Population decline of the Siberian Tit (*Poecile cinctus*) in southern Norway and an assessment of possible causes

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The Siberian Tit (*Poecile cinctus*) is an old-growth forest specialist in the northern taiga. The Finnish population has declined dramatically due to logging. An isolated population occurs in southern Norway. This population was estimated at 1,000 pairs based on surveys in 1979–80, and the Siberian Tit constituted 9% of all individuals in the whole bird community and 64% of all tits in lichen-dominated pine forest. In 2011–12 we censused tit species (Paridae) along 292.5 km line transects at 51 sites in southern Norway with potential occurrence of Siberian Tit. We found that the Siberian Tit constituted only about 1% of all tit territories or individuals. Recensuses of two sites which had Siberian Tits in 1979–80 showed no presence in 2011. The overall distribution range appears to have contracted over the past 30 years, and we suggest that current population size is only 50–150 pairs. We suggest three possible causes (climate change, competition with other tit species, forestry) for why the population of Siberian Tits in southern Norway has declined. A prospective assessment of available evidence indicated that 1) there was no change in elevation of historical records spanning > 40 years, 2) Great Tits (*Parus major*) and Willow Tits (*Poecile montanus*) were now common in areas where they did not occur in 1979–80, 3) there was a large overlap in habitat selection of the Siberian Tit and three other tit species, 4) there was only a weak association of Siberian Tits with old-growth forest, and 5) previously occupied sites had generally not been affected by logging. Thus, we suggest that future studies of population decline of the Siberian Tit should focus in particular on competitive interactions with other tit species.

1. Introduction

Large tracts of boreal forests are used for forestry, and logging leads to loss and fragmentation of old-growth forests. Forestry is a major threat factor for red-listed species in Fennoscandia (Gärdenfors 2010, Kålås *et al.* 2010). Logging has resulted in population declines of a number of bird species (e.g., Väisänen *et al.* 1986, Virkkala 1991), in particular resident cavity nesters (Imbeau *et al.* 2001) and species dependent on dead wood (Angelstam & Mikusinski 1994). Climate change is expected to have strong effects in the northern boreal zone (Virkkala *et al.* 2008), and may favour generalist

species (Hof *et al*. 2012). In the northern taiga forest, some resident species are dependent on stored food to survive the winter, but climate change may increase perishability of hoards (Waite & Strickland 2006). Thus, northern taiga species face multiple threats.

The Siberian Tit (*Poecile cinctus*) is a resident cavity-nesting passerine bird of the northern taiga zone. The distribution range covers continental areas with cold winters, and the Siberian Tit stores food for winter use (Haftorn 1971, Cramp *et al*. 1993). The Siberian Tit is an old-growth specialist with a broad foraging niche which may be an adaptation to northern conditions (Virkkala 1988). In Finland, the population size decreased with about 90% from the 1940s until the 1970s due to large-scale logging of northern taiga forests (Väisänen *et al*. 1986). Studies of habitat selection of Siberian Tits in Finland found a preference for old-growth forest (Virkkala 1987, 1990, 1991, Virkkala & Liehu 1990) and a low breeding success in heavily managed forest (Virkkala 1990). In Sweden, the species is currently classified as vulnerable on the Red List (ArtDatabanken 2015) because of population declines (Green & Lindström 2014). In Norway, the Siberian Tit is currently not red-listed, but there are no studies of the status of the species since the work of Bengtson and Sonerud (1991).

Bengtson and Sonerud (1991) summarized knowledge of the Siberian Tit in Norway, and focused in particular on the population in southern Norway which, together with a neighbouring population in southern Sweden, is isolated from the main distribution area of the species in northern Fennoscandia (Haftorn 1971, Gjershaug *et al*. 1994, Svensson *et al*. 1999, Valkama *et al*. 2011). Bengtson and Sonerud (1991) estimated the population in southern Norway to be at least 1,000 pairs (using census data from Sonerud 1982) distributed in northern Hedmark county and adjacent areas in Oppland and Sør-Trøndelag counties. The Siberian Tit was described as preferring open, lichen-dominated pine forests at high elevation (> 650 m a.s.l.) in the driest and most continental parts of southern Norway where it constituted 9% of all individuals in the whole bird community (Sonerud 1982, Bengtson & Sonerud 1991). In such forests few other tit species (Paridae) were present (Siberian Tit constituted 64% of all tit individuals, the remainder were Crested Tits (*Lophophanes crista-*

tus), whereas in somewhat richer forests with dwarf shrubs (Ericaceae) replacing lichens in the ground layer, there were few Siberian Tits, but instead the Willow Tit (*Poecile montanus*) was more common.

