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FACULTY OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

STUDY OF POPULATION CHANGING AND HABITAT USE OF THE
GOLDEN JACKAL (*CANIS AUREUS* LINNAEUS 1758)

Theses of Ph.D. dissertation

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1. BACKGROUND AND OBJECTIVES OF THE STUDY

Golden jackal (*Canis aureus* Linnaeus, 1758) is a widespread canid, a specific predator mainly of the tropical, semitropical and the southern, temperate-zone areas. Its distribution area includes East and North Africa, South East Europe, Asia Minor, the Caucasus, Near East, some parts of the Arabic Peninsula, Iraq, Iran, the Indian subcontinent from Sri Lanka through Burma to Thailand. Thanks to its uncommon adaptability it can occupy any habitats except extreme deserts or closed, dense forests (GIANNATOS 2003, JHALA és MOEHLMAN 2004).

Golden jackal is a native predator of Hungary (RAKONCZAY 1989), it has been a part of the fauna demonstrably since the middle ages (TÓTH et al. 2009). Hungary is in area-edge situation, the jackal is regarded as an alien species northwards and westwards. The jackal disappeared from the Carpathian basin by the middle of the XX. century because of the habitat transformation, habitat destruction (water management, braking crop lands) and constant persecution of the carnivore species. The last individual was shot officially in winter of 1942 close to Derecske (SZUNYOGHY 1957). Then the observations were only occasional and few young vagrant males were shot in the next fifty years. Due to these facts it is presumable that no breeding pair was living in the Carpathian Basin (DEMETER 1984 Based on this the golden jackal was registered in the Hungarian Red Data Book in 1989 and it was pronounced as an extinct species (RAKONCZAY 1989). After some rare observations in the 1980s (DEMETER 1984) the first breeding pairs were found in the south part of Hungary in the first half of 1990s, in Baranya, Bács-Kiskun and Somogy counties. The spreading from Croatia was probably linked to the River Drava (DEMETER és SPASSOV 1993). Presence of hidden populations might have been possible. Their residence in this region is continuous since then, significant populations are formed in the south counties of Hungary and more and more observations are registered over the country (HELTAI et al. 2000, LANSZKI és HELTAI 2002, HELTAI 2002, SZÚCS és HELTAI 2002). The increasing number of the population shows like in the case of invasive species within less than 10 years (HELTAI et al. 2004). Spreading of the species keeps going on nowadays. (LANSZKI et al. 2007, SZABÓ et al. 2007, SZABÓ et al. 2008, SZABÓ et al. 2009).

In general it is stated that the reasons of the re-colonisation are the warfare in the Balkans (formerly Yugoslavia) and the global climate changing. On the other hand there were more circumstances that helped the jackal to re-settle in the south region of Hungary. Significant changes happened in the agriculture in the '90s: Larger area of uninterrupted

fallow land was increased due to privatization; usage of artificials and insecticides/rodenticides was decreased. As a result of that the population density of the small mammals – which is the primary food source of the jackal – was increased.

Beside the changing of the habitats and the agricultural production it is possible that the predator management (e.g. oral immunization against rabies) controlled by the EU and international conventions also facilitated not just its re-colonization but also the continuous increasing of its population. Re-settlement of the jackal was difficult to follow because of its relative obscurity. Absence of the large carnivores could be prosperous for the species. Owing to these facts the population density of the golden jackal in Hungary could be higher than it was in the last centuries (TÓTH et al. 2009).

Recolonization of the jackal is interesting and controversial in several aspects. Survey of the Hungarian golden jackal populations has started in 1997 at that time when presence of breeding pairs was proved by hunters and nature conservationists in Somogy and Baranya counties. Research has been done by the Kaposvár University and the Szent István University (Institute for Wildlife conservation) together since then. I joined the program as an institute associate in 2003. As a result of our work the state and the changing of the golden jackal population is one of the mostly known of our carnivore species.

Jackal, which re-appeared in the Carpathian Basin raises questions regarding game management and nature protection by its invasive-like spreading. Despite the spreading of the species is extremely rapid, out of Hungary its ecological role and impact is poorly studied and known in general. Apart from some previous observation from Africa and Asia (LAWICK-GOODALL 1970; MOEHLMAN 1979, 1987, 1989, DEMETER and SPASSOV, 1993) the jackal returned almost unknown to its European areas. Due to re-appearance and increasing of its population classical predator-human conflicts were amplified in almost every affected countries. (SZABÓ et al. 2010, HELTAI et al. 2013). Area-edge situation of Hungary must be highlighted. It is important because the population of this alien species in the new areas in Europe could show a context to the density of the origin area. In addition to that the recognition of its ecological role could help to understand and manage the implied problems, could give answers to the arising questions.

