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Nestling growth of Great Tits *Parus major* with comparison among altitudes

Rast mladičev velike sinice *Parus major* s primerjavo med nadmorskimi višinami

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Abstract: Fledgling mass can have great influence on individual's life history and reflects the availability and quality of food in the breeding territory. Thus growth curve is used to compare the difference in the quality between different ecological conditions. The aim of the study was to fill the knowledge gap on nestling growth in Great Tit in Slovenia, to determine the influence of altitude on it and to present a tool for estimating age of nestlings and key dates in breeding phenology of Great Tit. Great Tits young were monitored using nest-boxes at three locations between years 2010 and 2012. At two locations nest-boxes were placed on three separate altitudinal belts. Weight growth curve was compared with the curves from other parts of Europe. Growth curve from Slovenia differs in growth parameters from other European populations but falls within their range. Difference in growth parameters between separate populations probably comes from the difference in ecological conditions. When comparing three altitudes weight parameters of hatchlings were similar at lower and middle but different at upper altitudes indicating that weigh growth changes with the altitude. Lower food abundance that comes with rising altitude may be offset by lower competition through lower breeding density (hence similar growth parameters in lower and middle altitude), but not past certain altitude. Weight parameters are useful when comparing different populations, but wing-length is better in determining the age of young in the nest.

Keywords: Great Tit, hatchling growth, altitude, Slovenia,

Izvleček: Masa mladičev v gnezdu je pomemben dejavnik, ki ima močan vpliv na življenje osebka. Masa mladičev v gnezdu odseva dostopnost in kvaliteto hrane na gnezdišču in je zaradi tega dober pokazatelj stanja v okolju. Namen raziskave je bil zapolniti vrzel v znanju o rasti velike sinice na območju JV Evrope ter o pomenu nadmorske višine na rast mladičev. Hkrati bodo rezultati lahko koristili tudi kot orodje za določanje starosti mladičev velike sinice v gnezdu. Meritve mladičev velike sinice v gnezdu so bile opravljene na treh lokacijah med leti 2010 in 2012. Na dveh so bile gnezdilnice postavljene na treh ločenih nadmorskih višinah. Rastna krivulja za maso se razlikuje od krivulj iz ostalih delov Evrope vendar je znotraj njihovih meja. Razlike verjetno izhajajo iz različnih ekoloških razmer v okoljih. Rast mase je podobna med spodnjim in srednjim ter različna od zgornjega višinskega pasu. Podobnost na spodnjih višinah je verjetno posledica kompenzacije manjše količine plena z nižjo konkurenco zaradi nižje gostote gnezdečih parov. Kompenzacija pa je uspešna le do določene nadmorske višine, nad to pa se zmanjševanje količine hrane pozna na počasnejši rasti mladičev. Rast mase je uporabno orodje za primerjavo med populacijami, dolžina peruti pa je boljše orodje za določanje starosti mladičev v gnezdu.

Ključne besede: Velika sinica, rast mladičev, nadmorska višina, Slovenija

Introduction

Environmental conditions change considerably with altitude and the most prominent of all is the change in ambient temperature (Newton 1998). Individuals breeding at the limit of species distribution show markedly different breeding parameters than their counterparts in more optimal environments (Orell and Ojanen 1980, 1983, Veistola et al. 1994). While the onset of breeding within certain species consistently change along altitudinal gradient, with later start at higher elevations (Gil-Delgado et al. 1992, Belda et al. 1998, Fargallo 2004), other breeding parameters like breeding density (Schmid et al. 1998) or clutch size (Gil-Delgado et al. 1992, Fargallo 2004) can show contradictory trends between and also within species. For example Fargallo (2004) found that the clutches of Blue Tit *Cyanistes caeruleus* were smaller with increasing altitude while Gil-Delgado et al. (1992) found that they were similar. In fact the clutch size can differ more among habitats than does across altitudes (Gil-Delgado et al. 1992).

