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Elaboration of a modelling framework to integrate population dynamics and sustainable use of the Saker Falcon *Falco cherrug*

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I. Executive summary

1. We reviewed demographic modelling of raptors, built models for the Saker Falcon, surveyed falconers and trappers in Saudi Arabia, developed a conceptual socio-economic model for Saker Falcon management and produced a costing of the main software tool that it would need.

2. We noted that data and techniques for monitoring Saker Falcon populations need refinement for populations with different ecological conditions in terms of breeding, migration and wintering areas.

3. For harvesting, more data on productivity, survival and attrition factors are needed to enable precautionary estimates of population resilience and persistence in the face of natural variation.

4. Observed productivity, and survival estimates of 50% through the first nine months after fledging, 65% of the next year and 80% thereafter predicted resilience of compact European and central Asian Saker populations above 80 pairs if not subject to trapping of breeding adults.

5. The IAF population model in Microsoft Excel is simple, flexible and transparent as a basis for stakeholders to reach agreement on safe harvest quotas from unfragmented populations that comfortably exceed an 80-pair threshold.

6. Trapping on migration of juveniles marked while nest recording can estimate population sizes, for cross checking through modelling nest densities across breeding areas, and size trends.

7. By engaging stakeholders in breeding areas, as well as in the falconry-interest community, mark-recapture estimation of populations could build trust and cooperation for managing wild Sakers.

8. Survey in Saudi Arabia indicated that trappers and falcon-hospitals in the Gulf States are capable of providing data to model demography of Sakers and socio-economics of their use in falconry.

9. On this basis, we recommend engagement of the CMS Saker Falcon Task Force with falconers, falcon hospitals and trappers, as well as biologists to build networks of local land managers in breeding areas and governments plus international NGOs to support cooperative management.

10. We also recommend work on radios that can give reliable long-distance signals from pre-breeding Sakers, genetics to identify falcon origin areas, and ways to motivate and facilitate engagement of falconers and trappers in exchange for data and local knowledge.

11. We propose development of a portal in Arabic to attract trappers and falconers (by providing useful knowledge, sponsoring of birds marked in breeding areas, surveys and competitions), to promote the idea of not trapping adults in breeding areas, to host tools for monitoring populations and potentially also a system for regulating trade.

II. Introduction

The Saker Falcon (*Falcon cherrug*) is the world's second largest falcon, with breeding populations distributed across the breadth of Eurasia, with some migration to Africa for winter. Falcons have for many centuries been trapped sustainably for use in falconry, typically while on migration and with subsequent release of trained birds back to the wild at the end of the hunting season.

Breeding is mainly in steppe and semi-arid land, on cliffs in the south and in trees in northern areas, with some also on man-made structures and in artificial nests. In parts of its range with limited nesting opportunities and recent increased access for trappers, trapping of breeding adults has been associated with population declines. Healthy populations still occur in other parts of its range although there are concerns about electrocution on poorly designed power cables and secondary poisoning during control of rodent populations. As a result of these factors, as well as large scale anthropogenic changes in land use, Saker populations declined globally, leading to Red Listing of the species as threatened, and growing pressure for action through the Convention on the Conservation of Migratory Species (CMS 2003) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1979).

The Saker Falcon Task Force (STF) was formally established by CMS Resolution 10.28 adopted at the 10th Conference of the Parties (COP10) in November 2011. The STF aims to bring together Range States, Co-operating Partners and other interested parties to develop a coordinated Global Action Plan, including a management and monitoring system to conserve the species.

During 2012, four STF Working Groups were established to contribute to a 1st draft of the Saker Falcon Global Action Plan (SakerGAP) by July 2013, to inform a Stakeholders' Workshop in September 2013. One Working Group takes forward issues related to the sustainable use of the species, primarily for falconry. The issue of sustainable use may be a central element to the future conservation and management of the Saker Falcon. The Task Force is clear that any management plan for the species should be founded on an objective evidence base; including, where appropriate, information obtained from population modelling, using the best available data.

As well as population modelling to ensure that use is sustainable, fundamental principles for conservation through sustainable use follow from the Convention on Biological Diversity (CBD 1992), in which sustainable use is the second pillar and a focus of 13 substantive articles. Some relevant aspects of the convention were expanded in agreement by CBD parties on the Malawi Principles for the Ecosystem Approach (CBD 2004a) and the Addis Ababa Principles and Guidelines for Sustainable Use of Biodiversity (CBD 2004b). Relevant principles may be summarised as (CoE 2007):

- *Supportive and linked governance at all levels with harmonised regulations that promote societal benefits from conservation;*
- *Transparent and adaptive management based on interdisciplinary science, monitoring and timely feedbacks;*
- *Encouragement of economic/cultural incentives with sharing of benefits (and costs) especially at the local level;*
- *Education, awareness and inclusion of managers, resource users, and society at large.*

To apply these principles from CBD would require further conceptual modelling, and the linking of socio-economic models to the computations to predict development of Saker populations. With these considerations in mind, a tender to report on conservation modelling for the species was placed with European Sustainable Use Group to meet 5 objectives:

1. Review existing population data, models and modelling techniques, including specifically any models that have already been developed for discrete Saker Falcon populations.
2. Develop a series of related demographic models covering the range of Saker Falcon populations to create a modelling framework for the global Saker Falcon population.
3. Using the best available evidence, the modelling should:

- Investigate the population dynamics of the Saker Falcon, including the effects of differing levels of productivity, recruitment and mortality.
- Simulate the potential effects of harvesting from declining, stable as well as increasing Saker Falcon populations.
- Investigate the effects of harvesting female and male specimens at different stages in their lifecycles, i.e. nestlings, fledglings, dispersing juveniles and adults, and breeding adults.
- Identify parameters which impose critically important pressures and therefore require the highest levels of data quality.