Due to the relative obscurity of the species it had emphasized importance to get knowledge about its ecological role in the present and in the future as well, about the possible management directives regarding game management, nature conservation, agriculture (including livestock breeding) and animal health. Further aims were to evolve new international connections, to base common projects, because questions raise not just locally

but also on European level. It is also important to render tissue samples for national and international laboratory studies in the future. The obscurity of the re-colonized carnivore encouraged us to inform not just the society but the affected farmers to introduce the species to them.

The following aims were drawn up during the research:

Survey of the golden jackal occurrence in a large scale in several aspects:

I. Collecting and analyzing data:

My aims were to explore the occurrence of the golden jackal with the help of official hunting bag database, mail questionnaire surveys and collecting proof specimen.

II. Post mortem survey:

My intention was to survey examine the collected jackal carcasses: body size, condition and reproduction. And also to compare it to the most important competitor species, the red fox (*Vulpes vulpes*)

III. By acoustic survey:

My goal was to monitor the changing of the population and to survey the population dynamics in two core areas; to follow its spreading and to find the green corridor.

My aim was also to study the habitat selection within the sample areas.

Finally I analyzed the reasons for its extremely rapid, invasive-like spreading.

2. MATERIALS AND METHODS

I used several, parallel methods during the research which completed each other

2.1. Mail questionnaire survey

Data have been collected about the golden jackal occurrence yearly since 1997. Questionnaires were sent every Game Management Unit in Hungary by post. The survey was based on voluntary response with the involvement of the GMUs as a well functioning data-supplying system. The aim was to sign up every GMU, where one observation was noticed at least.. Data were classified by county level thus we could separate the Transdanubian data and the East part of Hungary. Cartographical visualization of the results was done by 10*10 km UTM map (ArcInfo 3.0, ArcView GIS 3.1) which is a popular method to show presence/absence used by zoology or botany. Results were analysed by linear regression and significance test. Changes within counties were checked by Chi² and Bonferroni Z test.

2.2. Analysing official hunting bag data

I also analyzed hunting bag data on the basis of National Game Management Database between 1997 and 2014. The data were recorded in each county. Results were analysed by linear regression and significance test. I used Bonferroni Z-test to analyze the changes in each county. I also analyzed data of the red fox then I compared to jackal data (correlation) on country level and in the three counties where hunting bag of jackal is the highest. Aim was to brighten up if there is a correlation between the hunting bag of the two carnivores.

2.3 Collecting proof specimen

Whereas I aimed to monitor the population changing and occurrence of a newly recolonized species I shouldn't have dispensed with the use of collecting proof specimen and observations. Setting on new occurrence/reproduction areas were proved by these proof specimen. I used UTM code of the nearest settlement for the cartographical visualiation.

2.4 Post mortem examinations

104 carcasses were examined in all and data of 44 shot individuals were sent by hunters. The following data were collected during autopsy: body length, total length, body weight, tail length, kidney weight, placental scar number. The same data of 100 shot red fox carcasses were collected previously. Thanks to this I had an opportunity to compare body size

and reproductive fetures (breeding and non-breeding females). I used t-test (two sampled t-test, Welsch-test, Mann-Whitney test) for statistical analysis.

2.5 Acoustic method

Acoustic method was used during the survey which was applied successfully previously (HARRINGTON és MECH 1982, CREEL és CREEL 1996, JAEGER et al. 1996, MILLS et al. 2001, GIANNATOS et al. 2005, NOWAK et al. 2007). This method was developed for golden jackal by GIANNATOS et al. (2003) was used and adapted considering environmental features and technical facilities in Hungary

Technical equipments: Monacor PM-45 portable megaphone, Monacor PA-302 amplifier and Monacor NR-35KS hornspeaker. Jackal howling was played during the survey. Professional equipments (M-Audio MicroTrack 24/96 digital recorder and AudioTechnika AT815b shotgun microphone) were used to record howling (responses) in the fields. Compass and spotlight were also used.

2.5.1 Survey planning

Every localization point was marked by a high resolution (1:50.000) digital map (Garmin Ltd., Topoguide Hungary 2.1; Google Earth) before fieldwork. As a result of previous field tests 1km hearing distance was determined during playback at ~100dB (CREEL és CREEL 1996). Thus the minimal distance between two points was 2 kilometres. We kept this distance from human settlements to avoid disturbance or dog barking. Localization points were uploaded to GPS device (Garmin Nüvi770).

