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The primary moult of the Brambling *Fringilla montifringilla* evaluated by four different methods

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Abstract

The primary moult of the Brambling *Fringilla montifringilla* was studied between 1988 and 1991 at Ånnsjön (63°15' N; 12° 28'E) in the Swedish mountain region. The duration of primary moult was estimated in four different ways: 1) By linear regression of population data; 2) By calculating the mean duration of moult of 34 recaptured birds, assuming a linear relationship between time and moult progression; 3) By using data from the same recaptured birds but correcting for the non-linear progression of moult; 4) By using field data on the rate of shedding of different primaries and the growth rate of individual feathers to construct a moult score versus time curve. Linear regression of population data gave results varying from 32 to 70 days depending on population and method of analysis. The other three methods all resulted in a primary moult duration of 58-60 days. The recaptured birds often showed a weight decrease between captures but this seemed not to affect the moult speed. The mean starting date of moult of the population varied from 8 July to 18 July in the four years. The males tended to start a little earlier than the females, but the difference is not significant. The estimated duration of primary moult (ca 59 days) is considerably longer than the result (46.5 days) of another recently published study. The difference is probably due to different methods of analysis.

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Introduction

The moult of birds has been less studied than for example breeding and migration, probably due to practical and methodological problems associated with studies of free-living birds. Most passerines live a quiet and secret life during the moult period, which makes it difficult to capture a sufficient number of birds to study. It has also turned out to be rather complicated to get reliable estimates of the duration of moult. A majority of the estimates have been based on examination of individual birds captured once in their moulting period whereas relatively few studies have analysed birds examined on several occasions (e.g. Boddy 1983).

The period of primary moult of the Brambling has recently been analysed by Ottosson & Haas (1991). They found for a population in southern Swedish Lapland a primary moult duration of 46.5 days using linear regression of data from single captures. In contrast, Ginn & Melville (1983) give a moult period of 55-58 days based on data from Finland. The moult registrations of Bramblings and other species at Ånnsjön in 1990 have been analysed by Ylvén (1991). He estimated the total moult period of primaries and secondaries to be 58 days.

This study was carried out at Ånnsjön Bird Observatory in the southern part of the Scandinavian mountain region where the Brambling is one of the most common breeding birds. The purpose here is to estimate the duration of primary moult of the Brambling, mainly using data from recaptures, evaluating whether the short moult duration at Ammarnäs compared to Finland is due to differences between populations or between methods of analysis.

Methods

The birds were captured with mistnets in two areas on the west side of Lake Ånnsjön (63°15'N 12°28'E), 530 m.a.s.l. One area is situated in the delta of the rivers Enan and Handölan and the other three kilometers upstreams the river Handölan near the village of Handöl.

Table 1. Basic data for adult Bramblings ringed at Ånnsjön 1988-1991.
Basdata om bergfinkar ringmärkta vid Ånnsjön 1988-1991.

	1988	1989	1990	1991	Total *Totalt*
Numbers ringed *Antal märkta*	107	122	121	129	479
Recaptures within years *Återfångster samma år*	38	33	62	49	182
Recaptures from earlier years *Återfångster från tidigare år*	-	0	8	8	16
Moult cards *Ruggningsundersökningar*	18	24	146	122	310
Capture period *Fångstperiod*	12 July-28 Aug.	2 July-10 Sept.	3 July-30 Aug.	1 July-31 Aug.	
Net hours *Nättimmar*	6759	9728	8992	8747	34226

The study sites consist of mixed deciduous forests, mainly birch *Betula pubescens*, alder *Alnus incana* and willows *Salix sp*. The study was carried out in 1988 and 1991. The ringing period started in the beginning of July and continued to the end of August (Table 1).

During 1988 and 1989 moult was registered by counting the number of old primaries, secondaries and tertials. If all old feathers were shed we registered the number of growing feathers. Although this method allows a rough assessment of the moult stage it is not exact enough for a detailed analysis of the progression of the moult. A small number of moulting birds were, however, examined in detail, and from 1990 onwards this was the standard. The length of all the primaries and secondaries was estimated as tenths of full length, a method adopted from Kvismare Bird Observatory (Sondell 1977). This method was used instead of the five point scale recommended by Ginn & Melville (1983), because the proportional length of the feather should be a better base for analysis of feather growth and moult progression than the point scale. In this paper the stage of moult is expressed as the sum of new and growing primaries. The outer small tenth primary is excluded. Thus, a bird that has not started moult has a moult score of 0. A bird that has shed four primaries, which have been replaced by two fully grown feathers and two growing feathers, 7 and 6 tenths of full length has a moult score of 33 (10+10+7+6=33). A bird that has completed moult has a moult score of 90. The length scale can approximately be converted to the point scale by a factor of 0.5.