4. Develop a socio economic model to elaborate sustainable use of the species for falconry purposes, which can be integrated with the population demographic modelling.
5. The results are presented as a series of options comprising electronic, textual and graphical outputs, outlining the level and nature of taking from the wild that could be sustained in the long-term and the key factors in the population dynamics of the species that might prove to be limiting factors in this regard.

III. A review of existing models and parameters for the Saker Falcon

In order to identify existing models and to provide the most accurate input data for the recent model, a thorough review of literature was made. Population models and parameters for Saker Falcon were collected from the relevant – published and yet unpublished – articles and books, as well as from personal communication. Data cover most of the range from Central Europe to Mongolia. While there are some data from as early as the 1940s, most of them are from the end of the 20th and the beginning of 21st centuries.

III.1 Existing models for the Saker and other raptors

Although there are not many predictive population models for the Saker Falcon, models for other birds of prey species describing the dynamics of a given population and the importance of various factors determining the model's outputs can be found in the literature. The cited papers provide insights for our population modelling of the Saker Falcon, for carefully assessing the input data, as well as for evaluating and explaining the outcomes appropriately.

Data for population modelling can come from direct observations from regular counts of migratory populations (Farmer 2007) or monitoring the population of a certain geographic area (Sergio et al. 2011; Kauffman et al. 2004), they can be results of the classical capture-recapture method (Hiraldo et al. 1996) or if there is no other way to study a population of certain species in a given area, modern technologies like DNA sampling (Wink et al. 1999), as well as radio and satellite-tracking come into play to gather the necessary data (Kenward et al. 1988, 2007; Prommer et al. 2012). In the case of Sakers, in theory, all techniques except migration count data can be used (because relatively few migrating Sakers are counted); however there has been a tendency to prefer the latest technologies as they are more cost and time efficient.

Once the data are collected various mathematical methods are applied in order to conclude raw data. Although the methods are the same or very similar in many cases, conclusions in different articles may contradict depending on the species.

Sergio et al. (2011) argue that age-structured variation in multiple vital-rates (of survival and breeding parameters) is a fundamental determinant of population growth, with important implications for conservation management. However, for many long-lived vertebrates such as birds of prey, such variation has been usually examined in shorter-lived species. Their study on Black Kite (*Milvus migrans*) – a relatively long-living bird of prey – suggests that both survival and offspring production varies along the lifespan in conjunction with the sequence of major life history stages: they are lowest during the initial years of life, increase steeply during the period of progressive incorporation of non-breeders into the breeding sector of the population (age 2–6), level off between 7 and 11 years of life, decline with senescence after age 12, and increase again for the few high-quality individuals capable of reaching age 18–25. This pattern is more gradual, asymmetrical and protracted than in shorter-lived species. Matrix modelling estimates a stationary growth rate, which was more sensitive to changes in survival in early life rather than to survival in adult life, contrary to expectations for long-lived species. The results highlight: (1) a growing appreciation of the importance of juvenile survival for population dynamics, (2) the need for caution on the generalization that population-trends of long-lived species are primarily determined by adult survival, and (3) that the trajectory of the breeding populations of migratory species may be determined by environmental variation experienced in early life in staging areas located far away from breeding areas.

Unlike Sergio et al., working on the shorter-lived Lesser Kestrel (*Falco naumanni*), Hiraldo et al.

(1996) found that population growth was most sensitive for changes in adult survival, followed by juvenile survival, productivity of fledglings, proportion of adults that attempt breeding and age at first breeding. More interestingly, Katzner et al. (2006) confirm that finding, based on results of their study of the Eastern Imperial Eagle (*Aquila heliaca*), which is a longer-lived species, similar to Black Kite. They used novel sensitivity analysis of stochastic simulation models to analyse the demography of the world's highest-density and longest-studied population of Eastern Imperial Eagles, at the Naurzum National Nature Reserve in Kazakhstan. Single variable perturbation (a simple elasticity-type analysis) showed that population growth was most sensitive to changes in adult survival, but provided no information on how interactions between parameters may influence population growth. Multiple-variable perturbations (a more comprehensive elasticity-type analysis) suggested that population growth is relatively more sensitive to adult survival than is indicated by single-variable perturbation but also that when adult survival is within a biologically reasonable range, other parameters are still highly consequential to model outputs. This finding suggests that also for other structured populations of vertebrates, effective conservation and management likely requires an approach that addresses the importance of simultaneous variation in multiple vital rates including both survivorship and reproductive output.

