Dunlin Report

Growth and development of head started southern dunlin (*Calidris alpina schinzii*) chicks from egg till fledgling

Figure 1 Southern dunlin (Calidris alpina schinzii)

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NORDENS ARK

Growth and development of head started southern dunlin (Calidris alpina schinzii) chicks from egg till fledgling

A study on the development of southern dunlin chicks in captivity

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Preface

After previous collaboration with Nordens Ark in 2019, I decided to reach out again in 2024 for another opportunity. I was able to join the southern dunlin project in 2025. This bird is an endangered species, and I have a great interest in endangered species. That I could combine it with this school assignment was ideal.

Due to missing data on chick weight from 2023, invalid beak length to determine gender and complications in the analysis of embryo development, parts of my research could not be fulfilled. This caused me a lot of unrest for the final report because I didn't know if it would be enough.

I never anticipated how much time the data analysis would take me. If I knew then what I know now, I would already have started in 2019. I would like to thank Henry Kuipers for guiding me with RStudio and for the patience during our meetings.

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1. Introduction

This chapter describes the reasons for the poor condition of the southern dunlin (Calidris alpina schinzii) population and the efforts being made by Nordens Ark to restore it. It also explains the goal of the project and the research questions.

1.1 Introduction text

Biodiversity is declining worldwide, and more species become endangered or go extinct as time goes by. Great numbers of multiple wading bird species in Europe are strongly declining, including in Sweden (Roodbergen et al, 2012). Over the past years, the number of animal species on the Swedish red list has increased by 11%, especially wading bird species are declining (Projekt sydlig kärrsnäppa, n.d.). The southern dunlin (Calidris alpina schinzii) is one of those wading bird species, that breed on the ground, which is considered critically endangered on the Swedish red list (SLU Artdatabanken, 2020). Habitat loss and predation are major factors on why this bird is disappearing.

Öland has the largest remaining southern dunlin population in Sweden. For coastal meadowland habitats in Sweden, the southern dunlin serves as a flagship species (Projekt sydlig kärrsnäppa, n.d.). In 2005, the species was considered endangered and has been critically endangered since 2010, which shows the ongoing decline of the population (SLU Artdatabanken, 2020). To stop this negative trend, Nordens Ark in cooperation with Birdlife Sweden started the Southern Dunlin project in 2022 on Öland to save the bird species from extinction through habitat restoration and rearing chicks (head starting). By saving this species and improving the breeding grounds, biodiversity along with other coastal meadow species will benefit (Projekt sydlig kärrsnäppa, n.d.).

Because the eggs and chicks of these birds are hand-reared, it provides the opportunity to study this bird closely in its early life stages and look at the development of the eggs and chicks. According to Ms. Karin Amsten (personal communication, March 4, 2025), it is important to collect as much data as possible because this project with this species has not been done before. The size of an embryo indicates the age of an egg and with the weight of a chick you can determine the growth rate. The more we understand about this bird the better we can help it recover. This research could not be conducted in the wild because it would be too intensive and disruptive to the southern dunlin and the environment.

1.2 Organisation

Nordens Ark is a not-for-profit foundation with a zoo, founded in 1989. Their office is in Sweden where they work with endangered animal species, but they also have projects in foreign countries. Their work consists of breeding and rearing, nature conservation, education and conducting research (Nordens Ark, n.d.). They run multiple conservation projects involving mammals, insects, reptiles, amphibians and birds.

1.3 Problem analysis

The adult survival of the southern dunlin population in the Baltic region has been rapidly declining between 1990 and 2006 (Pakanen & Thorup, 2016). Chick survival has strongly declined in Scandinavia between 1985 and 2005 (Roodbergen et al., 2012). Predation on nest and chicks, nest destruction and chick mortality have major consequences for the southern dunlin (Pakanen & Thorup, 2016). On Öland the predation is still a big problem, around 50 90% of the wading bird eggs and chicks fall prey to predators by jackdaws, crows, foxes, badgers and mink (Projekt sydlig kärrsnäppa, n.d.). The population will continue to decline if there are not enough chicks who survive to match the number of adult mortalities.

The landscape type in which the southern dunlins breed are coastal open wetlands with short vegetation (SLU Artdatabanken, 2020). Human activity has altered these environments, through agricultural changes such as drainage. This has led to habitat destruction and fragmentation, which has had a major impact on landscapes inhabited by the southern dunlin. (Pakanen et al., 2017). The fragmented populations are less likely to exchange genes with one another which increases the chance of genetic diversity loss and inbreeding, which then can lead to extinction. (Blomqvist et al., 2010).

It is important that the male-female ratio of the breeding population is balanced. If there are fewer individuals of one gender, fewer breeding pairs will be formed, resulting in fewer eggs being laid and that means less numbers added to the already declining population. The number of remaining breeding pairs on Öland in 2024 was estimated to be between 35 and 40 pairs (Nordens Ark & Birdlife Sverige, 2023). It is a very small population and that's why it's important that Nordens Ark started the project.

1.4 Southern dunlin project

The southern dunlin project consists of four main activities (Nordens Ark & Birdlife Sverige, 2023).

- Improve the natural environment in which they live by predation control and restoring habitat.

- Breeding and rearing chicks by using the conservation method head starting.

- Monitoring nest sites and birds to gain more knowledge.

- Educating people and providing information on the distribution of the southern dunlin and the importance of wetlands to our ecosystem.

1.4.1 Improve the natural environment

Currently most of the breeding pairs are found on the south of Öland. The environment of the southern plateau of Öland has changed from a barren landscape with high grazing density to an area that is mostly covered with bushes, shrubs and rows of trees. That doesn't match the demand of the coastal open wetlands with short vegetation that is needed for the southern dunlin. Due to these changes, breeding pairs no longer breed in places that deviate too much from the ideal environment. (Projekt sydlig kärrsnäppa, n.d.).

To reverse this trend, the southern dunlin project has jointly funded a wetland project in 2024. An area on southeast Öland where the southern dunlin has been breeding in the past is now transformed into a suitable landscape again. Unwanted vegetation is removed, and multiple actions have been taken to keep water as long as possible to create wetlands. (Projekt sydlig kärrsnäppa, n.d.).

Besides restoring wetlands, predators must also be tackled. The project works with local hunters who actively hunt and place traps to reduce predation numbers. Predation control also involves removing trees and shrubs to reduce the suitable habitat for predators. ‘‘By reducing predation pressure, significantly more chicks survive to adulthood, and at the same time, more vulnerable species of waders in the same habitat also benefit’’ (Projekt sydlig kärrsnäppa, n.d., p. Why predator control?).