The duration of moult was estimated in four different ways: (a) By linear regression of data from single captures; (b) By using recapture data, assuming moult progression to be linear; (c) By using recapture data, after correction for non-linear progression of moult progression; and (d) By combining data on rate of shedding of different primaries and primary growth rate to construct a moult curve.

Results

From 1988 to 1991 we ringed 479 adult Bramblings at Ånnsjön Bird Observatory (Table 1). This is less than in the Ammarnäs study (637; Ottosson & Haas, 1991). However, the frequency of recaptures was higher at Ånnsjön. A total of 34 birds were examined at least twice with an interval of five days or more during primary moult (compared to 14 at Ammarnäs), three of them as many as four times. In seven cases there was an interval of 20 days or more between the first and last capture.

The Brambling is suggested to be a nomadic bird, i.e. individuals tend to breed in different areas in different years (Lindström 1987). Hence it is somewhat surprising

Table 2. The duration of primary moult for individuals estimated by linear regression of population data. The moult period of the population is about 90 days.
Den individuella ruggningstiden beräknad genom linjär regression av populationsdata. Populationens totala ruggningstid är ungefär 90 dagar.

Population *Population*	Capture period (days) *Fångstperiod (dagar)*	Estimated moult duration *Beräkn. ruggn.tid* time dependent *tidsberoende*	moult score dependent *ruggsummaberoende*	Number of birds *Antal fåglar*
Ånnsjön 1990	58	45	63	146
Ånnsjön 1991	57	32	53	92
Ånnsjön + Rödön 1991	90	47	70	98
Ammarnäs 1986 (Ottosson & Haas 1991)	36		47	100

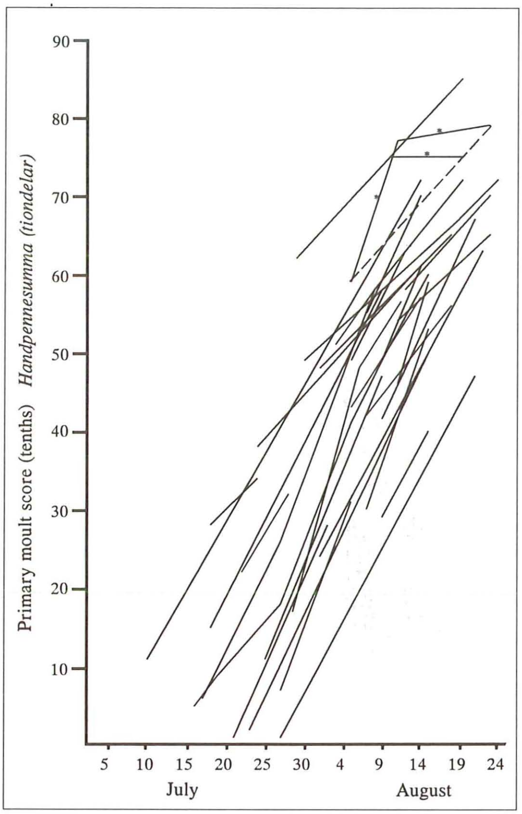

Fig. 1. Progress of primary moult of birds controlled at least once after first capture. Along the y-axis is primary moult stage expressed as number of new feathers in tenths. Along the x-axis is date. Data from 1988-1991. *) denotes observations excluded from the calculations (see text).

