

Golden jackal expansion in Europe: a case of mesopredator release triggered by continent-wide wolf persecution?

Miha Krofel, Giorgos Giannatos, Duško Ćirović, Stoyan Stoyanov, Thomas M. Newsome

Appendix S1 – Literature data used for schematic reconstruction of the relative population trends at continental scale for grey wolves and golden jackals since 1800

To document changes in relative abundance of grey wolves and golden jackals through time in regions of species' range overlap, we reviewed studies on wolf and jackal occurrence in southeastern and central Europe that compared distribution ranges, hunting bags or other records of species presence in different time periods. Below we specify literature data we used to reconstruct relative changes in the species' abundance (schematic reconstruction presented on Figure 2 in the main text).

1) WOLVES

Adamič et al. (1998):

We mainly used data from Fig. 1, which depicts data on the wolf hunting harvest in Slovenia from 1874 to 1996. Numerous harvest records suggest high wolf abundance until 1880s, after which harvest records decline almost 10-fold, suggesting low wolf numbers until 1915. No wolves were recorded shot during the World War I, which probably enabled the wolf population to rebound. This is confirmed by high harvest records in years after the war. Towards mid-1930s the harvest records again declined 10-fold, suggesting a reduction in wolf numbers. No wolves were recorded shot during the World War II, leading to next recovery of the population, again suggested by even higher (up to 25%) harvest records in post-World War II years compared to the post-World War I years. Harvest records were highest in the 1950s, which is followed by dramatic decline in wolves killed (25-fold). Harvest remained relatively low until the 1990s, when wolves gained protection from hunting. After protection, wolf abundance started to increase as suggested by the increasing number of wolf sightings (7-fold increase from 1991 to 1997; Tab. 1).

Jedrzejewska et al. (1996):

We used data from Fig. 3, which depicts reconstruction of temporal trends in wolf population dynamics in Białowieża, Poland from 1847 to 1993 based primarily on hunting harvest. Data suggest a relatively stable population size until 1880, when the population crashed and wolves became almost completely exterminated. The population rebounded during the World War I, only to be again reduced by about half due to persecution during the 1930s. During the World War II the wolf population increased again, this time to a higher (about 25%) level than during the previous war. After the World War II the population was again reduced to about one third until 1950 and it then reached the lowest levels during the 1960s. After 1970 wolves started to gradually recover, but never reached the densities of the 19th century or during both world wars.

Markov (2014):

Based on historic records from Bulgaria author describe “large-scaled and drastic control [of wolves] exercised in 1950s and 1960s”, which “strongly reduced the wolves' numbers and only small groups

have survived in the border zones [of Bulgaria]”. In the early 1980s poisoning of carnivores became forbidden and the wolves “began to increase” and “during this period the distribution area of the wolves has covered about 25% of the country” with experts estimating population size to 1000-1200 wolves. Data from game counts suggest a 1% annual increase in the population size during 2002-2012.

Mihaylov and Stoyanov (2012):

Authors reported the largest wolf harvest in Bulgaria at the end of the 19th century with peak in 1895 and 1896 (1300 and 1650 wolves shot, respectively), which was followed by a decline in wolf numbers. From 1950-1955 harvest numbers ranged from 600-1050 wolves. “Since 1960s the wolf population in Bulgaria has significantly decreased” and “until 1980 between 80 and 150 wolves were annually harvested”. Average annual harvest data increased to 179 wolves in the 1980s, 270 wolves in the 1990s and 389 wolves in the 2000s (Tab. 1). Since 2000 the number of harvested wolves stabilized.

Pimlott (1975):

Authors noted that “wolves occurred throughout Europe in earlier years, however during the past 300 to 400 years they have been gradually and progressively exterminated”. By the 1970s the wolves still occurred in 11 European countries (in three of them they were “virtually extinct”, in seven countries they occurred in “low populations” and in one country situation was not clear) and were extinct in 11 countries. In Romania the harvest of wolves declined from 2400 wolves in 1950 to 1030 wolves in 1972. In the republics of Yugoslavia (nowadays Slovenia, Croatia, Bosnia and Hercegovina, Serbia, FYR Macedonia, Montenegro and Kosovo) there was a similar (about 50%) decline in the number of harvested wolves from the 1950s to 1970s. An exception to this was Croatia, where an increase in harvested wolves was noted, but according to the author this was not related to changes in wolf abundance but connected with social changes and the bounty system. For Greece, the only harvest data for the 1960s and early 1970s were reported, but no obvious trends were observed.

Štrbenac (2005):

Wolves were considered to inhabit more or less the entire territory of Croatia until the end of the 19th century, but started disappearing from the lowland continental Croatia in the early 20th century. After World War II “extermination actions increased” and the population decreased to “approximately 50 individuals in the late 1980s in the areas of Gorski Kotar and Lika”. Harvest records for Croatia and Slovenia combined decreased from 120 wolves in 1892 to an average of 42 wolves per year in the period between 1891-1921, then again increased to 274 wolves per year in 1954-1972 and declined to 32 wolves in 1989-1990. For Gorski Kotar alone, harvest records declined from 15 wolves per year in 1945-1976 to 9 wolves per year in 1977-1986 and to one individual in the following year. It is considered that “wolf population in Croatia reached its minimum in the late 1980s, and in early 1990s started its gradual increase until the end of the decade”. According to the expert opinion 173 wolves lived in Croatia in 1999.