Fledgling mass has great influence on individual's survival (Tinbergen and Boerlijst 1990, Barba et al. 1993, Perrins and McCleery 2001) and fecundity (Perrins and McCleery 2001). Individual growth rate and fledgling mass is determined by the amount of food they receive (Gill 1994, Keller and van Noordwijk 1994). Since Great Tits are altricial nesters all food consumed by young is provided by the parents (Tanner et al. 2007). How much food they can provide is determined by the availability and quality of food in breeding territory (Gibb and Betts 1963) and can be further influenced by unfavourable conditions such as weather or competition (Minot 1981, Keller and Van Noordwijk 1994).

The growth curve can offer comparison between nestling development since it is defined mathematically by three values: initial size, growth rate and asymptotic value (Gill 1994). Difference between two environments can be reflected in fledging mass (Richner 1989), thus growth curve may be used for comparing the quality difference between breeding environments within the range of species (Janssens et al. 2003, Eeva et al. 2009). Also growth parameters can vary considerably between different populations (Barba et al. 1993), though this does not seem to be a general rule (King and Hubbard 1981). There are some studies that offer growth data of the Great Tit from other parts of Europe (Barba et al. 1993, Janssens et al. 2003, Eeva et al. 2009) but there hasn't been a study yet considering South-East Europe. In fact, apart from studies of Dolenec (2005) and Dolenec et al. (2005) remarkably little is known about Great Tit in this region. Scientific publications on Slovenian population of Great Tit are even scarcer. There are only a few reports about number of ringed birds per year and about exceptional recoveries (Božič 2009, Šere 2009).

Considering the altitude, there are some studies about influences on breeding phenology and clutch size of Tits in Europe (Gil-Delgado et al. 1992, Krementz and Handford 1984, Sanz 1998), but none that uses altitude as an influencing factor on growth parameters.

With the present study I aimed to fill the knowledge gap on Great Tits nestling growth in Slovenia. I also aimed to use weight of nestlings to compare influence of environmental conditions at different altitudes. Since conditions for nesting deteriorate with the rising altitude, e.g. less food (Hodkinson 2005), I hypothesise that this results also in slower nestling growth at higher altitudes. Presented data on growth curve of young Great Tits might also serve as a tool for other researchers to estimate key dates in breeding phenology of Great Tit (start of incubation, hatching time, age of nestlings, etc.) from body part measurements.

Methods and materials

Breeding biology of Great Tit using nest-boxes was studied at three locations in Slovenia between years 2010 and 2012. At the first location, Ljubljana (300 m asl), five nest-boxes were set to measure hatchlings weight and wing-length. Location 1 is a small forest fragment dominated by Beech *Fagus sylvatica*, White Fir *Abies alba* and Norway Spruce *Picea abies*. This location was chosen due to its easy accessibility and comparable altitude to study sites in other European countries (Barba et al. 1993). Hatchlings were measured two to four times a week. When their weight reached more than 10 g they were ringed and individual's size was monitored then after. The nest-box visiting frequency was high enough even before hatching, so the first measurements of all chicks have been taken within two days after hatching.

At locations 2 and 3, Mt. Krim and Mt. Pohorje respectably, nest-boxes were placed in similar habitat (mixed forest dominated by Beech, White Fir and Norway Spruce) on three altitudinal belts with an average altitude of 335 (Lower), 654 (Middle) and 1023 m asl (Upper belt). On each of the upper two belts 40 nest-boxes were placed while on the lower one 32 were placed. At locations 2 and 3 nest-boxes were checked once a week. Number of nest-boxes at each location has corresponded to our capability to survey them and was higher on higher altitudes due to lower breeding density of Great Tits there (Schmid et al. 1998).

Measurements from location 1 were used to produce logistic growth curves for wing-length and body-weight. This was done by calculating growth constant (k), which denotes relative speed of growing, and time it takes for hatchling to reach half their weight at fledging (t_{50}) (Ricklefs 1967, Tome 1995). Asymptotic value was estimated from individual chicks at the age of 17 days, since at about that age they leave their nest (Perrins and McCleery 2001) and the weight of chicks out off the nests levels of or may even drop after emergence (Tome 1995). Weight growth curve was than compared with the curves from other parts of Europe e.g. Spain, Finland, Great Britain, Germany and Netherland with the use of growth parameters published by Barba et al. (1993).