*Handpenneruggningens utveckling hos fåglar som kontrollerats minst en gång efter första fångsttillfället. Ruggningsstadium anges som antal nya fjädrar uttryckt i tiondelar. Data från 1988-1991. *) markerar observationer som uteslutits från beräkningarna.*

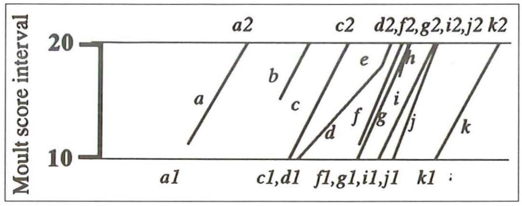

Fig 2. The principle for estimating mean moult time for a certain interval, here the interval 10-20 tenths (taken from Fig 1). The lines a-k represent different birds, except d and e which are from the same bird. Lines b, e and h are excluded since they cover less than half of the interval 10-20. a and f are extrapolated to the 10-line and d to the 20-line, respectively. The differences a2-a1, b2-b1 etc represent the time required to progress from moult sum 10 to 20. The mean value is calculated. Lines that cover more than one interval contribute to the mean value of all intervals that are covered at least halfways.

Principen för att beräkna genomsnittlig tidsåtgång för ett visst ruggningsintervall. Intervallet 10-20 tiondelar visas (taget från fig 1). Linjerna a - k representerar olika individer, utom d och e som är från samma fågel. Linjerna b, e och h utesluts eftersom de passerar mindre än halva intervallet 10-20. a och f extrapoleras till 10-linjen och d till 20-linjen. Skillnaderna a2-a1, b2-b1 etc är den tid det tar för individen att avancera från 10 till 20 i ruggningssumma. Medelvärdet för dessa beräknas. Linjer som täcker flera intervall kommer att bidra till medelvärdet för alla intervall som passerats till minst hälften.

that we also had a rather high frequency of recaptures between years. 16 birds were captured in two different years, one of them even in three. These birds were all ringed as adults.

Duration of primary moult

The results of linear regression of population data are given in Table 2. The data of Ottosson & Haas (1991) are also included. The estimated moult period varies from 32 to 70 days depending on population and method of analysis.

The progression of moult of all birds recaptured after at least five days is shown in Fig. 1. Three registrations in the upper part of the diagram have been excluded since they were either results of faulty registrations or examples of arrested moult. Assuming a linear progression of moult score the estimated moult period of the individuals varies from 29 to 111 days with a mean of 58.2 (S.D.= 21.8, n=39).

However, the primary moult curve is probably not a straight line. Rather it seems as if the moult rate slows down towards the end of the moult (Fig. 1). This problem can be overcome by dividing the moult progression into a number of stages and calculating the mean duration for each stage. An example of this is shown in Fig. 2 and Table 3 where the moult sum has been divided in eight stages, 0-9, 10-19 and so on until 60-69 and 70-89. Summing the moult duration of these different segments yields an estimate of the total primary moult time. The result is 58.8 days.

The moult curve

Many of the Bramblings at Ånnsjön were recaptured after a rather long interval, often after two or three weeks. This makes it impossible to analyse the moult curve in detail. In field studies it is neither possible nor recommendable to recapture the birds with very short

Table 3. Duration of different stages of primary moult calculated from recaptured birds. See Fig. 2 for explanations.
Ruggningshastighet i olika ruggningsstadier, beräknat från återfångade fåglar. Se Fig. 2 för förklaringar.

Moult interval *Ruggningsinterv.*	Mean duration in days (S.D.) *Medellängd i dagar*	No. of obs. *Antal obs.*
0-10	5.6 (1.3)	4
11-20	5.3 (1.5)	9
21-30	4.7 (0.9)	12
31-40	5.0 (1.8)	12
41-50	5.2 (1.7)	14
51-60	6.7 (2.3)	18
61-70	8.2 (2.4)	11
71-90*	18.1 (0.1)	2
0-90	58.8	39**

*) Note that this interval includes the last 20 tenths
**) Independent observations *oberoende observationer*

Table 4 Length difference between growing primaries.
Längdskillnad mellan växande handpennor.

