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LONG TERM STUDY OF THE REACTION OF THE EDIBLE DORMOUSE GLIS GLIS (RODENTIA: GLIRIDAE) TO CLIMATIC CHANGES AND ITS INTERACTIONS WITH HOLE-BREEDING PASSERINES

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This study is based on data collected in the course of a long-term study focusing on hole-breeding passerines in Frankfurt city and a low mountain range 70 km north-east of Frankfurt, Germany. Regular nest box checks have been carried out throughout the whole year in different sample areas, consisting of 2000 nestboxes, since 1969. Besides the collection of data on birds like the Great Tit (*Parus major*), bats and insects the occurrence of Common Dormouse (*Muscardinus avellanarius*) and Edible Dormouse (G*lis glis*) was registered. To investigate whether interspecific competetion occurs, data from 6 sample areas with a total of 1190 nestboxes have been analyzed. The data show that mean population densities of *G. glis* during the birds' breeding season have increased. While most species of hole-breeding passerines start their breeding period on average one week earlier due to higher temperatures in spring, *G. glis* appears on average four weeks earlier in the nest boxes. This leads to an increase in predation of eggs or juvenile birds. The Pied Flycatcher (*Ficedula hypoleuca*), a migratory bird and a late breeder, is especially affected.

Key words: global warming, competetion, *Glis glis*, *Parus major, Ficedula hypoleuca*

INTRODUCTION

Recently, discussions concerning climatic changes have become more and more popular. The mean temperature on earth has risen by at least 0.6 °C (TRENBERTH 1997) over the past 120 years (REICHERT 2002). A further rise of 1.4 to 5.8 °C is predicted for the next hundred years. Many scientists consider the anthropogenic greenhouse effect a plausible reason for global warming and a worldwide redistribution of precipitation (HOUGHTON 2002). There is a linear trend of warming in Germany which has intensified from the beginning of the 1990s (RAPP 1997). Milder temperatures in autumn and winter, as well as an earlier beginning of spring are some of the effects that have been observed. Flora and fauna show prompt reaction to this development, e.g. earlier frondescence of several species of forest trees, the expansion of the area of distribution of some birds and insects and changes in the habits of migrating species (SACHWEH & ROETZER 1995).

It is essential to evaluate these changes through long-term studies, embracing a large section of this climatic development, carried out in affected ecosystems (GRABHERR 2002).

In the course of a long-term study focusing on hole-breeding passerines in Frankfurt city and a low mountain range 70 km north-east of Frankfurt in the state of Hessia, regular nest box checks have been carried out since 1969 throughout the whole year in different sample areas consisting of 2000 nest boxes. Besides the collection of data on hole-breeding passerines, bats, mice and insects, the occurrence of Common Dormouse (*Muscardinus avellanarius*) and Edible Dormouse (*Glis glis*) was registered.

METHODS

This study focuses on data from 6 different sample areas in the state of Hessia around the towns of Schlüchtern (50°19'N, 9°28'E) and Steinau an der Strasse (50°18'N, 9°27'E) from the period April to late June 1970 until 1999. Regular nestbox checks and registration of their inhabitants were carried out. The hole-breeding passerines focused on were Great Tit (*Parus major*), Blue Tit (*Parus caeruleus*), Marsh Tit (*Parus palustris*), European Nuthatch (*Sitta europaea*) and Pied Flycatcher (*Ficedula hypoleuca*).

Study areas

The study areas include three with two-dimensional and three with linear arrays of a total of 1190 nestboxes with 32 mm entrance holes. In two-dimensional areas nestboxes are installed in 25 × 25 m grids whereas in linear ones they are placed in a single row at intervals of 25 m. Two-dimensional sample areas cover a total of 37.15 ha, linear areas include a total distance of 14.5 km.