We aimed to assess recent changes in distribution and population size of the Siberian Tit in southern Norway. On the basis of the reported declines of the Siberian Tit in Finland and Sweden, we expected that there has been a population decline in southern Norway as well. To test this, we recensused two sites censused by Sonerud (1982) to assess population changes of the Siberian Tit. Furthermore, we expected that climate change may have caused disappearance of Siberian Tits from lower elevation sites. To test this, we collected data on elevation of Siberian Tit records spanning > 40 years. Climate change may further have led to an increase in other tit species, in particular the Great Tit (*Parus major*) (Väisänen *et al*. 1986, Karvonen *et al*. 2012), and thereby altered competitive interactions between tit species regarding e.g., nesting cavities, foraging sites or hoarding sites (Alatalo *et al*. 1985, Alatalo & Carlson 1987, Newton 1998). We conducted about 300 km line transects of Siberian Tits and other tit species at more than 50 sites within the known distribution range of the Siberian Tit in southern Norway, and recorded habitat overlap among the tit species to assess the potential for competitive interactions. Finally, to evaluate whether forestry may have affected the Siberian Tit, we assessed preference for old-growth forest and we revisited locations with previous sightings of Siberian Tits to assess the extent of logging in Siberian Tit habitats.

2. Material and methods

2.1. Study area

The study area covered the known distribution range of the Siberian Tit in southern Norway, mainly in northern parts of Hedmark county, but also in adjacent areas in Oppland and Sør-Trøndelag counties. Within these areas dry and open pine-dominated forests at high elevation (> 650 m a.s.l.) represent the favoured habitat of the Siberian Tit (Bengtson & Sonerud 1991). Such

areas typically have a continental climate with cold winters and low precipitation. We visited 51 different sites which were mostly chosen on the basis that there had been previous reports of Siberian Tits either at the site or not far from the site (*n* = 46). In the latter cases we required that potentially suitable habitat was present at the site, and this was in general verified before the field work by consulting aerial photographs (www.norge-ibilder.no). Presence of potentially suitable habitat was in particular required for a smaller number of sites (*n* = 5) which were > 10 km from previous records. On the basis of published information (in particular Bengtson & Sonerud 1991) we identified sites that included old-growth or lichen-dominated pine forest. Previous reports were compiled from the literature (Haftorn 1971, Bengtson & Sonerud 1991), the Norwegian online database for bird reporting (www.artsobservasjoner.no) and personal communications. This resulted in a list of 175 previous reports of Siberian Tits in southern Norway (Hedmark, Oppland and Sør-Trøndelag; see Appendix 2 in Andreassen 2013).

2.2. Censuses

We performed a total of 292.5 km line transects at 51 sites during 2011 and 2012 (186.5 km in 2011, 106 km in 2012; Supplementary material, Fig. S1). A total of 657 individuals of all species of tits (Paridae) were recorded (337 in 2011 and 320 in 2012). However, individuals recorded > 100 m from the transect line were excluded from presentation and analyses unless otherwise stated. A total of 48 individuals were recorded > 100 m from the transect line (Siberian Tit: *n* = 3, Willow Tit: *n* = 27, Crested Tit: *n* = 1, Great Tit: *n* = 17). Thus, the main sample used in analyses consisted of 609 individuals of four species of tits.

Line transects were made during the breeding season (May–July). Most transects were made during the fledgling period (from the middle of June until the middle of July) when birds could be expected to be easily located. Other transects (36.5 km) were made in May. Transects were made by walking slowly (roughly 1 km / h) through suitable habitat (i.e., avoiding non-forested areas if possible) from sunrise until midday and avoiding rainy weather.