Primary Number *Handpenna nummer*	Mean length difference in tenths of full length (S.D.) *Medellängdskillnad i tiondelar (S.D)*	Number of observations *Antal observationer*
P1-P2	1.1 (1.4)	57
P2-P3	2.3 (1.5)	38
P3-P4	2.6 (1.2)	48
P4-P5	3.4 (1.3)	60
P5-P6	4.2 (1.4)	81
P6-P7	5.0 (1.4)	48
P7-P8	5.1 (1.2)	22
P8-P9	2.0 (1.3)	16

intervals. It would require a very high capture effort and it could greatly increase the risk of artefacts due to repeated handling. A curve which better describes the relationship between time and moult score can be constructed by combining different sets of field data. The moult curve is formed by the growth of a varying number of primaries. In the Brambling one to five primaries are growing at the same time. If one knows both the growth curve of individual feathers and the rate at which the feathers are shed, the exact moult curve can be constructed. The growth of an individual feather is a rather stereotype phenomenon showing little variation within the species (Ginn & Melville 1983). Studies of birds in captivity have revealed that the growth of the first two thirds of the feather is a nearly linear process, but the growth of the last third slows down (Newton 1967). The same study showed that feathers of different lengths grow at approximately the same speed expressed as mm/day. Thus, it takes longer to grow a long than a short feather.

In this study the length of a growing feather was recorded in tenths. To estimate the growth rate in mm/day the tenths must be transformed to millimeters, which is easily done if the length of the feather is known. The lengths of the individual primaries of two birds (a male and a female) were measured. The means are given in Table 5. A total of 35 primaries (No 1-7) have been examined twice during growth allowing an estimation of growth rate. The data set presented here is not accurate enough for a calculation of the growth rate of individual feathers. By combining data from all 35 primaries of the recaptured birds we can calculate a mean growth rate of the primaries. They have all together grown 1289 mm in 340 days giving a mean growth rate of 3.79 mm/day. Assuming a growth rate of 3.79 mm/day the rate of shedding of the feathers can be calculated from the differences in length between adjacent feathers (Table 4).

In Fig. 3 these values have been combined to construct a moult curve. Since the curve changes slope each time a primary is shed or terminates growth it gets a "broken" appearance. Moult duration estimated from this curve results in 60.3 days.

Is moult speed influenced by handling?

At Ammarnäs Ottosson & Haas (1991) noted that birds recaptured a short time after the ringing event lost weight. The same is true about the birds at Ånnsjön (Table 6). The weight decrease seems to be most pronounced after two days. After a week the birds have almost regained their original weight. The weight decrease may be caused by stress on the capture and ringing occasion. Could this stress and weight decrease influence moult speed, being a source of error when data from recaptured birds are used to estimate moult

Table 5. Length and estimated time of growth of Brambling primaries.
Längd och beräknad tid för utväxt av bergfinkens handpennor.

Primary no *Handpenna nr*	1	2	3	4	5	6	7	8	9
Length (mm) *Längd (mm)*	56	56	57.5	59.5	63	70.5	70.5	69.5	66
Time of growth (days) *Tid för utväxt (dgr.)*	14.9	14.9	15.2	15.8	16.8	18.8	18.8	18.5	17.6

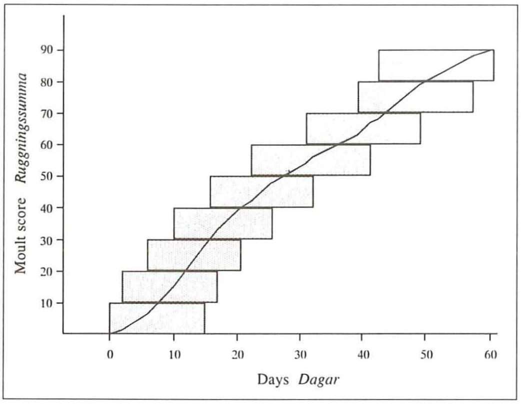

Fig 3. Mean moult progression of the Brambling. The horisontal bars represent the nine long primaries, beginning with the innermost, P1, from the bottom. The left end of the bar marks the shedding of the primary and the right end the finishing of growth. The line represents the moult progression curve calculated from measurements of the rate of shedding of the primaries and their growth rate. For details see text. The principle of the diagram is derived from Boddy(1983).

Handpenneruggningens fortskridande hos bergfink. De horisontella staplarna representerar de olika handpennorna, från den innersta, P1, i botten och så vidare uppåt. Stapelns vänstra kant markerar när pennan fälls och den högra när den är fullt utväxt. Den heldragna linjen visar ruggningskurvan beräknad från mätningar av intervallen mellan att de olika pennorna fälls och de enskilda pennornas tillväxthastighet. För detaljer, se texten. Principen för diagrammet är hämtad från Boddy (1983).

