Feather growth rates of different bird species in the Un Poco del Chocó Reserve in the Andes of Ecuador

Federwachstumsraten verschiedener Vogelarten im Un Poco del Chocó Reservat in den Anden Ecuadors

Bachelor Thesis towards the acquirement of the

“Bachelor of Science” (B.Sc.) degree in Biology

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Joscha Simon Schneiders

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First advisor: Prof. Dr. Werner Kunz

Second advisor: Prof. Dr. Sebastian Fraune

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1. Abstract

To investigate the feather growth rates (FGRs) in combination with the rectrix growth times (RGTs) of neotropical birds, 267 feathers of 71 different bird species belonging to 22 families were collected starting in October 2021 in about ten weeks of time at the Un Poco del Chocó Reserve northwest of Quito. To catch the birds, mist nets were used. The feathers were evaluated using ptilochronology. The mean feather growth rate and mean rectrix growth time for each species was calculated and correlated with selected parameters. The analysis considered individuals as well as clusters of birds. FGRs varied between 0,10 and 0,46 cm/day with a middle value of 0,22 cm/day across all species. RGTs varied between 15,7 and 35 days with a middle value of 26,6 days. Smaller species (<20 g) were the majority of entrapped birds and could be correlated to smaller FGRs and RGTs, meaning that despite having smaller FGRs, it did not take them as long to grow their rectrices as it did for larger birds. As granivores, invertivores and omnivores had higher FGR compared to frugivores and nectarivores, there was no trend to see for RGT with respect to type of nutrition. No clear connections could be determined between FGR, RGT and family affiliation. There were differences for some species with respect to FGR and sex to identify, but there was no general trend in FGR between the sexes to determine. However, RGT for males were higher than those for females. The time course of FGRs and RGTs for individuals, which were entrapped repeatedly, did not show any clear variation over time with only two exceptions. Ptilochronology proved to be a valuable tool for this analysis.

2. Introduction

There are three energy-intense annual events in the life of a bird; molt, breeding and in some species migration. Breeding may be skipped if conditions are unfavourable [Smart et al. 2021], as is true with migration – molt, however, is something a bird cannot just skip as it is paramount to their survival; a bird must molt to retain the quality of their plumage by replacing worn or damaged feathers (which, for example, is required for flight or thermoregulation) [Pageau et al. 2021]. And while molt is incredibly important in the avian life history, it is also an important tool to age birds and therefore important for population studies.

With 1654 described bird species in Ecuador, of which 39 are endemic [Freile et al. 2021], 15,1% of all 10.599 described species of bird [Catalogue of Life 2022] are represented in a relatively small country with an area of only 280.000 km^2. Compared to Germany, which is similar in size with an area of 360.000 km^2, there is more than three times as many species of bird (550 described species in Germany [Lepage 2022]), which is indicative of the high biodiversity found in the tropics. This also means that field work in tropical countries with high biodiversity is needed to better our understanding of these threatened ecosystems, while they are yet still intact. Since these countries are still developing and often lack the means to properly fund intensive researching, the activity of private researchers is needed. This holds true for the Un Poco del Chocó Reserve directed since 2009 by Mrs. Nicole Buettner [Un Poco del Chocó website]. At the Un Poco del Chocó Reserve over 280 species of birds have been banded, of which 17 are endemic to the Chocó ecoregion [Buettner unpublished data], which is also indicative of the biodiversity found in the Andes in general [Herzog & Kattan 2011]. For more detailed information of the location see the following section 2.1.

2.1. Geographical and ecological description of the Un Poco del Chocó Reserve

The Un Poco del Chocó Reserve is located on the western slopes of the Andes at an elevation of 950 to 1200 meters above sea level (see Figure 1). The site is 15 hectares of montane rainforest, covering both primary and secondary forest. The average temperature is 19°C and the annual precipitation is around 3800 mm and there is a dry season from June to November as well as a wet season from December to May (see Figure 2 [climate-data.org]). The data collection period for this thesis covered start of October to early December 2021, that means roughly the transition period between the seasons from drier to more wet. As is true with many of the tropical rainforests, the Chocó too is threatened by habitat loss and fragmentation through deforestation (for cattle and crops), but also climate change [Lopez et. al 2010].

Because of the tilt of the axis of the earth, there is summer on the northern hemisphere when there is winter on the southern hemisphere (and the other way around). The tropics however, always receive high amounts of radiation, with there being little fluctuations, which is also apparent in the day and night cycle that only deviates slightly around twelve hours. High levels of radiation not only means that more energy is available, but also leads to an increased water cycle due to higher evaporation. Together, these factors lead to an increased level of primary production as the physiological needs for efficient and constant photosynthesis are better met than compared to the temperate zones of the Earth, which have four seasons. This high productivity in turn allows for a greater biodiversity, as there are simply more resources available. This increase of biodiversity towards the equator is known as latitudinal diversity gradient [Mittelbach 2007].

Past ice ages did not affect the tropics as much as it affected the other areas of the earth that receive less radiation; the earth glaciates from the poles towards the equator. This means that the equator is last to glaciate. Therefore, throughout the history of the earth, the areas around the equator have always been sanctuaries of life. This means that, while other areas regularly experienced extinctions of species that were unable to adapt to new climate conditions, such effects were less impactful in the tropics, allowing species to persist in these places. The high biodiversity is therefore caused by 1. the ecological conditions [Brown 2014] (which can roughly be described by the tilt of the Earth's axis), and 2. historical conditions (less impactful events and a stable environment) [Mittelbach 2007].

Figure 1; location of the Un Poco del Chocó Reserve, the coordinates are 0°03'10.4"N, 78°50'31.9"W [Google Maps]

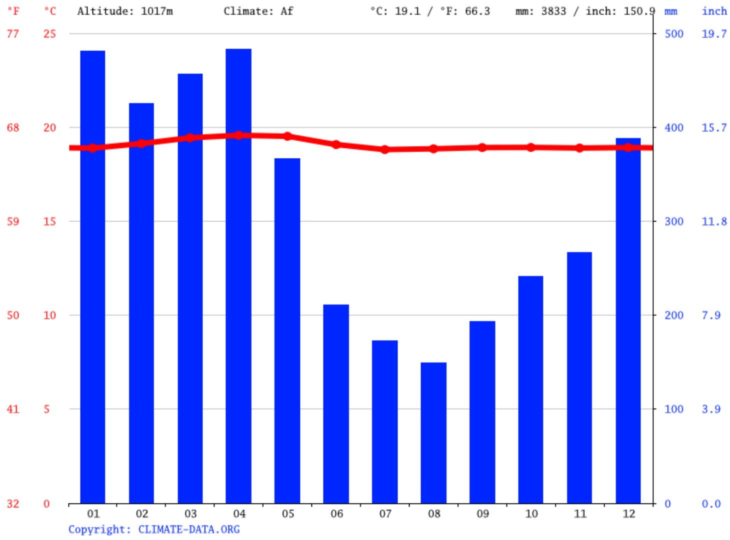

Figure 2; rainfall and mean temperature in San Miguel De Los Bancos (air distance of six kilometres to the station) [climate-data.org]

2.2. State of knowledge

Molt (and the resulting plumage) is a great tool to age birds and for a vast number of temperate species of birds such data is present, for tropical birds however such knowledge is often scarce [Ryder & Wolfe 2009]. While 80% of passerines, the largest clade of birds, are located in tropical latitudes [Stutchbury & Morton 2008], studies of temperate birds outnumber those of tropical birds by a margin of more than 100:1 [Stutchbury & Morton 2001].

Only little is known, if feather growth rates vary during the resting time, during breed and if there are differences for resident species. An influence of different seasons is also feasible and partly described [Tarroux 2003; Keats 2009], but not looked upon so far for the Un Poco del Chocó Reserve.

2.3. Intentions of this research

As explained (see section 2.2.), knowledge of the life cycles in birds of the tropics is scarce, despite there being a much higher concentration of species compared to the temperate zones. With the ever-increasing loss of biodiversity and fragmentation or destruction of habitats through deforestation for cattle or agriculture, invasive species and disastrous influences to the biosphere through climate change [Morris 2010], it also becomes more important to raise awareness for these issues.

For us to be able to protect habitats and the life they contain efficiently, we must try to understand the complex interconnections between the many species found in these threatened ecosystems. This, of course, includes birds, who often play a critical role in many niches, often pollinating or spreading the seeds of plants [Clout & Hay 1989]. Any insights generated by this work, be they small as they may, therefore aim at bettering our understanding of the bird life. To achieve this, this thesis concentrates on the description of FGRs and RGTs of a variety of bird species and its relationship to several parameters as described down below.

First; to catch and band birds and collect their tail feathers alongside other data such as species, age, sex, molt and more. The collected rectrices were measured and a FGR and RGT was to be appointed to all feathers, where possible.

Second: to use the evaluated feathers to correlate the received FGRs and RGTs with different parameters that would include; weight-based size-classes, dietary niches, relatedness (by using families), influence of sex within a species and comparing individuals that were caught during a time course.

Third: To discuss the results and also the usefulness of the FGR (and RGT) as sensible units and whether or not they can give worthwhile insight in the life of birds (in this location). Lastly, suggestions for further research will be discussed.

3. Materials and Methods

3.1. Preparations

Prior to arriving in Ecuador, matters of organization had been discussed with Prof. Dr. Kunz and graduate biologist Nicole Buettner, who is also the owner of the Un Poco del Chocó station, at which the data for this thesis was collected. Other than that, preparations would include researching the literature and papers in regards to the local avian fauna. The collection of feathers was already started by Mrs. Buettner prior to the sampling by the applicant of this thesis to enlarge the collection for evaluation.

3.2. Catching and banding the birds

Figure 3; a bird caught in one of the mist nets.

Bird banding usually took place every two weeks for three days in succession (Tuesday to Thursday), though on some days bad weather prevented banding, in which case bird banding was postponed. The iron beams on which the mist nets were installed, with which the birds were caught, were placed a day before banding. The nets were opened at around 6 am. Once the nets were up, the nets were checked every half hour. If a bird had been caught, it was freed from the nets before putting it in a bag of cloth and bringing it back to a central point, where all the equipment required to take its data was located. There, the bird was released from the bag and received a band (for identification) and data such as the location of the net, the date, the time, the species, whether or not there was a brood patch, fat, cloacal protuberance, molt of the body, tail and flight feathers, skull ossification (in passerines), striation (in hummingbirds), measurements of tarsus, tail, beak, weight, age and sex were documented. Once all relevant data was transferred into an excel sheet provided and administrated by Mrs. Buettner, a rectrix was plucked and put into a parcel with the bird's alpha code and band number upon it for later evaluation. Occasionally photographs were taken, after which the bird was then released. The photographs are used in this thesis to illustrate the different sizes of the birds (see Figure 4 and 5). Usually, bird banding continued until around 12 am after which a session was ended by taking down the nets. On the third day of bird banding the beams were taken down as well.