Table 1. Habitat variables recorded for each 500 m segment of transect line and for each location where tits (Paridae) were observed.

Elevation (m a.s.l.)
Proportion of area covered by[1]
    Pine trees (*Pinus sylvestris*)
    Spruce trees (*Picea abies*)
    Deciduous trees (mostly birch, *Betula pendula*)
    Regenerating forest (< 5 m high trees,
      maturity class 2)
    Clear-cut (maturity class 1)
    Naturally open areas (e.g., bogs)
Age of forest[1,2]
    Young (> 5 m high trees, maturity class 2)
    Middle-aged (maturity class 3)
    Old (maturity class 4–5)
Ground cover[1]
    Lichens (in particular *Cladonia stellaris*)
    Dwarf shrubs (species of Ericaceae)

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1) Categories sum to 100%
2) Referring to the areas covered by pine, spruce or deciduous trees

One line transect (8 km, Stadsbuøyi-Grimsmoen in Folldal municipality, Hedmark county) made in 2011 represented a recensus of a census made in late June 1979–80 by Sonerud (1982). In addition, we recensused a site (2 km^2, Åsen in Folldal municipality, Hedmark county) which Sonerud (1982) had censused with a territory mapping method in late May 1979. We recensused this site by making repeated full searches of the site over a period of 5 days in 2011. Both recensuses were done at approximately the same time of the year as done by Sonerud (1982).

2.3. Habitat variables

During line transects we recorded habitat variables (Table 1) for each 500 m length of the transect (and within 100 m on each side of the transect line). A total of 585 transect line segments of 500 m each provided data on habitat availability in the study area. In addition, we recorded habitat variables within a circle with a radius of 50 m around all locations were tits were observed. Elevation (range 600–965 m a.s.l., median 715 m) was measured with GPS. Maturity class (Table 1) is a forestry term used to categorize size and relative age of a stand, ranging from 1 (clear-cut) to 5 (mature fo-

rest where growth has culminated and ready to be harvested) (Fitje & Strand 1989). Proportion of area covered by each habitat variable was visually estimated to the nearest 5% while walking through transect segments and noted at the end of each segment.

2.4. Habitat and logging at locations of previous records of Siberian Tits

In 2011–12 we revisited observation sites of 51 records of Siberian Tits made during 1968–2011. The sample included all records for which we had exact information on the geographical coordinates given by the observers. The most recent of these records were used to provide additional information on habitat selection of Siberian Tits due to the low number of individuals observed during censuses (see also below and Results). Recent records (from 2006–11, n = 17) were ≤ 5 years old when they were revisited (median 2 years old). Older records (n = 34, median observation year 1994, range 1968–2003) were only used to assess whether areas used previously by Siberian Tits had been affected by logging after the record was made.

Within a 50 m radius from the position of previous observations we recorded habitat variables as described above. We assumed that current tree species composition and ground cover reflected that at the time of the sighting because these depend mainly on soil nutrients and moisture which are fairly constant over time (Larsson & Søgnen 2003). Because the study area was at high elevation and in dry and nutrient-poor areas, growth is slow and vegetation changes take long time. Thus, we considered that for the recent records vegetation changes during the short time period after the sighting would have minimal impact on our habitat classification. The age and height of the forest at the time of the sighting was back-calculated on the basis of yearly tree shoots. Pine is the dominating tree species and this species has well-defined yearly shoots separated by lateral branches.

We searched for evidence of logging in the form of tree stumps and obvious boundaries between younger even-aged forest and older forest. If there were indications of past logging, we evaluated the age of younger regenerating trees by counting the number of yearly shoots. We compared the estimated age of the regenerating trees with the year of sighting of Siberian Tit to assess whether logging had occurred before or after the sighting. If there was evidence of logging after the time of sighting, we assumed that the forest that had been logged was old.

Our subjective opinion was that because of fairly uniform habitat, a larger radius than 50 m around the location of previous sightings would not change the evaluation of habitat variables. Thus, possible errors in the geographical coordinates of previous records was considered to have little influence on the data. Note also that 13 previous records were nest sites (nest boxes or tree cavities) for which the position could be verified in the field.