Factors like available safe nests can also have significant impact on population dynamics of some raptor species, including Saker Falcons. Natural nests – mostly built by corvids – may not last until the end of the nestling period and their collapse often leads to breeding failure. During 1980-2002, 14% of all breeding attempts in Hungary (n=1065) failed due to collapse of natural nests. If we project that number only to breeding attempts in natural nests, during a period with a majority of breeding attempts already in artificial nests, that ratio is considerably higher. The long-run Saker conservation project in Hungary showed that the provision of artificial nests was a very efficient way to increase the number of successfully breeding Saker pairs, in areas where prey was abundant (Bagyura et al. 2004). Population modelling supports that observation. As a 2005 Vortex model for the International Action Plan for the Saker Falcon (based on the Hungarian Saker population data) suggests, providing safe artificial nests as an alternative to vulnerable natural nests, can contribute to successful breeding and effectively compensate for higher adult and juvenile mortality, thus supporting the increase of the population (Nagy, unpubl.).

Kenward et al. (2007) noted the importance of removing adults from raptor populations, when they studied the impact of harvesting in three species including Saker. They used age-specific survival and breeding data to parameterize a demographic model for a harvested Kazakh Saker Falcon population by radio tagging juveniles and estimating adult turnover with DNA-fingerprinting during 1993–1997. Similar data had been gathered during 1980–1998 to model the Northern Goshawk (*Accipiter gentilis*) in Sweden (Kenward et al. 1991, 1999) and during 1990–1998 for a model of the Common Buzzard (*Buteo buteo*) in Britain (Kenward et al. 2000). Leg-bands and implanted microtransponders provided ways to test for bias and to estimate the harvest of Sakers for falconry. Despite an estimated minimum first-year survival of only 23%, the observed productivity of 3.14 young per clutch would sustain a saker population with a breeding rate (at laying) of only 0.63 for adults or with a residual juvenile yield of 37%, if all adults breed. Higher first-year survival rates for goshawks and buzzards correlated with juvenile yields of up to 71%, but no more than half as many individuals, if adults also were harvested. According to their model, an annual population decline of 40% for Sakers in southern Kazakhstan could be explained by observed productivity of only 0.71 young per clutch, if there was also an estimated harvest of 55% of adults. Their study also suggests that demographic models can be built rapidly if nestlings are fitted with reliable and safe radio-tags and adult turnover is estimated from genetic analyses or other techniques.

Other models have studied the impacts of harvest. Saker population models in the feasibility study for Saker re-introduction to Bulgaria (Ragyov et al. 2009) showed that harvesting juveniles at a safe rate from an increasing donor population (for reintroduction in Bulgaria) does not have a strong impact on population size and dynamics. However, it is not the same for a decreasing population with a growth rate below zero when low juvenile survival rate and a small number of offspring per breeding pair have been assumed. In those cases, harvesting could cause further decrease in population size. As for the recipient population, after testing several scenarios with different estimations of survival and breeding success parameters, positive population growth was observed in all cases, which indicates the establishment of a viable population and, therefore, a successful reintroduction. The rather optimistic model predicts that ten years after initiating the reintroduction project (involving the release of ten male and ten female juveniles each year for five years), an increasing breeding population will be established with a population of between eight to fifteen breeding pairs. Survival rate for juveniles and adults are estimated at least to 30% and 80% respectively. First breeding is expected in the third year after the first cohort was released.

Millsap et al. (2006) studied the impact of harvesting for falconry on some North American raptor species' populations. They used population data and a deterministic matrix model that accounted for important aspects of raptor population biology to evaluate the likely impact of falconry harvest (including take of different age classes) on wild raptor populations in the United States. The harvest rate at maximum sustainable yield (MSY) ranged from 3% to 41% for the species examined. At least for Peregrine Falcons (*Falco peregrinus*), harvest rate at MSY was greatest for nestlings and lowest for adults. One important conclusion of the study is that the quality of demographic data for the species influenced MSY. They argue that in case of most species the state of current knowledge probably underestimates the capacity for allowed harvest because estimates of vital rates, particularly survival, are biased low, because emigration is not distinguished from survival. This is offset somewhat by biases that might overestimate sustainability inherent in MSY-based analyses and deterministic models. Taking these factors into consideration and recognizing the impracticality of monitoring raptor populations to determine actual effects of harvest, they recommend that falconry harvest rates for juvenile raptors in the United States not exceed one-half of the estimated MSY up to a maximum of 5%, depending on species-specific estimates of capacity to sustain harvest. Under this guideline, harvest rates of up to 5% of annual production are supported for Northern Goshawks, Harris's Hawks (*Parabuteo unicinctus*), Peregrine Falcons, and Golden Eagles (*Aquila chrysaetos*); lower harvest rates were recommended for other species until better estimates of vital rates confirm greater harvest potential.