Table 6. Weight changes of adult Bramblings previously captured. The figures denote deviation from the mean of the group of birds of the same sex captured in the same time period (since weight is dependent on time).
Genomsnittlig viktavvikelse hos bergfinkar som fångats tidigare. Siffran i tabellen anger avvikelsen från medelvärdet hos gruppen av fåglar av samma kön, som fångats under samma tidsperiod (eftersom vikten varierar över tiden).

	Days after capture *Dagar efter fångsttillfället*				
	0	1	2	3-5	6-8
Weight deviation, g *Viktavvikelse, g*	+0.19	-0.13	-0.80	-0.51	0.00
S.D.	1.6	1.2	1.5	1.2	1.8
Number *Antal*	109	23	17	30	25

duration? To test this hypothesis the correlation between weight decrease and moult speed has been tested by linear regression. There was no correlation between moult speed and weight decrease ($r=0.02, p>0.1, n=43$). Although handling seems to affect weight for a few days there are no signs that it affects moult speed.

The moult of the Brambling population

The moult curve in Fig. 3 expresses the relationship between time and moult score. By using this relationship I can extrapolate the start of moult of every moulting individual. Differences in moult speed between years or between individuals may be a source of error when estimating day of moult start. This error is considered to be of minor importance, especially as most of the moulting birds have been examined in the early stages of moult. The results of the four years of investigation are shown in Fig. 4. Mean date of moult start varies from 8 July (1990) to 18 July (1991). The males seem to start moult a little earlier than the females but the difference is small and amounts to a maximum of three days. The difference is not significant (two-sample t-test, $p=0.13, n=361$, all years combined). In all four years 80% of the population started to moult within a period of 18-20 days, so the main moulting period of the Bramblings at Ånnsjön covers about 80 days.

The ringing season at Ånnsjön terminates when the majority of the Bramblings are still moulting and data from the end phase of moult are very sparse. In the autumn of 1991 mist-netting was carried out at Rödön, along the shore of Lake Storsjön, 130 kilometres east of Ånnsjön. In that area Bramblings do not breed, but occur from August to the end of October. During September, 28 adult Bramblings were captured. Six of these (21%) had not completed moult. They all had a primary moult score of more than 80, making estimation of the end of moult relatively reliable (Table 7). Assuming a primary moult duration of 59 days, these birds had started to moult between 28 July and 6 August. This agrees very well with the Ånnsjön population of which the latest 21% started to moult between 25 July and 4 August that year. If, on the other hand, the moult duration of 46.5 days estimated by Ottosson & Haas (1991) is correct these six birds would all have started to moult after 8 August which is later than for any of the 357 birds at Ånnsjön for which moult start has been possible to establish.

The secondary moult ends a little later than the primary moult. For five of the birds examined in late stages of moult the termination of secondary moult could be estimated. The median time difference between end of primary and secondary moult was eight days (Table 7), resulting in a total moult duration of 67 days.