From the wing-length growth curve obtained from nestlings at location 1 age of hatchling from nests at locations 2 and 3 was estimated with an accuracy of ± 1 day. Then weight growth curves for chicks from all three altitudes were calculated separately (Ricklefs 1967, Tome 1995). Average weight of nestlings in individual nest on particular day from locations 2 and 3 was compared with the calculated value from nestlings in Ljubljana. The difference between these weights was used to compare nestling's condition among altitudes. Only data from nestlings at the age between 11 and 15 days was used, when growth is most constant and overlapping among estimated age classes is less likely. Statistical significance was tested with the use of nonparametric Kruskal-Wallis statistic test (PAST 2.03).

Results

Five nests and 35 hatchlings were monitored at location 1. One nest containing eight hatchlings failed and its measurement were later disregarded. At locations 2 and 3 altogether weekly measurements from 90 nests containing 644 hatchlings were gathered. Of those 369 hatchlings from 52 nest were from lower, 235 (31 nests) from middle and 40 (7 nests) from upper altitudinal belts.

The growth parameters from location 1 were for the wing-length: $k = 0.347$; $t_{50} = 9.252$; and the body weight: $k = 0.430$; $t_{50} = 5.928$. These two parameters were used for modelling wing-length and weight growth curves respectably (Fig. 1). Measurements and estimated values for wing-length at location 1 are presented in Tab. 1.

Weight growth curve of nestlings from Slovenia falls within the range of the curves from other parts of Europe (Fig. 2). Asymptotic weight is second only to that from Great Britain and only marginally higher than the one from Spain. Growth constant is highest and t_{50} is the second lowest behind Finland (Tab. 2).

Weight growth curves for location 1 and for lower and middle belts from locations 2 and 3 are similar (Fig. 3). Curve from the upper belt is somewhat lagging behind the rest. Nestlings at the upper belt had lower asymptotic value, lower growth constant and it took them longer to reach 50% of asymptotic value (Tab. 2). For 11-15 days old chicks weights at lower and middle altitudes were similar, but both were statistically heavier from those at the upper altitude (Kruskal-Wallis All: $H_3 = 7.18$, $p < 0.05$; Lower / Middle: $p = 0.905$; Lower / Upper: $p < 0.05$; Middle / Upper: $p < 0.01$).

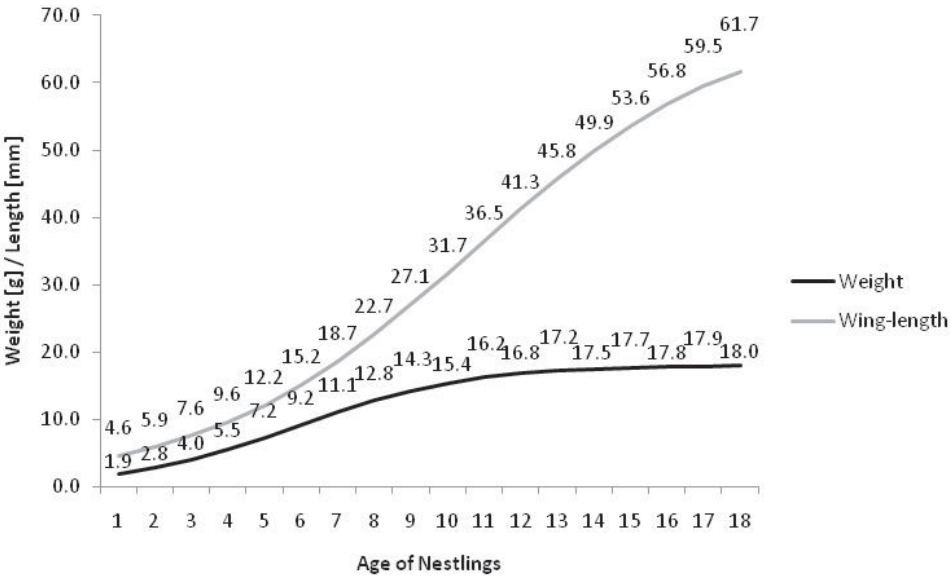

Figure 1: Calculated logistic growth curves for weight (asymptotic value: 18.1g) and wing-length (asymptotic value: 72mm) for Great Tit *Parus major* hatchlings in Ljubljana with values shown. Number of nestling monitored: 27.

