# PARUS program: wintering land bird monitoring in European Russia

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**Abstract.** For more than 30 years, the PARUS program has implemented annual censuses of wintering birds across a network of model sites in the European Russia forest zone. The scheme is run mostly by volunteers who make transect counts; it enables the estimation of bird population density in typical forest habitats. We present an analysis of wide-scale population trends in forest habitats using TRIM software for 17 common birds. Between 1988 and 2019, seven species had decreasing trends, populations of nine species were stable, and none showed a significant increase. Species associated with coniferous trees had a more pronounced decline in comparison to generalist species; declines were most dramatic for Goldcrest *Regulus regulus*, Willow *Poecile montanus* and Coal Tits *Periparus ater*. Similar tendencies were reported with monitoring schemes in neighbouring countries. We suppose that main negative factor was intense logging in boreal forests; climate change could also play a role.

#### Introduction

Bird dynamics are a widely used indicator for wildlife monitoring purposes, as birds are numerous and ecologically variable group which are relatively simple to count (Koskimies 1989). Usually, monitoring schemes are concentrated on the breeding season. However, population estimates on other life cycle stages are also important for the understanding of species' ecology and environment drivers of population changes. Winter survival influences breeding abundance in the next season and changes in winter conditions can be a crucial factor in determining multi-year population dynamics. Additionally, the state of resident species' populations can be more relevant environment indicator than migrants, whose dynamics depends on their wintering ground conditions (Fraixedas et al. 2015).

The aim of the PARUS program is the large-scale monitoring of wintering land birds in European Russia. The total area of the region is 3.3m km<sup>2</sup>, and about 1.655m km<sup>2</sup> is covered with forest (Shchepashchenko *et al.* 2015). For many species wintering in the forest and forest-steppe zones, this territory is the main population reservoir playing the crucial role in population dynamics.

The program was started in 1986; during the first years, it increased its coverage and has been producing comparable data since 1988, encompassing the majority of the target region. Today it unites more than 200 participants annually, who make regular censuses on more than 25 model sites (Bogolyubov & Preobrazhenskaya 2017; Fig. 1). Wintering bird censuses are made in typical, mainly natural landscapes, both forested and open or mosaic.

The purpose of this article is to introduce the PARUS program coordinated by E.S. Preobrazhenskaya (Bogolyubov & Preobrazhenskaya 2017), as the scheme is not necessarily familiar to many European ornithologists, and to present the results of 31 years of monitoring (1988 to 2019) for the 17 most common species in forest landscapes. Previously these data were analyzed only on the regional level (Preobrazhenskaya 2011, 2017); here, we use TRIM software (Trends and Indices for Monitoring data; Bogaart *et al.* 2018) to assess general tendencies for the whole territory.

## Methods

The study sites were distributed across the forest belt of European Russia (some sites located



Figure 1. Locations of the PARUS program monitoring sites. Colours show forest subzone: NT — Northern taiga, MT — middle taiga, ST — southern taiga, SB — subboreal forests, BF — broadleaf forests. Symbols indicate different longitudinal sectors: W — Western, C — Central, CE — Central-East, E — East.

 $\label{eq:construction} The map: @ OpenStreetMap contributors; green colour - forest, yellow-green - open landscape, blue - water bodies.$ 

in the westernmost part of South Siberia), divided into five subzones (the northern, middle and southern taiga, the subboreal (mixed) forests and the broadleaf forests including island forests in the forest-steppe zone). Each subzone included three or four longitudinal regions: Western, Central, Central-East (in two southernmost subzones only) and East. This resulted in 17 sectors (combinations of forest subzone and longitudinal regions), all of which, with the exception of the most remote eastern sectors of northern and middle taiga, contained at least one study site (Fig. 1). In each site, one or several distinct forest habitats prevailing in the landscape were chosen for study. Clear-cuts, young stands and settlements were omitted.