Banding took place on two different routes that were used interchangeably. One was close to the station and was more open and higher in elevation than the other one. The second route was closer to river in the valley of the reserve and had denser vegetation and the canopy of the trees was further up, too.

The height of the nets was around four meters; the height affected which birds were caught, as different bird species also use different elevations to get around the forest – some stick closer to the understory while others prefer the midstory and others yet (such as vultures) soar through the sky [Walther 2002].

Figure 4; **A** Purple-bibbed Whitetip, size-class I **B** Golden-winged Manakin, size-class I

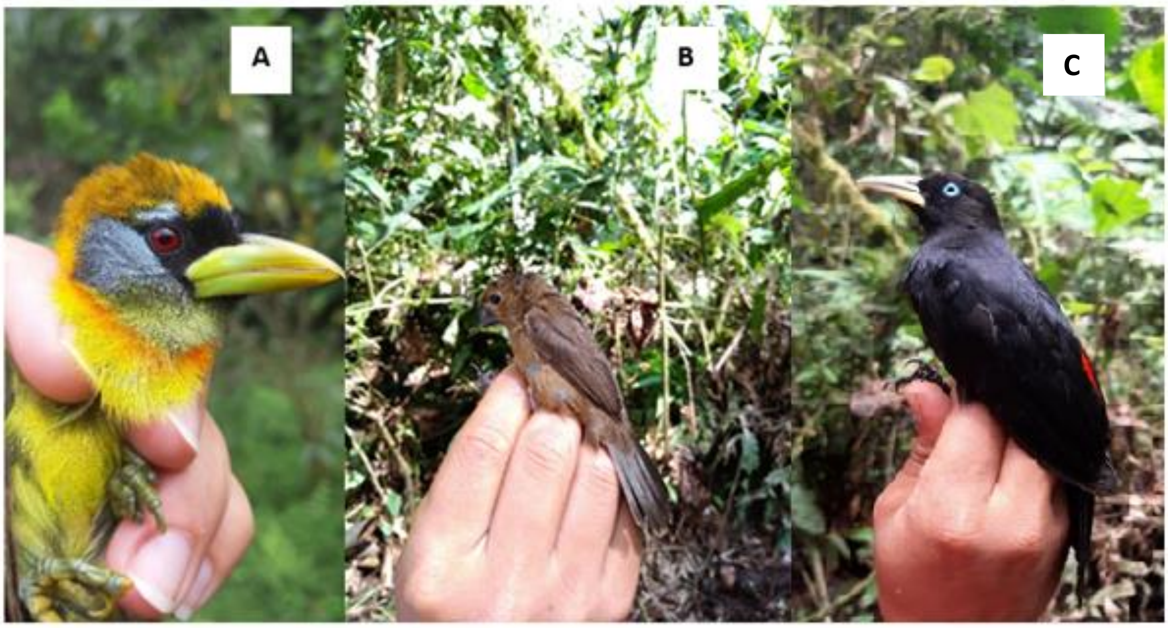

Figure 5; two types of banders grip. **A** Red-headed Barbet, size-class IV. **B** Tick-billed Seedfinch, size-class II. **C** Scarlet-rumped Cacique, size-class IV.

Figure 4 and 5 demonstrate different sizes of the captured birds. Figure 4 shows birds from size-class I while Figure 5 illustrates size-classes II and IV.

3.3. Evaluation of the feathers using ptilochronology

Fig 6; Feathers that show good visibility of the growth bars. Measuring the growth bars was easiest when light was projected onto the front with a dark contrast in the background, but this also depended on species.

The method known as ptilochronology utilizes the growth bars found in the feathers of all birds; each of the growth bars, which are apparent as a pigmentation that changes from dark to light and are perpendicular to the rachis, indicate a growth time of 24 hours, a full day [Grubb Jr. 1989]. Usually, the growth bars were best visible during broad daylight on a dark background for maximum contrast, but the best way to count the growth bars also varied for each species (see Figure 6 and 7).

When measuring the feathers, it was attempted to measure as many of the visible growth bars to reduce possible errors of mismeasurements; one millimetre is 10 % of one centimetre, but only 1 % of ten, therefore, in this case, reducing a possible error of one millimetre by a margin of ten.

How many growth bars a feather possessed often seemed to be dependent on the bird's size. The distance between each growth bar was usually greater when the bird was bigger, too. In some cases, a bird had an unexpectedly large or small tail feather despite its small or large size. This however was no trend.

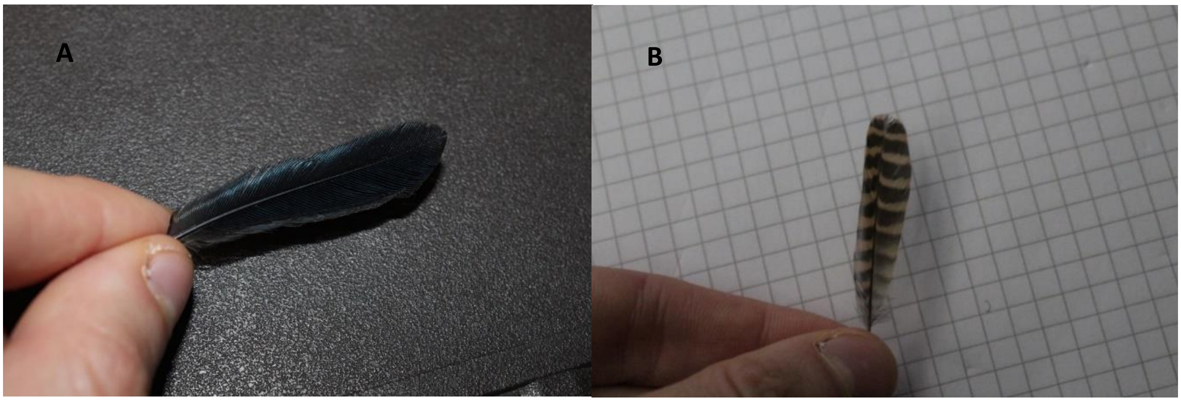

Figure 7; **A** Feather of a Green-crowned Brilliant; the growth bars are hard to distinguish and also very close to each other. **B** By contrast shows the feather of a Bay Wren with exceptionally good visibility of growth bars, which was common to all Wrens. The Bay Wren also has very large distances between each growth bar which resulted in a high FGR for a small species, which in turn had a small RGT as a consequence (see section 4.).

The quality of the visibility of the growth bars of a feather were inherently different for all species (though some genera shared similarities (Figure 7)) and this was the most defining factor. The condition of the feather however also affected visibility. There were many feathers where counting six consecutive growth bars was difficult, and others where nine and more were easily visible.

These bands of darker and lighter pigmentation (see Figure 7) were then measured and their combined length divided by the amount of measured growth bars to receive an estimate of the rates with which the feather had grown each day (FGR). A formula for better understanding is shown below. It was attempted to count six growth bars or more when possible. The measurement was conducted on two different occasions using two different callipers (see Figure 8). Both give an accuracy of three millimetre digits (or 10^{-4} cm). Sometimes two measurements of the same feather were too far off from one another in which case a third measurement was executed. At the beginning of this research, the third measurement replaced the first one in that case, while later a third column was added in the excel sheet instead. All measurements with a third column use the second and third measurement for a middle value.

Figure 8; The mechanical and the digital calliper. Both give an accuracy of 10^{-4}cm.

$$FGR\ [\frac{cm}{day}] = \frac{length\ of\ the\ measured\ growth\ bars\ [cm]}{the\ amount\ of\ growth\ bars}$$

In addition to the FGR, another unit that gives an estimate of the total growth time of the plucked rectrix was implemented. To acquire it, the total length of the feather with and without calamus was measured and divided with the afore calculated FGR. While all feathers were measured with both calamus and without, and a RGT was calculated for both for each feather, too, section 4. will only use the RGT with the calamus included.

$$RGT\ [days] = \frac{length\ of\ feather\ (with\ or\ without\ calamus)\ [cm]}{FGR[\frac{cm}{day}]}$$

For the further evaluation it was decided to use the total length with the calamus. The resulting values from each species were then compared with each other and put into perspective with characteristics of each species (size, diet). It was attempted to see if age or sex made a difference within a species.

Figure 9; Measuring the growth bars of a feather.

As mentioned above, Mrs. Buettner had collected an additional 40 feathers prior to the collection of the feathers used for the data set presented here. A total of 267 feathers was collected, of which 247 could be evaluated in Table 1.

3.4. Further Evaluation using the FGR and RGT in combination with different parameters

The mean FGR and RGT that was calculated for each individual of the dataset was made into a mean value that would represent each species (see Table 1). With this mean FGR and RGT value further analyses dove into different aspects that may affect FGRs. These include weight-based size-classes, dietary niches and relatedness based on family. These are tests that compare species (species-level). The data of all these values was retrieved on avibase – the worldbird database. In addition to this, for species of which there were enough individuals whose sex was determined, a test to see whether or not there are differences between the sexes of bird species was conducted on a level of individuals within a species.

In order to relate the size with the FGR, size-classes of the birds were formed arbitrarily (with the intent of trying to make somewhat evenly-sized groups) based on weight. Four classes were made and are as follows; size-class I ranges from 0 to 12 grams, II ranges from 12,1 g to 20 g, III ranges from 20,1 g to 30 g and IV includes all birds that weigh 30,1 g and more (examples of different weight classes are displayed in Figure 4 and 5). A mean value of both the FGR and RGT was made from all species that fell into their respective groups. Using excel these values were portrayed in bar graphs to visualize these results (Figure 10 and 12).

In similar fashion each bird species was put into a dietary niche based on the system of Pigot et. al [2020]. Though there are nine niches, only five of those are represented in the dataset that is available for this bachelor thesis. The five niches that are represented are as follows; invertivore, omnivore, granivore, frugivore and nectarivore. A mean value for both the FGR and RGT was constructed based on these groups and again visualized in a bar graph using excel (Figure 13).

To test whether or not relatedness (on a family level) of bird species affects the FGR and RGT in a meaningful way, all available species were put into groups based on the family they belong to. There were 22 families; again, a mean value for both FGR and RGT was constructed and then for better visualization made into a bar graph using excel.

As stated above, the FGR and RGT of bird species with suitable data availability were tested based on their sex, to see if FGR and RGT correlate with sex.

Also, the time course of FGR and RGT was plotted for those few individuals which were caught several times during the sampling period.

For further evaluation a mean value was constructed from each birds FGR and growth time of their rectrix (see Table 1). In a separate table all individuals are listed for a more in-depth analysis; these allow to compare individuals of a species based on age and sex with one another, to see what circumstances (such as breeding or migration) affect the FGR of a bird.

Other than initially planned, the analyses of migrating birds in comparison to resident birds and differences of FGR and RGT on account of habitats were not tested due to insufficient data.

