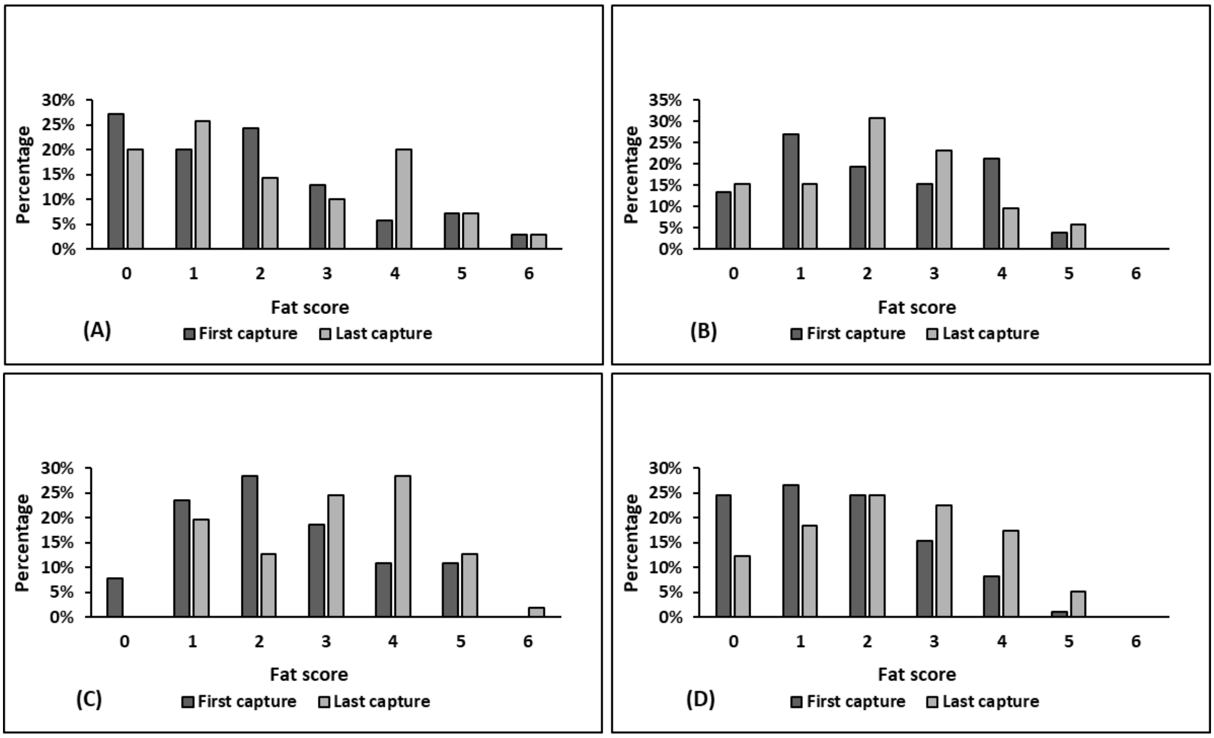

Figure 2: The distribution of the relative fat score over the total of years per species. For each species the left bar shows the percentage of the muscle score during first capture. The right bar shows the percentage of fat score during last capture.

A: Chiffchaff
B: Dunnock
C: Goldcrest
D: Robin

3.3 Change in muscle score

During the six ringing seasons, none of the recaptured individuals received a muscle score lower than 1 (figure 3). The percentage of individuals with a muscle score of 1 between first and last capture remained the same for the Dunnock. Muscle score 1 of the Chiffchaff, Goldcrest and Robin decreased between captures with 6.2, 12.0 and 7.4 percent respectively. All species had in increase in muscle score 3, with the Chiffchaff having the biggest increase of 10.8%. Overall, the Goldcrest saw the biggest increase in muscle score with 12%. The Robin, however, was the only species where a significant difference was found between the muscle score between the first and last captures ($p<0.05$).

