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SHORT COMMUNICATION

Golden jackal (*Canis aureus*) in Estonia: development of a thriving population in the boreal ecoregion

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Abstract

Golden jackals (*Canis aureus*) are undergoing a rapid range expansion in Europe, with the core of the expansion currently taking place in the Pannonian basin, and long-distance dispersers being noticed throughout the continent. In parallel, a dynamic nucleus has formed hundreds of kilometers away from source populations in Estonia. This northernmost population is unique because of its relative isolation, and the drastically different environmental conditions the species is experiencing with respect to the source populations. In Estonia, the first presence and reproductions of golden jackals were reported in 2013. Since then, the population size and distribution range have continuously increased, primarily along the western coast. In recent years, several reproductive groups have colonized islands, and settled along the northern coast and at the eastern border, reaching a total of 27 groups in 2020. Between 2013 and 2015, the golden jackal was officially defined as alien species. In 2016, it was reclassified as a naturally immigrating new species and considered game species. The number of harvested jackals reached its maximum to date in 2018 ($n = 76$). In Estonia, golden jackals primarily inhabit coastal grasslands, alvars with juniper and reed beds, where wolves are seldom present.

Keywords Mesocarnivore · Range expansion · Long-distance dispersal

Background

Extensive range expansion of golden jackals (*Canis aureus*) in Europe from the source populations in the Balkan and Caucasian regions started in the 1950s (Krofel et al. 2017). By the 1980s, the species reached Central Europe and individuals were reported in Austria, Italy, and Slovakia, where golden jackals had not been known to exist (Arnold et al. 2012; Krofel et al. 2017; Spassov and Acosta-Pankov 2019). Golden jackals are able to thrive and disperse in human-dominated landscapes (Lanszki et al. 2018; Fenton et al. 2021). Starting in the 2010s, long-distance dispersing jackals were first observed in the Baltic region (Rutkowski et al. 2015; Trouwborst et al. 2015). In parallel, golden jackal reproductions were reported north of their core distribution in Latvia in 2013 (Männil et al. 2019) and in Poland in 2015 (Kowalczyk et al. 2020). Today, sightings of dispersing golden jackals are increasingly common throughout the European continent, as far North as Finland (Honkala and Nummi 2019) and even beyond the Arctic circle, in Norway (Linnell et al. 2021). In this article, we present the development of a largely isolated population of golden jackals in Estonia, whose establishment will likely influence the future of the species in Northern Europe.

The arrival of golden jackals in Estonia

The existence of golden jackal in Estonia was first confirmed in February 2013, when one specimen was killed during a fox hunt in Matsalu National Park, West Estonia (58.70° N, 23.56° E). The species was identified by external physical characteristics, a diagnostic that was later confirmed by genetic analysis (Rutkowski et al. 2015). Following a thorough investigation in the area of capture by means of snow tracking, camera traps monitoring (Fig. 1a), and howling stimulations, it was subsequently demonstrated that at least two additional individuals were present. Age determination