2.5.2 Fieldwork

We started fieldwork after sunset and was carried out in standard weather conditions (windless and without rain/snow). When the optimal conditions had changed the fieldwork was stopped. Jackal howling was played three times at each points. Four minutes long pauses were kept between each playback, while we we listening to the responses. After the third playback we looked around with a spotlight for visual obervation if the field features (e.g vegetation) made it possible. Then we discussed the quality (lone or group) and the direction (azimuth) of the respons(es). Data were recorded on data sheets at every point. The following data were registered: name and code of the point, name of every person, date and time of the fieldwork, weather conditions, response (lone or group) or its absence, direction of respons(es), visual observation(s) and other commments. Over the presence or absence of the

species in the study area it is also possible to estimate the population density by the number of responses and the covered area. The fieldwork was carried out twice a year: in reproductive period (February-March) and in autumn (the first common huntings).

2.5.3 Data processing

Exact coordinates of each point was downloaded from the GPS device to PC and visualized in cartographical form by Mapsource (GARMIN Ltd) software. I also used GIS Arcview 3.1 (ESRI, USA) then QGIS, ArcMap (ESRI USA) and Google Earth Pro (Google Inc.). On the base of azimuth and the exact coordinates of the calling-stations I could draw conclusion if the same single individual or a group was heard from two points. In this case I excluded the affected individual or group to avoid over estimation. Results of each localization point are calculated on a 314 hectar area ($r^2\Pi$). The whole covered area could be calculated by this. Minimal number of groups (add all the counted families) and minimal density of the family packs (minimal number of families divided into the total studied area) were calculated. Two or more individuals were determined as a group. The following statistical tests were used (GraphPad InStat Demo): Kruskal-Wallis test (ANOVA), Dunns-test, Fischer-test.

2.5.4 Study areas

Acoustic survey was carried out in two study areas within one center of the golden jackal's occurrence area (Bács-Kiskun county, between River Danube and Tisza) where the presence of the species had been proved since the middle 1990s: Hajós-Szentgyörgy zone (~10000ha, Gemenc JSC. Hajós forestry) and district of Császártöltés-Kunfehértó (~150000ha, KEFAG JSC). I had 14 occasions in the Hajós area during 25 nights between spring 2004 – spring 2010. The jackal population was surveyed in the Császártöltés area 20 times (32 nights) between spring 2004 – 2014. Expanded survey was carried out primarily in Bács-Kiskun county between 2004-2014 (171 nights). Monitoring of the golden jackal presence along River Tisza was done in 2004-2005 focusing on those areas where the previous results of mail questionnaire survey had proved shot or observed jackal. During the survey of the possible spreading route (green corridor) I played the howling on 159 calling-stations.

2.5.4 Habitat survey

Base of the golden jackal habitat survey was the calling stations in the marked study areas. I chose those points for analyzing from which I heard a response in at least two following years in the whole survey period. After I selected the 30 points I marked a circle with 1km radius around each point according to the hearing distance. Then I compared these shapes to the Corine (Coordinaton of Information on the Environment) Land Cover (CLC2012) shapes (vegetation types). Then I specified the area of each category and their ratio. Finally I calculated the frequency of each land cover category.

3 RESULTS

3.1 Mail questionnaire survey

The number of those counties where golden jackal presence was observed increased continuously between 1997-2002 then it relatively stabilized (1997:4, 1998: 6, 2000: 9, 2001: 10, 2002: 14, 2003:12, 2004: 12, 2005:13, 2006: 12). Beside this the number of GMUs which registered jackal also showed increasing tendency year after year (1997:4, 1998:12, 2000:26, 2001:37, 2002:42, 2003:49, 2004:49, 2005:65, 2006:67). After a stable period (2003-2004) growing of GMUs number was experienced again. However dominance of the Transdanubia area became stronger again after the Millenium. Positiv answers almost doubled (from 21 to 41) in the west part of Hungary while number of the GMUs with jackal presence was decreased (from 28 to 26). All of the counties registered golden jackal occurrence between 1997-2006 except for Heves-county. Most part (95%) of the answers came from 3 counties (Somogy, Baranya and Bács-Kiskun) in every year. In the other counties there were only sporadic or rarely repeated observations. On the base of mail questionnaire survey the golden jackal population showed linear increasing in Hungary in the study period (1997-2006). Growing number of the observations were statistically significant on country level ($n=9$, $r=0,98$, $p<0,001$), in Transdanubia ($n=9$, $r=0,95$, $p< 0,001$) and to the East from the river Danube ($n=9$, $r=0,93$, $p< 0,001$) as well.