2) JACKALS

Banea et al. (2012):

The first confirmed jackal records from Romania were reported in 1929 from the southern part of the country, with possible mentioning of the species already in the 18th century. The authors suggested that

four “pulses” of jackal colonization occurred in Romania: 1930s, 1955-1970, 1980-1995 and 2000-present. In north-eastern Romania jackals were reported since 1954 and the first jackals apparently colonized western Romania in 1970. The population is considered to have “increased considerably since 1980”. Harvest data from southern Romania increased from 6 animals shot in 2004/2005 to 129 jackals in 2010/2011.

Giannatos et al. (2005):

The number of annually harvested jackals in Greece decreased from 903-1332 individuals during the 1974-1979 period to 369 jackals in 1980. In 2005 the population size was estimated to be 10% of the size in the 1970s.

Heltai et al. (2013):

The number of annually harvested jackals in Hungary increased from 6 jackals shot in 1995 to 1660 jackals shot in 2012 and the population size was estimated to 7000 jackals in 2013. In Serbia jackals were reported to start increasing strongly in the 1980s and by the end of the 20th century colonized half of the country’s territory and over 60% of the country by 2013. “Hunting bag increased from 180 jackals in the beginning of the 21st century and increased to more than over 2500 individuals in 2012”, when population size was estimated to 10000 animals.

Krofel (2008):

The first jackals appeared in Slovenia in 1952/1953, but after that no more jackals were recorded until the mid-1980s, when every year 1-2 jackals were reportedly shot. From 1990 till 2004 jackal records declined with only sporadic reports of shot or observed animals. After 2005 jackal records became more frequent.

Kryštufek and Tvrtković (1990):

Until 1920 the jackal population in Dalmatia (Croatia) was limited to the southern part of the region. Between 1920 and 1980 jackals gradually expanded in a north-westerly direction. They became more frequent in northern Dalmatia around 1950 and established a permanent population by 1980. After 1980 further expansion took place with colonization of the Istria peninsula, with first recorded reproduction in 1985. The authors also reported that in the 1980s jackals permanently settled in parts of Bosnia and Herzegovina adjacent to Dalmatia, where previously only vagrants were observed.

Kryštufek et al. (1997):

Jackals expanded their distribution area in Bulgaria 33-fold from 1962 to 1985. There was an increasing number of vagrants reported in Slovenia and north-eastern Italy since 1985.

Lapini et al. (2011):

The authors note three “pulsations” of jackal occurrences in North Adriatic mainland (Slovenia and Italy): the first in the 1950s, the second in the 1980s and the third starting at the beginning of the 21st century. The first record of jackal from Italy is reported in 1984, there was a decline in the jackal records from 1993 to 2002 and again an increase after 2003, when several successful reproductions were recorded.

Markov (2012):

In Bulgaria, “until the early 1960s, the jackal occurred only in the region of Strandzha Mountain, in the southeastern part of the country. After that, its number rapidly increased.” Harvest records increased from 5538 jackals in 1983 to 7422 jackals in 1999 and 26570 jackals in 2010. Population size estimates gradually increased from approximately 20000 animals in 1998 to 39343 animals in 2011.

Spassov (1989):

The distribution of jackals in Bulgaria “remained the same up to early 1930s” and during the 1930s and 1940s their range decreased. The jackals again expanded their range “somewhere in the early 1960s” with “real expansion northwards and westwards [...] in the 1970s” and “towards the 1980s the species had occupied almost entire country” with the highest numbers reported at the time of the publication (1989).

Herzig-Straschil (2008):

The first jackal was recorded in Austria in 1987 and 10 records were noted between 1987 and 1992. Afterwards the number of reports declined to two in 1993-2002. After 2003 the number of jackal records in Austria increased again and reproductions were detected since 2007.

Szabó et al. (2007, 2009):

Jackal disappeared from the Hungarian fauna by the 1950s and reappeared in the end of 1970s, with observations becoming more frequent in the beginning of the 1990s. Harvest records increased from 11 jackals in 1997 to 163 jackals in 2006. In the same period number of Game Management Units (GMU) with recorded presence of jackals increased from 4 GMU in 1997 to 67 GMU in 2006

Toth et al. (2009):

Until the 1920s, jackals in Hungary were limited to the region between the Danube and Tisza rivers. Records are almost missing in the 1920-1945 period (2 certain, 2 probable and 1 questionable record), they become more frequent between after the World War II. Since 1980 the Hungarian jackal population was “constantly increasing”.

Trouwborst et al. (2015):

A notable expansion of the species started in the twentieth century, with the first more pronounced “wave” of jackal expansion in central Europe occurring in the 1950s and another “wave” following in the 1980s. Since then jackal numbers have steadily increased with several new countries in Central and Northern Europe colonized since 2010, including Switzerland, Estonia, Latvia, Poland and Belarus. By 2015 jackals were recorded in 30 European countries, including the Caucasian region.

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