1.4.2 Breeding and rearing chicks by using head starting

“Head starting is a conservation technique that involves rearing newborn animals in enclosures for the duration that they are vulnerable to mortality that young animals encounter in the wild” (Thomas et al., 2019). Within the project it involves collecting eggs from wild breeding pairs to incubate them and raise the chicks in a safe environment. Predators, food availability, poor weather conditions (in the egg phase) and other environmental factors have little to no effect on the eggs and chicks in these safe environments, which will increase their survival chance during the most critical period.

When the chicks are old enough and ready to fly, they are released into the wild again. The goal of the project is to increase the number of fledge chicks to halt the decline and hopefully stabilize the wild population. Head starting have been used successfully on several wading bird (Loktionov et al., 2023) but this is the first time the method is used on the southern dunlins.

It is possible for the breeding pairs from which the egg clutches were taken to lay a second clutch, as they would if a predator destroyed the nest (Loktionov et al., 2023). This means that more eggs are laid, which increases the chance of more chicks surviving and population growth.

After the head started birds are released, they will migrate to the south. They stay around two years in the winter location before returning to the breeding grounds. This means that in 2025, the first head started birds from 2023 will be able to return to Öland (Nordens Ark & Birdlife Sverige, 2023).

In 2025, blood samples will be collected for the first time to determine gender and do research on genetics. The species is at risk of genetic drift and genetic loss due to their small population size what could lead to extinction of the population (Frankham et al., 2012). By determining the gender of the chicks, you get a possible picture of the ratio between male and female for a part of the breeding population in 2 years. Ideally it would be in balance. But if one gender is much less present, then that may predict a less successful breeding year in the future.

Beak length, figure 2, is said to be a way to figure out if a southern dunlin is male or female. The beak of a female is supposedly longer than the beak of a male (Malick Wahls et al., 2024). Within the project, this theory will be supported by the results of the bloodwork which can determine the gender. Once the gender is determined, difference in growth between male and female can also be studied. It will unfortunately take to long for the blood samples to return from the lab to use the results in this report. Therefore, assuming that the beak length theory is correct, the relation between weight and beak length will be studied.

Figure 2 Measuring the beak length

1.4.3 Monitoring nest sites and birds

Specialists are dispatched into the field to find the southern dunlin and locate the nests. The eggs that will not be collected are monitored throughout the hatching period and until the moment they fledge. Nest-, hatch- and fledge success will be noted.

If possible, the breeding pairs will be ringed to be able to follow them throughout the breeding period. Identifying the breeding pair gives the opportunity to be able to tell if they lay a second clutch of eggs if the first nest failed. It could also prevent that second clutches are collected for the project to hatch which is not the intention.

The chicks that are reared within the project get a usual bird ring and rings that are from the project. This way each chick has an individual ring combination so you can tell them apart and follow the growth and return of each individual chick (Projekt sydlig kärrsnäppa, n.d., p. Ringing of chicks).

1.4.4 Education people and providing information

Wetlands are not only particularly important for the southern dunlin but for many more species. The project wants to increase public awareness of the conditions of the wetlands and their inhabitants like waders, figure 3. In the zoo of Nordens Ark, there is a corner created near other birds in the park that has information about the southern dunlin project on Öland, figure 4.

On Öland itself there is information about the project in a visitor centre in Ottenby where the chicks also will be released in a nearby area. Both Nordens Ark and Birdlife Sweden give lectures and are present at events to talk about the project and share knowledge (Projekt sydlig kärrsnäppa, n.d., p. Information and education).

Figure 4 Information board about wetlands in Nordens

Figure 3 Information board about the southern dunlin in Nordens ark

1.5 Goal

The aim of this study is to gain as much insight as possible into the growth and development of head started southern dunlin chicks, reared in captivity. As this has not been done before, it is important to collect this data to create a baseline.

1.6 Research question

Main question: How do head started southern dunlin chicks develop in captivity?

Sub-question 1: How do southern dunlin eggs and embryos develop?

Sub-question 2: What is the growth rate of the southern dunlin chicks?

Sub-question 3: What is the relationship between beak length and weight?

2. Project approach

This chapter describes the research area and population. It also discusses the research method, data collection and analysis.

2.1 Study area

Öland is an island and contains the largest number of remaining breeding pairs of the southern dunlin in the country. The size of the island is 1.342 km2 and located in the Baltic Sea, southeast of Sweden. It has a flat landscape that is covered with wetlands despite the dry conditions, it has a limestone soil, waterbodies and is covered 63% by the agricultural sector (Seiferth et al., 2024). The northern part of the island is more overgrown and has more forest patches.

The number of remaining breeding pairs in 2024 was estimated to be between 35 and 40 pairs that were in the remaining open coastal meadows of Öland (Nordens Ark & Birdlife Sverige, 2023). The study collects data from 3 locations: Ottenby nature reserve, Stora Ören bird sanctuary and Beijershamns nature reserve (figure 2). Beijershamns nature reserve is a new location this year, meaning that no nests were collected from this place in 2023 and 2024.