3.2 Hunting bag data

Changing of the official hunting bag data shows exponential increase not just on country level ($n=20$, $r=0,99$, $p< 0,001$), but on Transdanubia ($n=20$, $r=0,99$, $p< 0,001$), and to the East from the River Danube ($n=19$, $r=0,94$, $p< 0,001$) too in the whole study period (1997-2014). Cumulate hunting bag data is 10177 within 20 years in Hungary. The number of shot jackals increased year after year (1995:6, 1996:10, 1997:11, 1998:22, 1999:38, 2000:59, 2001:70, 2002:80, 2003:85, 2004:95, 2005:140, 2006:163, 2007:349, 2008:452, 2009:674, 2010:786, 2011:1129, 2012:1660, 2013:1813, 2014:2535). 82 % of the total hunting bag was recorded from Transdanubia in the study period. Ratio of the increase in the East part of Hungary was higher till 2005 then balance was detected, but growing of the hunting bag in the East of the country is stronger again since 2011. The same three counties reported the most part of the hunting bag data in every year (cumulated average= 92%, $SD=8,2$). Thanks to the invasive-like spreading of the species this ratio shows a drop (1995:100%, 2014: 73%). No

negative correlation was found in the 3 counties regarding red fox and golden jackal hunting bag data.

3.3 Collecting proof specimen

In the total number of 217 cases proved specimen of golden jackal was reported. 104 carcasses were sent to our Institute until now. In addition to that hunters sent us detailed information of 44 shots. In most cases (83) the presence of the species is proved by photo (shot, hit by a vehicle, field observation, found dead animal, trapped individual, trail camera pictures). Beside the photos and video files (3) more furs and prepared skulls were collected. We could obviously prove the presence of breeding pairs in Hungary by the registered proof specimen: male (n=82), female (n=79), juvenil (n=54), adult (n=98). The most of the collected proof specimen originated from the three counties (Somogy, Baranya and Bács-Kiskun) similarly to results of other methods. Moreover spreading to northward also could be noticable in both parts of Hungary. Proof specimen were registered in many cases from the Tisza region or other rivers (Maros, Kőrösök) as well, which verifies the role of river-valleys in spreading.

3.4 Post mortem examinations

During the comparison of body sizes of golden jackal carcasses dimorphism was detected regarding bodyweight ($t=3,435$, $DF=60$, $p=0,001$). The average bodyweight of the female is only 88% of the male. Significant difference ($t=3,231$, $DF=70$, $p=0,002$) was also found between body length, it means that the male is longer than the female by 6% on average. The male is statistically ($t=2,084$, $DF=70$, $p=0,0408$) longer than the female. No significant difference was found between the male and the female neither regarding tail length ($U=593,5$, $U'=677,5$, $p=0,6365$), nor the length of the back leg ($U=578,5$, $U'=878,5$, $p=0,1266$). Kidney fat index (KFI) wasn't different between sexes in each season, but the rate of female's KFI was higher in every studied season (summer: $p=0,7517$, $t=0,3252$, NS. autumn: $p=0,699$, $t=0,5251$, NS. winter: $p=0,1488$, $t=1,486$, NS). During the seasonal comparisons significant difference was found: summer ($\bar{X}=0,32$, $SD=0,1$, $n=12$) and autumn ($\bar{X}=0,60$, $SD=0,22$, $n=13$), and winter ($\bar{X}=0,60$, $SD=0,27$, $n=29$).

The KFI comparison of male and female red foxes could be carried out in winter period only because of the necessary amount of data. No significant difference was found ($p=0,1156$, $t=1,615$, NS), although KFI of the female was higher.

By comparing the body size of the red fox and golden jackal it was proved that jackals are differ from foxes regarding body length ($p < 0,0001$), back leg length ($p=0,0175$, $p < 0,0001$) and bodyweight ($p < 0,0001$) in both sexes. Total length of the foxes were higher a bit, however it was because the tail of the fox is almost two times longer. Significant difference was found regarding condition (KFI): jackal KFI was higher in three seasons (spring: 280% $p=0,0048$, autumn: 207% $p=0,0001$, winter: 246% $p < 0,0001$). I had enough data to compare sexes and species in winter period. Results also show that jackal had better condition: (male: $p=0,0001$, $t=5,067$; female: $p=0,0005$, $t=4,298$). In autumn I had enough data for statistical analyses only in case of males: significant difference could be also proved ($p=0,0038$, $t=4,035$). Evaluable uterus was found in 33 individuals from 34 adult females. I could count placental scars in 6 individuals ($\bar{X}=5,5$, $SD=1,4$). I found embryos in three females ($\bar{X}=5,3$, $SD=3,7$). The same examination was carried out by the red fox: Number of placental scars was 7,5 on average ($SD=2,4$). Embryos were detected in 8 individuals ($\bar{X}=5,9$, $SD=3,6$). Comparison of the carnivore species regarding placental scars significant difference was found ($t=2,318$, $DF=15$, $p=0,035$). It was detected that while only 27% of the adult jackal females are active in reproductive period, in case of red fox this rate is almost three times higher (82%).