All sample areas are situated at an altitude between 240 and 370 m above sea level. They are covered with mixed forests consisting of oak (*Quercus* sp.), common beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*). The relative abundance of each species varies slightly in each area. Brush layers consisting of hawthorn (*Crataegus* sp.), raspberry (*Rubus idaeus*) and blackberry (*Rubus fruticosus*), and herbacious layers are mostly well developed.

Study period and relevant parameters

The nestboxes in all areas were checked at least weekly (daily in one sample area) during the breeding season of hole-breeding passerines (i.e. from early April to late June) and monthly during the winter from 1970 until 1999.

The relevant parameters used for this study were the start of nestbox occupation by different species and overlap occurring between them. Destruction of either eggs or hatchlings by *G. glis* was only registered as such if *G. glis* was still in the nestbox. Cases where the predator could not be identified were excluded from this study.

RESULTS

Figure 1 shows the mean date of first appearance of *G. glis* in the nest boxes in all 6 sample areas from 1972 until 1999. The mean date of first appearance varies annually but shows a significant tendency towards earlier occupation of nestboxes which on average happened 4 weeks earlier in 1999 than in 1972 (Spearman's correlation: R = –0.713; $p < 0.005$). The appearance of *G. glis* is negatively correlated with the average temperature of the period March–April (Spearman's correlation: R = –0.417; $p < 0.05$) and May–June (Spearman's correlation: R = –0.552, $p < 0.005$), which means that the higher the temperatures the earlier the appearance of *G. glis*.

Figure 2 shows the development of the mean *G. glis* population densities from April to late June from 1970 until 1999 in the two-dimensional sample areas (linear areas excluded). Apart from annual fluctuations and generally lower density in the 1970s, a continuous increase can be observed from the early 1980s onwards. This tendency has intensified dramatically since the early 1990s. The inserted columns represent the average density within a 10 year-period. They show a doubling of population densities from the mid-1980s until 1999. The increase in population densities over the study period is signifant (Spearman's correlation: R = 0.413, $p < 0.05$).

A change in overlap of nestbox use by passerines and *G. glis* can be observed by comparing the corresponding periods in 1975 and in 1999 for all 6 sample areas.

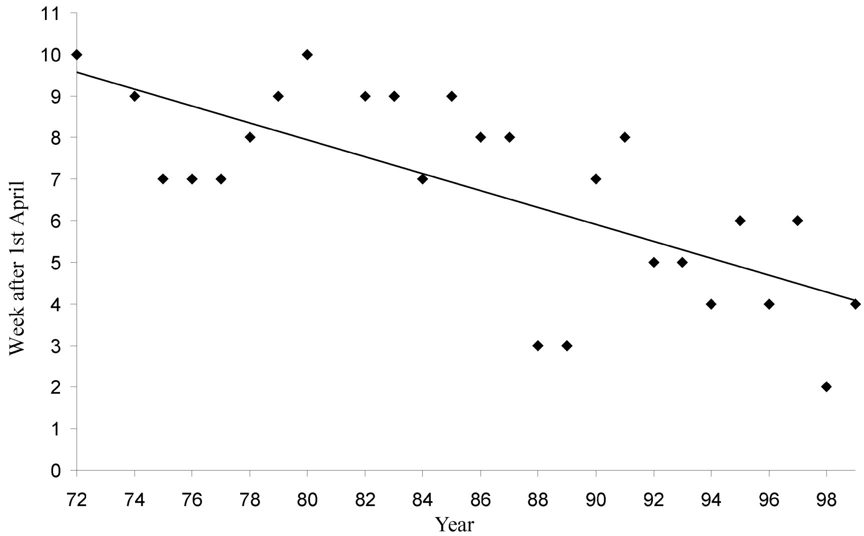


Fig. 1. Mean start of nestbox occupation of *G. glis* in all sample areas from 1972 to 1999

Figures 3 and 4 show the time of occupation of nest boxes by hole-breeding passerines and *G. glis* from April to late June in 1975 and 1999. For birds, we calculate approximately 6 weeks from the start of egg-laying until fledging date. The grey insert shows the period of nestbox occupation by *G.glis*.