Clearly, it is not only harvest that removes individuals from populations. Mortality caused by illegal killing can have significant impact as well, that can considerably slow down ongoing population recovery processes, as Smart et al. (2010) suggest. Red Kites (*Milvus milvus*) have been re-introduced to England and Scotland, following extinction due to widespread human persecution during the 19th century. Considerable regional variation in population growth exists. Productivity in north Scotland was high compared to other Scottish and Welsh populations and equal to English populations with high population growth rates. In north Scotland, annual survival of wild-fledged birds was low for first-year birds compared to other Scottish populations and second-year survival declined over time. In north Scotland, 40% of 103 Red Kites found dead were killed illegally, mainly by direct poisoning. In the absence of illegal killing, they estimate that annual survival rates in wild red kites might increase from 0.37 to 0.54, 0.72 to 0.78 and 0.87 to 0.92 for first, second-year and adult birds respectively. Models in which the additive illegal killing mortality is excluded, predict a population trajectory and size very similar to that found in the Chilterns, a rapidly growing population in south-east England re-introduced at the same time, but where rates of illegal killing are much lower. They concluded that illegal killing of Red Kites is the cause of poor population growth in north Scotland.

Similarly to the study above, there are studies suggesting that regional differences even within a relatively small area in populations must be strongly considered. This is certainly true also for the

Saker Falcon, which has an enormous geographic distribution.

Kauffman et al. (2004) found that the recovery of the Peregrine Falcon (*Falco peregrinus anatum*) in California has taken place amid strong geographical differences in habitat quality, potentially creating a sink population in the southern coastal habitat and source populations in the northern interior and urban habitats. They analyzed long-term monitoring data to investigate the mechanisms and consequences of spatial structuring for the recovery of this set of non-stable subpopulations. Dispersal rates between habitats were asymmetric, with extremely limited dispersal out of the interior habitat and a strong tendency for birds in the southern coast to disperse to the urban habitats. They used dispersal estimates and habitat-specific productivity rates to build a set of regional population models that describe population growth within and dispersal between each subpopulation. They tested for the existence of habitat-specific survival and territory acquisition rates by comparing model projections with the number of breeding pairs counted annually in each subpopulation. Analyses indicated a high rate of survival for interior birds and suggested that both the interior and urban subpopulations were regulated by territory availability over the study period. The inherent spatial structure of this regional peregrine falcon population has had a considerable influence on its recovery and management

One of the first steps to build such spatially specific models is to understand the factors determining distribution. This was done for the Hungarian Saker population by Fehérvári et al. (2010). They collected the data of all active territories during 2007-2010 to serve as the countrywide distribution pattern on a 10x10 Universal Transverse Mercator (UTM) grid scale. To explain this pattern they used landscape variables (Corine Landcover database, OTAB), and estimated densities of potential prey species deriving from the Common Bird Census database, or other records for mammals. They used a multi-level and multi-scale approach to data analyses. Initially they reduced the number of potential explanatory variables with an ensemble classifier (random forest algorithm). As a second step they constructed Conditional Autoregressive (CAR) models in a Bayesian framework with the pre-selected variables. Bayesian CAR models give robust estimates on the global effects of explanatory variables on the probability of Saker territory presence in a given grid cell; however, they lack the power to reveal local deviances. In order to correct that they built Generalized Geographically Weighted Regressions (GGWR) to estimate the scale of local effects of the same variables. The results indicated that Sakers avoid UTM cells with high ratio of forests, but prefer areas with large open areas of large arable fields and grasslands. Surprisingly, the association of estimated densities of Skylarks (*Alauda arvensis*) and Kestrels had high overall explanatory powers. The large spatial scale of the analyses suggests that these associated variables may reflect both the openness and overall good biodiversity state of these areas.

A geographical model of the population based on data from satellite tracking of more than a dozen breeding adult males and females, and on the available proper habitat and prey items in a specific geographical region (Pannonian basin) is under construction in the frame of LIFE NAT/HU/000384 project. That model will be able to help refining regional population models (Prommer, pers. comm.).

III.2 Data for recent and current Saker population modelling

There are extensive data from studies of Saker Falcons nesting at sites across Eurasia. These are listed in Annex I and summarised in Table 1. The most consistent data are on brood sizes from successful nests, since these were available from occasional and sporadic observations during brood rearing. However, there are also data from regular monitoring programmes in which nests were visited during incubation so that the nest success, from laying to fledging, could also be estimated and hence the total productivity of young per clutch (using the conventions of Newton 1979). Some data sets represent information for a whole country, while others cover only regions. In some cases data were deficient, but missing details could be calculated (as shown between brackets in the annex). Annex I also includes sources of information and links to the websites representing the data.

Hungary provided the longest and most detailed data set (from between 1980 and 2012), however, it relates to a relatively small part of the global population. At the same time, it neatly represents a recovery process from the population minimum to about the carrying capacity of the study area.

Sample size for the Mongolian data set is higher, but the studied time period is considerably shorter than in case of Hungary, while data from Russia cover a longer time period, but with a smaller sample size. Another important source of data is Kazakhstan, especially the eastern part of the country, where eight years of annual monitoring resulted in a good set of data and there are other data sets from other part of the country, as well as sporadic data from the mid-20th century. There are data sets from a number of other countries; however those cover shorter time period and/or have significantly lower sample sizes. Nevertheless, they are also considered for modelling.