Slika 1: Izračunana logistična rastna krivulja za maso (asimptotična vrednost: 18.1g) in dolžino peruti (asimptotična vrednost: 72mm) mladičev velike sinice *Parus major* v Ljubljani s prikazanimi vrednostmi. Število spremljanih mladičev: 27.

Table 1: Results of nestling measurements in Ljubljana with average, minimal and maximal measured wing-length compared with estimated wing-length gained from logistic curve. N represents number of measured nestling at particular age.

Tabela 1: Rezultati merjenj mladičev v Ljubljani s prikazano povprečno, minimalno in maksimalno izmerjeno dolžino peruti primerjano z izračunano dolžino peruti iz logistične krivulje. N predstavlja število izmerjenih mladičev za posamezno starost.

Age	Average wing-length (mm)	StD	Min – max wing-length (mm)	N	Estimated wing-length (mm)
0	4.3	0.5	4-5	6	4.6
1	5.8	0.5	5-6	4	5.9
2	7.1	0.7	6–8	7	7.6
3	9.6	0.9	8–11	13	9.6
4	12.4	1.1	11-14	16	12.2
5	14.7	1.3	13-16	11	15.2
6	19.5	1.6	15-21	15	18.7
7	24.0	1.4	21-26	20	22.7
8	29.1	1.6	26-31	15	27.1
9	33.1	1.4	30-36	15	31.7
10	37.5	1.3	34-39	19	36.5
11	42.3	2.0	38-45	12	41.3
12	46.1	1.9	43-50	19	45.8
13	47.9	2.1	44-52	14	49.9
14	50.8	1.4	48-53	8	53.6
15	55.9	0.8	55-58	14	56.8
16	60.0	0.7	59-61	9	59.5
17	62.3	1.3	61-44	4	61.7

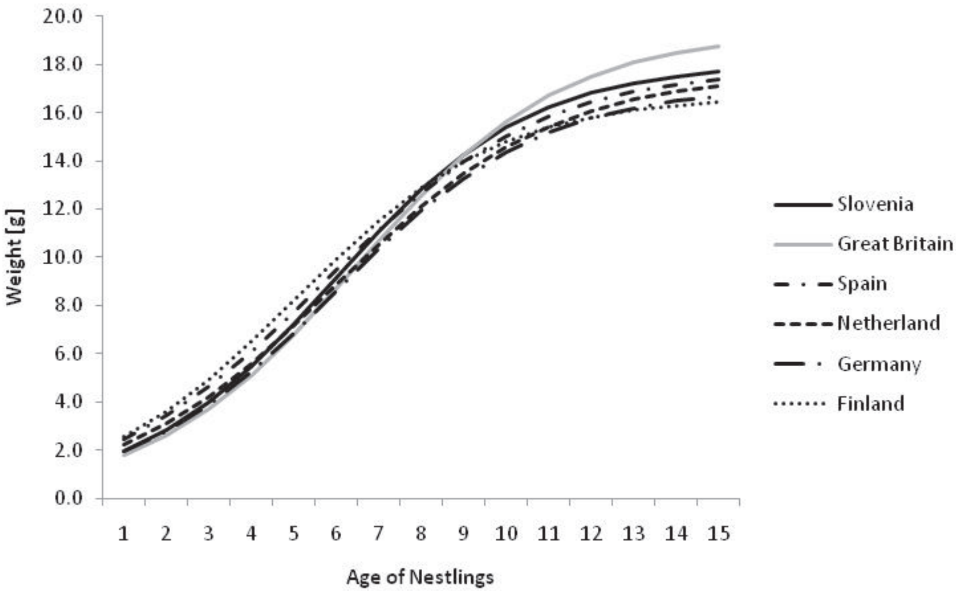

Figure 2: Calculated logistic growth curves for hatchlings weight of Great Tit *Parus major* from separate European populations. Curves from other parts of Europe are from Barba et al. (1993).

Slika 2: Izračunana logistična rastna krivulja za maso mladičev velike sinice *Parus major* iz ločenih evropskih populacij. Rastne krivulje za ostale dele Evrope so iz Barba et al. 1993.