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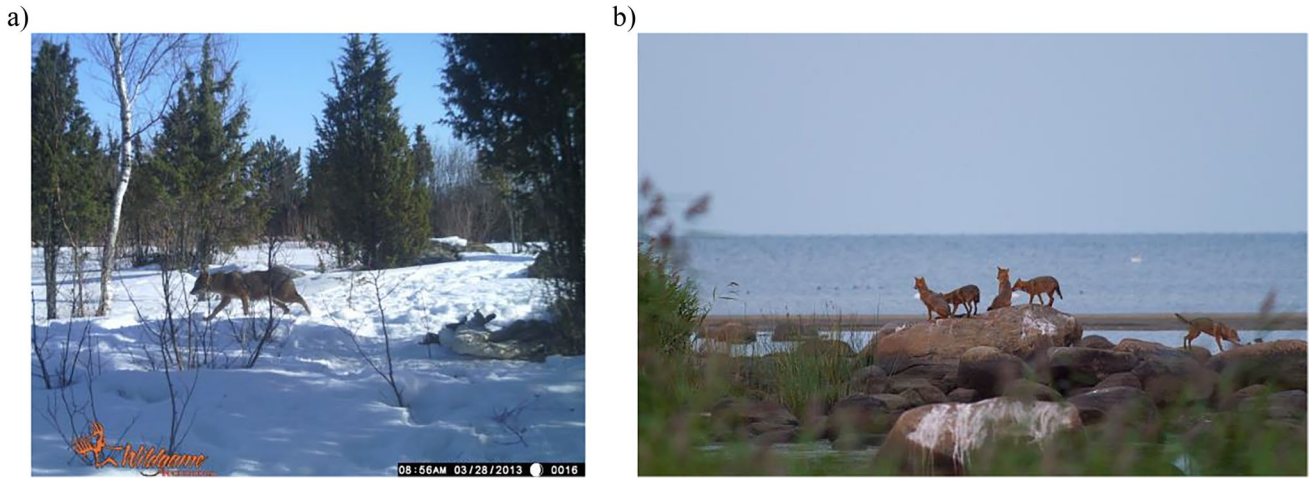

Fig. 1 Golden jackals were first reported in Matsalu National Park in 2013. **a** First photographic evidence of a golden jackal in Estonia, taken on 28/03/2013 (photo by Tonis Ulm). **b** Photographic evidence of the territorial group in South-Western Estonia known since 2013, taken in August 2015 (photo by Eugen Kaur)

of the first harvested individual using the pulp cavity-tooth width ratio criterion (Knowlton and Whittemore 2001) indicated that it was a juvenile. It was therefore concluded that the first reproduction of golden jackal in Estonia occurred not later than 2012. Information from local residents suggests that golden jackals may have been residents, and perhaps reproducing in the area as early as 2011. Two confirmed reproductions—one in the same area and one 90 km to the South-East in 2013 (Fig. 1b)—were the early indicators of the development of a population of golden jackals in Estonia.

Spatial expansion and population development

Data on the distribution of golden jackals in Estonia are collected annually and come from a combination of (primarily opportunistic) monitoring techniques—hunting bag and traffic accidents, verified camera trapping and visual observations, small-scale howling surveys, and livestock depredation reports conducted by experts. The identification of territorial groups was based on the detection of multiple individuals or juveniles; the separation of groups was made through spatio-temporal clustering of observations. Since the first reproduction in 2012, the range and number of groups regularly increased in Estonia, reaching its maximum during the last survey, in 2020, when 27 territorial groups were recorded (Fig. 2). This expansion has been particularly important along the western coastal areas of the Baltic Sea (Fig. 3). The first reproduction away from the western coast was confirmed in 2016 on a little island in Peipus Lake, in the eastern part of the country. Golden jackals reproduced again in 2018 (one group) and 2020 (two groups) nearby, indicating that the colonization of the Eastern part of the country may be underway. In the recent years, golden jackals have been confirmed outside of these main areas. First, starting in 2018, golden jackals have successfully colonized several islands (Muhu, Saaremaa, and Vormsi) off the western coast, reaching a total of five groups in 2020. It is likely that dispersing jackals took advantage of the winter ice to colonize these islands. Second, a group of golden jackals reproduced for the first time in northern Estonia, on the coast of the Finnish Bay, in 2020 (Fig. 3). Third and last, in spring and summer 2021, a group of golden jackals reproduced in a relatively urbanized area, at the western edge of Tallinn, the capital of Estonia. As of today, all the golden jackal groups known in Estonia are established on coastal areas (Baltic Sea or Peipus Lake) while the interior is still unoccupied.