Table 1 Average brood size, nest success and productivity in studies of Saker Falcons. The data are presented fully in Annex I.

Europe	**Years**	**Nests**	**Average brood size** (nestlings/ fledged brood)	**Nest success** (proportion of clutches that fledged young)	**Productivity** (nestlings per clutch)
BULGARIA	?	7	2.00		
CZECH	1976-2010	345	3.23	0.72	2.31
HUNGARY	1982-2012	2819	3.02	0.67	2.02
ROMANIA	2013	3	2.00	0.67	
SERBIA	1986,1994,2004	21	2.33		
SLOVAKIA	1976-2010	345	3.23	0.72	2.31
UKRAINE	1986-2004	22	2.33	0.41	
MEAN VALUES			2.59	0.64	2.21
C. Asia					
KAZAKHSTAN	1993-1996	63	3.59	0.86	3.08
MONGOLIA	2002-2006	330	3.70		
MONGOLIA grids	2005-2010	69	3.55	0.84	2.99
MEAN VALUES			**3.61**	**0.85**	**3.04**
RUSSIA (Altai)	1999-2011	436	2.67	0.71	1.90

Summarising, the extensive data on breeding, productivity in Europe and Asia appear to differ. The average sizes of successful broods did not exceed 3.25 in 7 European countries, while in Central Asia the average in 3 studies was above 3.5. Similarly, the proportion of nests with eggs that fledged at least one did not exceed 72% in Europe and was more than 80% in Central Asia. Russian (Altai) data were reduced appreciably by trapping of breeding adults and were therefore excluded from the estimates. Although nest success can be overestimated if many are found late (e.g. through single-visit surveys to mark young), brood sizes are straightforward to record.

III.3 Survival data from satellite tracking and population growth records

New survival data are available from 42 satellite-tracked individuals tagged as juveniles between 2007 and 2010 in Hungary and Slovakia (Prommer et al. 2012). In many cases when the satellite-received transmitters stopped, it was impossible to discern whether the tag had failed on a living bird, or ceased to transmit because its solar cells or antenna were covered when a bird died, or perhaps was destroyed when a bird was deliberately killed or captured. In these cases it was assumed that all birds had died, to estimate minimum survival rates of birds still moving and transmitting at a particular age, as is normal practice to obtain conservative survival estimates from radio-tagging (Kenward 2001: 238). Birds found dead with tags transmitting provided some information on causes of mortality. More juveniles have been tagged and tracked since 2010, in Hungary, Slovakia, Romania, Ukraine and Serbia, however those data have not yet been analysed, therefore those data are not considered here.

As it has been very difficult to calculate reliable survival rate to adulthood (first breeding) and rates from satellite-tracking appeared to be low, another approach was applied. Analysing the population data of the Hungarian pairs, correlation analysis shows strong correlation between a given year's juvenile cohort and the number of newly established pairs three years later, especially for the decade during which numbers increased from 30 to 80 pairs at natural sites. That suggests that most Sakers in Hungary during that period were starting to breed by age 3. Knowing the number of juveniles in the given year and the number of new pairs three years later, an estimation could be done for the survival rate until breeding age. Differences between sexes were ignored due to lack of detailed data, and this calculation could not consider

(1) immigration from other countries (although it is probably negligible);
(2) emigration from the study population (it may add 1-2% at least, but no accurate data exist);
(3) the number of non-breeding adults, which may be considerable (see later).

Although this analysis indicated majority first breeding at age three, in the first decade the strongest correlations had a two-year interval. Moreover, three of 16 pairs in a depressed southern Kazakh population had females at 9 months post-fledging, i.e. in first year plumage (Kenward et al. 2007). We therefore modelled first breeding at 21 months post-fledging.

III.4 Recent and current Saker population modelling

Recent modelling includes work for an action plan on the species in Europe (Nagy & Demeter 2006), in which population targets were set with the Vortex modelling suite (Lacy & Pollak 2013) that predicts population viability. Similar modelling was done within the LIFE+ project on Sakers in Hungary (MME & RPS 2010), and to estimate the growth in Saker production in Mongolia resulting from construction of artificial nests (Dixon et al. 2011). Vortex adds stochasticity (chance) to the matrix modelling used in other projects.

The principle of matrix-modelling is that the number of animals in age class $\boldsymbol{x}$ is the number produced $\boldsymbol{x}$ years ago multiplied by the product of survival rates ($\boldsymbol{s}$) for each preceding age class. In year $\boldsymbol{j}$, the number of adults in age class $\boldsymbol{x}$ ($\boldsymbol{n_{xj}}$), of which an age-specific proportion ($\boldsymbol{b_x}$) breed with a productivity of ($\boldsymbol{y_x}$) young per pair, produces $\Sigma \boldsymbol{n_{xj}}.\boldsymbol{b_x}.\boldsymbol{y_x}$ young. The total number of young produced that year is then the sum across all age classes from the first breeding year to the greatest breeding age ($\Sigma \boldsymbol{n_x}.\boldsymbol{b_x}.\boldsymbol{y_x}$), from which cohort the total of surviving adults in each successive year can in turn be estimated. Partitioning the attrition rate ($\boldsymbol{a}$) for each age class into $\boldsymbol{k}$ attrition classes (e.g. harvest, electrocution, natural) enables modelling of $\boldsymbol{s}$ as $1-\Sigma \boldsymbol{a_k}$ if attrition rates are additive.