Route censuses were made in December-February using the method proposed by Ravkin & Luk'yanova (1967). While walking a linear transect, the observer writes down the number of birds and radial distances to individuals or flocks in the moment of registration. These radial distances, grouped into five intervals (<10, 10-25, 25-100, 100-300 and >300 m), are used to obtain a coefficient which allows one to calculate the population density using the number of registered individuals. This coefficient, called effective census band, is counted as the harmonic mean of registration distances, separately for birds with different perceptibility - just sitting or moving in the canopy, singing, and flying. The density of each group is the product of this coefficient and the number of counted birds, divided by the transect length. For flying birds, the value was additionally divided by average flight speed, typically assumed as 30 km/h. The final population density is the sum of values of all groups (Ravkin & Luk'yanova 1967). Most observers did not record distances by themselves, and their data were processed with pre-obtained standard coefficients specific for different species, habitats and forest subzones (Bogolyubov & Preobrazhenskaya 2017).

Censuses were made either on a random or on a constant transect not less than 2 km long, crossing more or less uniform landscape (e.g. coniferous or deciduous forest). Transects were chosen freely by fieldworkers and sometimes were changed for a new one at a distance of no more than 100 km away from the previous one. The total length of census routes in a study site per winter season was at least 20 km for each habitat.

During the multi-year survey, time series of annual density values were produced for every species in each study site. If several habitat types were explored within a site and a species density significantly differ among them, these habitats were treated as separate time series. Otherwise, the density values were averaged for all habitats. If a habitat type was completely or almost avoided by a species, it was excluded from calculations.

We used rtrim 2.1.1 package for R 4.0.2 (R Core Team 2020) to estimate missing data and calculate trend parameters. The function rtrim fits log-linear Poisson regression to the data and provides annual abundance indices as well as slope for a multi-year population change (Bogaart et al. 2020). As the forest zone sectors differed strongly in the area of suitable forests, they made an unegual contribution to the total population dynamics. Because of this, we used weight coefficients reflecting the relative impact of time series. We consider each site as equally contributing to the population dynamics within a sector. If a site contained several time series, its weight was distributed among them proportionally to the area ratio of corresponding forest types in the sector. Thus, the weight coefficients (W) for a time series was calculated in the following way:

## $W = F \times P / N$ ,

where **F** is the forest area in a sector, **N** is the number of study sites within a sector and **P** is the proportion of habitat type corresponding to a time series (equal to 1, if only one habitat type was studied within a site).

The forest area was calculated with state forestry data (USSR forest fund 1990; Russian forest fund 2003), using average figures for 1988 and 2002 (without young stands; Table 1). However, these estimations are very rough; the between-year differences apparently did not show real forest dynamics, due to differences in assessment methods and quality. Because of this, we used constant weights for all years, though actually their figures might change over time. Six species are considered to be conifer forest specialists: during the winter season, they predominately use coniferous or mixed forests, which are typical late-succession habitats on the whole studied territory except the southernmost subzone. Other species use deciduous forests as well, sometimes along with non-forest habitats, or even prefer them (Dement'ev & Gladkov 1954). Accordingly, for each species we selected the area of coniferous and mixed, deciduous or all forest stands (Table 2).

We made estimations of species abundance in different ecological regions, having calculated their multiyear average density and population size for each forest subzone. Population size was obtained as the product of average density and the area of forest habitats used in trend calculations. Definitely, these estimations were very rough and cannot be considered as complete, because not the whole spectrum of habitats was explored. Nevertheless, they allow us to reveal general patterns of species distribution across the forest belt and to compare the relative importance of different subzones as species wintering area.

To obtain annual population indices and multiplicative trend parameters (log-growth rates), we used the linear trend model with corrections for autocorrelation and overdispersion in *rtrim*. All years were included as changepoints and the stepwise procedure was used to remove non-significant ones. For population indices, the base period was set on 2017–2019 years, because fewer routes were missed during this period than in the initial years. For assessment of dynamics tendencies, overall trends for imputed indices were used.

To check the possible association between species characteristics and multiyear changes, we compared multiplicative trend parameters using weighted Mann-Whitney test (*weighted\_mannwhitney* function in *sjstats* 0.18.0 package for R; Ludecke 2020). As trend parameters had unequal preciseness, the reverses of their standard errors were used as weight coefficients. Table 1. Forest area (thousands of ha) for different forest subzones and longitudinal sectors of European Russia. Average values for 1988 and 2002 years (USSR forest fund 1990; Russian forest fund 2003). Young stands excluded. C — coniferous and mixed forests; D — deciduous forests; A — all forests. Acronyms for forest subzone are NT = Northern taiga, MT = middle taiga, ST = southern taiga, SB = subboreal forests, BF = broadleaf forests, and acronyms for longitudinal sectors are W = Western, C = Central, CE = Central-East and E = East.