While these birds start their breeding season on average one week earlier than 24 years ago, the occupation of nest boxes by *G. glis* starts on average 4 weeks earlier. This development causes intensified competition that leads to destruction of clutches of eggs, hatchlings and sometimes adult birds.

In 1970 the juveniles of the early breeding Marsh Tit and European Nuthatch had already fledged and those of later breeding Blue Tit and Great Tit were about to fledge at the time of immigration by *G. glis*. In 1999 *G. glis* moved into the nestboxes during the nestling period or even during egg laying. The strongest effects of competition are on the Pied Flycatcher, a migratory bird, whose nesting time in 1999 was completely within the occupation period of *G. glis*. As a result, no

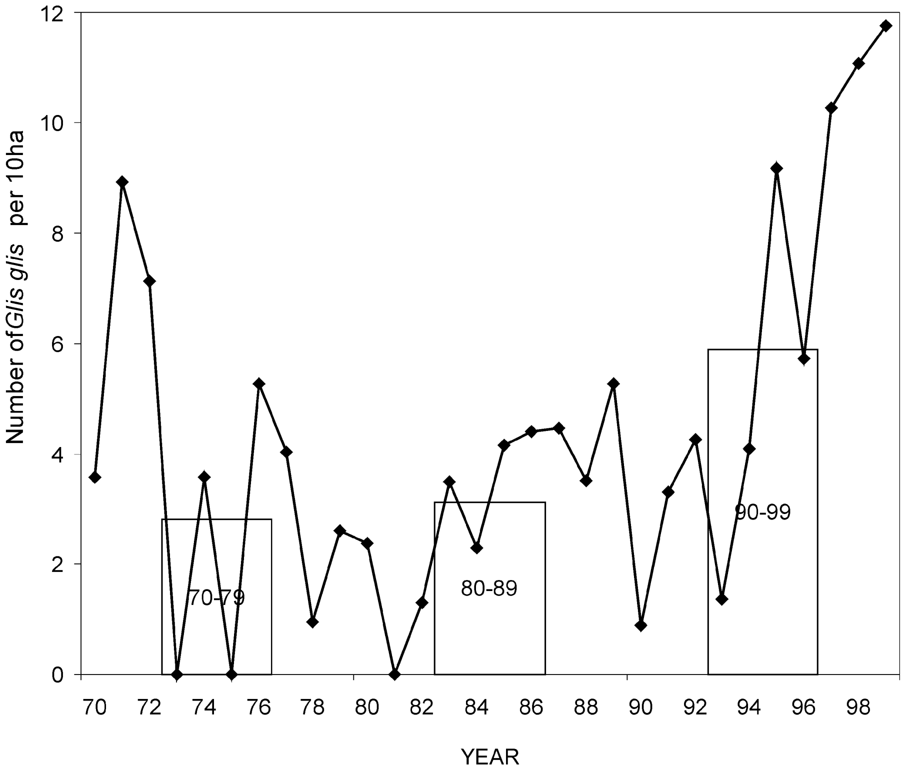


Fig. 2. Development of mean *G. glis* population densities in sample areas with two-dimensional arrays of nestboxes from April to late June