2.5. Statistical analyses

The relationship between elevation of observation sites and observation year was analysed with Spearman rank correlation. Analyses of habitat selection of Siberian Tits was based on recordings (n = 5) made during the censuses performed in this study, and, due to the small sample size, supplemented with other recent records with exact geographical coordinates available (n = 17) which permitted collecting retrospective data on habitat selection (see above). Thus, Siberian Tit habitat selection (n = 22) was compared to habitat selection of the other tit species (n = 38–191) and to habitat availability in the study area (n = 585 transect line segments of 500 m each). Habitat selection of the Siberian Tit, that of other tit species and habitat availability is reported as means with standard errors. However, due to unequal variances and skewed distributions, we chose to compare distributions of variables with non-parametric tests (Mann–Whitney U-tests).

3. Results

3.1. Population and distribution changes

Recensuses of two sites which had Siberian Tits in 1979–80 (Sonerud 1982) showed no presence of the species in 2011. Based on all reported sightings

Table 2. Status of the Siberian Tit (*Poecile cinctus*) in the main subpopulations in southern Norway. For each county areas have been sorted by municipality.

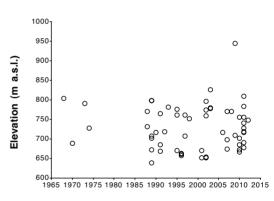| Region	Status
Hedmark county	
Folldal	Still present at several sites
Alvdal	Still present at least in Aumdalen/Valleråkjølen
	No recent observations in Finnbudalen (last record 1992)
Rendalen	A few recent observations in Sølendalen south to Fiskevollen,
	but not seen during 25.5 km line transect in 2011–12
Engerdal	Present around Lake Femunden (mainly south and east),
	but nearly all recent observations (last 10 years) only in the north-east
	(Femundsmarka National Park)
Sør-Trøndelag county	
Røros	Still present in Femundsmarka National Park and adjacent areas,
	no recent records (last 10 years) further north and north-west
	(Feragen, Hådalen)
Oppland county	
Dovre	No recent observations (last record in potential breeding area 1989)
Nord-Fron/Vågå	No recent observations in the Jotunheimen area (last record 1918)
Sør-Fron	Recent observations in extreme NE, part of the Folldal population

of the species, the distribution is now limited to four main areas (Table 2, see also Supplementary material, Fig. S1): Folldal, Alvdal, Sølendalen, and around Lake Femunden, and the distribution appears to have become more restricted in recent years in the three latter areas (Table 2, see Appendix 2 of Andreassen 2013 for a list of all known observations of Siberian Tits in southern Norway up to 2012).

3.2. Temporal pattern in elevation of Siberian Tit records

There was no significant relationship between the elevation of observation sites for Siberian Tits and year of observation (spanning a period of > 40 years; $r_s = 0.02$, $n = 60$, $p = 0.90$; Fig. 1; sample size included records for which elevation was known exactly).

3.3. Relative commonness of tit species

In 292.5 km line transects made during 2011–12 in the general distribution range of Siberian Tits, we found a low number of Siberian Tits compared to the other tit species (Table 3). The Siberian Tit constituted only 0.9% of all tit territories (3 / 341) and 0.7% of all individuals observed (4 / 609).

Year of sighting

Fig. 1. Relationship between elevation and year of sighting for previous records (n = 60) of Siberian tits (*Poecile cinctus*). The sample included observations made during censuses in the present study and all published (historical) records for which elevation was known exactly. Thus, the data also illustrate the altitudinal distribution of the species in southern Norway.

Even if including tit individuals observed > 100 m from the transect line, the Siberian Tit constituted only 1.4% of all territories (5 / 364) and 1.1% of all individuals (7 / 657).

In two sites in Folldal with lichen-dominated open pine forest which had Siberian Tits in 1979–

Table 3. Number of tits (Paridae) recorded during 292.5 km line transects at 51 sites in 2011–12 in Southern Norway. Flocks or family groups as well as single individuals were considered to represent one territory each.