4. Results

In Table 1 the results of this bachelor thesis have been illustrated on a species level. Table 3 in the appendix lists all birds individually but is hard to oversee. All data, except the FGR and the RGT, was retrieved from Avibase – the world bird database. After a broad explanation of the results of the measurements, the species were additionally put into different groups on account of the different parameters and their relationship with the FGR and RGT.

Some species were caught far more often than others (see Olive-striped Flycatcher; 16 samples) and many of the species that are part of this thesis have only been caught once. Low sample numbers for a species also means that their statistical analysis is not exact, as it must be considered, that a single sample is likely not to represent the average value of that species.

The weight (and therefore their size) of the trapped birds ranged from 5 grams to the very exception of 199 grams (see Table 1); the majority ranged from 10 to approximately 40 grams. In other words: most of the birds tend heavily towards smaller weights (see Figure 10), which, interestingly, is mostly in accordance to the weight distribution observed of bird species worldwide [Pigot et al. 2020].

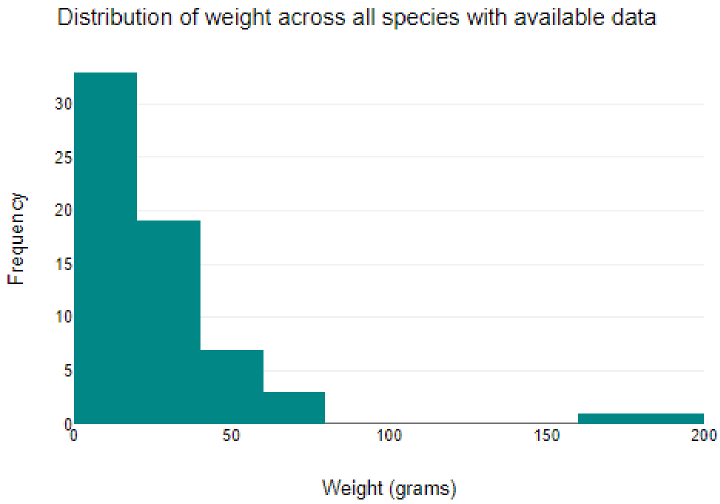

Figure 10; weight distribution of species with the available weight data. A logarithmical figure of the avian morphospace by Pigot et al. [2020] shows that most birds species range from 10 to 100 g. The distribution of the birds caught in the Un Poco del Chocó Reserve differ from this; while the graph of Pigot et al. shows only a few species around 1 g, that number rises and reaches its peak at a weight of 10 g and thereafter the number of species of higher weight decreases slowly. Both figures share, that the distribution of the species concentrates at lower weights, Figure 10 (and the data set it represents) however misses the heavy-weight bird species and the decline from the 50 g mark is rapid.

The lowest FGR was 0,10 cm/day for the Club-winged Manakin, who, on average, weighs 13 g. The highest FGR of all sampled species was 0,46 cm/day for the Northern-barred Woodcreeper – a bird with an average body weight of around 67 g. However, there also only is one bird as a representative of this species. Interestingly, the largest bird of the collection sampled, the Crimson-rumped Toucanet had an average body weight of 199 g and only exhibited a FGR of 0,19 cm/day. The majority of feather growth rates varied between 0,14 and 0,30 cm/day and the average of all species combined is 0,22 cm/ day with a standard deviation of 0,07 cm/day across all species and therefore a somewhat high spread of the FGR (see Table 1). The standard deviation for the FGR within any species varied from 0,05 cm/day in Esmeraldas Antbird to 0 cm/day in Ochre-breasted Antpittas. Most species however have a very low standard deviation of around 0,01 cm/day, and this of course excludes species of which there is only one sample available as no standard deviation can be constructed from a single value.

The rectrix growth times varied from 15,73 days (Bay Wren) to 35,06 days (Plain brown Woodcreeper) with an average of 26,61 days for all species combined. The standard deviation across all species was 3,92 days, while the standard deviation within the species varied far stronger than that of the FGR; from 0,06 days in the Ochre-breasted Antpittas to 8,78 days in the Wedge-billed Woodcreeper. Surprisingly, the Club-winged Manakin exhibited a relatively small rectrix growth time of 23,67 days despite his small FGR of 0,10 cm/day. The Northern-barred Woodcreeper, the bird with the largest FGR displayed a small RGT of only 23,98 days. Interestingly, the largest of the trapped birds, the Crimson-rumped Toucanet (one sample), had a comparable rectrix growth time of 24,63 days despite its relatively small FGR and comparatively high weight (see Table 1). It's rectrix, however, was measured to be 4,8 cm (with the calamus (see Table 3)), which is small compared to other species that are in size-class IV. The Rufous Motmot (one sample), the second heaviest bird of the data set at around 162 g also has a small FGR in relation to its size (see section 4.1.) and despite this a relatively small RGT, too. Like the Crimson-rumped Toucanet, it too possesses a relatively small rectrix of only 4,41 cm (with calamus), which is likely to be the explanation for this. In most of the species, it's observed that the higher the FGR in relation to their size is, the lower the RGT will be (see Bay Wren; size-class I and an average FGR of 0,37 cm/day lead to the smallest RGT of 15,73 days). In some species however, the size of rectrices is not proportionate to their body size.

To sum up, it can be seen that the FGR varies far stronger by nearly five times (the smallest is 0,10 cm/day in the Golden-winged Manakin and the largest is 0,46 cm/day in the Northern-barred Woodcreeper). Most of evaluated species FGR huddle around the average of 0,22 cm/day however. In contrast, the distribution of the RGT varies by only two times (the least time it takes is around 16 days in the Bay Wren and the most is around 35 days in the Plain-brown Woodcreeper and the Uniform Treehunter). Most RGTs vary between 25 to 30 days with only a few species being out of that range (see Figure 11).

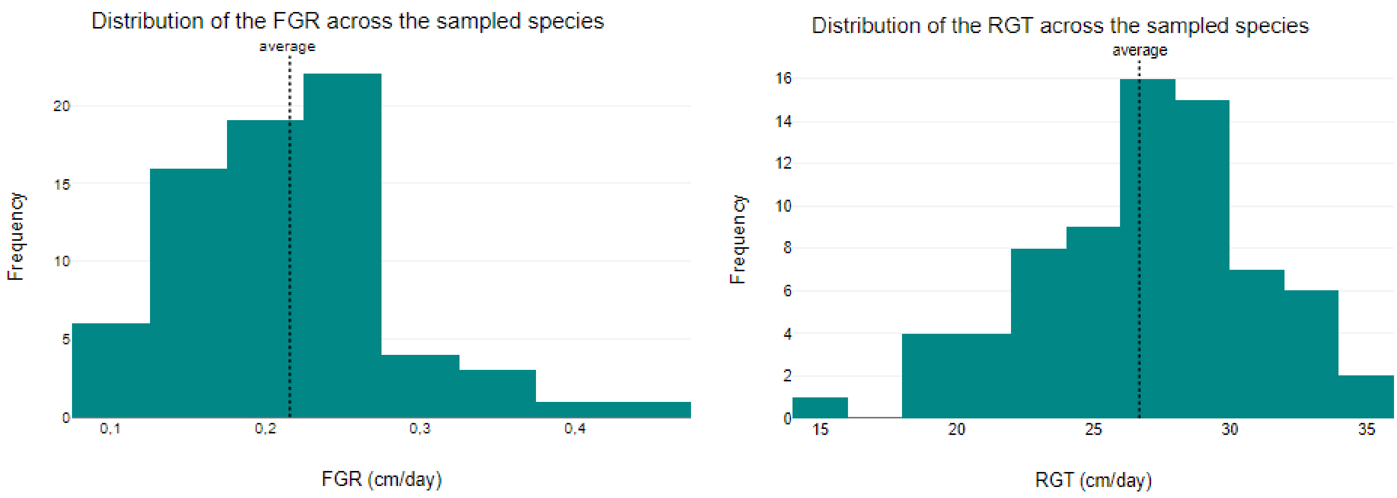

Figure 11; A histogram to illustrate the distribution of the FGR and RGT in Table 1. **A** The distribution is not Gaussian, but skewed toward the left. **B** The RGT is less densely packed and almost approaches a Gaussian distribution.

Table 1; FGRs, RGTs, family name, diet as measured by trophic level and niche, weight as well as the size-class which were arbitrarily constructed from that weight and lastly, the amount of individual birds whose feathers were measured for each species. For the evaluation of the of diet only the trophic niche (according to Pigot et al.) was used to make classes. Although there are nine in the classification by Pigot et al., only five of those are part of the 71 species that were caught. The weight data is an average value from all available weight data found on avibase – the bird world database, as is the case with the diet and family names. The size classes are as follows; I ranges from 0 to 12 g, II ranges from 12,1 to 20 g, III ranges from 20,1 g to 30 g and the fourth size-class based on weight includes all other birds, though only two species weigh more than 100 g.

Species	**Latin Name**	**Family**	**Diet (trophic level) (trophic niche)**	**Weight [grams]**	**Size-class**	**Amount of individuals**	**Mean FGR [cm/day]** and (standard deviation)	**Mean RGT (with calamus) [days]** and (standard deviation)
Acadian Flycatcher	Empidonax virescens	Tyrannidae	Carnivore (invertivore)	13,1	I	1	0,23 (0,00)	27,68 (0,00)
Andean Solitaire	Myadestes ralloides	Turdidae	Omnivore (invertivore)	28,6	III	3	0,24 (0,01)	32,08 (2,57)
Bay Wren	Cantorchilus nigricapillus	Troglodytidae	Carnivore (invertivore)	23,7	III	3	0,37 (0,01)	15,73 (3,87)
Bicolored Antbird	Gymnopithys bicolor	Thamnophilidae	Carnivore (invertivore)	26,6	III	7	0,20 (0,01)	27,03 (0,93)
Black-and-white Becard	Pachyramphus albogriseus	Tityridae	Omnivore (omnivore)	17	II	1	0,22 (0,00)	26,15 (0,00)
Bronze-olive Pygmy Tyrant	Pseudotriccus pelzelni	Pipromorphidae	Carnivore (invertivore)	10,9	I	4	0,18 (0,01)	28,22 (0,49)
Brown-billed Scythebill	Campylorhamphus pusillus	Dendrocolaptidae	Carnivore (invertivore)	40,5	IV	1	0,25 (0,00)	32,08 (0,00)