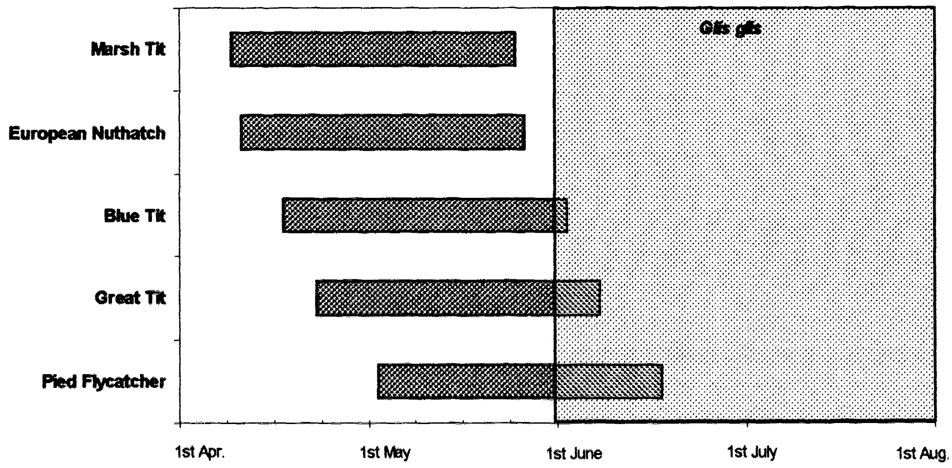


Fig. 3. Overlap of nestbox occupation of *G. glis* and holebreeding passerines in 1975

successful breeding (i.e. breeding with successfully fledged young) of the Pied Flycatcher was registered in all sample areas from 1997 until 1999.

Focusing on the period of increasing *G. glis* population densities from the early 1980s onwards, a total of 778 clutches of Blue Tit, Great Tit, Marsh Tit, Eu-

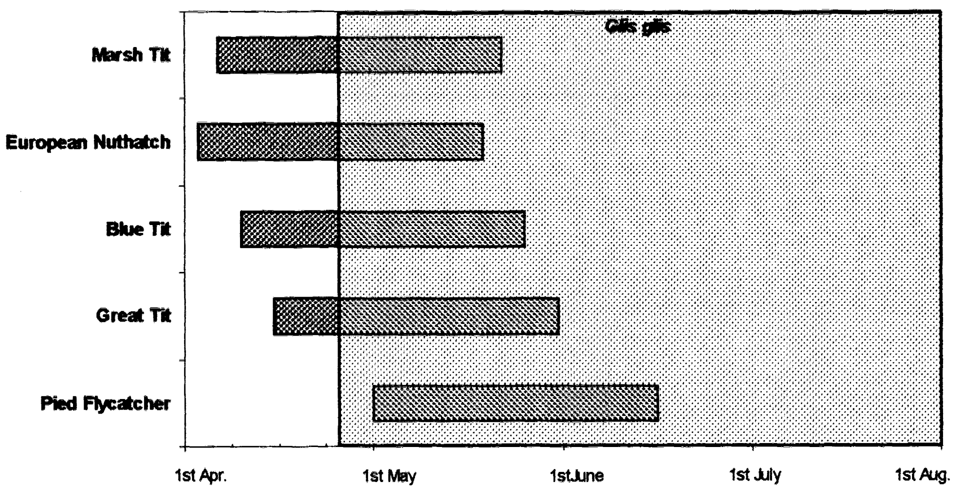
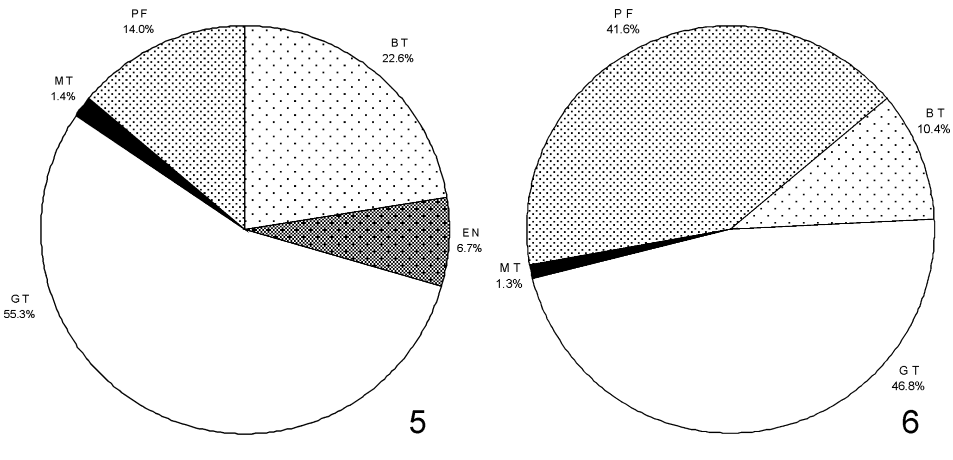