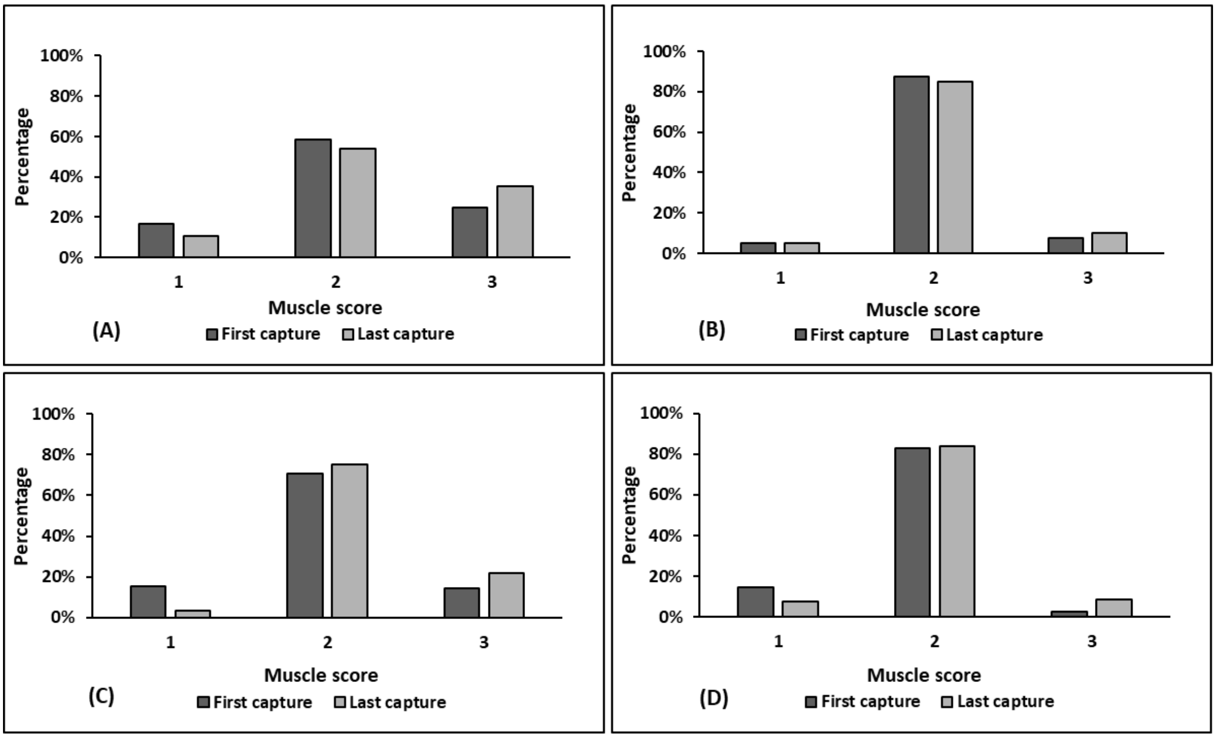

Figure 3: The distribution of the relative muscle score over the total of years per species. For each species the left bar shows the relative distribution of the muscle score during first capture. The right bar shows the distribution of muscle score during last capture.

A: Chiffchaff
B: Dunnock
C: Goldcrest
D: Robin

3.4 Correlation between weight and fat- muscle scores

The highest mean weight of all species had a muscle score of 3 (figure 4). The highest mean weight of the Dunnock, Goldcrest and Robin also scored the highest for the fat score (score 5 or 6). Most of the lowest measured mean weight goes a long side a muscle score of 1 and a fat score of 0. There is only an exception with the Dunnock whose lowest weight had a muscle and a fat score of 3. The Chiffchaff and Dunnock show a significant positive correlation between weight and fat score ($p<0.05$). The Goldcrest and Robin show a significant positive correlation between weight and both the fat - and muscle score ($p<0.05$).