Species	Latin Name	Family	Diet (trophic level) (trophic niche)	Weight [grams]	Size class	Amount of individuals	Mean FGR [cm/day] and (standard deviation)	Mean RGT (with calamus) [days] and (standard deviation)
Buff-fronted Foliage-gleaner	Dendroma rufa	Furnariidae	Carnivore (invertivore)	25,4	III	2	0,29 (0,04)	28,49 (2,90)
Buff-throated Saltator	Saltator maximus	Thraupidae	Herbivore (frugivore)	46,7	IV	1	0,37 (0,00)	24,18 (0,00)
Chestnut-backed Antbird	Poliocrania exsul	Thamnophilidae	Carnivore (invertivore)	26,4	III	1	0,16 (0,00)	27,13 (0,00)
Chestnut-capped Brush-Finch	Arremon brunneinucha	Passerellidae	Omnivore (invertivore)	44	IV	6	0,27 (0,02)	29,98 (2,88)
Chocó Warbler	Myiothlypis chlorophrys	Parulidae	Carnivore (invertivore)	12,9	II	7	0,23 (0,02)	22,91 (2,65)
Club-winged Manakin	Machaeropterus deliciosus	Pipridae	Herbivore (frugivore)	13,2	II	3	0,10 (0,01)	23,67 (2,32)
Crimson-rumped Toucanet	Aulacorhynchus haematopygus	Ramphastidae	Herbivore (frugivore)	199,1	IV	1	0,19 (0,00)	24,63 (0,00)
Crowned Woodnymph	Thalurania colombica	Trochilidae	Herbivore (nectarivore)			6	0,15 (0,03)	26,19 (4,25)
Dagua thrush	Turdus daguae	Turdidae	Omnivore (invertivore)	59,4	IV	1	0,32 (0,00)	25,79 (0,00)
Dot-winged Antwren	Microrhopias quixensis	Thamnophilidae	Carnivore (invertivore)	8,5	I	1	0,17 (0,00)	30,35 (0,00)
Dusky Antbird	Cercomacroides tyrannina	Thamnophilidae	Carnivore (invertivore)	16,7	II	1	0,20 (0,00)	28,13 (0,00)
Dusky Bush-Tanager	Chlorospingus semifuscus	Passerellidae	Omnivore (invertivore)	19,6	II	5	0,21 (0,02)	27,48 (1,15)
Esmeraldas Antbird	Sipia nigricauda	Thamnophilidae	Carnivore (invertivore)	24,4	III	3	0,20 (0,05)	28,55 (4,27)
Golden-winged Manakin	Masius chrysopterus	Pipridae	Omnivore (frugivore)	11,2	I	11	0,16 (0,01)	25,56 (1,73)
Green-crowned Brilliant	Heliodoxa jacula	Trochilidae	Herbivore (nectarivore)	8,2	I	7	0,16 (0,02)	28,25 (4,29)
Green-fronted Lancebill	Doryfera ludovicae	Trochilidae	Herbivore (nectarivore)	5,7	I	2	0,12 (0,01)	28,46 (2,79)
Grey-breasted Wood-wren	Henicorhina leucophrys	Troglodytidae	Carnivore (invertivore)	16,6	II	5	0,15 (0,04)	19,81 (5,25)
Thick-billed Seedfinch	Sporophila angolensis	Thraupidae	Omnivore (granivore)	13,1	II	2	0,26 (0,02)	20,24 (0,69)
Lineated Foliage-Gleaner	Syndactyla subalaris	Furnariidae	Carnivore (invertivore)	28,9	III	9	0,24 (0,01)	28,83 (4,31)
Northern barred Woodcreeper	Dendrocolaptes sanctithomae	Dendrocolaptidae	Carnivore (invertivore)	67,4	IV	1	0,46 (0,00)	23,98 (0,00)
Ochre-breasted Antpitta	Grallaricula flavirostris	Grallariidae	Carnivore (invertivore)	17,7	II	2	0,14 (0,00)	20,02 (0,06)
Ochre-breasted Tanager	Chlorothraupis stolzmanni	Cardinalidae	Herbivore (frugivore)	39,3	IV	5	0,26 (0,02)	27,88 (1,85)
Olive-striped Flycatcher	Mionectes olivaceus	Pipromorphidae	Herbivore (frugivore)	14,9	II	16	0,19 (0,02)	28,25 (3,10)
One-coloured Becard	Pachyramphus homochrous	Tityridae	Omnivore (omnivore)	37,3	IV	4	0,26 (0,03)	27,21 (2,82)
Orange-bellied Euphonia	Euphonia xanthogaster	Fringillidae	Herbivore (frugivore)	12,9	II	11	0,16 (0,02)	22,71 (1,32)
Orange-billed Sparrow	Arremon aurantiirostris	Passerellidae	Herbivore (omnivore)	34,5	IV	9	0,23 (0,02)	26,75 (1,91)
Pale-vented Thrush	Turdus obsoletus	Turdidae	Omnivore (omnivore)	72,6	IV	1	0,35 (0,00)	26,40 (0,00)
Plain Xenops	Xenops minutus	Furnariidae				2	0,19 (0,03)	24,75 (3,06)
Plain-brown Woodcreeper	Dendrocincla fuliginosa	Cardinalidae	Carnivore (invertivore)	40,1	IV	5	0,25 (0,03)	35,06 (4,73)
Purple-bibbed Whitetip	Urosticte benjamini	Trochilidae	Herbivore (nectarivore)	3,9	I	3	0,12 (0,03)	30,00 (2,92)
Red-headed Barbet	Eubucco bourcierii	Ramphastidae	Herbivore (frugivore)	36,5	IV	1	0,22 (0,00)	22,95 (0,00)
Ruddy Foliage-gleaner	Clibanornis rubiginosus	Furnariidae	Carnivore (invertivore)	39,4	IV	1	0,25 (0,00)	28,29 (0,00)
Rufous Motmot	Baryphthengus martii	Momotidae	Carnivore (omnivore)	162,3	IV	1	0,16 (0,00)	28,15 (0,00)

Species	Latin Name	Family	Diet (trophic level) (trophic niche)	Weight [grams]	Size class	Amount of individuals	Mean FGR [cm/day] and (standard deviation)	Mean RGT (with calamus) [days] and (standard deviation)
Rufous-tailed Hummingbird	Amazilia tzacatl	Trochilidae	Herbivore (nectarivore)	5	I	3	0,13 (0,02)	28,96 (6,42)
Russet Antshrike	Thamnistes anabatinus	Thamnophilidae				3	0,20 (0,01)	29,23 (1,91)
Scale-crested Pygmy-Tyrant	Lophotriccus pileatus	Pipromorphidae	Carnivore (invertivore)	7,6	I	2	0,14 (0,02)	28,07 (1,12)
Scaly-breasted Wren	Microcerculus marginatus	Troglodytidae				3	0,12 (0,04)	19,56 (6,65)
Scaly-throated Foliage-gleaner	Anabacerthia variegaticeps	Furnariidae	Carnivore (invertivore)	27,8	III	2	0,21 (0,01)	32,68 (0,94)
Scarlet-rumped cacique	Cacicus uropygialis	Icteridae	Omnivore (invertivore)	61	IV	1	0,29 (0,00)	31,65 (0,00)
Silver-throated Tanager	Tangara icterocephala	Thraupidae	Herbivore (frugivore)	21,9	III	2	0,21 (0,01)	23,64 (1,05)
Slate-throated Whitestart	Myioborus miniatus	Parulidae	Carnivore (invertivore)	9,8	I	4	0,24 (0,02)	23,88 (1,19)
Slaty Antwren	Myrmotherula schisticolor	Thamnophilidae	Carnivore (invertivore)	9,6	I	8	0,14 (0,01)	23,28 (1,63)
Slaty-capped Flycatcher	Leptopogon superciliaris	Pipromorphidae	Carnivore (invertivore)	11,3	I	1	0,21 (0,00)	30,32 (0,00)
Spotted Barbtail	Premnoplex brunnescens	Furnariidae				8	0,18 (0,03)	30,17 (4,67)
Spotted Woodcreeper	Xiphorhynchus erythropygius	Dendrocolaptidae	Carnivore (invertivore)	46,8	IV	3	0,26 (0,03)	33,95 (2,49)
Stripe-throated Hermit	Phaethornis striigularis	Trochilidae				2	0,14 (0,03)	26,08 (2,41)
Summer Tanager	Piranga rubra	Cardinalidae	Carnivore (invertivore)	29,5	III	1	0,31 (0,00)	25,60 (0,00)
Swainson's Thrush	Catharus ustulatus	Turdidae	Omnivore (invertivore)	30,1	IV	5	0,38 (0,02)	19,79 (0,71)
Tawny-breasted Flycatcher	Myiobius villosus	Onychorhynchidae	Carnivore (invertivore)	14,1	II	5	0,20 (0,01)	31,74 (1,20)
Tawny-faced Gnatwren	Microbates cinereiventris	Polioptilidae	Carnivore (invertivore)	11,9	I	1	0,12 (0,00)	26,01 (0,00)
Three-striped Warbler	Basileuterus tristriatus	Parulidae	Carnivore (invertivore)	12	I	4	0,24 (0,03)	24,00 (2,57)
Tricoloured Brush-Finch	Atlapetes tricolor	Passerellidae	Omnivore (omnivore)	36,5	IV	1	0,27 (0,00)	28,54 (0,00)
Uniform Antshrike	Thamnophilus unicolor	Thamnophilidae	Carnivore (invertivore)	24,3	III	2	0,25 (0,01)	26,22 (0,57)
Uniform Treehunter	Thripadectes ignobilis	Cardinalidae	Carnivore (invertivore)	47,1	IV	1	0,25 (0,00)	34,54 (0,00)
Variable Seedeater	Sporophila corvina	Thraupidae	Herbivore (granivore)	10,6	I	1	0,25 (0,00)	19,24 (0,00)
Violet-tailed Sylph	Aglaiocercus coelestis	Trochilidae	Herbivore (nectarivore)	5,7	I	1	0,14 (0,00)	31,01 (0,00)
Wedge-billed Hummingbird	Schistes geoffroyi	Trochilidae	Herbivore (nectarivore)	3,8	I	1	0,12(0,00)	25,22 (0,00)
Wedge-billed Woodcreeper	Glyphorynchus spirurus	Dendrocolaptidae	Carnivore (invertivore)	14,3	II	10	0,21 (0,02)	25,13 (8,78)
White-necked Jacobin	Florisuga mellivora	Trochilidae	Herbivore (nectarivore)	7,2	I	3	0,18 (0,03)	21,09 (2,76)
White-throated Spadebill	Platyrinchus mystaceus	Platyrinchidae	Carnivore (invertivore)	9,4	I	1	0,14 (0,00)	26,13 (0,00)
White-tipped Sicklebill	Eutoxeres aquila	Trochilidae	Herbivore (nectarivore)	10,4	I	2	0,26 (0,01)	20,04 (1,69)
White-whiskered Hermit	Phaethornis yaruqu	Trochilidae	Herbivore (nectarivore)	5,5	I	1	0,17 (0,00)	26,20 (0,00)
Yellow-throated Bush-Tanager	Chlorospingus flavigularis	Passerellidae	Herbivore (frugivore)	25,9	III	3	0,25 (0,01)	24,61 (0,86)
Zeledon's Antbird	Hafferia zeledoni	Thamnophilidae				4	0,23 (0,01)	32,10 (4,00)

4.1 Correlation of the FGR and the RGT based on bird weight/size-classes

Only 64 of the 71 species that are part of the data set were used for this test, as the data for the other seven could not be found. The species that are part of the data set are mostly relatively lightweight when compared to avian morphospace by Pigot et al. [2020]. The four size-classes (Figure 12) were formed to put the relative weight of the species of the dataset into perspective with each other, but they are not representative of the actual weight distribution of the species worldwide.