3.5 Results of the acoustic survey

3.5.1 District of Hajós-Szentgyörgy

Acoustic survey was done 14 times between spring 2004-2010. The howling was played at 21 calling stations on average (289 points in 7 years), the covered area was between 5340 ha – 7536 ha ($\bar{X}=6480$ ha, $SD=760$). Response of 7 groups were detected on average in each period ($SD=5,1$). Approximately at one third (31%) of the calling stations jackal howling was heard ($\bar{X}=6,2$, $SD=3,4$). Response was detected in 118 cases in total, 23% of them were from lone individuals, 77% came from family pack. Significant difference was found in years 2004 ($p=0,010$; $n=39$), 2006 ($p=0,043$; $n=38$) and in 2008 ($p=0,048$; $n=47$). Ratio of the calling stations where response was detected were higher in springs in those three years. Although I heard answers more often in springs than in autumns, no significant difference was found between seasons ($t=0,253$). Highest density (2,8 group/1000 ha) was estimated in the autumn of 2005. It seems that the estimated population density is decreasing in the whole survey period, but it could not be confirmed statistically ($r=0,576$; yearly average $\bar{X}=1,1$ group/1000ha, $SE=0,9$).

3.5.2 District of Császártöltés

Acoustic survey was carried out in 20 periods between spring 2004-2014. The howling was played at 20 calling stations on average (402 points in 11 years), the covered area was between 3140 ha – 8164 ha (\bar{X} =6310 ha, SD=1538). Response of 6 groups were detected on average in each period (SD=4,3). Although answers were heard more often in springs than in autumns, no significant difference was found between seasons ($t=0,715$). At about the quarter (26%) of the calling stations jackal howling was heard ($n=104$, in periods: $\bar{X}=5,2$, SE=2,38). Responses were detected in 150 cases in total, 23% of them were from lone individuals, 77% came from family pack. More individuals than groups were heard once only during the whole study period. No significant difference was found between spring and autumn in the rate of positive-negative calling stations. Changing of the density of family groups seems to be decreasing in the whole survey period, but it wasn't statistically confirmed ($r=0,330$, $\bar{X}=0,9$, SE=0,6). Density of the estimated lone individuals seems to be well-balanced ($r=0,017$).

3.5.3 Large area survey

Acoustic survey was carried out in 22 periods between spring 2004-2014. The howling was played at 77 calling stations on average (1707 points in 11 years), the covered area was between 9,4km² – 606km² (\bar{X} =244km², SD=59). Response of 13 groups were detected on average in each period with huge differences (SD=9,4). Jackal howling was heard in 381 cases in total, about three-quarter (74%) of them came from groups and the others from lone individuals. More individuals than groups were heard twice only during the whole study period (autumn of 2008, summer of 2009). With this method presence of the species was proved on some hunting grounds where it wasn't before. We were working in some areas without any responses for many periods, but finally we found new territorial jackal groups. These areas were: district of Kunbaracs, Kerekegyháza, Szabadszállás, or Harkakötöny. Probably we could not prove presence of jackal groups close to Monor, Pusztavacs or Pécel because of the low density of population, although hunters reported shots or observations previously.

3.5.4. Study the possible spreading route by the acoustic method – green corridor

Only three (district of Tiszabog, Tizsakürt, Csongrád) out of 58 calling stations were positive in the autumn of 2004. None of the 10 calling stations were positive in the Borsodi-Mezőség in March, 2005. Only one response was detected from 91 calling stations close to Tizsakécske in the autumn of 2005.

3.5.5 Analysing the responses

Jackal howling was played 1967 times in total during the whole survey. We could count 526 responses (26%). Answers were detected in 238 occasions for the first playback, 156 for the second and 132 for the third. Statistical analyses showed that more responses had detected for the first playback ($\text{Chi}^2=22,4$, $p<0,001$) and less for the last playback ($\text{Chi}^2=10,7$, $p<0,001$) than we expected. It proved that the number of responses is decreasing by the increasing number of playbacks ($Z=2,39$). Important difference was found during analyses: approximately one third (28%) of the total responses ($n=147$) came from lone individuals, 379 derived from family pack (72%). 42% ($n=62$) of the lone responses arrived directly after the first playback, 26% ($n=38$) after the second and 32% ($n=47$) for the third. Although the number of answers decreased parallel to the number of playbacks but the difference wasn't significant statistically ($p=0,05$; NS). In case of group responses significant difference ($p<0,001$; S) was found: most of the answers ($n=178$) arrived after the first playback (47%), 31% ($n=117$) for the second and only 22% ($n=84$) for the last. Group response mostly arrived for the first playback.