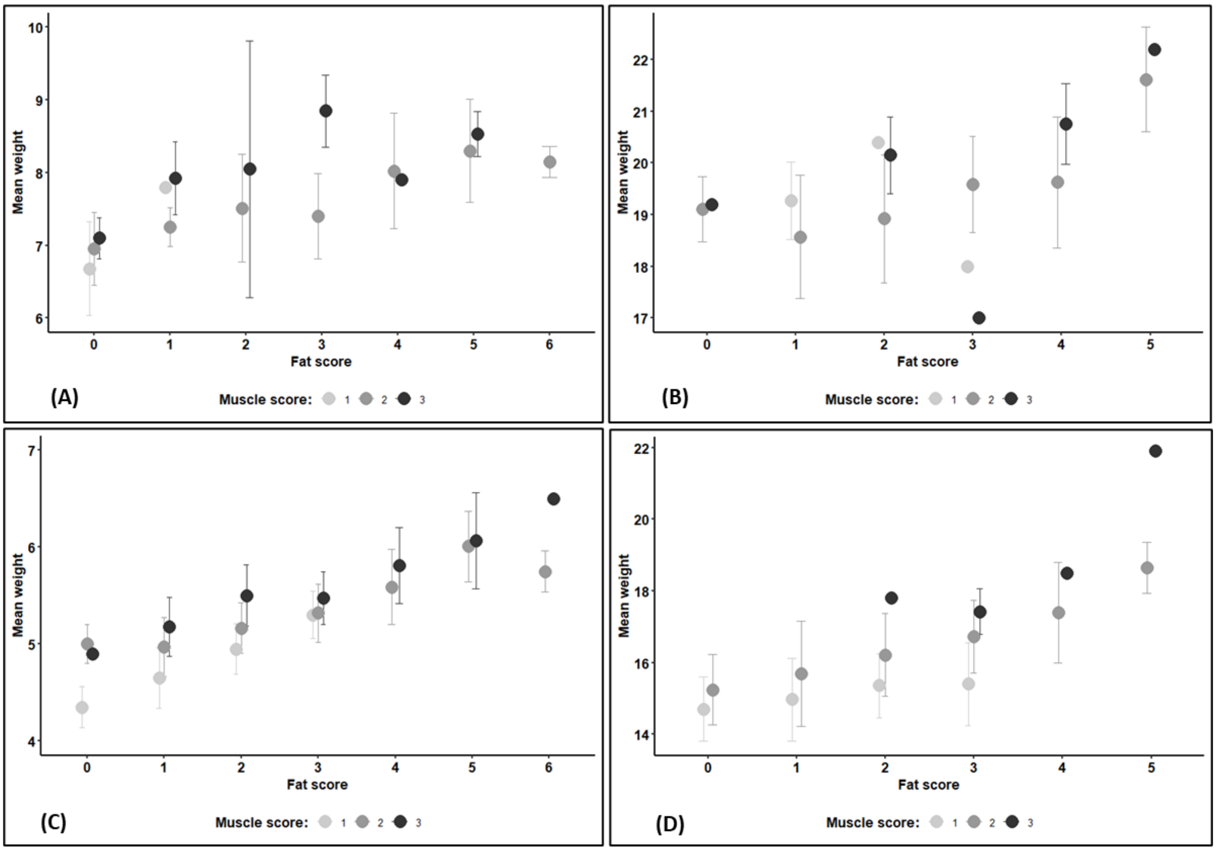

Figure 4: Regression of weight in relation to fat - and muscle score. The x-axis shows the fat scores, the y-axis the mean weight in grams. The scatter plot is divided in the three muscle scores. The error bars show the standard deviation. The letters in the top left corner of the graphs indicate the species.

A: Chiffchaff
B: Dunnock
C: Goldcrest
D: Robin

3.5 Stopover duration

Comparing the stopover duration between species, the Robin had the longest mean stopover duration of 6.8 days and shows a significant difference with all other species ($p<0.05$) (figure 5). The stopover duration of the Chiffchaff and Dunnock were the shortest, with a mean of 3.8 days. No correlation has been found between mean arrival weight and stopover duration ($p > 0.05$).

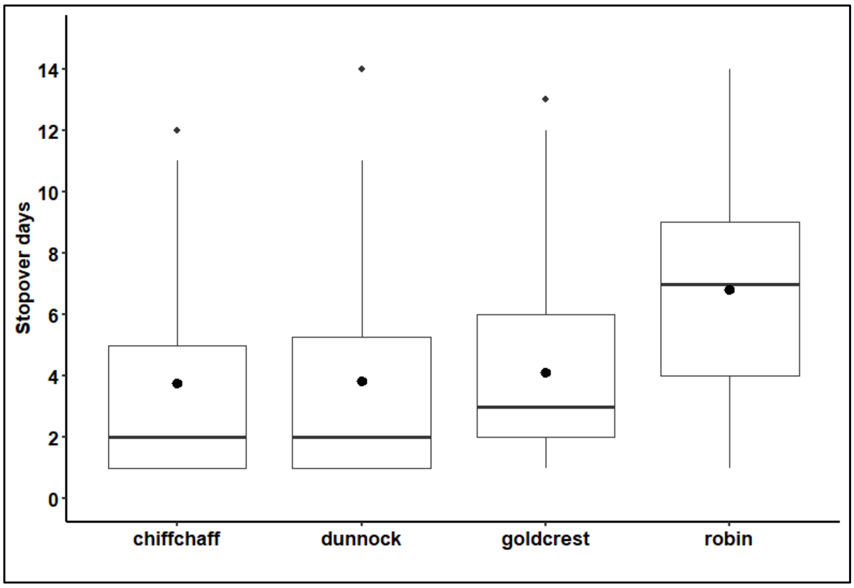

Figure 5: Stopover duration of the five research species. The point above the box and whisker shows the outliers. Point within the box show mean and the horizontal line within the box the median.