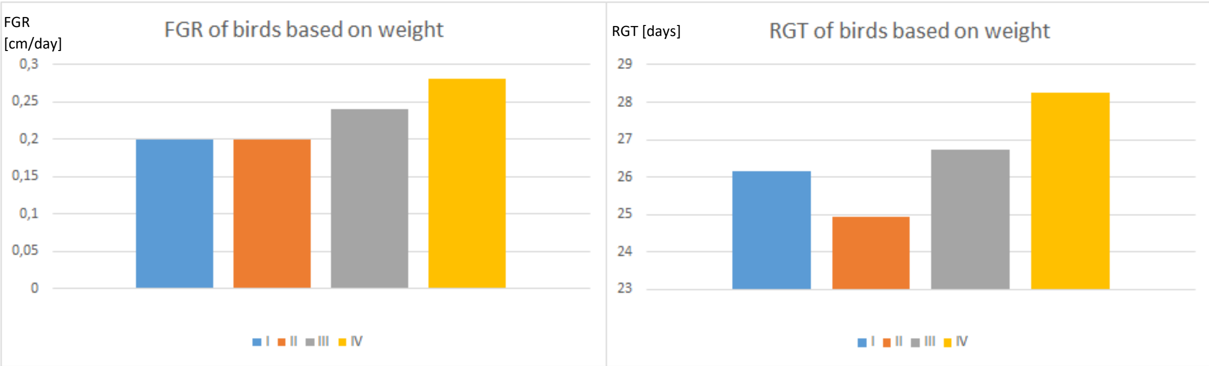

Figure 12; Illustration of the FGR of each constructed weight-class. The weight-classes are ordered as follows: I ranges from 0 to 12 g, II from 12,1 to 20 g, III from 20,1 g to 30 g and IV includes all species from 30,1 g, though only two of these were above 100 g. Of the 64 species 22 are in I, 13 are in II, 12 in III and 17 are in IV. A trend is visible where the FGR increases in accordance to the size from each class to the next with the exception from I to II where the FGR has the same value. The RGT in turn shows a similar trend, only the exception being that it doesn't take class II longer to grow their rectrices than class I. With this exception in mind, this increase in time consumption of rectrix growth times seems to be proportionate to the increase of the FGR.

Testing bird species and putting them into four size classes based on their weight revealed, that the bigger the bird is, the bigger their FGR will be. The RGT also increases over the four size classes, though weight-class II is an odd number as an increase in weight should also mean a bigger RGT if the FGR is the same as in class I. In section 4. it has been explained, that the assumption made in section 3. that a higher weight is in accordance to a bigger size of the birds and therefore, in general, also bigger rectrices is most of the time correct, but not always. This of course works both ways, a lightweight bird may have unusually large rectrices, and a heavyweight bird unusually small rectrices. Both graphs in Figure 12 also show, that although the FGR increases the heavier a bird gets, it still takes them longer to grow their rectrices, which in turn indicates that this increase of FGR that comes with increased weight cannot compensate the increase of the RGT proportionately to the increase in size. This means that in general, larger birds need longer time to finish their rectrices. An example would of a species that escapes this trend is the Crimson-rumped Toucanet, who, despite large size, possesses a small FGR and still finishes its rectrices relatively fast. This makes it clear, that the RGT also depends on the size of feathers (see section 4.).

4.2 Correlation of the FGR and RGT based on five dietary classes

Another hypothesis that was tested was whether or not diet was a factor in determining the FGR of the species. For this sake five different diet classes that are based on Pigot et. al [2020] were compared with one another. Only 65 of the 71 bird species were part of this test because the data for the other six was not found.

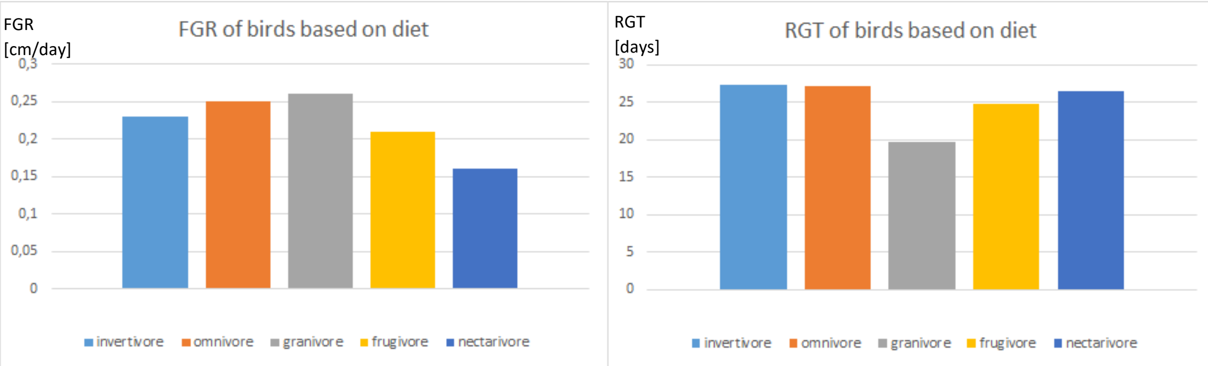

Figure 13; The distribution of the FGR and RGT in birds based on the dietary classes introduced by Pigot et. al [2020].

The FGR is highest in granivores at 0,25 cm/day; high in fat seeds contain a lot of energy, however, the sample size for this dietary niche consisted of only two species. Omnivores are second at 0,25 cm/day, but it’s not possible to make a profound estimate of their exact diet just based on the dietary niche. Invertivores are third at 0,23 cm/day; their diet is a mixture of mostly protein and fat, Frugivores and nectarivore are fourth and fifth (0,21 and 0,16 cm/day) of the dietary niches that were compared, both have high contents of sugar which is a carbohydrate. Both, carbohydrates and protein burn at 4 kcal/gram while fat burns at 9 kcal/gram. Unlike section 4.1. the RGT is almost evenly distributed among the five niches, with the exception of the granivore species who take considerably less time to grow their rectrices (about 20 days as opposed to around 25 days in the other four niches). This shows that the RGT not only depends on the FGR, but instead also depends on other factors such as feather lengths. In section 4.2. there is a direct correlation between FGR and RGT; the heavier the bird, the higher their observed FGR is. In addition to this, the assumption of the tested hypothesis (of 4.1.) is, that the heavier the bird is, the larger their size is and therefore their feathers which influence RGT. However, no such clear connection between dietary niche and RGT can be made.

4.3. Relationship of the FGR and RGT based on family affiliation

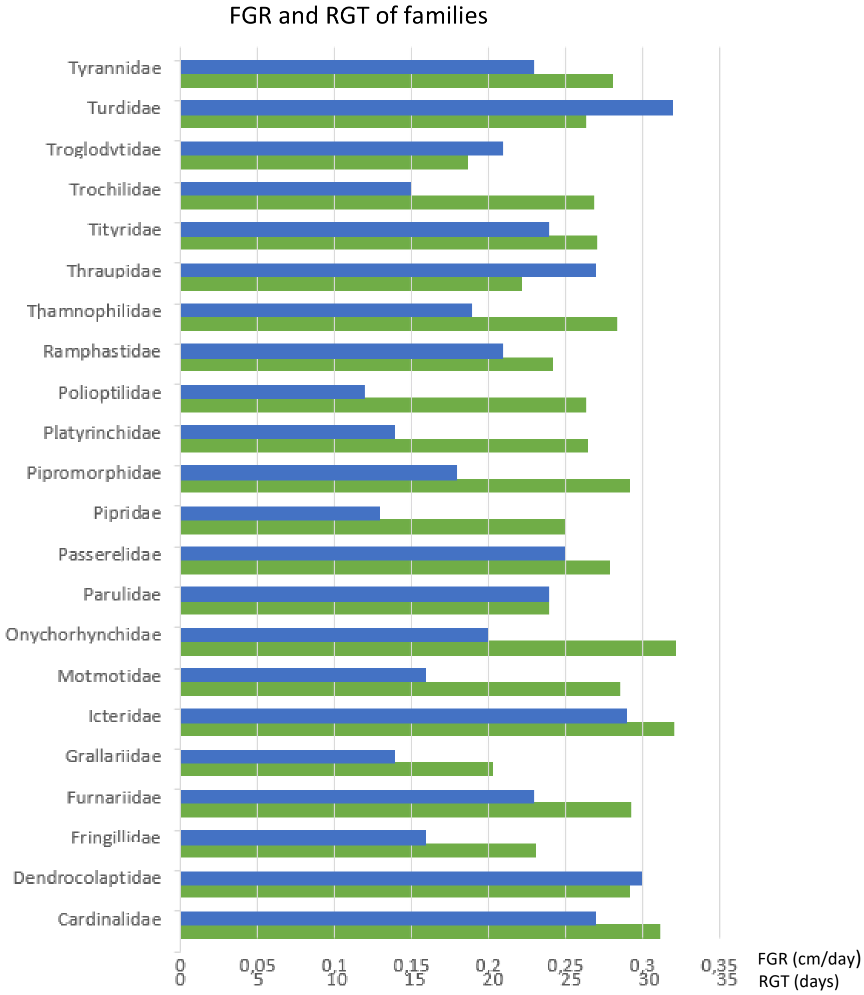

Figure 14; The FGR (blue) and RGT (green) displayed for all the families.

Figure 14 displays all the combined FGRs and RGTs of the species that make up their respective families. Polioptilidae have the lowest FGR with 0,12 cm/day while Turdidae have the highest with 0,32 cm/day. The FGR of the different families differs greatly between the lowest and the highest value. Interestingly, the RGT does not show such great variation and varies beween 18,37 days in Troglodvtidae and 31,74 days in Onychorhynchidae. Similarly, to section 4.2., no connection between FGR and RGT can be made like in section 4.1.; families like Dendrocoloptidae or Icteridae showcase high FGRs together with high RGTs, while families like Grallariidae and Fringillidae have low FGRs with lower RGTs than those of Dendrocoloptidae and Icteridae. Therefore, there does not seem to be any dependency of the RGT of the FGR based on family affiliation.