| Zone | Sector | С     | D    | А     |  |
|------|--------|-------|------|-------|--|
| NT   | W      | 3649  | 421  | 4070  |  |
|      | С      | 5817  | 683  | 6500  |  |
|      | E1     | 6530  | 710  | 7240  |  |
| MT   | W      | 3548  | 582  | 4130  |  |
|      | С      | 20608 | 3322 | 23930 |  |
|      | E1     | 7041  | 1409 | 8450  |  |
| ST   | W      | 4491  | 2099 | 6590  |  |
|      | С      | 4596  | 2744 | 7340  |  |
|      | E      | 2488  | 1052 | 3540  |  |
| SB   | W      | 1342  | 919  | 2260  |  |
|      | С      | 1718  | 1192 | 2910  |  |
|      | CE     | 2322  | 2358 | 4680  |  |
|      | E      | 2257  | 793  | 3050  |  |
| BF   | W      | 353   | 397  | 750   |  |
|      | С      | 552   | 1128 | 1680  |  |
|      | CE     | 477   | 2034 | 2510  |  |
|      | E      | 1865  | 2965 | 4830  |  |

<sup>1</sup> No censuses were made in these sectors

The multi-species indicator (MSI) summarizes the general state of the forest wintering birds community; it is defined as the geometric mean of species indices (Gregory et al. 2005). We calculated it with the MSI tool for R (Statistics Netherlands 2017, Soldaat et al. 2017), also allowing to estimate the significance of multi-species trend. The indicator included all analyzed species except Common Redpoll Carduelis flammea and Common Crossbill Loxia curvirostra, because these species had very irruptive population dynamics due to their nomadic movements. In addition, during the non-breeding period redpolls widely use open habitats (Dement'ev & Gladkov 1954), which were not covered with the current study). The MSI algorithm does not support a base period of multiple years, so 2019 was used in this case. We assess the significance of the multi-species trend for the whole the study period as well for its first and second parts (16 years before/since 2004). To reveal which species contributed most to the indicator, we calculated its correlations with all population indices (Spearman rank correlation, *cor.test* function).

## Results

Fig. 2 shows the average density and estimated size of studied populations for each forest sub-

zone. Most of species analyzed were present in all forest subzones, though some of them were rare or absent on the northern- or southernmost extremes. We divide species into two groups based on their distribution: "northern", with highest population sizes in the middle taiga zone (eight species), and "southern", with highest values in south taiga or further south (nine species; Table 2).

In 1988–2019, seven of the 17 studied species had moderately decreasing trends, populations of nine were stable, and one species had uncertain trend (Table 2, Fig. 3). The species with the strongest declines were Coal Tit *Periparus ater* (Fig. 3h), Goldcrest *Regulus regulus* (Fig. 3c) and Willow Tit *Poecile montanus* (Fig. 3f).

In general, species associated mostly with coniferous or mixed forest decline more than habitat generalists or species preferring deciduous stands (Table 2). It was confirmed both by their trend values (Fig. 4; weighted Mann-Whitney test:  $\chi^2$  = 2.71, df = 15, p = 0.016) and higher proportion of significantly decreasing trends (66.7% vs. 27.2% for species not associated with conifer trees). We found no difference between general tendencies in "northern" and "southern" species groups ( $\chi^2$  = 0.52, df = 15, p = 0.610).



Figure 2. Average population density and size of 17 bird species (a–q) in preferred forest habitats for five subzones of European Russia forest belt during 1988–2019. Bars represents estimated total population size (ind.) and red dots show estimated mean density (ind./km<sup>2</sup>). NT is Northern taiga, MT is middle taiga, ST is southern taiga, SB is subboreal forests and BF is broadleaf forests.

As negative tendencies, though not always significant, were demonstrated by the most of the studied species, the MSI for wintering forest birds showed a long-term moderate decline (Fig. 5). The highest correlation values for multi-species and population indices ( $r_s \ge 0.70$ , p < 0.01) were for Goldcrest *Regulus regulus*, Willow Tit *Poecile montanus* and Great Spotted Woodpecker *Dendrocopos major* (Table 2). Short-term MSI trends both before and after 2004 were insignificant and classified as stable, indicating that the most pronounced decline had place at the turn of these periods.