4 Discussion

The results show that the research species gain body mass during their stopover in the research area, Blåvand. Weight increase and fuel deposition (increase of fat and muscle tissue) is mainly influenced by food availability during stopover (Bibby & Green, 1981; Graber & Graber, 1983; Fransson, 1998; Danhardt & Lindstrom, 2001). The results indicate that the stopover area Blåvand has enough food resources available for the passerines to refuel before continuing their migration.

There have been different findings in fat- and muscle score increase during stopover between the species. Among the Goldcrest and Chiffchaff, who are both insectivores, the Goldcrest showed a clear increase in fat during stopover. This difference in fat increase between the two species is not likely the cause from a difference in diet. Both insectivores feed on similar small (flying) insects that they predominantly forage from the foliage in tree branches (Clement et al., 2020; Martens & Päckert, 2020). The difference in fat- and muscle score increase between the Dunnock and Robin, the two generalists, also does not appear the be caused by a difference in diet. Only the Robin showed an increase in fat- and muscle score. Both the Dunnock and Robin feed on similar seeds and insects that they find foraging on the ground (Hatchwell, 2020; Collar, 2020).

Based on the methods used in this study, no clear conclusion can be drawn on the differences in fuel deposits between the species. For better understanding of the difference in fuel deposition the actual diet could be analysed. This can be done by both observing foraging behaviour during stopover and by analysing faeces contents (Musseau et al., 2014; Jenni et al.,1990). Another possibility is to analyse blood samples for plasma indicators of fat deposition, fat catabolism and protein catabolism to have a better understanding of fuel deposition during stopover (Smith & McWilliams, 2010; Gannes, 2001; Schwilch & Jenni, 2001).

Although not all species show an increase in fat- or muscle scoring during stopover,a clear correlation has been found between body mass and fat scoring and for the Goldcrest and Robin this also accounted for the muscle scoring. The visual scoring method may not be as concise on fat- and muscle deposition like blood plasma analyses is, but it is a cost friendly and practical applicable method that many bird observatories can utilise. The results indicates that the visual scoring system is an adequate method of monitoring the change in the fat and muscle condition of birds during stopover that can be used in citizen science, which is an important source of data in the field of ornithology (Barbosa et al., 2021; Kelling et al., 2015; Randler, 2021; Greenwood, 2007; Weisshaupt, 2002).

In the findings of this study, no correlation was found between body mass on first capture and stopover duration. Preexisting research shows contradicting findings on the topic of stopover duration based on body mass. Older studies indicate that birds with low body mass at capture have a longer stopover duration (Cherry, 1982; Bairlein, 1985, Biebach et al., 1986; Moore & Kerlinger, 1987; Loria & Moore, 1990). While newer studies show no relation between body mass and stopover duration (Safriel & Lavee, 1988; Kuenzi et al., 1991; Ellegren, 1991; Morris et al., 1996; Dierschke & Delingat, 2001). A study by Liechti & Bruderer (1998) suggests that weather aloft is a heavy factor in stopover duration for passerines. Passerines would make the trade-off of migrating with preferable weather conditions instead of taking the time to refuel. For a better understanding of stopover duration at Blåvand local weather conditions such as wind and precipitation could be analysed in correlation with stopover duration.

The local temperature did not seem to influence the body weight during stopover for any of the species. This would mean that the local weather during the stopover period has no impact of fuel availability and on the forage behaviour of the passerines. Fuel availability is more often affected by seasonal or even annual weather conditions (White, 2008). Better conditions throughout the year will influence the growth of vegetation and populations of invertebrates and determine the fuel availability. To gain insight on the effects of temperature and other weather conditions more clearly, the weather and its effects on body conditions could be analysed on a yearly basis. There are however not enough recaptures per year to analyse the weather effects on a yearly basis on the stopover site. On a 6-year scale however, no effects have been found on the weight increase of the birds.

While it is clear that the research species are able to regain body weight during their stopover at Blåvand, it is unclear were the difference lies between the species when it comes to fat and muscle deposition, since diet and foraging behaviour does not seem to be a clear factor in the difference in fuel deposition. Local weather and arrival conditions do not appear to have an effect on the fuel deposition. For further insight into fuel deposition at the stopover sight, foraging observations is a applicable and cost effective method for the Blåvand Bird station to utilize.

Bibliography

Bairlein, F. (1985). Body weights and fat deposition of Palaeartic passerine migrants in the central sahara. Oecologia 66: 141-146.

Barbosa, K., Develey, P., Ribeiro, M. & Jahn, A. (2021). The contribution of citizen science to research on migratory and urban birds in Brazil. Ornithology Research. 29: 1-11.