The family of Trochilidae coincides with the dietary group of nectarivores and almost shows the same FGR and RGT. One of the species that make up Trochilidae is not part of 4.2. because it's dietary niche was not found, which is why the FGR is 0,15 cm/day here and 0,16 cm/day in 4.2.

4.4. Correlation of the FGR and RGT between select species based on their sex

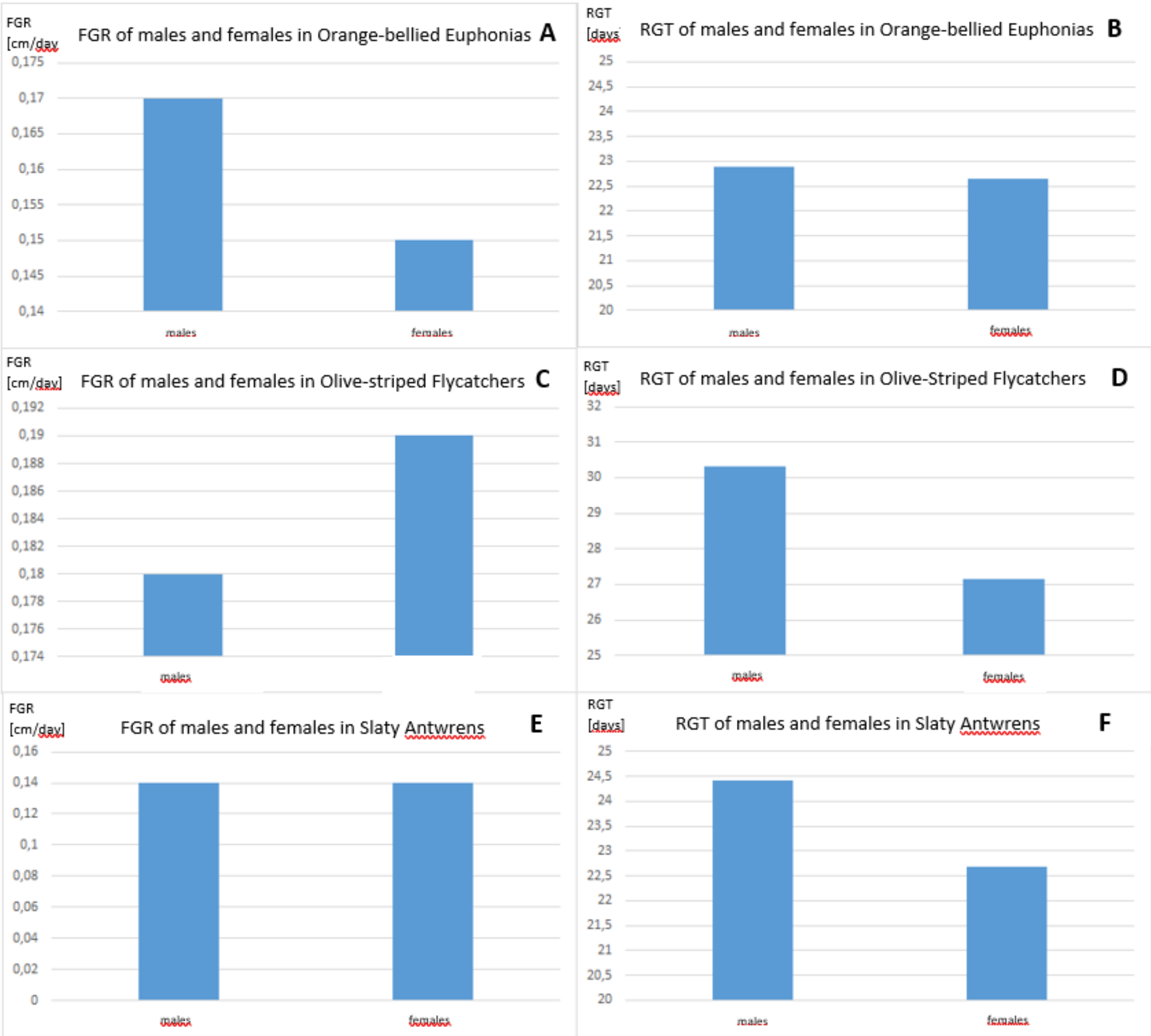

Figure 15; A comparison of the FGR and RGT in three species that were eligible for this test (due to a bigger sample size).

The results vary for each of the three species (see Figure 15): **A** in the Orange-bellied Euphonia males have a considerably larger FGR than females, yet seem to take (even though it's only slight) longer to grow their tail feathers. This strongly hints that the males are generally larger than the females or have larger rectrices. **B** in the Olive-striped Flycatcher, the opposite is true in regards to the FGR; the females have a larger FGR. It takes the males about 10 % longer to grow their rectrices than the females. Whether this is because they have smaller FGRs or larger bodies/rectrices or perhaps both is uncertain. **C** Lastly the Slaty Antwren shows an even FGR over both sexes, the RGT of the males however is bigger than that of the females, again indicating a difference in size or rectrices.

4.5. Time course of FGR and RGT of individual birds

Initially, it was not planned to set up a time course of birds that were caught more than once and so, when a bird was recaptured and a feather was already available, a second feather was not plucked. On some occasions, a second feather was plucked because it was uncertain whether there was already a feather available or not. This gave the opportunity for this test.

In most birds, there was only slight variation of FGRs and RGTs between the different catching dates. Exceptions are the Spotted Barbtail and Lineated Foliage-Gleaner; in case of the Spotted Barbtail the FGR is 0,22 cm/day on 20.10.21 (from here on out, the year will not be stated anymore), while roughly a month later on the 1.12. it's 0,18 cm/day, a 18 % decrease of feather growth rates. It's RGT is 35,03 days on the 20.10., while on the 1.12. it's only 24,75 days, a 29 % decrease. In case of the Linneated Foliage-Gleaner the FGR was 0,26 cm/day on the 6.10. while, again, roughly a month later on the 11.11. it was 0,31 cm/day; a 19 % percent increase of feather growth rates. However, all other individuals do not show such a heavy increase or decrease of FGRs over time. The decrease of the RGT of the Linneated Foliage-Gleaner is proportionate to the increase of the FGR; a decrease of 19 % from 29,43 days on the 6.10. to 24,81 days on the 11.11.

In case of the Zeledon's Antbird and the Andean Solitaire both birds were caught on the same day again and in both cases little to no variation for the FGR is occurrent, hinting at high accuracy of the measurements.

Table 2; Time course of individual birds that were caught at least two times.

Catching date	**Band Number**	**Species**	**FGR (cm/day)**	**RGT (days)**
29.04.2021	4120	Ruddy Foliage-gleaner	0,27	27,92
30.07.2021	4120	Ruddy Foliage-gleaner	0,25	28,30
20.10.2021	1545	Spotted Barbtail	0,18	35,03
01.12.2021	1545	Spotted Barbtail	0,22	24,75
04.05.2021	01072	Tawny-breasted Flycatcher	0,20	31,80
21.10.2021	01072	Tawny-breasted Flycatcher	0,20	32,35
29.07.2021	0967	Wedge-billed Woodcreeper	0,24	25,52
21.10.2021	0967	Wedge-billed Woodcreeper	0,24	26,80
24.11.2021	0967	Wedge-billed Woodcreeper	0,23	25,89
04.05.2021	4121	Zeledon's Antbird	0,24	33,72
04.05.2021	4121	Zeledon's Antbird	0,24	34,08
24.02.2021	1456	Andean Solitaire	0,23	35,66
24.02.2021	1456	Andean Solitaire	0,22	36,87
11.11.2021	3341	Lineated Foliage-Gleaner	0,31	24,81
06.10.2021	3341	Lineated Foliage-Gleaner	0,26	29,43

5. Discussion

The aim of this thesis was to describe feather growth rates of different bird species in the Un Poco del Chocó Reserve of the Andes adding information towards this subject, which is scarce for this region [Buettner 2020]. Any of the correlations presented in the results heavily depend on the correctness of the measurements. Several factors may have had an influence (see section 5.1.), which are discussed first, as they are the basis of the results discussed in this section.

As mentioned in the introduction, there aren't too many who have conducted FGR measurements, especially not in the Andes of Ecuador [Buettner 2020], which is why it wasn't possible to find any mean feather growth rates that might confirm the results presented here, or refute them. This means that further studies similar to this one are needed. For a more in-depth analysis of the physiological limits of the FGR of any one bird species different approaches may be valuable.

5.1. Possible errors of measurements and possible inaccuracies of the groups for the hypotheses tested

Errors may have occurred as early as measuring the feathers; Both callipers that were used gave an accuracy of 10^{-4} centimetres, the bottleneck for the accuracy however was most likely the fact that all measurements were done by hand and eye, while a digital software with more standardized means would have been able to securely give measurements with less room for (human) error. Factors that may have had an impact on measurements may include lighting, feather quality (i.e., some were bent and thus straightening them out all whilst measuring may affect the measurement) or poor visibility of growth bars. However, measuring each feather twice, or in some cases thrice (see chapter 3), clearly reduced such errors to an acceptable degree and the standard deviations from Table 1 are mostly 0,01 cm/day for the FGR and the highest standard deviation was calculated for Esmeraldas Antbird with 0,05 cm/day, which is 25% of its 0,20 cm/day FGR. Additionally results from section 4.5. hint at the accuracy of the measurements, as little to no variation was seen in the birds with band number 1456 and 4121, of which both were caught twice on the same day. That concludes the possible errors of the initial measurements.

In case of the hypotheses and the groups that were constructed to test these, many of these groups would often contain few or just one species and many of the 71 species that were caught for this thesis often only have one individual representing the species as a whole. The problem with a species only having a single individual is as such; any such an individual may be a statistical anomaly, this becomes less likely the more individuals represent that species (for example, a bird may be very old, very young, breeding, malnourished – all of which may influence feather growth rates). Most of these factors were not available in the individuals sampled. The same is true if a group contains only a few species; even if those species are statistically robust, if there are only one or two species that make up that group, it may still be the case that a trend is overseen, because the species that make up the group are not actually representative of the parameters in question.

However, the FGRs and RGTs were correlated to other factors in order to find tendencies answering the question if relations could be discovered.

5.2. Possible dependencies of the FGR

Possible dependencies of the FGR were tested by correlating the FGR and RGT with different parameters (see section 2.3. and 4.). These would in include weight-based size-classes, dietary niche and the differences between families. These were tested on a species level. Other than that, individuals of the same species were tested based on their sex and individuals with available information were compared with themselves.

In section 4. it was made apparent, that the FGR of the species is not evenly distributed but rather strongly skewed towards the left (see Figure 11). Interestingly a similar skewness can be observed when one takes a look at the distribution of avian body masses from lightest to heaviest. The results of 4.1. also indicate that the higher the body mass of a birds is, the higher their FGR will be, while their RGT also grows, meaning that the larger a bird is, though their FGR may rise, so will their rectrix growth time. The connection of size of body, which influences the size of the rectrices, is directly connected to RGT via the FGR.