#### Discussion

In comparison with similar winter bird monitoring schemes in European countries (Heldbjerg

Table 2. Population trend parameters for common wintering birds by the PARUS monitoring program. FT — preferred forest type, the type of forests, whose area was used in trend calculation: A — all forests; C — coniferous and mixed forests; D — deciduous forests. DT — distribution type: N — "northern", S — "southern" (see Results). Abbreviations for trend classes (Bogaart *et al.* 2018):  $\psi$  — moderate decrease, — stable, ? — uncertain. MAC (%) — mean annual changes of population indices,  $r_s$  — Spearman's rank correlation coefficient between species' population indices and the multispecies indicator (MSI); it is given for species included in the MSI calculation. Asterisks show parameters' statistical significance: \* — p < 0.05, \*\* — p < 0.01.

| Common name              | Latin name            | FT | DT | Multiplicative slope (±SE) | Trend class    | MAC (%) | r <sub>s</sub> |
|--------------------------|-----------------------|----|----|----------------------------|----------------|---------|----------------|
| Black Woodpecker         | Dryocopus martius     | А  | N  | 1.008 ± 0.009              | _              | +0.75   | 0,32           |
| Great Spotted Woodpecker | Dendrocopos major     | С  | N  | 0.982 ± 0.005              | ↓**            | -1.85   | 0,70**         |
| Goldcrest                | Regulus regulus       | С  | S  | 0.966 ± 0.009              | $\downarrow^*$ | -3.36   | 0,73**         |
| Long-tailed Tit          | Aegithalos caudatus   | А  | S  | 0.987 ± 0.008              | _              | -1.35   | 0,60**         |
| Marsh Tit                | Poecile palustris     | D  | S  | 0.986 ± 0.012              | _              | -1.43   | 0,38*          |
| Willow Tit               | Poecile montanus      | С  | N  | 0.968 ± 0.005              | ↓**            | -3.21   | 0,71**         |
| Crested Tit              | Lophophanes cristatus | С  | N  | 0.985 ± 0.009              | _              | -1.51   | 0,49**         |
| Coal Tit                 | Periparus ater        | С  | S  | 0.966 ± 0.011              | $\downarrow^*$ | -3.41   | 0,58**         |
| Blue Tit                 | Cyanistes caeruleus   | А  | S  | $1.001 \pm 0.007$          | _              | +0.09   | 0,05           |
| Great Tit                | Parus major           | А  | N  | 0.964 ± 0.006              | ↓**            | -3.62   | 0,65**         |
| Eurasian Nuthatch        | Sitta europaea        | А  | S  | 0.977 ± 0.004              | ↓**            | -2.29   | 0,51**         |
| Eurasian Treecreeper     | Certhia familiaris    | А  | S  | 0.989 ± 0.006              | _              | -1.10   | 0,34           |
| Common Raven             | Corvus corax          | А  | N  | 0.995 ± 0.008              | _              | -0.47   | 0,13           |
| Eurasian Siskin          | Spinus spinus         | А  | S  | 1.008 ± 0.017              | _              | +0.76   | 0,18           |
| Common Redpoll1          | Carduelis flammea     | А  | N  | 0.987 ± 0.010              | _              | -1.27   |                |
| Common Crossbill         | Loxia curvirostra     | С  | N  | 0.957 ± 0.034              | ?              | -4.31   |                |
| Eurasian Bullfinch       | Pyrrhula pyrrhula     | А  | S  | 0.984 ± 0.007              | $\downarrow^*$ | -1.56   | 0,45**         |

<sup>1</sup> The data include registrations of Arctic Redpoll (*C. hornemanni*) which were much less abundant and usually impossible to identify.

et al. 2016), the monitoring network of PARUS program has much wider spatial coverage (large part of European Russia) but limited habitat representativeness and a lower density of survey routes. This means that only well-pronounced changes with similar vector in the most part of the population can be detected, and the assessments may be biased if the trends were different in unexplored regions or habitats. The latter was particularly important for species often using human settlements (Great Tit Parus major, Blue Tit Cyanistes caeruleus, and Eurasian Bullfinch Pyrrhula pyrrhula) or non-forest landscapes (Siskin Spinus spinus, Eurasian Bullfinch, Common Redpoll; Dement'ev & Gladkov 1954). For example, winter density of the Great and the Blue Tit in human settlements is usually much higher than in natural forests, so they may contribute substantially to the total abundance - despite the fact that human population density is low in most of the studied region. Because of this, we cannot be sure if the observed tendencies are relevant for the whole populations. However, for