3.5.6 Habitat survey

11 land cover categories were distinguished within 1km buffer of the calling stations: 1. Discontinuous urban fabric, 2. Non-irrigated arable land, 3. Vineyards, 4. Fruit trees and berry plantations, 5. Pastures, 6. Complex cultivation patterns, 7. Broad-leaved forest, 8. Coniferous forest, 9. Mixed forest, 10. Transitional woodland-shrub, 11. Inland marshes. Cumulated area of forest (Broad-leaved forest, Coniferous forest and Mixed forest) give half (~51%) of the total area with huge differences between points ($SD=13$ to $SD=23$). Transitional woodland-shrub habitats are important (average 25%) regarding the spreading because it gives potential hiding place for the jackal.

Where broad-leaved forest was found (frequency: 73%) the average area ratio was 30% (coniferous forest freq. 67%, ratio: 15%; mixed forest freq. 87%, ratio 23%). Where transitional woodland-shrub type was found (frequency: 80%) the average area ratio was relatively high (32%). However the frequency of arable land type was 60%, ratio for the total points was only 11%. Frequency of open areas (pastures) was 53%, area ratio was under 20%. Negligible frequency characterized 3 categories: 2 (Discontinuous urban fabric, inland marshes) from 3 were found only at 1-1 points (3-3%), while fruit trees and berry plantations occurred at 3 points (10%).

3.6 NEW SCIENTIFIC RESULTS

1. Thanks to the first successful test and the adaptation of the acoustic method in Hungary a long-time (~10 years) study on the re-colonized carnivore's population was carried out in two sample regions in the middle of its occurrence area. Not just the presence of the stable population was proved but changing of the population density was also followed. Both the responses of the territorial groups and the estimated population density was calculated by this hectic changes in the sample areas: Hajósszentgyörgy: 289 points in total, for 867 playback ($\bar{X}=1,1$ group/1000ha, SE=0,9); Császártöltés: 402 points, for 1206 playback ($\bar{X}=0,9$ group/1000ha, SE=0,6), but no statistically significance changing was proved for the whole study period. Territorial groups were verified in large area surveys. After 5121 playbacks (1707 calling stations) the estimated group density was 0,6 group/1000 ha (SE=0,3).

2. Body size, condition and reproductive parameters were described of 104 jackal carcasses for the first time in Hungary. Significant differences were found between sexes by the comparison of body size: bodyweight (male: $\bar{X}=11,6$ SD=1,6, female: $\bar{X}=10,3$ SD=1,4; p=0,001), body length (male: $\bar{X}=82,6$ SD=7,7, female: $\bar{X}=78,0$ SD= 6,0; p=0,02) and total length (male: $\bar{X}=105,8$ SD=7,4, female: $\bar{X}=102,4$ SD=6,4; p=0,041). No significant difference was found in a point of condition (KFI: $\bar{X}=0,32-0,64$ SD=0,06-0,31). Number of placental scars was $\bar{X}=5,5$ SD=1,4, 25% of the adult females were active by this.

3. Increasing of the golden jackal population and its occurrence area in Hungary was proved obviously by several methods applied at the same time.

4. Results of parallel methods to study the spreading of the species in Hungary showed the importance of the River Tisza as a green corridor.

5. Habitat analysis was carried out in two sample areas by the using the acoustic results. Importance of the vegetation coverage (forests and woodland-shrubs) and hiding places was shown by land cover categories which could be dominant and primary for the jackal to settle down in new territories.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Population changing by the data of mail questionnaire survey and official hunting bag data

As our previous results show (HELTAI 2002, LANSZKI és HELTAI 2002, HELTAI et al. 2004, SZABÓ et al. 2004, LANSZKI et al. 2007, SZABÓ et al. 2009) both the occurrence area and the population is increasing continuously in Hungary. The strongest populations live in the south part of Hungary (Baranya, Bács-Kiskun and Somogy counties), but expansion can be seen northward from these areas.