Bibby, C. J., & Green, R. E. (1981). Autumn Migration Strategies of Reed and Sedge Warblers. *Scandinavian Journal of Ornithology*.12: 1–12.

Biebach, H., Friedrich, W., Heine, G. (1986). Interaction of bodymass, fat, foraging and stopover period in trans-sahara migrating passerine birds. *Oecologia.* 69: 370-379.

Bitterlin, L. R., & Van Buskirk, J. (2014). Ecological and life history correlates of changes in avian migration timing in response to climate change. *Climate Research*. 61: 109–121.

Catry, T., Granadeiro, J. P., Gutiérrez, J. S., & Correia, E. (2022). Stopover use of a large estuarine wetland by dunlins during spring and autumn migrations: Linking local refuelling conditions to migratory strategies. *PLoS ONE*. 17: e0263031.

Clement, P., del Hoyo, J., Collar, N., Kirwan, G. M. & Christie, D. A. (2020). Common Chiffchaff (*Phylloscopus collybita*), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

Cherry, J.D. (1982). Fat deposition and length of stopover of migrant white-crowned sparrows. *The Auk* 99: 725-732.

Randler C. (2021) Users of a citizen science platform for bird data collection differ from other birdwatchers in knowledge and degree of specialization. *Global Ecology and Conservation*. 27: e01580.

Collar, N. (2020). European Robin (*Erithacus rubecula*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

Dierschke, V. & Delingat, J. (2001). Stopover behaviour and departure decision of northern wheatears, Oenanthe Oenanthe, with different distances to migratory destination. *Behavioural Ecology and Sociobiology* 50: 535-545.

Duijns, S., Jukema, J., Spaans, B., Horssen, P., & Piersma, T. (2012). Revisiting the proposed leap-frog migration of Bar-tailed Godwits along the East-Atlantic Flyway. *Ardea*. *100*: 37–43.

Eck, S., Fiebig, J., Fiedler, W., & Bernd, H., Bernd, I., Bernd, N.,Töpfer, T., van den Elzen, R., & Woog, F. (2011). Measuring Birds – Vögel Vermessen. Deutsche Ornithologen-Gesellschaft. Wilhelmhaven. 118 p.

Eeva, T., Veistola, S., & Lehikoinen, E. (2000). Timing of breeding in subarctic passerines in relation to food availability. *Canadian Journal of Zoology*. 78: 67–78.

Eikenaar, C., Klinner, T., de Lille, T. et al. (2014). Fuel loss and flexible fuel deposition rates in a long-distance migrant. *Behavioural Ecology and Sociobiology.* 68: 1465–1471.

Greenwood, J.J.D. (2207). Citizens, science and bird conservation. *Journal of Ornithology* 148: 77–124.

Gordo, O. & Sanz, J. J. (2008). The relative importance of conditions in wintering and passage areas on spring arrival dates: The case of long-distance Iberian migrants. *Journal of Ornithology*. *149*: 199–210.

Hatchwell, B. (2020). Dunnock (Prunella modularis), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

Hüppop, O., & Hüppop, K. (2003). North Atlantic Oscillation and timing of spring migration in birds. *Proceedings of the Royal Society B: Biological Sciences*. *270*: 233–240.

Jenni, L., Reutimann, P. & Jenni-Eiermann, S. (1990). Recognizability of different food types in faeces and in alimentary flushes of Sylvia warblers. *International Journal of Avian Science*. 132: 445-453.

Jenni, L. & Schaub, M. (2003). Behavioural and Physiological Reactions to Environmental Variation in Bird Migration a Review. *Avian Migration.* 6204:155–171.

Kelling, S., Fink, D., La Sorte, F.A. *et al.* (2015). Taking a 'Big Data' approach to data quality in a citizen science project. *Ambio* 44: 601–611.

Keyes, B. E. & Grue, C. E. (1982). Capturing Birds with Mist Nets: A Review. *North American Bird Bander.* 7:2–14.

Kuenzi, A.Y., Moore, F. R. & Simons, T.R. (1991). Stopover of Neotropical landbird migrants on East ship Island following trans-Gulf migration. *Condor.* 93: 869-883.

Loria, D. & Moore, F. R. (1990). Energy demands of migration on red-eyed vireas, *Vireo olivaceus*. *Behavioural Ecology* 1: 24-35.

Marra, P. P., Francis, C. M., Mulvihill, R. S. & Moore, F. R. (2005). The influence of climate on the timing and rate of spring bird migration. *Oecologia*. 142: 307–315.

Martens, J. & Päckert, M. (2020). Goldcrest (*Regulus regulus*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA.