Species	Terri-tories	Indivi-duals	Territories / km
Poecile cinctus	3	4	0.01
Poecile montanus	191	402	0.65
Lophophanes cristatus	38	68	0.13
Parus major	109	135	0.37

80, there were no Willow Tits or Great Tits at that time (Sonerud 1982). In 2011, line transects in these two sites (total of 13.5 km) produced 20 individuals of Willow Tit and 2 individuals of Great Tit. From six sites in Folldal (including the two previous sites), a selection of 79 individual line transect segments (each of 500 m length) which all had ≥ 50% lichen cover, we found 36 Willow Tits and 16 Great Tits in 2011–12.

3.4. Habitat selection

Overall, there were few significant differences between the habitat selection of Siberian Tit and other tit species, or between the habitat selection of Siberian Tit and habitat availability (Table 4). Compared to habitat availability in the study area, Siberian Tits were found in places with a lower proportion of clear-cut and young forest (Table 4). Siberian Tit locations had a somewhat higher percentage of old-growth forest than expected from habitat availability (Table 4), but this difference was not formally significant ($p = 0.07$).

Mean availability of old-growth forest was 21% ($n = 585$ line transect segments), but 41% (9 / 22) of Siberian Tit locations had ≤ 21% old-growth forest.

Compared to other tit species, Siberian Tits favoured areas with more naturally open areas than the Willow Tit and more deciduous trees than the Crested Tit (Table 4). Other tit species used old-growth forest as much as the Siberian Tit (Table 4), and none of them used old-growth less often than expected by habitat availability (Mann–Whitney U-tests: $p > 0.19$ in all three comparisons). Similarly, there were no significant differences in amount of lichen in locations were Siberian Tits were found compared to other tit species (Table 4), but the Great Tit had a lower proportion of lichen than expected from habitat availability ($p = 0.002$; $p > 0.18$ for the other two species).

Table 4. Comparison of habitat at observation locations of four species of tits [Siberian Tit (*Poecile cinctus*): $n = 22$ observations (5 during censuses, 17 other recent records), Willow Tit (*P. montanus*): $n = 191$, Crested Tit (*Lophophanes cristatus*): $n = 38$, Great Tit (*Parus major*): $n = 109$] and habitat availability ($n = 585$ line transect segments of 500 m each) in southern Norway. Mean values and SEs (in parentheses) for each habitat variable are shown (see Table 1 for explanations). Significant Mann–Whitney U-tests involving Siberian Tit are shown in bold, and letters indicate which comparisons were significant (Siberian Tit versus: A – Willow Tit, B – Crested Tit, C – Great Tit, and D – habitat availability).

Habitat variable	Siberian Tit	Willow Tit	Crested Tit	Great Tit	Habitat availability	Test[1]
Elevation (m a.s.l.)	733.2 (13.1)	726.5 (4.3)	746.2 (9.1)	726.2 (6.0)	727.1 (2.5)	–
Pine (%)	61.8 (5.1)	61.7 (1.5)	70.8 (3.1)	54.1 (2.2)	58.1 (0.8)	–
Spruce (%)	0.0 (0)	0.5 (0.2)	0.8 (0.6)	1.0 (0.6)	0.5 (0.2)	–
Deciduous (%)	**14.6 (3.7)**	13.7 (1.2)	**5.2 (1.5)**	19.7 (2.1)	14.6 (0.7)	B**
Regenerating forest (%)	9.1 (2.0)	9.8 (0.8)	9.7 (1.5)	10.2 (1.1)	11.5 (0.4)	–
Clear-cut (%)	**6.0 (1.9)**	11.1 (1.0)	9.1 (1.8)	9.8 (1.3)	**11.1 (0.4)**	D**
Naturally open areas (%)	**8.6 (3.7)**	**3.5 (0.7)**	4.5 (1.8)	5.4 (1.2)	4.4 (0.4)	A**
Young forest (%)	**15.6 (3.2)**	19.7 (1.4)	21.3 (3.4)	18.7 (1.6)	**19.8 (0.6)**	D*
Middle-aged forest (%)	58.4 (2.9)	59.7 (1.5)	56.8 (3.7)	56.2 (2.0)	59.0 (0.7)	–
Old forest (%)	26.2 (3.5)	20.6 (1.4)	21.8 (3.5)	25.2 (2.1)	21.3 (0.8)	–
Lichen (%)	35.0 (6.0)	36.8 (2.0)	43.6 (4.9)	29.8 (2.8)	37.5 (1.2)	–
Dwarf shrub (%)	65.0 (6.0)	63.2 (2.0)	56.5 (4.9)	70.2 (2.8)	62.5 (1.2)	–