The results of the dietary niche comparison in section 4.2. of 65 of the total of 71 species also indicates that there is a correlation between diet and FGR; granivore birds have the highest FGR which may be due to the generally high contents of fat that are usually found in seeds and nuts. Fats burn with 9 kcal/gram while carbohydrates and proteins burn with 4 kcal/gram. The omnivore diet of a bird species is impossible to distinguish when they are put into big groups as they are here, therefore the contents of such omnivore diets are not exactly known. Invertivore birds come in third; their diet is a mix of protein and fat, which makes for a high density both nutrients and energy. The fourth and fifth highest FGR go to the frugivore and the nectarivore dietary niche. Both contain high amounts of sugar (carbohydrates) and are less nutritious, which may be the reason that in general they have lower FGRs than the other groups [Keats 2009]. Another reason for the lowest FGR of the nectarivores may depend on the nearly permanent flight modus; they need more energy for catabolism than the others.

To see whether or not there is a correlation between FGR and relatedness of birds, in section 4.3. all of the 71 species were put into their respective families and then the average FGR was compared with one another. However, the sensibility of this test must be questioned; though differences are apparent, whether these are there because of relatedness or not is not certain. As seen above, there appear to be many factors that influence the FGR and correlation does not mean causation. Another problem of this hypothesis is that many of the families only have a single species as a representative, which denies the point of making an average value and comparing that average value with other average values.

In section 4.4. a test between individuals of the same species based on their sex revealed that there is no indication that there is a trend among species where males or females have the larger FGR. Instead, it seems that this varies among the species (see Figure 15). All three species show the same trend in the RGT however, where it takes the male longer to grow their rectrices. This may be due to a difference in size, a difference in the FGR (see Olive-striped Flycatcher), or perhaps both of these things.

In section 4.5. a time course of individual birds was set up to see if their FGRs and RGTs would change over time. It can be derived from the literature available, that seasonal changes may have an effect on molting [Keats 2009] or not [Tarroux 2003]. The data collected in the reserve for this thesis suggests, that over all FGRs and thereby RGTs, vary only slightly, while there may be some exceptions to this, as are found in the Spotted Barbtail and Linneated-Foliage Gleaner. To find the reasons that cause these exceptions, it's probable that a more in-depth analysis of these individuals and their life history is required to acquire profound data that may be linked to such increases or decreases of FGRs.

Two of the individually caught birds were each caught on the same day; on the 4.5. Zeledon's Antbird was caught twice, while on the 24.2. an Andean Solitaire was caught twice. Both individuals show little to no difference in FGRs and RGTs, which indicates good quality of measurements, as the measurements for these days are independent from each other but still confirm each other. However, these are only two individuals and therefore this can only be seen as an indication (see section 5.1.).

Hypotheses that were intended to be tested but were not included; habitat as an influencing factor (because groups would either be far too loosely defined (i.e., differentiating between descriptions such as open and semi-open), or far too specific with each group only having a single member). Age could not be tested due to insufficient data availability; only a few species exceeded an individual count of ten (which – for this test – would still be scarce), and in those rare cases where it did, age groups still did not display a distribution off all age classes.

The accuracy of the measurements is likely to decrease when FGR was low. Despite these limitations it is clear, that larger birds exhibit typically the higher FGRs than smaller ones. Also, the type of nutrition has an influence on FGR; the more energy dense the diet is, the higher is the FGR. All other analysed aspects gave no clear signals so far. One major reason is probably the incomplete availability of the data, mostly due to low numbers of individuals per species. However, for further evaluation a larger dataset with more species and more individuals for each species should be used to confirm whether or not these results are repeatable.

For this research it could not be differentiated, if seasonal aspects, breeding or migration could play a role for FGR, as they are suggested by [Keast 2009] for an Australian dry area. Also, no information could be derived, if there are differences for subpopulations living in the primary rain forest of the Choco or in the secondary part of the Reserve. This work concentrated on a near-ground based situation. Therefore, another interesting aspect for further research is, to look also onto the other floors of the forest.

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7. Appendix

7.1. Tables

Table 3; data from the individuals that make up the basis of Table 1; of the 267 collected feather 247 were used for Table 1. Another 15 were used for Table 3, of these 15 some are also in Table 3 (one per individual). The feathers weren't used didn't have a second measurement and therefore no middle value.

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
1567	Acadian Flycatcher	0,23	27,68	6,4
2546	Andean Solitaire	0,25	30,54	7,51
1456	Andean Solitaire	0,23	35,66	8,04
1534	Andean Solitaire	0,25	30,04	7,46
2556	Bay Wren	0,37	20,97	7,85
2528	Bay Wren	0,38	11,73	4,4
2379	Bay Wren	0,35	14,50	5,06
3305	Bicolored Antbird	0,20	26,78	5,46
3215	Bicolored Antbird	0,19	29,03	5,37
3015	Bicolored Antbird	0,19	27,52	5,29
3268	Bicolored Antbird	0,19	26,83	5,04
3349	Bicolored Antbird	0,22	26,64	5,95

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
3240	Bicolored Antbird	0,21	25,84	5,47
3327	Bicolored Antbird	0,21	26,60	5,56
1564	Black-and-white Becard	0,22	26,15	5,7
0598	Bronze-olive Pygmy Tyrant	0,19	28,01	5,24
01148	Bronze-olive Pygmy Tyrant	0,18	29,06	5,28
01149	Bronze-olive Pygmy Tyrant	0,16	27,96	4,51
01159	Bronze-olive Pygmy Tyrant	0,17	27,85	4,79
3253	Brown-billed Scythebill	0,25	32,08	8,01
3357	Buff-fronted Foliage-gleaner	0,32	25,59	8,28
3239	Buff-fronted Foliage-gleaner	0,25	31,39	7,78
4104	Buff-throated Saltator	0,37	24,18	8,85
2264	Chestnut-backed Antbird	0,16	27,13	4,39
4035	Chestnut-capped Brush-Finch	0,29	26,52	7,66
3355	Chestnut-capped Brush-Finch	0,25	32,29	8,18
4135	Chestnut-capped Brush-Finch	0,25	32,98	8,19
4075	Chestnut-capped Brush-Finch	0,29	28,36	8,1
3362	Chestnut-capped Brush-Finch	0,31	26,63	8,16
4037	Chestnut-capped Brush-Finch	0,25	33,07	8,33
0821	Chocó Warbler	0,28	18,14	5
1115	Chocó Warbler	0,21	23,49	5,02
01147	Chocó Warbler	0,24	19,87	4,86
01041	Chocó Warbler	0,20	25,24	5,11
0814	Chocó Warbler	0,20	25,93	5,17
0678	Chocó Warbler	0,22	24,31	5,44
1467	Chocó Warbler	0,24	23,42	5,57
01139	Club-winged Manakin	0,09	26,87	2,46
01142	Club-winged Manakin	0,12	21,44	2,53
01157	Club-winged Manakin	0,11	22,68	2,39
5A014	Crimson-rumped Toucanet	0,19	24,63	4,8
ec0360	Crowned Woodnymph	0,21	24,02	5,01
ec0329	Crowned Woodnymph	0,13	24,36	3,15
ec0814	Crowned Woodnymph	0,14	24,28	3,5
EC0799	Crowned Woodnymph	0,13	33,31	4,18
EC0774	Crowned Woodnymph	0,14	30,34	4,1
EC0800	Crowned Woodnymph	0,19	20,81	3,88
3347	Dagua thrush	0,32	25,79	8,31
0646	Dot-winged Antwren	0,17	30,35	5,07
2545	Dusky Antbird	0,20	28,13	5,62
2390	Dusky Bush-Tanager	0,22	26,74	5,96
2261	Dusky Bush-Tanager	0,21	29,06	6,04
2547	Dusky Bush-Tanager	0,21	28,03	6,02

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
2548	Dusky Bush-Tanager	0,18	27,86	5,06
2525	Dusky Bush-Tanager	0,24	25,71	6,08
2479	Esmeraldas Antbird	0,27	23,57	6,33
3356	Esmeraldas Antbird	0,16	34,00	5,28
2496	Esmeraldas Antbird	0,18	28,07	5,03
01059	Golden-winged Manakin	0,14	29,54	4,04
01137	Golden-winged Manakin	0,15	26,58	4,05
01141	Golden-winged Manakin	0,17	23,88	4,08
01152	Golden-winged Manakin	0,16	26,60	4,19
01140	Golden-winged Manakin	0,16	24,14	3,83
0460	Golden-winged Manakin	0,18	23,89	4,4
0926	Golden-winged Manakin	0,16	25,72	4,03
01162	Golden-winged Manakin	0,15	26,23	3,82
01073	Golden-winged Manakin	0,14	26,76	3,78
01166	Golden-winged Manakin	0,16	23,79	3,91
0221	Golden-winged Manakin	0,17	24,06	4,13
ec0824	Green-crowned Brilliant	0,14	30,56	4,3
ec0772	Green-crowned Brilliant	0,17	22,85	3,82
EC0184/EC0776	Green-crowned Brilliant	0,18	21,39	3,85
EC0753	Green-crowned Brilliant	0,16	31,88	5,22
EC0049	Green-crowned Brilliant	0,13	32,82	4,34
ec0752	Green-crowned Brilliant	0,14	31,55	4,48
EC0771	Green-crowned Brilliant	0,21	26,67	5,49
EC0815	Green-fronted Lancebill	0,12	31,25	3,62
ec0805	Green-fronted Lancebill	0,13	25,67	3,38
1400	Grey-breasted Wood-wren	0,19	14,29	2,75
1555	Grey-breasted Wood-wren	0,10	27,16	2,67
1562	Grey-breasted Wood-wren	0,20	13,53	2,66
1568	Grey-breasted Wood-wren	0,12	23,40	2,9
1537	Grey-breasted Wood-wren	0,12	20,65	2,49
01163	Thick-billed Seedfinch	0,25	20,93	5,16
01160	Thick-billed Seedfinch	0,28	19,54	5,41
3158	Lineated Foliage-Gleaner	0,25	26,75	6,74
2131	Lineated Foliage-Gleaner	0,26	30,62	8,08
3341	Lineated Foliage-Gleaner	0,26	29,43	7,59
3354	Lineated Foliage-Gleaner	0,24	32,25	7,76
3345	Lineated Foliage-Gleaner	0,24	31,45	7,69
3044	Lineated Foliage-Gleaner	0,23	17,63	4,07
2157	Lineated Foliage-Gleaner	0,23	32,68	7,39
3313	Lineated Foliage-Gleaner	0,24	29,27	6,91