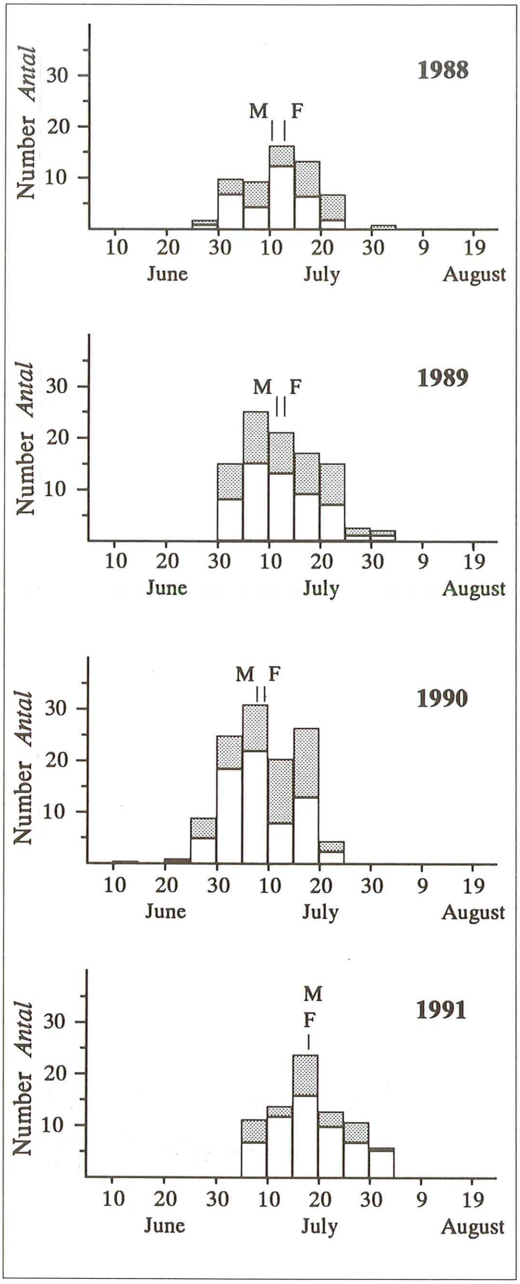

Fig. 4. Start of moult of adult birds at Ånnsjön 1988-1991. White columns - males, stippled columns - females. M and F denotes mean starting dates of males and females respectively.

Ruggningsstart för gamla fåglar vid Ånnsjön 1988-1991. Ofyllda staplar - hanar, skuggade staplar - honor. M och F visar genomsnittligt startdatum för hanar respektive honor.

Discussion

Linear regression of population data as a method to estimate the indvidual moult period has been analysed by, among others, Ginn & Melville (1983). They conclude that linear regression with time as the dependent variable gives an unbiased estimate of moult duration, provided data from the whole moult period are available. In practice, this is rarely the case, due to either a short capture period or the birds leaving the capture area before moult is completed. If data are "cut off" either in the beginning or in the end of the moult period the slope of the regression line will become steeper and the duration of moult will be underestimated. At Ånnsjön in both 1990 and 1991 (Table 2) the capture period was short and the estimated moult duration (45 and 32 days respectively) is then also expected to be too short. Data from Ånnsjön in 1991 combined with data from Rödön in 1991 cover the whole moult period, but the capture effort was very unevenly distributed with only 6 of the 98 examined birds from the last third of the moult period. Consequently, this estimate (47 days) is also probably biased towards a low value. As a solution when data are incomplete, Ginn & Melville (1983) recommended to draw the regression line "by eye" in a scatter diagram of population data. Obviously, it is easier to compensate for missing parts of the diagram by eye than by mathematical operations. However, this method has its limitations, especially if the purpose is to compare different groups or populations. Boddy (1983) solved this problem by using only the first part of the moult period for regression analysis. The advantages are two: First, in the early part of moult, the moult score progression is approximately linear, allowing a correct estimate of start of moult. Second, lack of data of the late stages of moult does not bias the analysis.

Analysis of recapture data is less liable to systematic errors, especially if handling can be ruled out as a factor affecting moult speed. Boddy (1983) took the handling effects into consideration and arrived at the conclusion that the effects must be of minor importance. The same conclusion can be drawn from this study. However, the weight decrease noted in connection with handling deserves attention and shows that stress should be minimized on the capture event.

The two methods used here to estimate moult duration from recapture data – assuming linearity of moult progression and correcting for non-linearity, respectively – give almost identical results, 58 and 59 days. The accordance is not surprising. Substituting a moderately bent curve with a straight line probably has little effect on the distance (on the x-axis) between the two end-points (in this case y=0 and y=90). It requires, however, that data are evenly distributed over the moult period. The second method, correcting for the non-

Table 7. Birds caught in late primary moult showing time difference between end of primary and secondary moults. Data from Rödön.
Fåglar fångade i slutet av handpenneruggning som illustration av tidsdifferensen mellan slutet av handpenne- och armpenneruggningen. Data från Rödön.