1) *: $p < 0.05$, **: $p < 0.01$

3.5. Logging at previous observation sites

Out of 34 records of Siberian Tits made during 1968–2003, revisits suggested that 27 of the sites (79%) had not been logged after the sighting. There was evidence of logging after sightings at seven sites, and before sightings at six sites. Two sites had become overgrown with younger forest between the older trees, probably due to cessation of grazing by livestock.

4. Discussion

4.1. Changes in population size and distribution

We did not find Siberian Tits in the two areas we recensused (Åsen and Stadsbuøyi-Grimsmoen in Folldal, Hedmark; see Fig. S1) which had a Siberian Tit density of 1.6 pairs / km^2 in 1979–80 (Sonerud 1982). The Åsen area has experienced logging in recent years, at least after the most recent observation in the area (1995). We performed line transects at 51 sites which were at or close to locations with previous reports of Siberian Tits, but we found the species at only 5 of these sites. Across our sites, the Siberian Tit constituted only about 1% of all tit individuals recorded, and even in the most lichen-dominated pine forests (those in Folldal) the figure was still only 2.5%. In contrast, Sonerud (1982) found that the Siberian Tit constituted 64% of all tit individuals in lichen-dominated pine forests. Furthermore, compilation of previous reports indicated that some areas, in particular the southern part of Femunden and Sølendalen (see Fig. S1), had few recent sightings which may indicate a contraction of the distribution range. In addition, observers who have made repeated visits over years to the distribution area of the Siberian Tit have reported that the species has recently become increasingly difficult to find (Jon Bekken, Gunnar Ådne Solbakken and Morten Venås, pers. comm.).

During line transects we found only 0.01 Siberian Tit territories / km. This was based on a line width of 200 m which would translate into a density of 0.051 territories / km^2. A conservative assumption could be that we detected at least half of all birds, giving a density estimate of 0.1 territo-

ries / km^2. Adding the three recordings of Siberian Tits that were just outside the 100 m transect line would still yield an estimate of only 0.17 territories / km^2. In comparison, Sonerud (1982) found 4 pairs in 2 km^2 at Åsen, Folldal (2 pairs / km^2) and estimated an overall average of 1.6 pairs / km^2 in lichen-dominated forest in Folldal, whereas Haftorn (1973) found at least 4 pairs in 3 km^2 (1.3 pairs / km^2) at another site in Folldal. Thus, a substantial decrease in both distribution and density appears to have occurred during the last 30–40 years.

Bengtson and Sonerud (1991) estimated the population of Siberian Tits in southern Norway to be at least 1,000 pairs. This was based on the assumption that the core areas for the Siberian Tit in southern Norway had more than 1,000 km^2 suitable pine forest and a mean density of at least 1 pair of Siberian Tits per km^2. Based on our compilation of historical observations and knowledge of habitats in the study area, we find the size of the potential distribution area estimated by Bengtson and Sonerud (1991) to be reasonable (our estimates: ca. 250 km^2 in Folldal, ca. 50 km^2 in Alvdal, ca. 100 km^2 in Sølendalen, and ca. 700 km^2 around Femunden, note that these figures concern area of suitable forest types, but do not say anything about the quality of these areas). Thus, with density estimates suggested above (0.05–0.17 territories / km^2), the current population size of Siberian Tits in southern Norway may be around 50–150 pairs considering the whole potential distribution area, corresponding to a decline of roughly 90% since the 1980s. However, substantial parts of the potential distribution areas may be less suitable for the Siberian Tit than the sites we censused (because census sites were chosen on the basis of actual records of the species), and the species may have disappeared from parts of the potential distribution area. This suggests that the lower population estimate may be most realistic.