Mehlman, D. W., Mabey, S. E., Ewert, D. N., Duncan, C., Abel, B., Cimprich, D., Sutter, R. D. & Woodrey, M. (2005). Conserving Stopover Sites for Forest-Dwelling Migratory Landbirds, *The Auk*. 122(4) 1281–1290.

Maggini, I., Trez, M., Cardinale, M. et al. (2020). Stopover dynamics of 12 passerine migrant species in a small Mediterranean island during spring migration. *Journal of Ornithology*. 161: 793–802.

Martin, T.G., Chadès, I., Arcese, P., Marra, P. P., Possingham, H.P., et al. (2007) Optimal Conservation of Migratory Species. *PLOS ONE* 2(8): e751.

Moore, F.R. & Kerlinger, P. (1987). Stopover and fat deposition by notrth American wood-warblers (Parulidae) following spring migration over the Gulf of Mexico. *Oecologia* 74: 47-54.

Moore, F. R., (2000). Stopover Ecology of Nearctic-Neotropical Landbird Migrants: Habitat Relations and Conservation Implications. *Journal of Wildlife Management. 65(2):368*

Morris, S. R., Holmes, D. W. & Richmond, M. E. (1996). A ten-year study of the stopover patterns of migratory passerines during fall migration on Appledore Island, Maine. *Condor* 98: 395-409.

Musseau, R., Herrmann, V., Bénard, S., Kerbiriou, C., Herault, T. & Jiguet, F. (2014). Ecology of Aquatic Warblers Acrocephalus paludicola in a Fall Stopover Area on the Atlantic Coast of France. *Acta Ornithologica*. 49(1): 93-105.

Safriel, U. N. & Lavee, D. (1988). Weight changes of cross-desert migrants at an oasis – do energetic considerations alone determine the length of stopover? *Oecologia* 76: 611-619.

Schaub, M. & Jenni, L. (200). Fuel deposition of three passerine bird species along the migration route. *Oecologia* 122: 306–317.

Schaub, M., & Jenni, L. (2001a). Variation of Fuelling Rates among Sites, Days and Individuals in Migrating Passerine Birds. *Ecology*. 15: 584-594.

Schaub, M., & Jenni, L. (2001b). Stopover durations of three warbler species along their autumn migration route. *Oecologia*. *128*: 217–227.

Sillett, T. S., & Holmes, R. T. (2002). Variation in survivorship of a migratory songbird throughout its annual cycle. *Journal of Animal Ecology*. 71: 296–308.

Smith, S. B. & McWilliams, S. R. (2010). Patterns of Fuel use and Storage in Migrating Passerines in Relation to Fruit Resources at Autumn Stopover Sites. *The Auk*. *127*: 108–118.

Szostek, K. L., Bouwhuis, S. & Becker, P. H. (2015). Are arrival date and body mass after spring migration influenced by large-scale environmental factors in a migratory seabird? *Frontiers in Ecology and Evolution*. *3*: 42.

Weisshaupt, N., Lehikoinen, A., Mäkinen, T. & Koistinen, J. (2021) Challenges and benefits of using unstructured citizen science data to estimate seasonal timing of bird migration across large scales. *PLOS ONE.* 16(2): e0246572.

White, T.C.R. (2008), The role of food, weather and climate in limiting the abundance of animals. *Biological Reviews*. 83: 227-248.

Yom-Tov, Y. (2001). Global warming and body mass decline in Israeli passerine birds. *Proceedings of the Royal Society of London. Series B: Biological Sciences*. *268*: 947–952.

Appendix I: Ringing Guidelines

General guidelines

Please find in this document the general guidelines for ringing in Blaavand. As the ringing of birds is part of a scientific program, it is important that every ringer comply with these guidelines and let the ringing responsible know if you stray from these. Here is the general list of guidelines:

- Ringing at Blåvand Bird Station must at all times take place within the framework of the applicable regulations, and it is at all times the welfare of the birds that comes first.

- In the spring, ringing takes place from 1st of March to 15th of June and in autumn from 20th July to 15th November. These are the standard periods for the ring marking.

- The nests are op a minimum of five hours a day. If there is conditions and energy for more, the ringing may be continued beyond the five hours, but all birds ringed beyond the standard period must be noted as “not standard time” in the database.

- Before setting the net, check the weather on DMI (or other relevant weather services) and not least the precipitation radar. If there is precipitation nearby, no, or only a few nets are opened, as the showers can be quite powerful and quickly cost birds lives. If the wind is strong, you may only open the nets that are sheltered - or none at all. The birds must not be harmed!