In parallel of this spatial expansion, the number of legally hunted jackals has rapidly increased in Estonia. Between 2013 and 2015, 12 individuals were hunted, while four were killed in car accidents. All of the specimens killed in this period were juveniles, subadults, or adult males. The apparent survival of reproductive females likely resulted in the establishment of a stable population in the country. Starting in 2016, the first breeding females (identified thanks to the occurrence of placental scars in uteri) were harvested. Monitoring in the following years suggests that it did not significantly affect the overall growth of the population. In 2018, the hunting bag reached its maximum with 76 golden jackals legally harvested. This important harvest likely triggered the small (and transitory) decrease in the population observed in 2019, as shown by the smaller hunting bag (Fig. 2) and the lower number of detected territorial groups. However, this apparent decrease could also have been the result of an extremely warm and nearly snow-free winter that negatively affected both hunting success and monitoring. Since 2012,

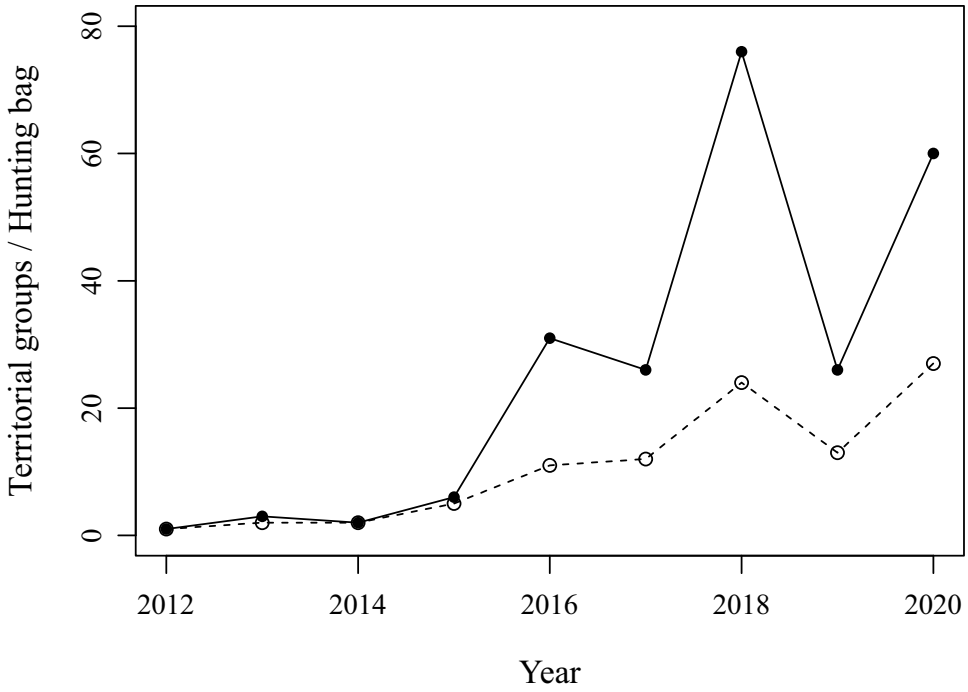

Fig. 2 Minimum number of territorial groups (open dots, dashed line) and hunting bag (closed dots, solid line) of golden jackals in Estonia between 2012 and 2020. The hunting year begins on March 1 and ends on February 29 the following year

231 golden jackals have been legally harvested in Estonia, a population characterized by an even sex ratio (103 females, 102 males, 26 unknown) and a strong bias towards juveniles (67 juveniles, 4 subadults, 24 adults, 136 unknown). In average, harvested jackals weighed 12.1 kg (standard deviation: 2.0, range 6.0–20.4 kg, $n = 191$). In addition, nine animals were killed in car accidents (sex: 6 females, 3 males; age: 2 juveniles, 2 subadults, 1 adult, 4 unknown).

The ecology of golden jackals in an unusual environment

In Estonia, golden jackals have primarily settled along heterogeneous coastlines composed of small bays, peninsulas, and islets and covered with grasslands (Fig. 4a), marshlands and reeds (Fig. 4b), shrubberies with juniper (Fig. 4c), woodlands, and semi-cultural landscapes (Fig. 4d). The preference for coastal areas over the country's interior may be explained by multiple factors. First, in the boreal ecoregion, the severity of winters may represent an important constrain to golden jackal survival and reproduction, which have evolved in considerably warmer climates; winters are milder and snow cover is more limited along the coasts. Second, the heterogeneous coastal habitats may provide a high abundance of resources (e.g., carcasses of wading birds and waterfowl, seals, and fish) as well as shelter in the reeds, juniper, and shrubberies vegetation communities. Third, and perhaps most importantly, the semi-open coastal landscapes are typically not inhabited by stable wolf (*Canis lupus*) packs, which are presumed to be a major biological constrain on golden jackal distribution and abundance (Krofel et al. 2017; Newsome et al. 2017). In contrast, wolves are permanently present across most of Estonia's interior (Kaczensky et al. 2012).