4.2. Possible causes of population decline

4.2.1. Climate change

Climate change has influenced the distribution of birds and other organisms (Walther *et al.* 2002, Parmesan & Yohe 2003), and species which are at an elevational limit may suffer population declines

if vegetation zones do not move fast enough upward in response to climate change or if potential habitat area at higher elevations is limited (Şekercioğlu *et al*. 2008). Furthermore, climate change may impact Siberian Tits directly because winter storage of food may be compromised if temperature and precipitation increase (Waite & Strickland 2006). However, we did not find evidence that Siberian Tits had disappeared from lower elevation sites over time. This was despite an increase in the annual mean temperature of 1.5°C over the last 45 years in the study area (based on climate data from Drevsjø at the southern end of Femunden, data retrieved from eklima.met.no), and up to 3.5°C for some of the winter months. Stronger evidence for an influence of climate change would be to assess if there have been changes in the relationship between elevation and breeding success, but no such data are available from southern Norway.

4.2.2. Competition with other tit species

Climate change could have indirect effects through community changes which could alter interspecific competition patterns (Alatalo *et al*. 1985, Newton 1998). Sonerud (1982) found that the Siberian Tit was the most common tit species in lichen-dominated pine forest, and he found no Willow Tits or Great Tits in such areas. In contrast, in the same areas in 2011, we found no Siberian Tits, but numerous Willow Tits and Great Tits. In half of our own observations of Siberian Tits ($n =$ 6), there were Willow Tits close by (and in two cases they formed a mixed-species flock), and most of our 51 sites had Willow Tits and Great Tits. Even the most remote areas of Femundsmarka National Park had at least a few Willow Tits and Great Tits.

An increase in population size and distribution of Great Tits in Fennoscandia has been observed at the northern margin of the distribution area (Väisänen *et al*. 1986, Karvonen *et al*. 2012), although the cause for the expansion may be winter feeding of birds as well as climate change (Robb *et al*. 2008). Winter feeding increases survival which may drive population expansion into previously uninhabited areas (Orell 1989, Robb *et al*. 2008). The Great Tit was previously recorded as "patchily

distributed at low density" in Folldal in 1979–80 (Sonerud 1982), whereas we found it to be widespread and fairly common in Folldal (0.46 territories / km transect line). The Siberian Tit, unlike its relative the Willow Tit, often breeds in cavities made by woodpeckers (Haftorn 1971). Thus, the expansion in particular of the Great Tit which does not excavate own nest sites, may have increased interspecific competition for nest sites (Newton 1998). Competition for nest sites may further increase if loss of old-growth forests have decreased populations of woodpeckers (Angelstam & Mikusinski 1994). A general increase in the number of tits may also increase diffuse competition for food (Minot 1981, Alatalo *et al*. 1985), in particular because our results indicated a large overlap in habitat selection of the four species of tits (i.e., there were few habitat variables which showed a difference between the species; note also that *p*-values reported in Table 4 were not corrected for multiple testing, this would lead to an even lower number of significant differences).

4.2.3. Forestry and logging

Studies in Finland have indicated that Siberian Tits prefer old-growth forest (Virkkala 1987, 1990, 1991, Virkkala & Liehu 1990), and that logging in the northern taiga forest caused a dramatic population decline of the Siberian Tit and other old-growth species (Väisänen *et al*. 1986). We therefore expected to find that observation sites of Siberian Tit had older forest than the forest in general in the study area and that areas affected by forestry were avoided. We did find trends that Siberian Tits avoided clear-cuts and young forest. Observation sites had a somewhat larger proportion of old-growth forest than expected from habitat availability (mean 26% versus 21%), but this difference was not statistically significant. Our sample size for habitat selection of Siberian Tits ($n = 22$) was smaller than for other tit species, and the lack of a significant difference may be due to low power. However, the absolute difference in proportion of old-growth forest was not very large and 41% of Siberian Tits had ≤ 21% old-growth (which was the mean availability of old-growth forest). The absence of clear evidence in our field data for an important role of old-growth forest for Siberian

Tits may be related to the fact that much of the forest in the study area has been affected by forestry. Perhaps a large proportion of the remnant population of Siberian Tits in southern Norway cannot avoid using a mix of different-aged forest. On the other hand, we note that Femundsmarka National Park protects old-growth pine forest and remains a stronghold for the Siberian Tit with a larger number of recent observations than in Folldal, Alvdal, Sølendalen or the southern Femunden area.