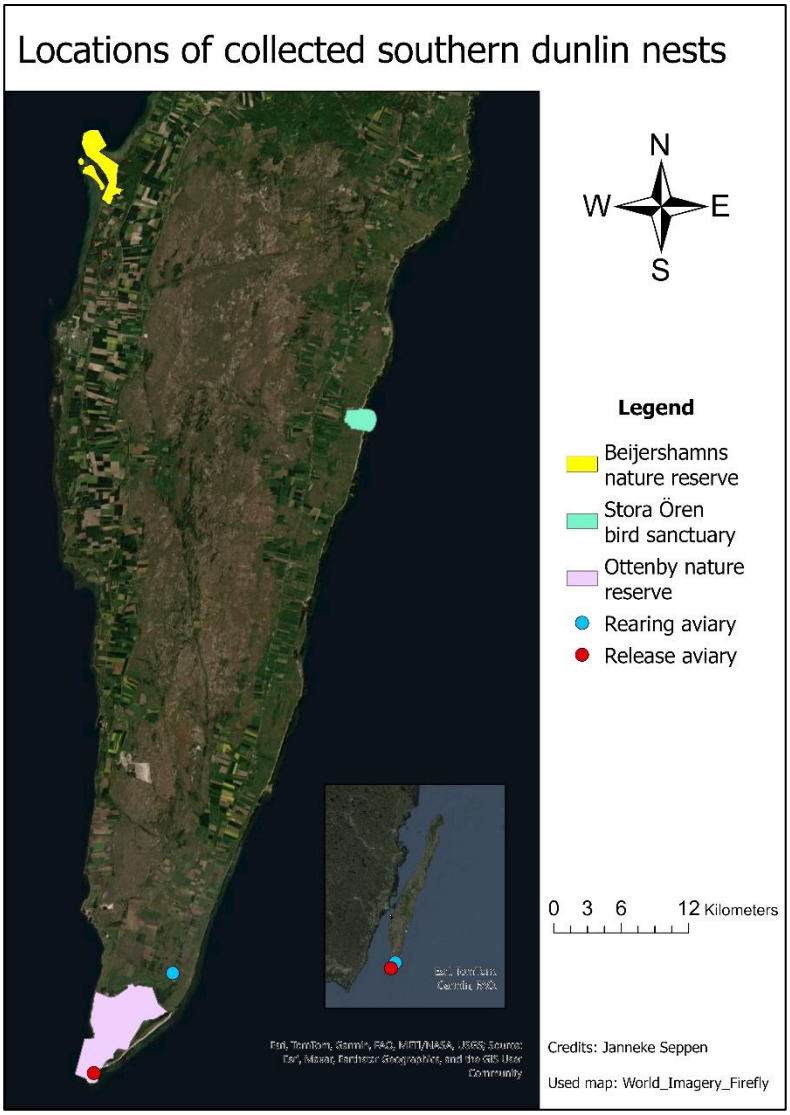

Figure 5 Locations of collected southern dunlin nests on Öland

2.2 Research method

All eggs will be collected from three locations on Öland: Ottenby nature reserve, Stora Ören bird sanctuary and Beijershamns nature reserve. All found clutches from the southern dunlin with four eggs will be collected. If a nest has fewer eggs, the nest is monitored until there are four eggs to be collected. Except for incomplete nests that have been abandoned or damaged by predation. There is a chance that the embryo in the eggs is still alive and will therefore also be collected. When a nest is from a different species, the nest remains untouched.

In 2023, fourteen breeding pairs were seen in total during the entire breeding season. Six clutches (twenty-four eggs) were collected at the beginning of the breeding season, fourteen chicks were released. In 2024, nine clutches (thirty-six eggs) were collected, and twenty-six chicks were released. This year it is expected to collect between nine and eleven clutches (thirty-six / forty eggs). The previously gathered data from 2023 and 2024 will be used in this research. The data collected from the previous two seasons will be analysed and each year compared to each other. Beak length, weight and gender will be compares to each other to find a possible relation between them.

Around the same time of day, eggs will be weighted every day and candled every other day to monitor vitality and embryo growth. During the candle sessions, pictures are taken of the embryo to later study the development. Of all chicks, weight will be taken until they are moved outside, then only half of the chicks will be weighed until they are relocated again. This will be done with half of the sample size because weighing can cause some stress and that can in turn affect the weight. The heaviest and lightest chick of each clutch from the moment they hatch will be taken for these measurements to capture the outlines. On the day the chicks are relocated, all of them will be weighed to observe any possible difference. The chicks will all be released on the south of Öland in Ottenby nature reserve.

2.3 Data collection

Each year the data collection takes place between April and June. Eggs were collected in April and May. The weight is measured in May and June. Near the end of June, all chicks have been released. The collection of the data has been done by a small group of people who each had their own task in collecting it. Dick Liljegren took the responsibility to weight and measure the eggs, candle them and take the beak length of the chicks. Julia Westergren took the responsibility of taking the pictures of the embryo’s and Janneke Seppen took responsibility of weighing the chicks. Usually, more than one person was present during the data collection. Everyone was aware of how to collect all the data in case someone had to step in for another.

The collected eggs will be measured once to determine the length and width. The weight of the eggs will be measured every day until they pip. First, they make an internal pip to break through the air sack which is not visible from the outside, then they will break through the eggshell. The first pip in the eggshell is barely noticeable because of the micro cracks in the shell. However, it causes to lose more weight after pipping so therefore weight can indicate when the pipping has begun.

Five days after the egg is laid, development of the embryo becomes visible by candling which will be done every other day until the egg starts to pip. After day fifteen, development will be more difficult to see, as the chick is almost fully grown and only a black mass is visible. Monitoring of the candling will be done with pictures to compare embryo size with the age of the egg.

When an egg made the first pip, it is moved from the incubator to the hatcher. When it starts to show signs of hatching, it is monitored until the chick is out of its shell. In the previous two years, similar data was collected, except embryo development is now being examined more closely.

The beak will be measured twice: once directly after hatching and again when they are moved to the release aviary at approximately 15 days old. Measuring the beak is a new addition to the project. Beak length might indicate the gender of the birds, as females have on average longer beaks than males (Malick-Wahls et al., 2024). This hypothesis can be tested through blood samples from the chicks. Knowing the gender of the chicks is important to determine the survival between male and female, is there a difference in growth rate between them? If significantly more individuals are released from one gender compared to the other gender, it could indicate that in two years when the birds return the breeding population is of balance. In the future of the project, the gender of the head started birds that return can be used to calculate survival rates between males and females.

Unfortunately, these samples will not return in time to be included in the report but will be analysed by Nordens Ark afterwards. Therefor gender is not a part of the sub-question: What is the relationship between beak length and weight? However, the beak length and weight can be compared to each other to determine whether there is a relationship between those factors. Do birds with a longer beak (possibly females) also have a different growth rate than the ones with a shorter beak (possibly males)?

When the chicks hatch, their weight will be recorded every day for five days when they remain in an inside enclosure. Chicks from the same clutch are kept together during the study and will receive coloured rings to identify individuals. After those five days inside, the chicks are moved to an outside enclosure where they will remain for approximately ten days. Previously they would stop weighing the chicks once they go outside but now a selected few individuals (heaviest and lightest) from each clutch will still be weighed until they will be moved to the release aviary after those ten days. In the release aviary, no study will be done and the contact with humans is limited. After five to seven days, the doors of the release aviary will be opened for the birds to leave. No pressure is applied to get the birds out of the aviary, they can fly independently.

For two weeks, the released birds are observed to see how they adapt to the wild. It is noted when they were last seen on the breeding ground since they will migrate south and stay there for approximately two years. When a head started bird is spotted it means that it was at least alive around that time. If it is not spotted it could mean the following: the bird is predated, the bird has migrated or the bird is still present but not observed. The same has been done in the previous 2 years. The actual survival of the head started birds can be determined when they return to the breeding area. It is the first year to possibly see the return of the head started dunlins in 2025, it is yet too early to determine whether this conservation method is successful in the long term.

2.4 Data analysis

All data analyses were performed in RStudio.

2.4.1 Embryo development

To measure embryo development, the surface area and area occupied is calculated. The area occupied by the embryo will be converted to percentage. The average cover on every other day is calculated to get an idea of the growth rate within the egg that does not include weight.