Band Number	**Species**	**FGR (cm/day)**	**RGT (days)**	**Feather length ((cm) with calamus)**
2351	Lineated Foliage-Gleaner	0,25	29,39	7,44
3351	Northern barred Woodcreeper	0,46	23,98	11,1
1561	Ochre-breasted Antpitta	0,14	19,95	2,86
1576	Ochre-breasted Antpitta	0,14	20,08	2,83
3138	Ochre-breasted Tanager	0,29	25,29	7,33
3166	Ochre-breasted Tanager	0,28	26,70	7,51
3244	Ochre-breasted Tanager	0,23	30,50	7,05
3361	Ochre-breasted Tanager	0,26	27,58	7,24
3340	Ochre-breasted Tanager	0,26	29,32	7,49
1203	Olive-striped Flycatcher	0,20	26,87	5,4
01138	Olive-striped Flycatcher	0,19	28,69	5,57
0900	Olive-striped Flycatcher	0,18	30,24	5,38
01092	Olive-striped Flycatcher	0,16	32,59	5,28
0650	Olive-striped Flycatcher	0,18	31,22	5,5
01151	Olive-striped Flycatcher	0,20	26,23	5,35
0996	Olive-striped Flycatcher	0,23	25,04	5,7
0868	Olive-striped Flycatcher	0,16	31,97	5,02
01092	Olive-striped Flycatcher	0,16	34,12	5,41
01155	Olive-striped Flycatcher	0,19	28,72	5,33
0604	Olive-striped Flycatcher	0,19	27,10	5,24
01037	Olive-striped Flycatcher	0,20	25,29	5,05
0723	Olive-striped Flycatcher	0,19	26,51	4,92
0428	Olive-striped Flycatcher	0,20	24,95	5,01
0360	Olive-striped Flycatcher	0,22	22,72	4,95
0838	Olive-striped Flycatcher	0,17	29,80	5,06
2554	One-coloured Becard	0,28	24,53	6,78
2555	One-coloured Becard	0,22	31,78	6,86
2535	One-coloured Becard	0,28	25,28	7,16
2562	One-coloured Becard	0,26	27,25	7,17
1205	Orange-bellied Euphonia	0,18	21,89	3,95
1552	Orange-bellied Euphonia	0,16	22,53	3,54
1556	Orange-bellied Euphonia	0,15	22,97	3,38
1565	Orange-bellied Euphonia	0,15	22,37	3,43
1559	Orange-bellied Euphonia	0,16	22,17	3,51
1571	Orange-bellied Euphonia	0,14	23,17	3,18
1574	Orange-bellied Euphonia	0,15	24,18	3,73
1570	Orange-bellied Euphonia	0,18	20,90	3,8
1528	Orange-bellied Euphonia	0,15	22,71	3,39
0731	Orange-bellied Euphonia	0,17	21,14	3,58
1532	Orange-bellied Euphonia	0,13	25,84	3,48
2123	Orange-billed Sparrow	0,23	26,04	5,98

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
2140	Orange-billed Sparrow	0,21	30,44	6,48
2544	Orange-billed Sparrow	0,23	27,70	6,25
2551	Orange-billed Sparrow	0,22	28,95	6,26
2532	Orange-billed Sparrow	0,24	26,67	6,42
2553	Orange-billed Sparrow	0,25	24,67	6,09
2563	Orange-billed Sparrow	0,24	24,95	6,05
2564	Orange-billed Sparrow	0,20	26,85	5,35
2542	Orange-billed Sparrow	0,25	24,44	6,03
3360	Pale-vented Thrush	0,35	26,40	9,26
1558	Plain Xenops	0,16	27,81	4,45
1531/0912	Plain Xenops	0,23	21,68	4,92
2543	Plain-brown Woodcreeper	0,25	31,97	7,95
2488	Plain-brown Woodcreeper	0,19	44,32	8,41
2484	Plain-brown Woodcreeper	0,27	31,40	8,43
2129	Plain-brown Woodcreeper	0,26	33,67	8,73
2561	Plain-brown Woodcreeper	0,26	33,94	8,9
EC0458	Purple-bibbed Whitetip	0,10	33,03	3,18
ec0812	Purple-bibbed Whitetip	0,16	26,07	4,15
EC0773	Purple-bibbed Whitetip	0,11	30,90	3,38
3348	Red-headed Barbet	0,22	22,95	5,05
4120	Ruddy Foliage-gleaner	0,25	28,30	7,12
5028	Rufous Motmot	0,16	28,15	4,41
EC0715	Rufous-tailed Hummingbird	0,09	37,94	3,56
ec0775	Rufous-tailed Hummingbird	0,14	25,68	3,52
EC0764	Rufous-tailed Hummingbird	0,15	23,27	3,44
2438	Russet Antshrike	0,19	31,73	5,87
2559	Russet Antshrike	0,21	28,86	6,06
2526	Russet Antshrike	0,20	27,09	5,37
0905	Scale-crested Pygmy-Tyrant	0,12	29,24	3,53
01161	Scale-crested Pygmy-Tyrant	0,16	26,91	4,24
1551	Scaly-breasted Wren	0,10	21,48	2,23
2560	Scaly-breasted Wren	0,15	15,22	2,27
1039	Scaly-breasted Wren	0,10	21,97	2,16
3359	Scaly-throated Foliage-gleaner	0,20	33,62	6,68
2478	Scaly-throated Foliage-gleaner	0,23	31,74	7,22
4137	Scarlet-rumped cacique	0,29	31,65	9,1
2475	Silver-throated Tanager	0,20	24,70	4,97
1563	Silver-throated Tanager	0,21	22,59	4,78
0780	Slate-throated Whitestart	0,22	25,45	5,56
01143	Slate-throated Whitestart	0,27	22,27	5,99

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
01125	Slate-throated Whitestart	0,23	23,36	5,4
01130	Slate-throated Whitestart	0,24	24,47	5,75
01126	Slaty Antwren	0,15	22,26	3,37
01043	Slaty Antwren	0,15	23,50	3,52
0947	Slaty Antwren	0,14	25,20	3,45
0753	Slaty Antwren	0,14	24,82	3,51
01097	Slaty Antwren	0,14	24,53	3,54
01124	Slaty Antwren	0,14	20,03	2,84
0220	Slaty Antwren	0,13	23,89	3,02
01127	Slaty Antwren	0,15	22,02	3,4
01129	Slaty-capped Flycatcher	0,21	30,32	6,4
1363	Spotted Barbtail	0,17	33,00	5,63
1300	Spotted Barbtail	0,17	31,26	5,26
1554	Spotted Barbtail	0,14	36,96	5,17
1543	Spotted Barbtail	0,15	32,98	5,05
1569	Spotted Barbtail	0,18	28,57	5
1572	Spotted Barbtail	0,25	21,51	5,47
1575	Spotted Barbtail	0,18	32,33	5,81
1545	Spotted Barbtail	0,22	24,75	5,38
2536	Spotted Nightingale Thrush	0,22	32,20	7,16
3062	Spotted Woodcreeper	0,29	31,65	9,25
3262	Spotted Woodcreeper	0,25	37,41	9,26
3060	Spotted Woodcreeper	0,23	32,78	7,63
ec0006	Stripe-throated Hermit	0,16	23,67	3,89
ec0034	Stripe-throated Hermit	0,11	28,49	3,26
2552	Summer Tanager	0,31	25,60	7,85
2549	Swainson's Thrush	0,38	20,36	7,69
2550	Swainson's Thrush	0,40	18,83	7,51
2565	Swainson's Thrush	0,36	20,64	7,52
2239	Swainson's Thrush	0,39	20,01	7,82
1566	Swainson's Thrush	0,35	19,10	6,77
0101	Tawny-breasted Flycatcher	0,21	30,29	6,33
01072	Tawny-breasted Flycatcher	0,20	32,35	6,54
01154	Tawny-breasted Flycatcher	0,20	31,59	6,42
01164	Tawny-breasted Flycatcher	0,21	30,87	6,57
01045	Tawny-breasted Flycatcher	0,19	33,62	6,22
0806	Tawny-faced Gnatwren	0,12	26,01	3,1
1553	Three-striped Warbler	0,26	22,14	5,7
1560	Three-striped Warbler	0,26	22,60	5,85
1573	Three-striped Warbler	0,20	28,42	5,59
1530	Three-striped Warbler	0,24	22,81	5,51

Band Number	Species	FGR (cm/day)	RGT (days)	Feather length ((cm) with calamus)
3350	Tricoloured Brush-Finch	0,27	28,54	7,82
2558	Uniform Antshrike	0,24	26,80	6,5
2557	Uniform Antshrike	0,26	25,65	6,58
3278	Uniform Treehunter	0,25	34,54	8,7
01156	Variable Seedeater	0,25	19,24	4,78
EC0804	Violet-tailed Sylph	0,14	31,01	4,27
EC0281	Wedge-billed Hummingbird	0,12	25,22	3,13
0487	Wedge-billed Woodcreeper	0,24	24,68	6,04
0953	Wedge-billed Woodcreeper	0,20	0,23	5,65
01064	Wedge-billed Woodcreeper	0,20	29,49	5,75
01150	Wedge-billed Woodcreeper	0,23	27,09	6,19
01153	Wedge-billed Woodcreeper	0,22	27,56	6,15
01158	Wedge-billed Woodcreeper	0,18	35,22	6,45
0967	Wedge-billed Woodcreeper	0,23	25,89	6,04
0502	Wedge-billed Woodcreeper	0,22	25,88	5,74
01165	Wedge-billed Woodcreeper	0,22	29,53	6,57
0936	Wedge-billed Woodcreeper	0,18	25,69	4,57
ec0802	White-necked Jacobin	0,20	19,06	3,88
ec0791	White-necked Jacobin	0,20	19,23	3,79
EC08006	White-necked Jacobin	0,14	24,99	3,57
0102	White-throated Spadebill	0,14	26,13	3,56
ec0826	White-tipped Sicklebill	0,25	21,73	5,36
ec0830	White-tipped Sicklebill	0,27	18,36	4,88
EC0055	White-whiskered Hermit	0,17	26,20	4,46
2348	Yellow-throated Bush-Tanager	0,24	23,46	5,58
2395	Yellow-throated Bush-Tanager	0,24	24,88	6,06
2531	Yellow-throated Bush-Tanager	0,26	25,50	6,65
4122	Zeledon's Antbird	0,22	25,38	5,58
4087	Zeledon's Antbird	0,24	33,35	8,09
4138	Zeledon's Antbird	0,22	35,93	7,75
4121	Zeledon's Antbird	0,24	33,72	8,1

7.2. Photographs

Figure 16; more birds that were caught during banding, but without species allocation.

7.3. Acknowledgements

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7.4. Statement of authorship

I hereby declare that I am the sole author of this bachelor thesis and that I have not used any sources other than those listed in the bibliography and identified as references. I further declare that I have not submitted this thesis at any other institution in order to obtain a degree.

Düsseldorf, 01.11.2022

Joscha Simon Schneiders