predominately forest-dwelling species such gaps in coverage are unlikely to distort the observed tendencies, which generally were driven by the most preferred and widespread habitat types. Another source of bias was that the area of forest was assumed to be stable in our trend calculations. Because of this, we were only able to estimate bird population trends in relation to their density dynamics, without including effects of changes in forest area. The preciseness of estimations of forest area change was also questionable, as we lack detailed forest statistics data. In addition, we are aware that our monitoring network is very sparse for such a large region, so it provides very rough estimations. However, it is hard to explain simultaneous tendencies in different parts of the region with specific local conditions only; such results suggest some widescale factors have played a role. Most of the census sites were situated on areas with low human impact, so population dynamics likely reflected large-scale changes, not local ones. Here, we make some general hypotheses about them.



Figure 3. Winter population trends of 17 common wintering species (a–q) based on PARUS monitoring data in the European Russia forest zone. Grey area show 95% confidence intervals. Footnotes show trend classes (Bogaart *et al.* 2018) and significance.

The forest wintering species showed a general decline, particularly notable in early 2000s (Fig. 5), and none of species had significant positive tendencies (Table 2). The group of negative trends unites species with diverse ecology features such as habitat and feeding specialization, so there was probably more than one factor causing their dynamics. However, the decline of conifer forest specialists (see Table 2) was the most common and pronounced change in the bird community. The members of this group showed the lowest growth rates and had the largest impact on the total decline of the MSI. Among them were species with different latitudinal distribution, e.g.



Figure 4. Population trend slope in two species groups of forest type preference during the winter (coniferous or other; see Table 2). "Boxes" represent group medians (central bar) and quartiles, weighed with the reversed standard errors of slope parameters; "whiskers" show total ranges. Species parameters are shown with dots, with bars representing its standard errors; dot colors correspond to trend class (red — moderate decrease, blue — stable, black — uncertain; see Table 2).



Figure 5. Multispecies indicator for 15 common wintering species in the forest zone of European Russia. Error bars show 95% confidence interval for year figures. The grey line and area show smoothed trend with its 95% confidence interval.

Great Spotted Woodpecker most numerous in the middle taiga zone (Fig 2b) and Goldcrest with the largest wintering population in subboreal forests (Fig. 2c). These species represent "northern" and "southern" groups (Table 2) and we found no difference between trend parameters for them. This suggests that habitat specialization, and not regional specificity, was the prevailing factor influenced on the species dynamics.

It seems likely that the specialists group suffered from decreasing of area and quality of coniferous stands. The main reasons for this are assumed to be intense logging (Gromtsev 2008), coupled with bark beetle outbreaks (Komarova 2015) and dieback of spruce stands in some regions. This has resulted in the changing of old coniferous forests to deciduous, mainly birch stands (Gromtsev 2008; Maslov *et al.* 2014). Even for species who do not predominately use coniferous forests during winter, such changes could affect breeding habitats (e.g. for Eurasian Bullfinch) or preferred habitats in other regions which can be sources of winter migrations to European Russia (e.g. Eurasian Nuthatch *Sitta europaea*, depending on cedar stands in Siberia; Dement'ev & Gladkov 1954).

Climate change could also play a role, possibly non-uniformly in different parts of the region. An analysis for Northwest Europe showed that northern areas are generally more prosperous in respect to wintering bird numbers than southern ones: the latter are more negatively affected by climate change (Lehikoinen *et al.* 2016). In severe climate conditions, wintering species can benefit from the rise of winter temperatures (Bourski 2009; Lehikoinen *et al.* 2016). However, in milder climates such increase can lead to adverse effects, e.g. winter thaws and subsequent frosting of foraging substrate. This can make access to prey items difficult for birds searching for small Table 3. Trend classes for common wintering land bird species. Finland — Finnish mid-winter census scheme in 1957–2012 (Fraixedas *et al.* 2015), Estonia — Estonian mid-winter census scheme in 1987–2015 (Elts 2016), ER — European Russia (1988–2019, our results). Trend classes are abbreviated as follows: ↑ — moderate increase, ↑↑ — strong increase, ↓ — moderate decrease, — stable, ? — uncertain. Tendencies with the same sign as in our region are highlighted with bold, and with different signs with italic font. Cells are empty if the species' trend is not discussed in corresponding publication.