2.4.2 Egg weight

Only the eggs that survived will be included in the analysis. Individual chick weight from each individual year will be analysed and an average will be calculated. The same will be done from all years combined. A confidence interval of 95% will be calculated over the average egg weight. An exponential decay model is used to calculate the significance of the daily decline of egg weight from all years.

To calculate the average chick weight in Rstudio, formula sample mean is used, equation 1.

1 Formula sample mean

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

To calculate the confidence interval of 95% in RStudio, formula Student's t confidence interval for the mean is used, equation 2.

2 formula Student's t confidence interval

$$\mathrm{CI}_{95\%} = \bar{x} \quad \pm \quad t_{0.975,\, n-1} \cdot \frac{s}{\sqrt{n}}$$

2.4.3 Chick weight

Only the chicks that survived were included in the analysis. To calculate chick development, weight and age will be used to make a growth model. The Gompertz growth model will be used to calculate age-specific mass in grams by: M = A·exp(−exp(−K·(t−i))) (Saalfeld et al., 2024). The results of the growth rate can help future projects on southern dunlins. This data is not ethical to obtain in the wild since it will cause a major disturbance to the breeding birds and surrounding area. However, when age needs to be determined from a wild chick, these results may give a good estimate.

2.4.4 Beak length

A study of two Dunlin populations in Norway in 2024 showed that bills over thirty-two mm were always female in one population and in the other population over thirty-four mm. "However, they should not be applied indiscriminately to Dunlins elsewhere, as the species is too morphometrically variable for the relationships we report to hold across all populations" (Malick-Wahls et al., 2024). The results of study from Malick-Wahls will be used as a guideline and the blood test can confirm the results. Assuming it is correct, the difference in weight between male and female is analysed.

3. Results

In this chapter the results of the research are discussed and shown in various figures and tables.

3.1 Embryo development

Researching embryo development proved to be more difficult than anticipated. Unfortunately, it became so complicated that this part could not be included in the analysis.

3.2 Egg weight

From the twenty-four eggs that were collected, twenty hatched successfully. On average, chicks started pipping on day eighteen and hatched on day twenty-one. In figure 6 the average egg weight of 2023 is shown. Unfortunately, on May third, 2023, no egg weight was noted which causes the dent in the line. Most of the clutches were also added halfway because of incubation in the wild which creates data gaps in the beginning. In appendix 1, figure 14, is shown of all the individual eggs that hatched in 2023.

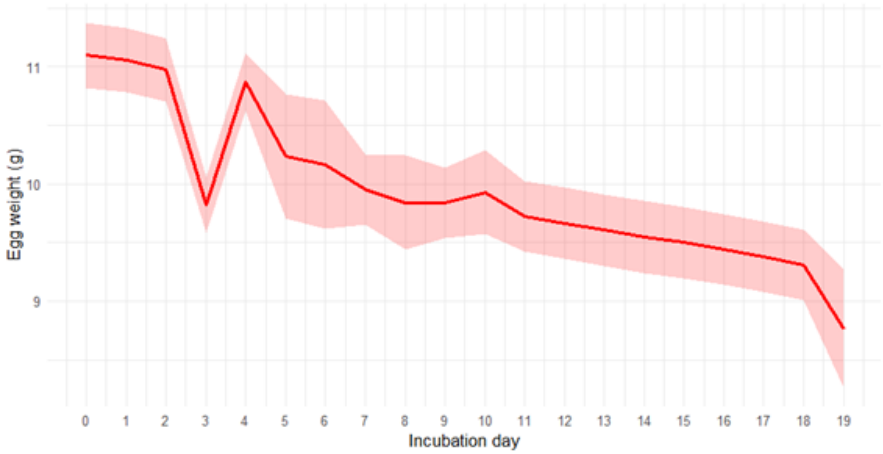

Figure 6 Average survived egg weight from 2023 (95% CI)

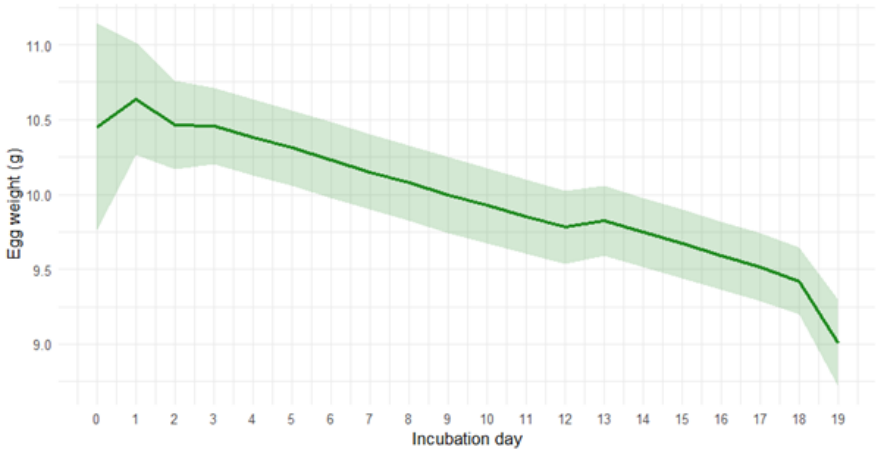

Figure 7 Average survived egg weight from 2024 (95% CI)

Both 2023 and 2024 show a dip in the line near hatching. This is the moment the chicks start pipping and making cracks in the eggshell what causes the weight to decrease faster. In 2024 all weight was correctly noted what causes the average line to be straighter but remains a nonlinear line, figure 7. Multiple clutches started between day zero and three, one clutch was added when it was at incubation day 13. This has effect on the average and is visible in the line. In appendix 1, figure 15 is shown of all the individual eggs that hatched in 2024.

In 2025 the nonlinear line goes up near hatching, figure 8. This is caused by some clutches that were predated and abandoned, therefore no longer incubated in the wild. When the temperature drops, the growth of the embryo slows down and can completely stop if it stays unattended. These eggs took a day longer to pip, most likely because of the unfavourable conditions. From the eight clutches collected, only three were complete and the other five had less than four eggs. The total number of eggs from these half clutches is twelve and eight managed to hatch. From those eight, five were able to be released. In appendix 1

figure 16 is shown of all the individual eggs that hatched in 2025.