The process in Vortex is in principle the same, except that terms are added to investigate the sensitivity of variables, and small populations, to stochastic events. The effects of changing productivity and attrition rates can be investigated, separately for each sex, in matrix models first, and then evaluated for small populations with Vortex. It is preferable to examine these preliminary “what-if” questions first in a deterministic spreadsheet-based matrix model, not least because such a model is transparent to audit of the estimation processes.

IV. Modelling Saker Falcon populations across their Eurasian distribution

IV.1 The International Association for Falconry and Conservation of Birds of Prey model

Parameters in the previous section were used to populate a matrix model developed by Janusz Sielicki for the International Association for Falconry and Conservation of Birds of Prey (IAF). The model is similar to the "age and sex-specific survival and breeding" matrix models used by Millsap & Allen (2006) and Kenward et al. (1991, 2007) to predict sustainable yields for falconry from raptor populations. The advantage of the IAF model is its Microsoft Excel format, which can be used reasonably easily and transparently to investigate effects of harvest, pollutants and other additional mortality factors, as well as to investigate populate decline and growth, including changes in breeding rates during growth until breeding sites become saturated. The functioning of the model was checked mathematically, and then through its ability to produce the same results as in these models.

The principle of all these matrix models is to estimate survival in each year to the point at which adults in the population lay eggs, and then apply the observed productivity of young per clutch laid (i.e. nest success x brood size) to those birds that lay. This means that survival is estimated for the first nine-months after fledging, and subsequently for 12-month intervals. The model applies an age of first breeding and then applies to each older age class a similar proportion of adults breeding (the breeding rate). The breeding rate may not be the same for all age classes: it is quite possible that few or none will breed in the youngest age classes, and most will breed when older, producing an average for all adults of the predicted value. In buzzards, for example, only 14% bred at age 2 in a stable population but 40% in a population rebuilding with released birds (Walls et al. 2004).

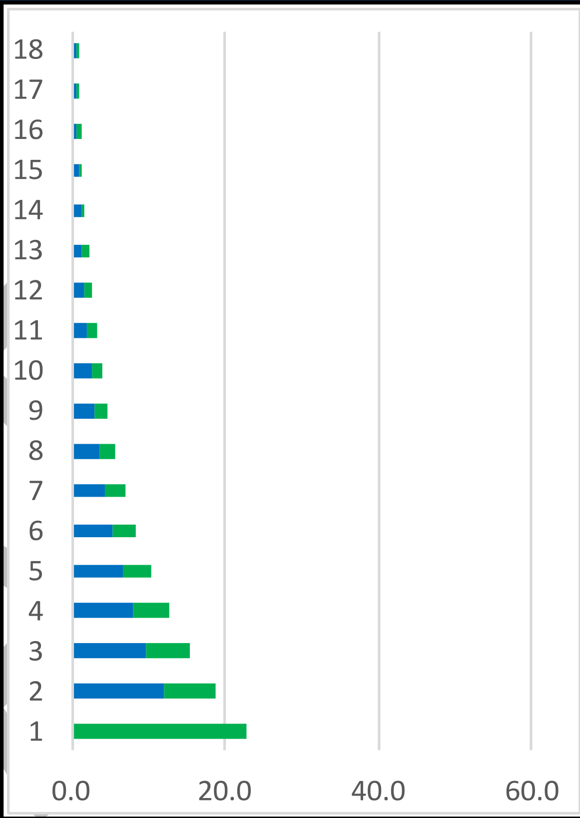
For the first scenarios modelled, the approach was to estimate the breeding rate for population stability, i.e. neither increase for decrease. The lower the proportion of adults which need to breed to replace mortality, for a given productivity, the greater is the resilience of the population to perturbations. In the absence of evidence that survival differs between sexes, equal numbers of males and females were assumed for each age class.

The IAF model was tested using Saker data from Northern Kazakhstan, where daily listening from a tower for VHF signals from 61 falcons tagged at fledging recorded the return of only 14 (23%) in their following or second breeding season. Adult turnover, estimated by DNA from young in the same nest sites sampled at 1-3 year intervals (Wink et al. 2003), gave annual adult survival of 82%, which was used for all older years. Even with such a low rate for survival to 9 months, the high productivity of 3.1 young produced a stable population with just 64% of adults expected to be breeding in the IAF model (Table 1), as in Kenward et al. (2007).