Date	Primaries *Handpennor*		Secondaries *Armpennor*		Time
	Moult score	Estimated end of moult	Moult score	Estimated end of moult	difference
Datum	*Ruggsumma*	*Beräknad slutdag*	*Ruggsumma*	*Beräknad slutdag*	*Tidsskillnad*
910921	85	0926	46	1002	6
910921	89	0923	49	1001	8
910922	89	0924	53	0927	3
910922	87	0925	31	>1009	>14
910922	87	0925	51	1004	9

linearity, better follows the actual moult registrations, probably resulting in less random variation of the estimated moult duration. This method is also less sensitive to errors caused by uneven distribution of data, since the registered moult progression rates only affect the interval they cover. For these reasons, 59 days is considered to be the most correct estimate of the duration of the primary moult of the Brambling. This is 12.5 days more than Ottosson & Haas (1991) estimated at Ammarnäs. I argue that this difference cannot be explained by different moult strategies of the two populations, since the ecological conditions are much the same. Instead the different results are probably due to different methods of analysis. Additional support for a moult duration of 59 days rather than 46.5 days come from: a) The registered end of moult at Rödön in 1991 corresponds well with a moult duration of 59 days; b) Four birds of the Ammarnäs study (Ottosson & Haas 1991) captured in heavy moult and later recaptured had an estimated mean moult duration of 67 days.

The result of the last method – the moult curve – depends largely on the rate of feather growth which might be difficult to get for free-living birds. Therefore it is probably less suited for field studies of moult duration. On the other hand, combined with data from birds in captivity it can be a valuable tool in analysing differences between groups and populations. In such cases it may be an advantage to break down the curve in its smaller components, the rate of shedding of different feathers, which, according to Ginn & Melville (1983), is the proximate reason behind most of the variation in moult speed within species.

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Sammanfattning

Bergfinkens handpenneruggning vid Ånnsjön

De flesta undersökningar av ruggningstidens längd hos olika fågelarter grundar sig på uppgifter om individer som bara undersökts en gång. I den här uppsatsen presenteras några olika metoder för beräkning av tiden för bergfinkens handpenneruggning huvudsakligen grundade på analyser av data från fåglar som fångats flera gånger vid Ånnsjöns fågelstation i Jämtland. Det görs också en jämförelse med en i Ornis Svecica nyligen publicerad undersökning av bergfinkens handpenneruggning i Ammarnäsområdet i Lappland, drygt 30 mil norr om Ånnsjön (Ottosson & Haas 1991).

Fåglarna fångades med nät i två områden strax väster om Ånnsjön, dels i Enans delta, dels längs Handölan vid Handöl åren 1988 – 1991. Biotopen utgörs av blandlövskog, huvudsakligen björk med videbuskage. Ringmärkningssäsongen pågick från början av juli till

slutet av augusti. De två första åren registrerades ruggningen huvudsakligen enligt en förenklad metod som inte lämpar sig för detaljanalyser av ruggningens förlopp. Från och med 1990 har ruggningsundersökningarna utvecklats till att omfatta en uppskattning av längden hos alla arm- och handpennor (utom den förkrympta, yttersta handpennan) uttryckt i tiondelar av full längd, enligt modell från Kvismaren (Sondell 1977). Den metoden lämpar sig bättre för detaljanalyser av ruggningsförloppet än den internationellt använda femgradiga skalan (Ginn & Melville 1983). En fågels ruggningsstadium uttrycks som summan av alla nya eller växande pennor. Denna ruggningssumma varierar från 0 hos en fågel som inte börjat rugga till 90 hos en fågel som ruggat klart. Basdata om bergfinkfångsten vid Ånnsjön visas i Tabell 1. Vi har fram till och med 1991 ringmärkt 479 gamla bergfinkar, drygt 20% färre än i Ammarnäs (637). En viktig skillnad är att vi har betydligt fler kontroller från samma säsong. Totalt 34 fåglar har undersökts vid minst två tillfällen under ruggningen. Dessutom har vi fler mellanårskontroller. Sexton fåglar har återfångats ett följande år, en av dem under två på varandra följande år. Alla fåglar som fångats under två häckningssäsonger är märkta som gamla fåglar.

Beräkning av ruggningstiden genom linjär regressionsanalys av populationsdata (=ruggningsstadium hos fåglar som bara fångats en gång) redovisas i Tabell 2. I samtliga fall ger regressionsanalys med tid som beroende faktor sannolikt en underskattning av ruggningstiden på grund av att fångstperioden är för kort eller att fångsten är ojämnt fördelad under ruggnings-perioden. Regressionsanalys med ruggningssumman som beroende faktor ger möjligen en korrekt uppskattning av ruggningstidens längd under förutsättning att fångstperioden är ungefär lika lång som den individuella ruggningsperioden. För detaljer angående regressionsanalys av ruggningsdata hänvisas till Ginn & Melville (1983).