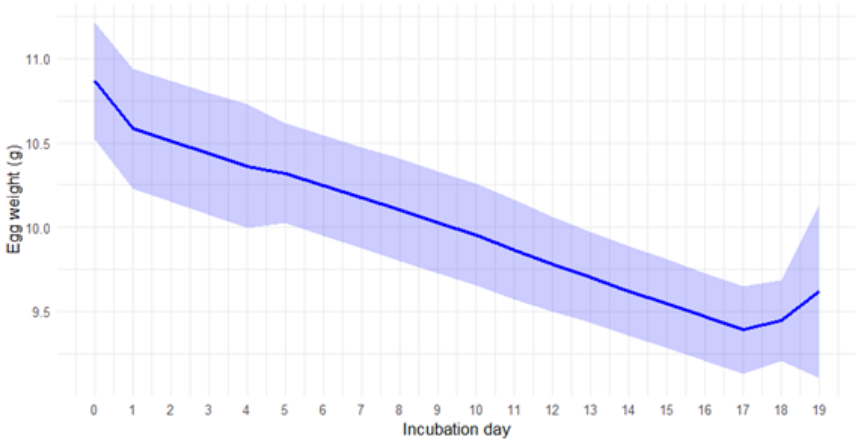

Figure 8 Average survived egg weight from 2025 (95% CI)

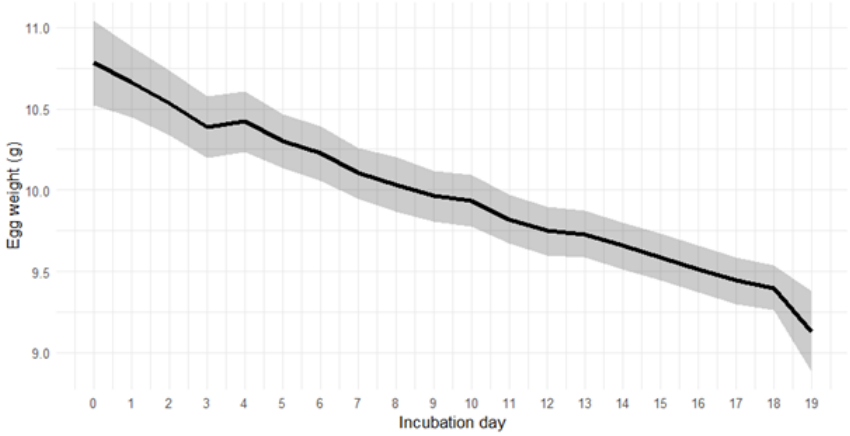

Figure 9 Average survived egg weight from all years (95% CI)

In figure 9 the average of all years combined is showed. It shows that the average initial weight of eggs is between 10,5 and 11 grams. In 2023 this was between 10,8 and 11,8 grams. 2024 has a bigger spread with 9,75 and 11,12 grams. In 2025 it was between 10,5 and 11,5 grams. In the appendix 1 figure 17 is shown of all the average lines without the 95% CI.

The exponential decay model shows that the daily decline of egg weight from all years is significant.

Parameters:

	Estimate	Std. Error	t value	Pr(>|t|)
a	10.688413	0.041033	260.48	<2e-16 ***
b	-0.007399	0.000346	-21.39	<2e-16 ***

3.3 Chick Weight

Chick weight from 2023 could not be provided to me, therefore chick weight is only analysed from 2024 and 2025. The date the chicks were ringed was recorded. These rings were weighed and subtracted from the weight of the chicks from the moment they wore them, so the weight of the rings was not included in the calculations. In 2024, the rings were approximately 0.9 grams, and in 2025, approximately 0.6 grams.

From the twenty-seven chicks that hatched successfully in 2024, twenty-six chicks survived and were released. In 2024 the last day that multiple weights were taken was on day eighteen, figure 10. There is one dot sticking out on day twenty-two, one individual was weighted that had some complications and was behind on weight.

From the twenty chicks that hatched successfully in 2025, fifteen chicks survived and were released. Despite there being more chicks in 2024, more measurements were taken in 2025, figure 11. In appendix 2 figure 18 is shown with the weight per day of surviving chicks from all years.