Table 2: Growth parameters of Great Tit *Parus major* nestlings from different European populations and different altitudes. Growth parameters published by Barba et al. (1993) were used for other parts of Europe.

Tabela 2: Rastni parametri mladičev velike sinice *Parus major* z različnih delov Evrope in ločenih višinskih pasov. Rastni parametri objavljeni v Barba et al. (1993) so bili uporabljeni za ostale dele Evrope.

Population	**Asymptotic weight (g)**	**Growth constant (k)**	**t_{50}**
Great Britain	19.3	0.413	6.486
Spain	17.9	0.389	5.695
Netherland	17.6	0.390	5.970
Germany	17.1	0.412	5.964
Finland	16.7	0.418	5.075
Ljubljana	18.1	0.430	5.422
Lower	18.2	0.420	6.173
Middle	18.0	0.436	6.382
Upper	17.5	0.426	7.133

t_{50} – time it takes hatchlings to reach 50% of asymptotic weight

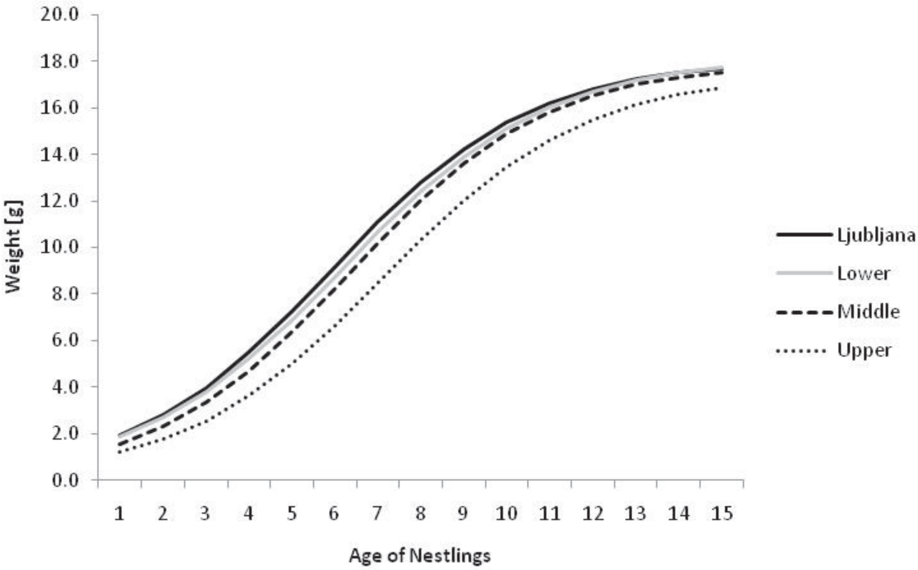

Figure 3: Calculated logistic weight growth curves for hatchlings of Great Tit *Parus major* from Ljubljana and separate altitudinal belts from Mt. Krim and Mt. Pohorje.
Slika 3: Izračunana logistična rastna krivulja za maso mladičev velike sinice *Parus major* iz Ljubljane in ločenih višinskih pasov na Krimu in Pohorju.

Discussion

Weigh growth of Great Tit nestlings changes with the altitude (Fig 3.) but it seems that this does not happen linearly. The nestlings from middle and lower altitudes have similar growth curve and similar weight at the age of 11 to 15 days. Both indicate similar food availability for the young. Although conditions usually deteriorate with altitude (Hodkinson 2005), lower food abundance in the field, one of the major factors influencing growth (Keller and van Noordwijk 1994), may be offset by the lower competition through lower breeding density (Schmid et al. 1998). This could explain similar results of growing parameters from lower and middle altitude on our study site – there were more nest-boxes occupied on lower as on middle altitude indicating higher breeding density. But this obviously has a limit. The upper altitude in our study site has even lower breeding density (7 compared to 31 nests at middle altitude with the same nest-box availability) but also lower weight growth rate of the nestlings. It seems that presumably larger home-ranges of pairs on the highest altitudes cannot offset lower food availability. Thus hypothesis that higher altitude reduces average nestlings weight can be accepted but only after the effect of altitude can no longer be offset by lower intraspecific competition.