| Common name              | Latin name            | Finland            | Estonia      | ER           |
|--------------------------|-----------------------|--------------------|--------------|--------------|
| Black Woodpecker         | Dryocopus martius     | $\uparrow$         | ?            | -            |
| Great Spotted Woodpecker | Dendrocopos major     | $\uparrow$         | $\uparrow$   | $\checkmark$ |
| Goldcrest                | Regulus regulus       | $\downarrow$       | -            | $\downarrow$ |
| Long-tailed Tit          | Aegithalos caudatus   | $\uparrow$         | ?            | -            |
| Marsh Tit                | Poecile palustris     |                    | $\downarrow$ | -            |
| Willow Tit               | Poecile montanus      | $\downarrow$       | $\downarrow$ | $\downarrow$ |
| Crested Tit              | Lophophanes cristatus | $\downarrow$       | -            | -            |
| Coal Tit                 | Periparus ater        | ?                  | ?            | $\downarrow$ |
| Blue Tit                 | Cyanistes caeruleus   | $\uparrow\uparrow$ | -            | -            |
| Great Tit                | Parus major           | $\uparrow$         | -            | $\downarrow$ |
| Eurasian Nuthatch        | Sitta europaea        |                    | $\uparrow$   | $\checkmark$ |
| Eurasian Treecreeper     | Certhia familiaris    | -                  | -            | -            |
| Common Raven             | Corvus corax          | $\uparrow$         | $\uparrow$   | _            |
| Eurasian Siskin          | Carduelis spinus      | $\uparrow$         | -            | -            |
| Common Redpoll           | Carduelis flammea     | -                  |              | -            |
| Common Crossbill         | Loxia curvirostra     | $\downarrow$       |              | ?            |
| Eurasian Bullfinch       | Pyrrhula pyrrhula     | $\downarrow$       | $\downarrow$ | $\downarrow$ |

invertebrates on tree bark, such as Long-tailed Tit *Aegithalos caudatus* (Fig. 3d), Treecreeper *Certhia familiaris* (Fig. 3I) and all Paridae species (Fig. 3e–j). Unusually high summer temperatures could also negatively influence invertebrate abundance and winter foraging resources; a prime example was extremely hot weather in European Russia in summer 2010 (Mokhov 2011). Subsequent depression of many passerine bird species (Preobrazhenskaya 2011; Zablotskaya 2015) were well reflected with our data on wintering populations (Fig. 5).

Given the constraints discussed above, we can make some comparisons with winter monitoring projects in neighbouring countries. The closest ones to our territory and most similar in their natural conditions are Finland (Fraixedas *et al.* 2015a) and Estonia (Elts 2016). In these countries, several species have tendencies of multi-year dynamics coinciding with ours (Table 3): there are six such species in Estonia and five in Finland, with two of them (Willow Tit and Eurasian Bullfinch) decreasing in all countries. In Finland, the decline of forest species populations, especially associated with late-succession coniferous forests, was shown both for wintering (Fraixedas *et*  *al.* 2015a) and breeding populations (Fraixedas *et al.* 2015b); for wintering populations, these negative tendencies have been exacerbated since end of 1990s. The detailed analysis showed that the effect of climate change was relatively low in comparison to the intensification of forestry, resulted in decreasing of old-growth forest area. Both timing and direction of changes are similar to our results, and we assume its main reason was the same as well.

However, three species (Great Spotted Woodpecker, Eurasian Nuthatch and Great Tit) had opposite trend signs in different countries; it may be a question for further regional analysis whether the tendencies in adjacent parts of our study region also differed from general ones. An example of such analysis for Karelia (Yakovleva 2017) shows that this region, as well as Finland, had more positive tendencies that the European Russia in general (e.g. for Great Spotted Woodpecker, which showed a positive trend). Unfortunately, such studies are still scarce for our territory, and we need more data to unweave the importance of climate change and forestry effects on nest habitats quality, reproduction success, wintering conditions and migration patterns.

# Acknowledgements

We wish to thank all volunteers involved in the PARUS monitoring program, who provide high-quality data for the current study.

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Received: 2 December 2019 Accepted: 27 October 2020