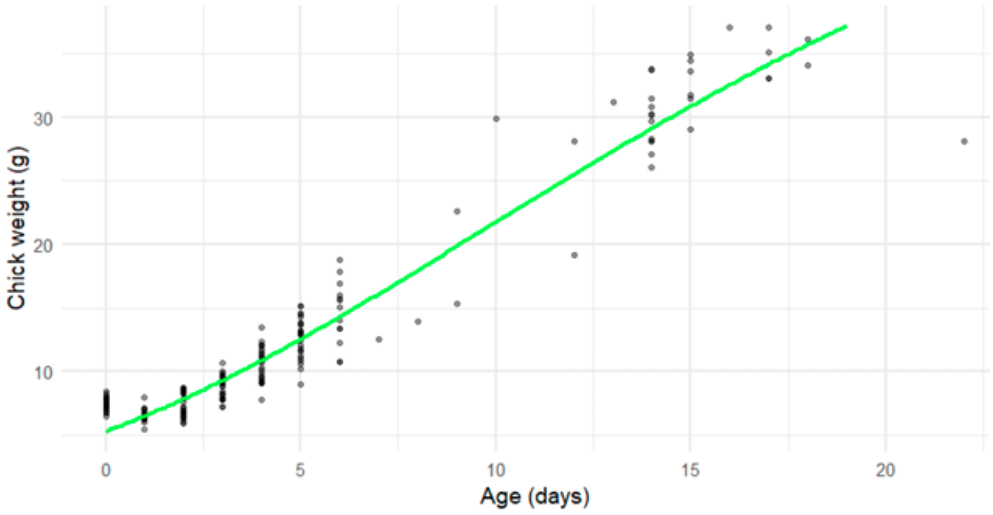

Figure 10 Average survived chick weight from 2024

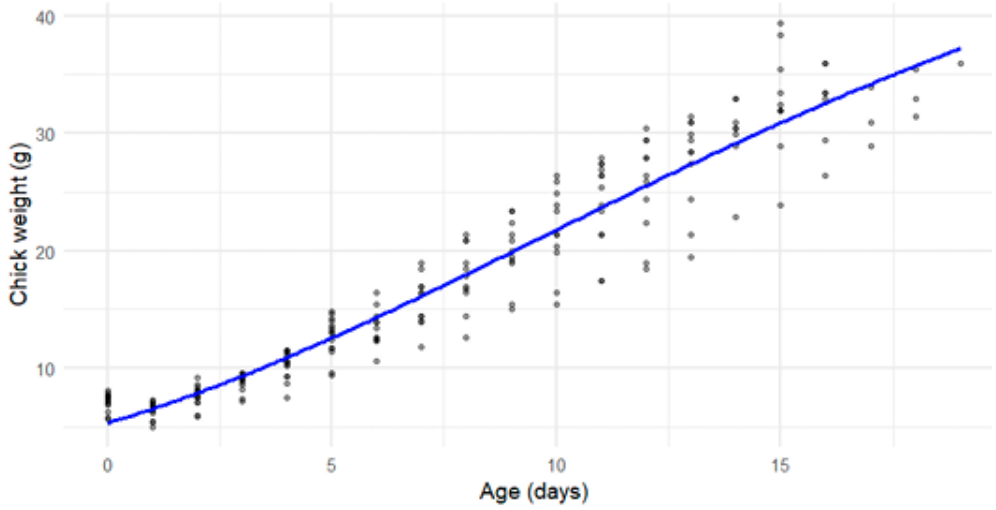

Figure 11 Average survived chick weight from 2025

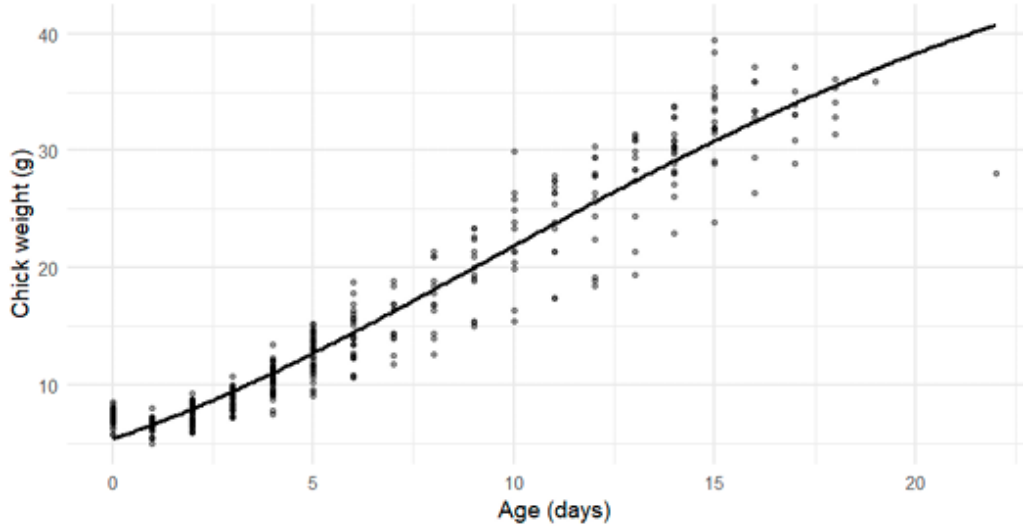

Figure 12 Average survived chick weight from all years

The chicks grow according to an S-shaped curve (Gompertz). They grow rapidly in the first few days, with growth leveling off towards the maximum. The results of the chick weight are strongly significant. Gompertz does not calculate an average growth rate because of the S shaped curve. On average, chicks grow to a maximum weight of about 55 grams. The maximum growth rate (inflection point) is t∗= ln(2.34)/ 0.91≈0.85/0.91≈0.93 This means that the relative growth rate is highest immediately after day 1.

Parameters: Estimate Std. Error t value Pr(>|t|)

Asym 55.402293	3.897356	14.21	<2e-16 ***
b2 2.335794	0.052897	44.16	<2e-16 ***
b3 0.911946	0.005957	153.09	<2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The Gompertz model fits the data well: on average it is off by only 2.4 g. Figure 12 can be used to estimate the age of wild chicks between zero and eighteen days old.

3.4 Beak length

The beak length of each chick is shown in a figure 13. Because it was only measured twice, the growth line is an estimate. It is noteworthy that the large beaks in the beginning are not necessarily also the larger beaks when the chicks are older, the lines cross each other.

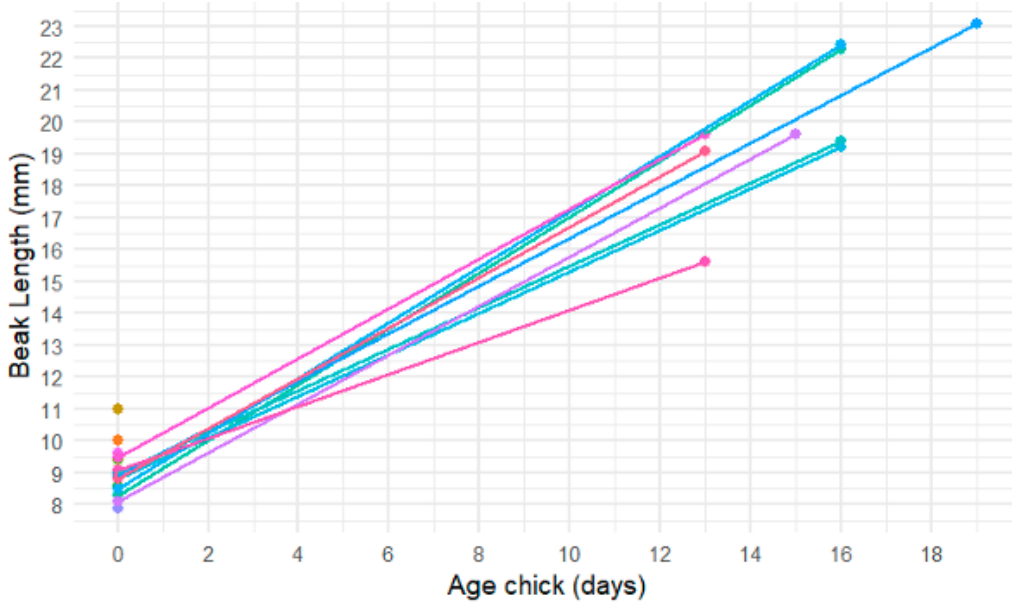

Figure 13 Beak length chicks 2025

The second measurement is taken on the day the chicks move to the release aviary. Multiple clutches from different hatch dates were moved together to form bigger groups when released. Therefore, not all chicks were the same age when measured. In table 1 you can see the average beak length per measured day. Unfortunately, from the twenty chicks, five have deceased and the first six chicks were forgotten to measure. Therefor only nine chicks had a second measurement.

Table 1 Average beak length 2025

Day number	Average beak length (mm)	Number of chicks
0	9,17	20
13	18,1	3
15	19,6	1
16	20,8	4
19	23,1	1

4. Discussion

The discussion will look at areas for improvement and points that went well in the process.

4.1 Method discussion

The goal was to collect eleven nests each with four eggs. If all eggs hatch successfully and all chicks fledge, that would be forty-four fledgelings. Now only 8 nests have been collected, most of which were incomplete, with a total of twenty-four eggs. That is 54,55% of the goal. Of those twenty-four eggs, fifteen chicks fledged successfully. That is 34,09% of the goal and 62,5% from the collected eggs in 2025. No more nests were collected as none had been found.

In 2023 and 2024 weight wasn’t measured at fixed times, so there wasn't always a 24-hour interval between each weight. More time meant more weight loss, and less time meant less weight loss for egg weight and the same counts for gain in chick weight.

The data collection in 2025 was structured and went almost without any problems.