Fig. 4. Overlap of nestbox occupation of *G. glis* and holebreeding passerines in 1999

ropean Nuthatch and Pied Flycatcher were recorded in sample area 2 from 1980 to 1999. The most frequent hole-breeding passerines were Great Tit and Blue Tit, followed by Pied Flycatcher, European Nuthatch and Marsh Tit (see Fig. 5). During this time a total of 77 clutches (eggs or hatchlings) were destroyed by *G. glis*. Figure 6 shows how the different passerine species were affected. Most clutches belonged to the Great Tit. Blue Tits face a comparatively small temporal overlap with *G.glis* and therefore lost fewer clutches than Great Tit, whose breeding season starts one week later. Although the Pied Flycatcher (*Ficedula hypoleuca*) represents only 14% of breeding passerines (Fig. 5), it comprises more than 40% of the clutches destroyed.

There is a significant relationship between the population densities of *G. glis* in spring and the number of destroyed clutches of hole-breeding passerines (Spearman's $R = 0.688$, $p < 0.005$). We also investigated whether there is a correlation between the number of clutches destroyed and the number of pairs of breeding passerines in the following year. For this, only first clutches were considered (i.e. no replacement clutches after destruction). Pied Flycatcher shows the most significant correlation: the more clutches that have been destroyed in the previous season the fewer breeding birds can be found during the next (Spearman's $R = -0.7079$ $p < 0.001$). After years when many Blue Tit clutches were destroyed a significantly lower number of clutches were found (Spearman's $R = -0.5121$, $p < 0.005$). For Great Tit and Marsh Tit no such correlation could be found.



Figs 5–6. 5 = Distribution of passerine species breeding in sample area 2 from 1980 to 1999, n = 778. 6 = Species-based distribution of clutches destroyed by *G. glis* in sample area 2 from 1980 to 1999, n = 77. Legend: BT = Blue Tit, EN = European Nuthatch, GT = Great Tit, MT = Marsh Tit, PF = Pied Flycatcher)

DISCUSSION

The results show that since the early 1970s *G. glis* has pre-dated its original date of appearance in the nestboxes by a mean of four weeks. As the date of appearance is negatively correlated with the temperatures in spring, *G. glis* appears to be reacting to changed climatic conditions. It is very likely that the decisive factor to make *G. glis* wake up from hibernation in spring is the temperature and not the photoperiod. This cannot be perceived in the burrows in the soil where the animals hibernate. As the photoperiod is constant throughout the year it is very unlikely to be the trigger for an altered date of reappearance after hibernation. As soil temperatures follow air temperatures (SCHEFFER & SCHACHTSCHABEL 1992) a rise of the latter causes a rise of the former.

The data also show that the population densities of *G. glis* increased which could be related to a decline in winter mortality due to higher temperatures throughout that season. The earlier appearance, as well as the increase in population densities, cause a different situation in respect of interspecific competetion: as hole breeding passerines have adjusted their breeding season by only one week, competition resulting in looting of the clutches is the consequence.

The Pied Flycatcher as a migratory bird is not constantly exposed to the highest recent global warming rate which has been observed in the Northern Hemisphere and therefore has not changed its date of return and start of its breeding season. With an increased probability of encountering *G. glis* in the nestboxes, plus being generally rare in the sample areas, proportionally high losses of clutches are inevitable.

This study shows that different effects of global warming on *G. glis* and hole-breeding passerines can be observed in the course of a long-term monitoring programme. Further data analysis will be carried out to help understand the impact of global warming on our fauna.

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