The model was also tested by comparison with Vortex, using population sizes of more than 150 breeding pairs. Vortex uses similar age-specific survival and breeding rates as a deterministic matrix-based model of the IAF type, but can also vary breeding and survival parameters stochastically (at random) in order to investigate the risks of extinction in small populations from annual variations. Large Saker populations with parameters used in the IAF models persisted at the same average level. To avoid assumptions of stochasticity (which may in reality be offset by density-dependent effects not accommodated in Vortex), the IAF model was used to assess effects of variation in productivity, survival and harvest, and Vortex then used to investigate how large populations might need to be to avoid risk of extinction from stochastic events. Although the IAF model was set for stability in the following 3 tables of analyses, by allowing either breeding or harvest rates to reach equilibrium, it can also be used to simulate population growth, decline, or maximum harvest under conditions of limitation by breeding sites or additive impacts on mortality and/or survival.

Table 2 The IAF model can be used to predict breeding rates for stability at given age-specific survival and breeding parameters, or to show how populations develop with breeding-site limitation and changes based on additive impacts on survival and mortality. In this case the low juvenile survival is offset by high subsequent survival and productivity to that the population is stable with few of 100 fledglings surviving in each age class (on the right), and only 64% of adults breeding (blue) from all survivors (green) in their second year onward.

Original Kazakhstan parameters	
survival rate to 9 months	23%
survival rate 10-21 months	82%
survival rate 3+ year	82%
expected breeding rate for single adult	64%
young produced per pair that lay eggs	3.10
adjustment for proportion of each sex that breeds if survival differs between sexes (=0.5 for equality)	0.5
maximum capacity of breeding pairs	unused
negative impacts (additive mortality factors) for 1st year birds from (e.g. electrocution)	0% (i.e. no impacts)
additive positive impact on 1st year birds (e.g. feeding, protecting nests)	0% (none)
negative impacts (additive mortality factors) for older birds from (e.g. electrocution)	0% (none)
additive positive impact on older birds (e.g. feeding, protecting nests)	0% (none)
probability of harvested bird returning to wild to breed	0% (none)
harvest rate of juveniles	0%



The principles behind such modelling are simple. From 100 birds fledged, 77 die in their first year and 23 enter their second year; of the 23, there are 4 (18% of 23) that die in the next year and 19 that survive to the next breeding season, then 3 (18% of 19) with 16 survivors, and so on. If that continues for 18 years, a total of 100 birds have died. In a stable population, where that continues year after year, there are also 23+19+16+ ... (to 18 years) of birds in this population, a total 122 birds. Of those 122 birds which breed from their second year, 19+16+... (totalling 99) are deemed breeders. Those 99 breeders are producing 100 young with 3.1 young per pair, so there are 32 pairs, involving 64 birds, and only 65% of the adult population is breeding. If they were deemed only to breed from their third year of life, there would be 80 “breeders”, and 81% would be breeding. In fact, what happens in a healthy stable population is that age of first breeding advances and fewer young birds breed.

IV.2 Modelling with new parameters

However, improved survival data were used for further modelling. Of 42 Hungarian Sakers that wore tags for tracking by satellite (Prommer et al. 2012), 15 (36%) were known to survive 9 months (Prommer unpublished). Of the 15, only 6 had returned to their natal area, which indicated that estimates based on philopatry in Kazakhstan could have been substantially low: overall survival might have been more than double the 23% recorded in Kazakhstan. This was also likely because some radio tags used in Kazakhstan, and for tracking by satellite, may have failed or themselves contributed to deaths of long-distance migrants. However, the 36% survival gives a conservative estimate for the first 9 months (Box 1).

Box 1. Survival of juvenile and sub-adult Sakers

Returns of VHF-tagged Sakers were 23% at Naurzum from VHF radio-tagging, but satellite-tracking in Hungary gave only 40% philopatry of survivors, so this could represent 58% survival for Naurzum.

Hungarian satellite-tracking gave 36% minimal survival to 9 months, but the attrition includes tag impacts, tag failures and trapping for falconry and is therefore a conservative survival estimate.

Only 15 Hungarian satellite-tracked birds were transmitting at 9 months, so interpolated survival is used for months 9-21 and a severe knowledge gap noted among the general data gap for survival.

Hungarian ringing data gave 55% survival to 9 months (46% to 1 year), and by analogy with other comparisons of ringing and radio-tag data may also be low because ring recoveries overestimate early deaths (Kenward et al. 2000); more ringing and better analyses of the data are needed too.

Too few data were available from both VHF tagging in Kazakhstan and the tracking by satellite in Europe to estimate survival from 9-23 months: however, when adequate data are available, raptor second year survival tends to be appreciably higher than survival to 9 months but somewhat less than for adults (Kenward et al. 2007). The original adult turnover estimate from Kazakhstan was revised to account for the possibility of double partner changes during two year recording intervals, and gave an estimate of 80% for breeding adults (Box B). Although Dixon (pers comm.) re-sighted only 7 survivors from 12 wing-tagged adults (58%), this is a small sample and trapped adults tend to be poorer birds. Moreover, adult survival of large falcons generally exceeds 80% (Cade at al. 1988). Initial model scenarios therefore used survival of 36% for the first 9 months, 80% for adults and a value of 58% interpolated for sub-adults. Maximum breeding age was set at 18 years.