There was no clear trend that locations of historical records of Siberian Tits had been exposed to logging after the last sighting, but we acknowledge that our assessment was only based on a small area (50 m radius) around each observation site, and therefore only represent snapshots of how the forest has been affected by logging. However, logging was absent in most of the sites (79% had no signs of logging despite a median of 17 years since the record was made) which suggests that availability of old-growth has not decreased dramatically during this period. Our data indicated a rate of logging of 21% over an median of 17 years (corresponding to a rotation time of 81 years) which was far from the rate of population decline (ca. 90% over 32 years). In addition, even if old-growth is logged, it is likely that there is some recruitment of new areas of suitable old-growth forest which partly offsets the loss of old-growth to logging. Hence, logging seems unlikely to explain the population decline of Siberian Tits. Furthermore, it should be noted that the study area had been subjected to substantial logging already during the 1960s and 70s (Andreassen 2013), i.e., *before* Sonerud (1982) made censuses in these areas. However, without detailed behavioral studies of how Siberian Tits utilize forest stands of different ages and how forest age affects breeding success and survival in southern Norway, it is difficult to conclude what role logging may have had in the observed population decline.

4.3. Conclusions

The Siberian Tit has declined substantially in southern Norway. The population density is now critically low in many areas, and we predict that several of the subpopulations may suffer from demographic problems of small populations

(Simberloff 1998). The population is split into several small and isolated subpopulations (perhaps < 50 pairs each, Folldal/Alvdal subpopulations separated by > 50 km from Femunden subpopulation) which may suffer from population losses through emigration of females and consequently reduced population productivity (Dale 2001). We suggest that the population decline may be related to a combination of logging of old-growth forest, climate change and in particular increased populations of other tit species. Management plans to prevent the extinction of the Siberian Tit in southern Norway should focus on assessing the impact of competition from other tit species and forest structure on breeding success and survival. If Great Tits appear to be a primary problem, one might need to consider 1) supplying an excess of nestboxes if availability of nesting sites is the limiting factor, or 2) if there is competition for food during the summer season one should consider restricting winter feeding of tits in these areas which should reduce numbers of the Great Tit, but not the Siberian Tit which has own winter food stores (cf. Haftorn 1953, Orell 1989).

Lappmesens tillbakagång i södra Norge – en granskning av möjliga orsaker

Lappmesen (*Poecile cinctus*) förknippas ofta med gammal skog i det nordliga taigabältet. Det finska beståndet har uppvisat en dramatisk tillbakagång på grund av skogsbruk. I Syd-Norge finns ett isolerat bestånd, som på basis av taxeringar 1979–80 uppskattades till ca 1 000 par, vilket då motsvarade ca 9 % av alla individer i fågelsamhället och 64 % av alla mesar i tallhed.

År 2011–12 taxerade vi mesar (Paridae) längs sträckor på sammanlagt 292,5 km, på 51 områden i Syd-Norge där det sannolikt kunde förekomma

lappmes. Vi fann att lappmesen utgjorde bara ca 1 % av alla revir eller individer av mes. På två områden där arten förekom 1979–80 återfanns den inte längre överhuvudtaget. Utbredningsområdet ser ut att ha krympt under de senaste 30 åren och vi estimerar att nuvarande beståndet är bara 50–150 par.

Vi föreslår tre möjliga förklaringar till varför bestånden av lappmes i Syd-Norge har gått tillbaka: klimatförändringar, konkurrens med andra mesarter och skogsbruk. En evaluering av tillgänglig information tyder på att: 1) det inte förekommit någon förändring i höjd över havet för historiska observationer från över 40 år, 2) talgoxe (*Parus major*) och talltita (*Poecile montanus*) är numera vanliga i områden där de inte förekom 1979–80, 3) det finns stort överlapp i val av habitat mellan lappmes och de tre andra mesarterna, 4) lappmes var bara svagt bunden till gammal skog, och 5) ställen där lappmes tidigare förekommit hade bara i liten grad utsatts för hyggen. Vi föreslår därför att framtida studier av nedgången av lappmes skall fokusera speciellt på konkurrensförhållandet med andra mesarter.

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