4.2 Post mortem examination

The maximum bodyweight of the golden jackal is 15-17 kg. Jackals with the same weight were measured in the Balkan-peninsula (15kg, ATÁNASSOV 1953), in the Caucasus (15.5 kg, ALIEV 1968), in Dalmatia (16.4 kg, KRYŠTUFEK and TVRTKOVIĆ 1990), Austria (16,8 kg, HOI-LEITNER és KRAUS 1989). The heaviest individual we measured was 16,0 kg. Hungarian jackals' body length is similar to others. While our data of the males' body length is 82,6cm on average, then in Bulgaria 85,2 cm (DEMETER és SPASSOV 1993) and 79,9 cm (ATANASSOV 1953) and 79,3cm in India (JHALA és MOEHLMAN 2004). Our females ($X=78\text{cm}$) are similar to Bulgarians (77,5; 80,3), in Caucasus (80cm) or in India (76cm). Our results verified that the bodyweight of the jackal is almost twice of the red fox's, and the body length of the fox is about 86% of the jackal's. The results confirmed that the jackal is bigger, stronger, more robust than the red fox, so it could be more successful as a competitor than the smaller red fox.

No significant difference was found during the condition examination between male and female, although KFI of the female was higher in every season. Comparison of the condition of the two carnivores showed that KFI of the jackal was two or three times higher than the red fox's in every case (also in seasonal and gender examination Large fat quantity around the kidney suggests that jackal's feeding habit is more effective, could be a more prosperous hunter. It could be caused by its larger body, stronger habit or its developed social structure. Whereas the red fox is a soliter hunter, the golden jackal could hunt for bigger prey in pairs or in packs (LAMPRECHT 1978, KRUK 1972, BEKOFF et al. 1984, GITTLEMAN 1989).

Significant difference was shown between the two species regarding reproductive data. We found three times more active adult fox females than jackals. This distinction presumably

arises from the jackal's reproductive structure. In the first place the dominant female reproduces, while the other mature females stay inactive (MACDONALD 1983, 1993, MOEHLMAN 1986). We found 5,5 placental scars on average (minimum 4, maximum 8) similar to other international research results.

4.3 Acoustic survey

Adaptation of the method was successful because jackals responded to the playbacks. Effectiveness of the method is also proved by the fact that jackals approached the calling station many times despite they must have felt the presence of human. Minimal density of the population was estimated beyond that occurrence area previously defined by indirect methods was also checked by the responses in accordance with our aims. Presence of the golden jackal was proved directly so results of the mail questionnaire survey and collection of proof specimen were confirmed this way. Response of the family packs (breeding pair and the offsprings) directly verified the territorial golden jackal family pack attendance in the study area.

The acoustic method is suitable to estimate the minimum density of the jackal population by the responses to playbacks (SZABÓ et al. 2004). Success of the method is influenced seriously by environmental factors (e.g. human disturbance, weather) (POCHÉ et al. 1987, GIANNATOS et al. 2005) and also by the fact that jackals do not always answer to the playback even if they hear it (JAEGER et al. 1996). For example, five individuals were observed by a spotlight at a calling station in summer 2007, but they didn't respond to our playback.

4.3.1 Habitat use

Due to its uncommon adaptability golden jackal live and occur in various habitats. Nothing proves it better than the fact that the species which originally preferred marshlands and flood basins could spread in completely new kind of habitats. Results of our acoustic survey verified this because we found territorial groups in many types of habitats. Strong populations live in some artificial afforestations – like in Bulgaria (GENOV és VASSILEV 1991) – where excessively dense, impenetrable shrub (hawthorn, sloe) can be found under the akacia, populus or pine trees. Floodplain forests (e.g Gemenc area), large areas of reed (e.g Lake Velence) or grassy steppe, fallow lands could also hold dens jackal populations. Rows of trunks open the door to dig a den after deforestation on sandy soiled habitats (SZABÓ et al. 2009). We heard jackals close to settlements many times (LANSZKI et al. 2007). Despite we

never registered a response from large agricultural areas. The same situation was experienced in Romania (BANEÁ et al. 2012), Bulgaria (ACOSTA PANKA et al. 2014) and in other countries (SALEK et al. 2013). Other international studies (GIANNATOS et al. 2005, SALEK et al. 2013) also found that large and intensive cultivated lands, areas with increased human presence, spacious mountain forests are unsuitable for the golden jackal.

Golden jackal seems to prefer transitional woodland-shrub habitats where food sources of both woodlands and fields are available. Frequency of this kind of habitat reached 80%, it had the highest ratio (~ 25%) for the whole area. During the survey we experienced that jackal population density can reach extremely high value within a sample area or a region, but significant difference was found between each regions. That is why data of some region cannot be extrapolated to large areas or country –level. This result is similar to other international experiences where it was explained by the special social structure which eventuates patchy occurrence with high density data (KROFEL 2008).