Utvecklingen av handpennornas ruggningssumma för alla fåglar som kontrollerats med minst 5 dagars intervall visas i Fig. 1. Om ruggningssummans utveckling över tiden hade ett linjärt förlopp skulle det innebära en genomsnittlig ruggningsperiod på 58.2 dagar med en variation från 29 - 111 dagar. Av Fig. 1 framgår att ruggningsutvecklingen sannolikt inte är helt linjär. Ruggningshastigheten tenderar att minska mot slutet av ruggningen. Man kan i viss mån korrigera för detta vid beräkning av ruggningsperiodens längd genom att dela in ruggningsförloppet i intervall. Därefter beräknas genomsnittlig tidsåtgång för varje intervall (se Fig. 2 och Tabell 3) och tidsintervallen summeras. Beräknad på detta sätt blir ruggningstiden 58.8 dagar, dvs knappt en dag längre än med den första metoden.

Återfångster av fåglar sker ofta med intervall på en vecka eller mer. Det försvårar detaljanalyser av ruggningskurvans förlopp utifrån data på återfångade fåglar. En ruggningskurva kan dock konstrueras om man känner de enskilda pennornas tillväxthastighet och tidsintervallet mellan att pennorna fälls. Längdskillnader mellan olika växande pennor ger upplysningar om hur tätt pennorna fälls (Tabell 4). Den genomsnittliga tillväxthastigheten hos enskilda pennor har beräknats till 3.79 mm/dag utifrån återfångster och mätningar av handpennelängder (Tabell 5). Den resulterande ruggningskurvan visas i Fig. 3. Med den här metoden blir ruggningsperiodens längd 60.3 dagar.

I likhet med Ottosson & Haas (1991) har vi noterat en viktnedgång hos fåglar som återfångats en kort tid efter märkningen, möjligen utlöst av stress i samband med hanteringen vid märktillfället (Tabell 6). Det finns emellertid inget påtagligt samband mellan graden av viktnedgång och ruggningshastighet vilket talar emot att hanteringen i sig är en felkälla vid ruggningsundersökningar på återfångade fåglar. Däremot är viktnedgången som sådan ett observandum som understryker vikten av skonsamhet, täta nätkontroller och korta hanteringstider vid nätfångst av fåglar.

Fångstsäsongen vid Ånnsjön avslutas normalt innan bergfinkarna ruggat klart. Kompletterande fångst hösten 1991 på Rödön, 13 mil öster om Ånnsjön, visade att de sista bergfinkarna blir klara med sin ruggning i slutet av september. Detta stämmer väl med Ånnsjöpopulationen om man antar en ruggningstid på 59 dagar. Armpenneruggningen avslutades hos fem fåglar i medeltal 8 dagar senare än handpenneruggningen (Tabell 7) vilket innebär en total ruggningstid på cirka 67 dagar.

Med hjälp av kurvan i Fig. 3 kan beräknad tidpunkt för ruggningsstart extrapoleras för samtliga ruggande fåglar. Resultatet för de fyra undersökningsåren visas i Fig. 4. Genomsnittsdatum för ruggningsstart varierade från 8 juli (1990) till 18 juli (1991). Hanarna börjar i regel sin ruggning något tidigare, men skillnaden är liten och inte statistiskt signifikant. Det tidsintervall inom vilket ruggningstarten sker är påfallande konstant. Alla fyra åren har 80% av populationen startat inom en period på 18-20 dagar.

De här redovisade beräkningarna ger en ruggningsperiod som är ca 12 dagar längre än den Ottosson & Haas (1991) presenterade. Deras uppskattning baseras på regressionsanalys av populationsdata. Skillnaden beror sannolikt på de olika analysmetoderna. Linjär regressionsanalys av populationsdata är behäftat med många felkällor och kräver ett enhetligt utgångsmaterial för att ge ett korrekt resultat. Felkällorna är färre vid analys av återfångstdata, men det är i stället ofta svårt att samla ihop ett tillräckligt stort material. I sådana fall kan ett alternativ vara att kombinera fältdata om hur fjädrarna fälls med uppgifter om pennornas tillväxthastighet hos burhållna individer.