Barba et al. (1993) found that the growth rates differ between populations of Great Tit (Table 1), and this also applies for Slovenian population, which is none the less within the range of other growth rates. What is more, growth rate differs also between habitats (Richner 1989) and climatic zones (Barba et al. 1993). Presented data shows that the same applies also for altitudes. Difference in growth parameters between separate populations probably comes from the difference in ecological conditions in which a particular population lives (Barba et al. 1993). Lower asymptotic weight in Finland population and higher growth constant is probably the response to the shorter breeding period (Veistola et al. 1994). On the other hand reasons affecting higher asymptotic weight in Great Britain population are harder to explain, but more stable and milder climatic conditions may suggest the answer.

Weight is useful for studies of environmental differences between populations as shown higher up, but is less so for determining age of young in the nest. Not only that the weight differs between birds from different climatic zones (Barba et al. 1993), altitudes (*this study*), along pollution gradient (Eeva et al. 2009) and habitats (Richner 1989), it also changes between years (Orell 1983) and differs between sex (due to different asymptotic weight; females are lighter) and the first and the second clutches (Orell 1983). Wing-length on the other hand is less variable parameter (Tome 1995, Tome 2007) and thus wing measurements for ageing young Great Tits in the nest seems a better choice.

Conclusions

Altitude influences weight-grow parameters in Great Tit nestlings, but only on the highest altitudes, while on the middle altitudes deteriorated environmental conditions are possibly offset by lower breeding density and hence lower competition.

Growth rates differ between populations of Great Tit, and this applies also for Slovenian population, which is none the less within the range of other growth rates.

Weight is useful for studies of environmental differences between populations, but wing-length is a better tool for determining the age of young.

Povzetek

Masa mladičev v gnezdu je pomemben dejavnik, ki ima močan vpliv na nadaljnjo življenje osebka. Pogosto imajo mladiči z večjo maso več potomcev. Masa mladičev v gnezdu odseva tudi dostopnost in kvaliteto hrane na gnezdilnem teritoriju staršev. Zaradi tega je rast mase v gnezdu dober pokazatelj stanja v okolju in jo lahko uporabimo za primerjavo med posameznimi populacijami. Namen raziskave je bil zapolniti vrzel v znanju o rasti velike sinice na območju JV Evrope ter o pomenu nadmorske višine, ki je slabo raziskana povsod po JV Evropi. Hkrati bodo rezultati uporabni tudi kot orodje za določanje starosti mladičev velike sinice v gnezdu, ter pomembnih gnezditvenih parametrov, ki iz tega izhajajo. Gnezditvena biologija velike sinice je bila spremljana na treh lokacijah med leti 2010 in 2012. Na dveh, Pohorje in Krim, so bile gnezdilnice postavljene na treh ločenih nadmorskih višinah (32 na spodnji in 40 na srednji in zgornji višini). Meritve mladičev v petih gnezdilnicah v Ljubljani so služile za določitev logistične rastne krivulje dolžine peruti in mase. Krivulja rasti peruti je bila uporabljena za določanje starosti mladičev na Krimu in Pohorju, krivuljo rasti mase smo primerjali s podatki iz Evrope. V Ljubljani smo dnevno merili 27 mladičev, na Krimu in Pohorju pa tedensko skupaj 644 mladičev (369 spodnja, 235 srednja, 40 zgornja višina). Rastna krivulja za maso se razlikuje od krivulj iz ostalih delov Evrope vendar je znotraj njihovih meja. Razlika med rastnimi krivuljami verjetno izhaja iz razlike v ekoloških pogojih, ki vladajo posameznim populacijam. Rast mase mladičev je podobna med spodnjim in srednjim vendar je različna od zgornjega višinskega pasu. Ocenjujem, da sta spodnji višini podobni med seboj zaradi kompenzacije manjše količine dostopnega plena na srednji višini z nižjo gostoto gnezdečih parov. Ta kompenzacija pa je uspešna le do določene nadmorske višine, saj je bila rast mladičev na zgornji nadmorski višini počasnejša kljub majhni gnezditveni gostoti. Masa je dobro uporabno za primerjavo med različnimi ekološkimi pogoji, dolžina peruti pa je boljše orodje za določanje starosti mladičev v gnezdu.

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