4.2 Result discussion

Some nests were already incubating in the wild before being collected. Therefor some data is missing from those nests. For example, a nest hatched after 5 days. The weight for those days is recorded as day 0-4. This makes it appear as the starting weight, but it is the final weight. So, to correct this the day numbers have been manually moved to align the actual hatch day with the average hatch day. What does happen in the data is that when a nest is added that was already partly incubated in the wild, it adds data halfway and affects the results. The average line should be linear, but it now has some bumps because the incubation days are not consistent.

Since the chicks were not yet fully grown at the time of release, beak length analysis was difficult to perform. At the first measurement of beak length there were chicks with shorter beaks and at the second measurement they had much longer beaks than others which was unexpected. Therefore, it is impossible to say what the length of the beaks will be when they are adults as growth is unpredictable. Unfortunately, the analysis between gender and weight could not be continued because gender could not yet be determined from the undeveloped beaks.

5. Conclusion

This chapter links back to the research question to answer it.

The main question during this research was, how do head started southern dunlin chicks develop in captivity? To answer this question, the sub-questions will be looked at and answered.

Sub-question 1: How do southern dunlin eggs and embryos develop? After analysing the data and creating results, we can conclude that egg weight decreases significantly and predictably during incubation according to an exponential curve. Three years were compared with one another and all these results led to this conclusion.

Sub-question 2: What is the growth rate of the southern dunlin chicks? The growth is not linear as expected, so there is not just one growth speed. They grow rapidly in the first few days (fastest just after day 1), with growth levelling off towards the maximum of 55 grams.

Sub-question 3: What is the relationship between beak length and weight? To answer this question the chicks would have had to been fully grown. However, literature research concludes that beak length is indeed a way to determine gender in this bird species. However, the study from (Malick-Wahls et al., 2024) shows that females would have longer beaks than males.

In captivity these dunlin eggs and chicks were growing steadily. These results can be used for other studies on southern dunlin birds.