The study of golden jackal ecology in the boreal ecoregion is still nascent; however, interesting aspects are emerging. In spite of the peculiar ecological conditions encountered by golden jackals in Estonia, the species' diet is surprisingly consistent with studies conducted in the core distribution of the species, in Hungary (Lanszki and Heltai 2002, 2010; Lanszki et al. 2015) and Serbia (Ćirović et al. 2016). Indeed, the systematic analysis of stomach contents ($n = 36$ legally harvested individuals) suggests that golden jackal diet in Estonia is also dominated by anthropogenic food sources such as slaughter and hunting remains, as well as small rodents in autumn and winter (Jõgisalu et al. 2019). Evidence of predation on birds and large mammals could not be found in the analyzed stomachs. However, camera trap surveys of coastal grasslands subsequently revealed the occurrence of nest predation on ground-nesting birds such as northern lapwing (*Vanellus vanellus*) and common redshank (*Tringa totanus*). The impacts of such predation on the breeding success of waders is currently under investigation (Kaasiku et al., in review), and requires the consideration of both negative effects (predation and disturbance) as well as indirect (possibly compensatory) positive effects through intraguild influence on smaller carnivores, e.g., red fox (*Vulpes vulpes*) (Scheinin et al. 2006) and raccoon dog (*Nyctereutes procyonoides*).

Fig. 3 Distribution of golden jackal territorial groups in Estonia between 2012 and 2020 confirmed by camera trapping, visual observations, hunting bag data, and/or howling surveys. The distribution is given every second year for conciseness (annual numbers are given in Fig. 2). Color background indicates landcover (water bodies: blue; natural vegetation: green; agricultural land: yellow; urban areas: gray). Thin dark lines delineate Estonia's counties

Interestingly, a decrease in the occurrence of raccoon dogs, an invasive species in Europe, has been reported by local mangers in several areas recently colonized by golden jackals, in concordance with prior reports in Ukraine (Rozhenko and Kormyzhenko 2018). Scientific research is urgently needed to clarify the relationships between golden jackals, potential preys, and other carnivores (especially, red fox and raccoon dog).