- Opening the nets begins in the station garden and ends with the lighthouse garden. The last net must be opened ½ hour before sunrise.

- The nets are emptied at least every ½ hour. However, up to an hour can usually go by without the birds being harmed (good weather conditions). If it is cool or windy, the nets are checked more often. If there is drizzle in the air, you must be above the nets constantly. Especially on days with many Goldcrests, it is a good idea to go more frequent rounds. If there is a lot of wind in the nets, it can also exhaust the birds, which is why in such situations you also have to walk more often. If in doubt, consult the station manager.

- If there is death or damage to the birds in the nets, this must be noted, and the cause must be stated. E.g. taken by a fox or bird of prey, bird in poor condition (fat score), net problems or the like.

- In order for the day's catch to be included in the standard program, a minimum of 60 net meters must be open during the five standard hours. If the nets must be closed after four hours due to increasing bad weather, a shower or other events, the marking can still be used as standardized data. Are the nets closed within the five hours due to bad weather or other incidents, but is opened again before an hour has passed, the results (numbers) can also be included in the standard program.

- The vegetation and grass around the nets are trimmed and mowed regularly, so that the catching conditions are as optimal as possible at all times.

- The day's ring marking is entered into the ring database, preferably every day, so that the risk of errors is minimised.

Opening the nets

Before opening any net, please make sure the weather conditions are good enough for capturing birds. Winds should be less than 9 m/s in mean wind and there should be no or only a little precipitation (<0,2 mm pr. hour). If conditions are not acceptable, there will be no ringing. If the weather is not acceptable from the morning, but improves during the day, the ringing can the postponed. The same goes for the situation where weather is good from the morning but turns bad during the day – then the nets must be closed.

The nets should be open and ready for operation 30 minutes before sunrise. Start opening the nets around one hour before sunrise on the given day or make it fit with your speed and experience in ringing with mist nets.

The nets should be clean, tight and without holes. If there are dirt, branches, leaves or other things in the nets, please remove it. If the net is loose, please tighten it using the line and plug/peg. If there are holes, please maintain the net using needle and thin black thread. If the net is in too bad shape, please replace it.

In the Helgoland trap, release the plates at the end and close the door is the birds can fly into the capture box.

Ringing in operation

When ringing birds, you have a huge responsibility in making sure no bird is injured or neglected. Also, you must follow the rules based on your Danish ringing license level:

- A- or B-license: you can ring completely on your own with no supervision.
- C-license: you can ring completely on your own, but under responsibility of a A- or B-license holder. Please contact the responsible person if you have any trouble.
- X-license: you can only handle and ring birds when a A-, B- or C-license holder is present. There will be absolutely no ringing without the right license holder is present.
- If you have no valid license, you cannot handle, hold, or ring any birds. But you can watch and learn.

By the Danish ringing/banding rules, it is required that the nets are inspected every 30 minutes, but they can be inspected with one-hour intervals without damage on the birds. For rounds with more than 20 birds, this is impossible to uphold, and you can consider the weather conditions. If the weather conditions are less good, you will need to collect less data from each bird or call for help. If the conditions are good, the inspection frequency can be reduced a bit. Read the chapter about “in case of fallout” for how to prioritize the data.

The two gardens

Ringing is conducted in two gardens around Blåvandshuk: the station garden and the lighthouse garden. As standard, both gardens should be operated. On days with uncertain weather conditions, the station garden could be operated as the only one, as you can easily open and close the nets.

Each garden has its own ringing lab. When ringing, the birds are collected in bags and brought to the individual ringing labs for processing. Make sure to bring enough bags and make sure the bags are clean and dry. If a bag becomes dirty, put it aside and wash it along with other dirty bags, as often as needed.

To make it easier for the processing, you can use a colour of bag, corresponding to the saze of ring, the given bird need.

Processing the birds

In the ringing labs, each bird is processed, and data is collected neatly:

- Species
- Age (if possible)
- Sex (if possible)
- Wing length
- Weight
- Fat score
- Muscle score

It is your responsibility as a ringer to acquire the needed competences for processing the birds. If you are not confident, please let the station ringing responsible know.

Start by putting a ring on the bird, so it is ringed in case it escapes. Choose the right ring size based in the overview. Some birds can fit two different ring sizes, depending on the individual size (e.g., greater whitethroat), but almost every species fits only one ring size.

Use relevant literature to age and sex the bird. The rest is standard for every bird.

Data entry system

There is one white binder for each ringing lab/garden that contains all the data schedules. There is one sheet for each ring size and this sheet contains all the fields you will need to fill. There is also a separate sheet for recaptures. When one sheet is full, you will find new, empty sheets in the back of the binder. If you are running low, print new ones or ask the ringing responsible to do so.