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Appendix 1: Egg weight

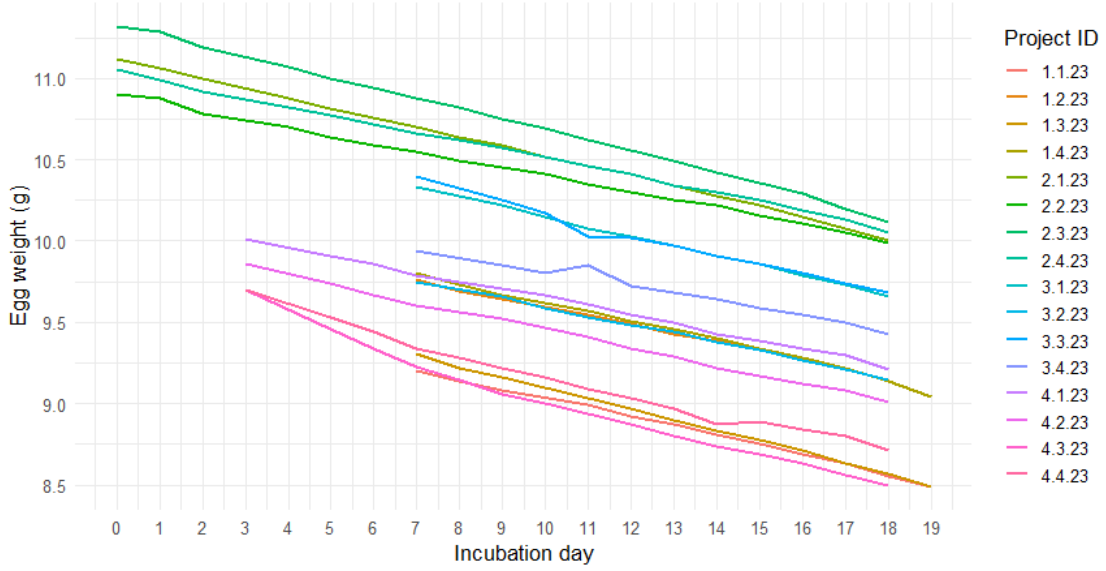

Figure 14 Egg weight per surviving egg 2023

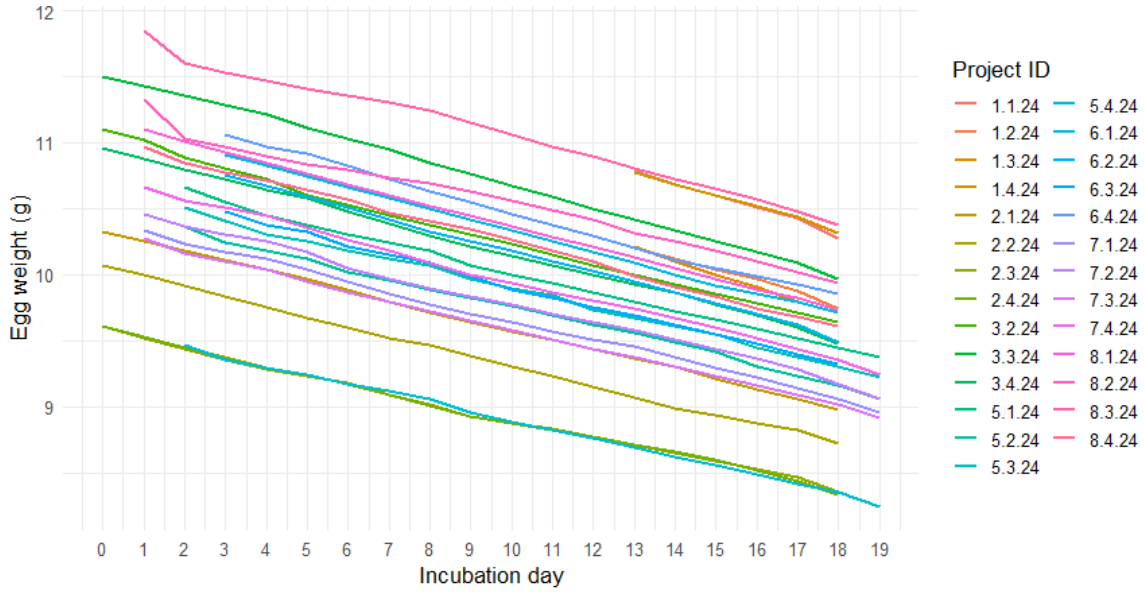

Figure 15 Egg weight per surviving egg 2024

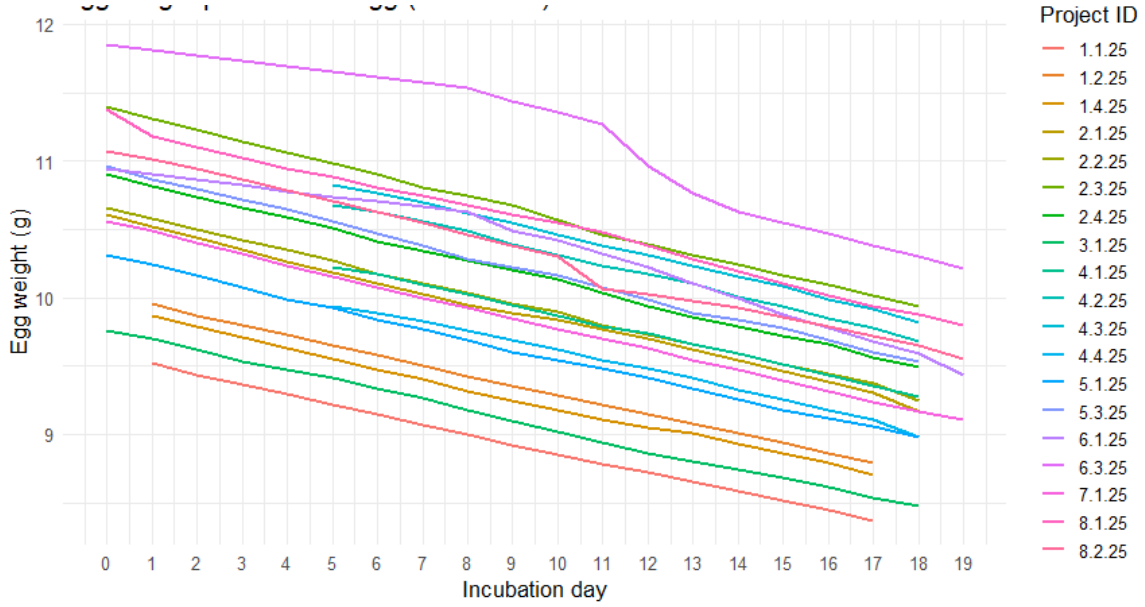

Figure 16 Egg weight per surviving egg 2025

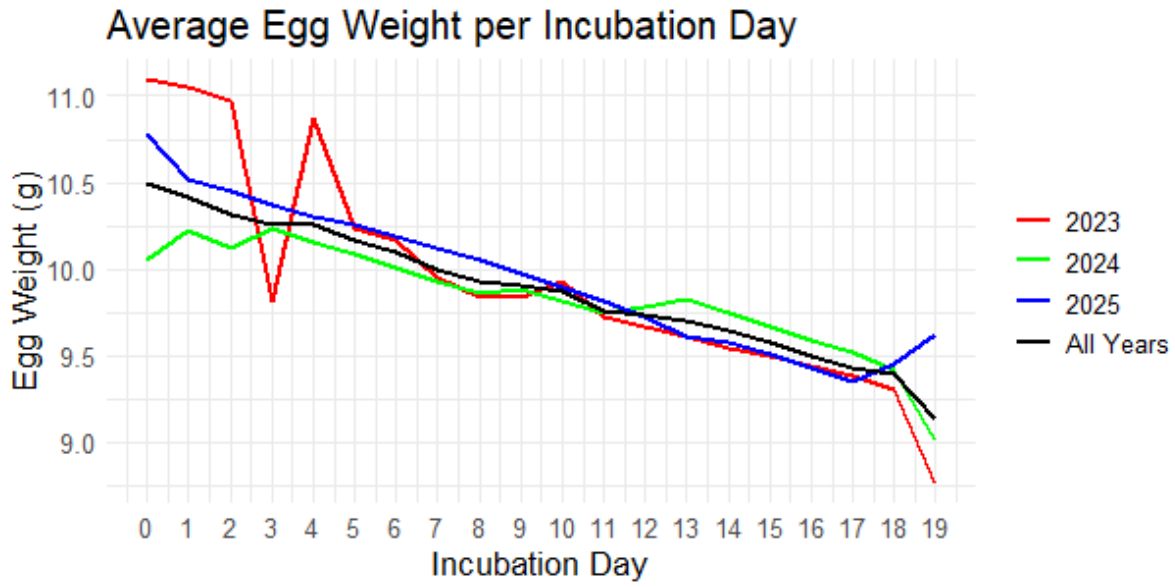

Figure 17 Average egg weight per surviving egg, all years

Appendix 2: Chick growth

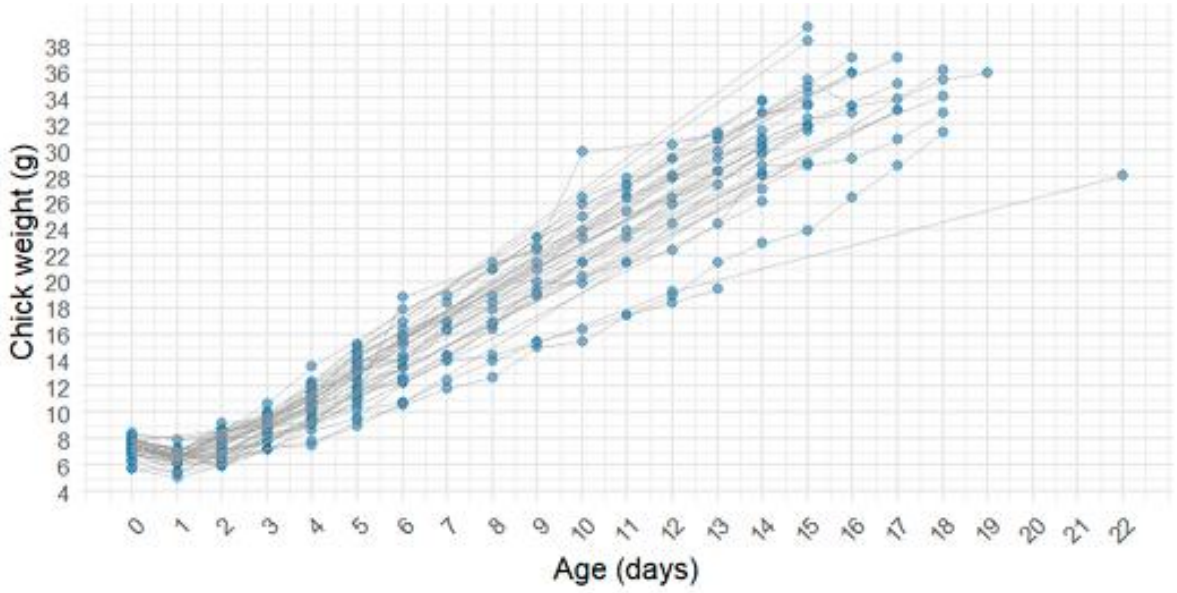

Figure 18 Individual chick growth of all years