On the base of previous studies in the Balkan peninsula (KRYSTUFEK et al. 1997, DEMETER és SPASSOV 1993) our hypothesis was that jackal uses river valleis to occupy new areas. Our supposition was confirmed by the results of the fieldwork in 2004-2005. Jackal howling was heard in both years close to the River Tisza. Presence of territorial groups were verified in the district of Csongrád and Lakitelek (middle part of the Tisza), beyond this some proof specimen were collected from the upper sessions of the river (area of Karcag, Abádszalók, Borsodivánka, Gelej). It is assumed by abovementioned that the route of the spreading could be linked to River Tisza and its affluents (SZABÓ et al. 2006).

More lone individual response were detected than group during the whole survey period: Hajósszentgyörgy 2 (autumn of 2006, spring of 2010) of 14 cases (14%), Császártöltés 1 (autumn of 2012) of 20 periods (5%), large area survey 1 (autumn of 2008) period (4,5%). It is clear that family packs answered more often than lone individuals. We can state our previous suppositions and other international results (HARRINGTON és MECH 1982), that ratio of the answering family packs is higher than the vagrant young individuals’.

It is experienced that in most cases (45%) response was arrived for the first playback, and only 30% for the second. Similar results were published by GIANNATOS et al. (2005): 71% of the responses came for the first and the second playback together. BANEÁ et al (2012) registered 70% for the first playback, while KROFEL (2008) noted 33% for the first and 38 % for the second playback. LANSZKI et al. (2007) found similar results to BANEÁ et al (2012): 70% for the first and only 4% for the third playback.

Although the estimated data shows significant deviation, but could be compared to other results of international studies. GIANNATOS et al. (2005) found the population density between 0,8-5,0 group/1000 ha. Our results on the sample areas shows alike (0,2–2,8 group/1000 ha). Other comparable results: Croatia 0,61-1,15 group/1000 ha (KROFEL et al. (2008), Bulgaria 0,8-2,1 group/1000 ha (ACOSTA PANKA et al. 2014), Romania 0,17-2,64 group/1000ha (BANEA et al. 2012).

The first jackal observations were in the second part of the '90s in the sample areas. Then more and more shots were reported after the Millennium. Knowing the exponential population increasing ability of the species it is supposed that beside some fluctuation the population density stabilized by the early 2000 when the acoustic survey started there. Reasons of the hectic changes within a short or long period couldn't be defined unambiguous: Could be a methodological error (moon period, weather conditions). Biological factors: for example, family pack falls apart because of hunting/predator controll, so the left alone individual responses smaller odds.

The acoustic results show that beside some fluctuation the golden jackal have stabile populations in the study areas. These core areas could play an important role (like source populations) in the further spreading in Hungary by their location and vegetation character.

4.4 SUGGESTIONS

a.) The acoustic method – compared to other field monitoring methods for population estimation – beside the errors and faults could be a quick, cheap and useful tool supplying reliable data. It is important to observe the rules of the protocoll. Thanks to the long term study important experiences were acquired. We found that the wind could cause distorsion. Our suggestion is to do the survey without rain and wind and previously defined regularity. It is no suggested to estimate the distance between the centre of the calling station and the answering individuals because of the obscureness. Predator management should be based on the density results estimated by acoustic method on GMU level.

b.) The official hunting bag data shows exponential growth countrywide. Conflicts and attacks against golden jackal usually miss any scientific knowledge of the species. It is very interesting if we take a look at the official hunting bag and estimated data reported by the hunters. It can be seen that the species is fairly under-exploited despite the jackal is a huntable carnivore from 1st of January until the last day of December. It is known that golden jackal

population cannot be controlled only by weapons (RAICHEV 2011). Because of these I suggest to use some other legal methods for example killing traps which is more effective in game management than shotguns. Another effective tool would be to do den-hunts systematically to decrease the population.

c.) Sample collecting: to get to know the most precise data of reproductive parameters/system the most shot female or its genitals should be collected. Knowledge could help the game managers in population regulation also.

d.) Prognosis of the possible routes and areas could be solved by the help of further and more detailed GIS studies. Bioacoustic survey should be continued in future. I have more than 100 good quality sound recordings from the fields. Accuracy of population estimation could be better by the help of sound analyses. It is possible to distinguish individuals in a recorded choir by using the sound analysing software (PASSILONGO et al. 2015).

It is very important to get to know more about the species and its ecological role. Setting up a management plan on golden jackal based on scientific results, experiences and usage in practise should be reached in future.

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