You find the ring protocols here.

Preferable, all ringing data is entered in the digital ringing database every day. This is to distribute the workload over more days and to ensure data quality.

In case of fallout or just many birds

A few times pr year, we experience days with a lot of birds. On these days, it is important that you adjust the processing to the number of birds. In case of fall out (>100 birds pr. hour), call all relevant personnel to the gardens for help. They must also possess a valid ringing license to help.

The priority of data for each bird is:

1. Species
2. Age
3. Sex
4. Fat score
5. Wing length
6. Weight
7. Muscle score

Typically, fall out include single species, e.g., Robin, Willow Warbler or Goldcrest, in which case you can take a full ring sting, and extract and ring the birds at the nets. Use one individual ring series for each species.

It is also an option to close the net, when it is empty to prevent more birds to fly in.

Species that require extra focus

Fast handling

When catching Bullfinches, it is important to handle them quite fast and not to squeeze the bird too hard. They are quite fragile and can easily die in the hand if you are not careful.

Birds with thin legs

Some species have very thin legs compared to the power of the wings. It is important that you do not hold these species in the legs along but use another grip, also in case of presentation of the bird. This includes the following species(groups):

- Waders
- Owls
- Raptors
- Rails
- Cuckoo
- Nightjars
- Kingfishers
- Bee-eaters
- Swallows
- Flycatchers

Dead birds and their rings

If you ring a bird and it dies in the process, you should take off the ring and reuse it again on the same day. If you find a dead bird with a ring from another day on in the ringing or a member of the public brings a bird to you that they found, you leave the ring on and enter it as recapture. If the ring is from the same day, you should reuse it otherwise enter it as recapture.

Registering dead or injured birds

If a bird is dead or injured during the ringing activities, it must be noted. Please use the form for the current year, found in this folder. Fill out all relevant information directly into the online form. Dead birds may be put in a plastic bag with a note slip including species, date, and information about sex/age. The bag with the bird is then put in the big freezer in the tool shed.

Closing the nets

When you are done with the ringing for today, all nets must be neatly closed so no bird can be trapped in the nets when absent.

Join all the side nooses around the line knot on the metal pole. Now lift the top noose around 15 to 20 cm up in both ends of the net. Wrap the excess netmasks into the nooses, so it does not flap. Not roll the net masks into the top field using circular motions. Close the top field in both ends and give the net another couple of rolls. The net should now look like a uniform black, tight sausage.

In the Helgoland trap, close the two plates and open the door at the end, so every bird can easily pass through the trap.

Make sure all nets are close properly, e.g., by walking the same way back. Leaving just one net open could be catastrophic.

Appendix II: Muscle score

score class **0**:
sternum sharp,
muscles depressed

score class **1**:
sternum easy to distinguish
but not sharp;
muscles neither depressed nor
rounded

score class **2**:
sternum yet distiguishable,
muscles slightly rounded

score class **3**:
sternum difficult to distinguish
due to rounded (full) muscles

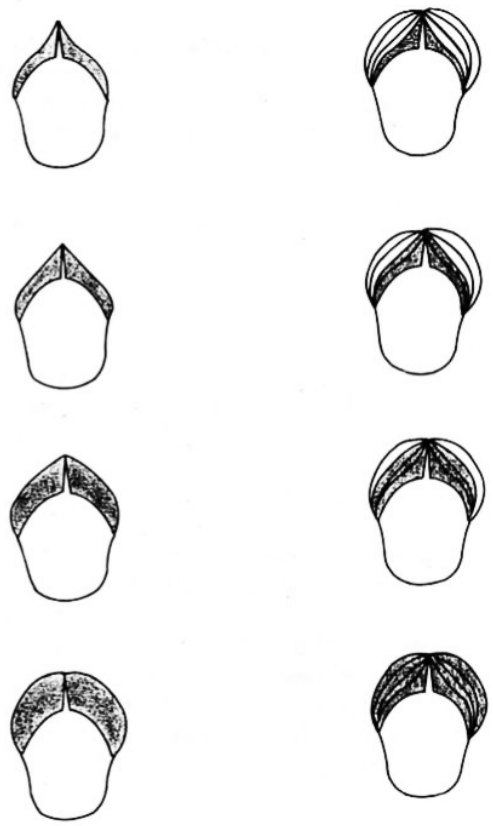

Figure 4: Taking the muscle score. The right column shows the relative difference between the scores. The stippled area are the muscles.

Appendix III: Fat score