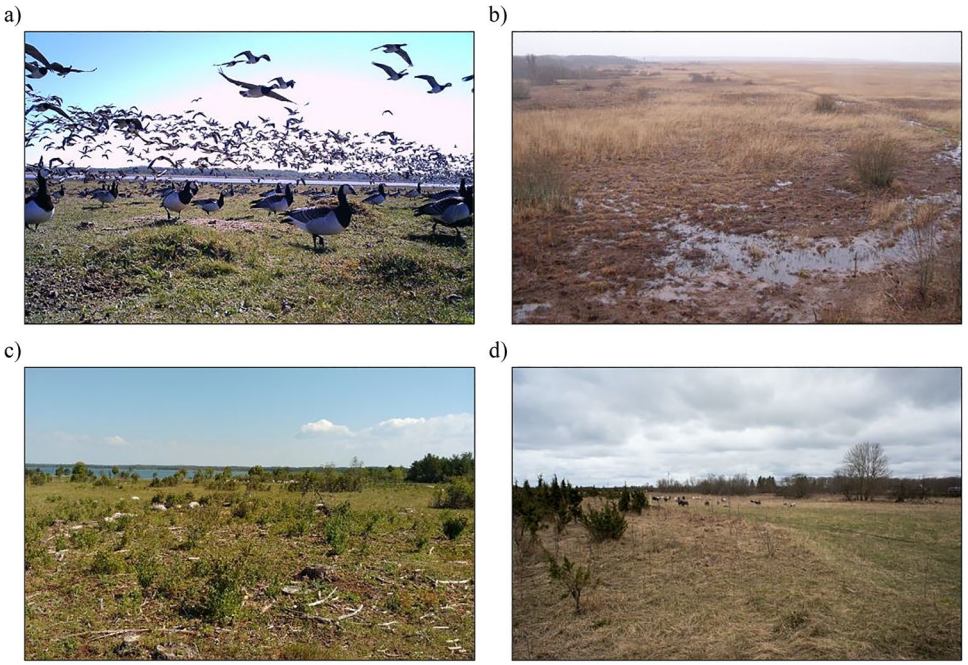

Fig. 4 In Estonia, golden jackals are primarily found in coastal environments and wetlands. **a** Coastal meadow in Matsalu National Park with migrating barnacle geese (*Branta leucopsis*). **b** Reed bed in Matsalu National Park. **c** Alvar with juniper on Muhu Island. **d** Pasture near the village of Virtsu (photo by Peeter Vissak)

Management

Based on early emotional reactions and without sufficient knowledge about the expansion of the species in Europe, the golden jackal was defined as alien species in 2013 and special culling permission was issued in 2013–2015. In 2016, policy makers reconsidered the species management. Taking into account complementary information on the species biology, undergoing range expansion (Rutkowski et al. 2015; Stratford 2015) as well as legal aspects (Trouwborst et al. 2015), the status of golden jackals was reassessed to native species and included on the list of game species (small game). Currently, golden jackal hunting is allowed annually from September 1st to February 29th and with no quotas; trapping is however forbidden. Although golden jackals are listed as small game, hunters have a legal obligation to report date, exact location, group size, sex, and body measurements of individuals killed or found dead, as is also the case for the three larger carnivores (brown bear *Ursus arctos*, Eurasian lynx *Lynx lynx*, and gray wolf). In addition, tissue samples for DNA analyses, canine root cuts for aging, and uteri with ovaries for investigating the reproductive status of females are systematically collected.

The appearance of a new species of carnivores surprised both stakeholders and the general public. The paucity of information on the species ecology led to a wide range of speculations about golden jackal's potential impacts on other wildlife and domestic species. The biosemiotic study conducted by Maran (2015) revealed that stakeholders and the general public were mainly concerned about the possible predation of jackals on ground-nesting birds and amphibians as well as depredation on domestic sheep but also identified the species' possible positive impact for controlling invasive raccoon dogs.

As of today, the main conflict between golden jackals and stakeholders concerns the perceived or real depredation on sheep, particularly on lambs. During the period 2016–2020, an average 22 depredation events were recorded by the experts of the Environmental Board. Care should be used in interpreting these numbers as some depredations may not be reported due to an absence of compensation scheme (underestimate), and to the difficulty to separate golden jackal depredation from scavenging based on indirect evidences (likely overestimate). Most reported depredations arose on small-scale sheep husbandry subsidized by the state to manage semi-cultural habitats (e.g., coastal meadows, alvars, and wooded meadows), and where damage prevention measures were either not implemented or difficult to implement (e.g., pastures bordering water bodies). To date, there has been no specific complaint regarding golden jackal depredation on poultry or pets.

Conclusion

A separate, largely isolated population of golden jackals is now thriving in Estonia. The expansion of golden jackals in the country is still ongoing and it remains unclear whether the species will eventually be able to colonize the potentially suitable landscapes of the interior. The success of golden jackals at such a high latitude, in the boreal ecoregion, suggests that there may be ample suitable habitat for the species

in Northern Europe, at least along the coasts. As of today, the lack of information on the species ecology and behavior in Europe, and in the boreal ecosystem in particular, appears to be the main challenge for golden jackal management and conservation.

Declarations

Ethical conduct No approval of research ethics committees was required to accomplish the goals of this study.

Conflict of interest The authors declare no competing interests.

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