Box 2. Survival of adult Sakers

During 10 single-year intervals for 1993-1997 at Naurzum, Kazakhstan, turnover was 4 birds in 20 falcon-years (i.e. 20 birds across consecutive breeding years), giving 20% turnover and 80% survival.

There were also 3 double-year intervals; with a single turnover in 2 of them and 20% chance of two turnovers, this gives 2.4 turnovers in 12 falcon-years, again 80%.

Similarly, there were 4 three-year intervals, with two-bird turnovers in 2 of them, representing 4 definite and 0.8 further possible losses in 24 falcon years or again 80% survival.

Effectively, there were 10 observed and 1.2 estimated turnovers in 56 falcon-years, or 20% adult turnover, but this will be low because some birds may have changed partner without dying.

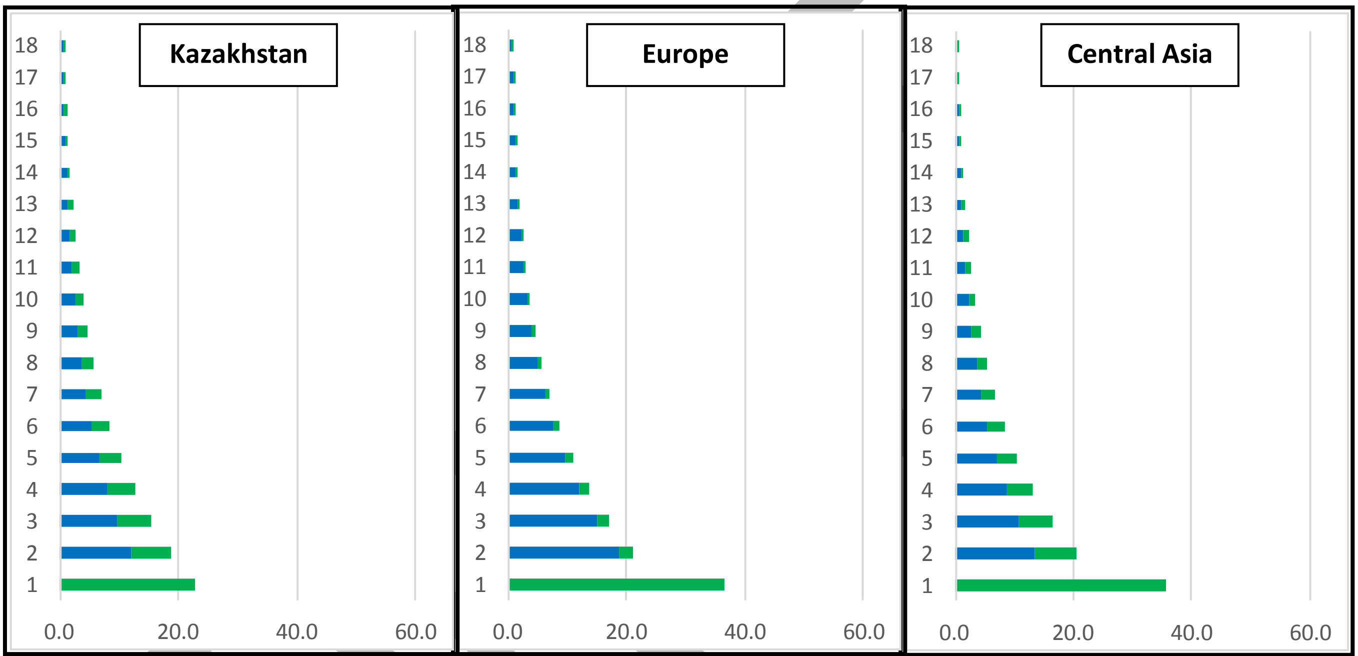
Thus the most reasonable survival estimate for 34 adult falcons is probably 80%, which is at the low end of many ringing studies of raptors with 1-2 kg body-mass and may therefore be conservative.

These survival data were used together with two productivity scenarios, because productivity in Europe and Asia appear to differ (Table 1). Brood size from three multi-decade studies in Europe averaged 3.1 chicks and 72% nest success, giving productivity of 2.2 chicks/pair. In Central Asia, broods can average 3.6, with 85% success, which suggests productivity above 3 chicks/pair in good conditions. Modelling was therefore based on 3 chicks/pair for Asia and 2.2 chicks/pair for Europe.

With survival rates of 36%, 58% and 80% in consecutive life-stages, this European scenario was stable only if 89% of adults were breeding from their second year of life in Europe (Table 3, column 3); a relative absence of resilience to factors reducing survival or productivity is indicated by a low proportion of non-breeders (in green) after the first year. However, productivity of 3 young per clutch, averaged across Asia, gave a stable scenario with breeding expected by 65% of adults (Table 3, column 4); the green portion of the estimated numbers for each age category shows the resilience.

Table 3 As in Table 2, breeding rates for stability are estimated for productivities observed in Europe and Asia. Parameters not used in further analyses are not shown. The non-breeding proportion of each year class, shown with green bars, indicates low resilience in Europe.

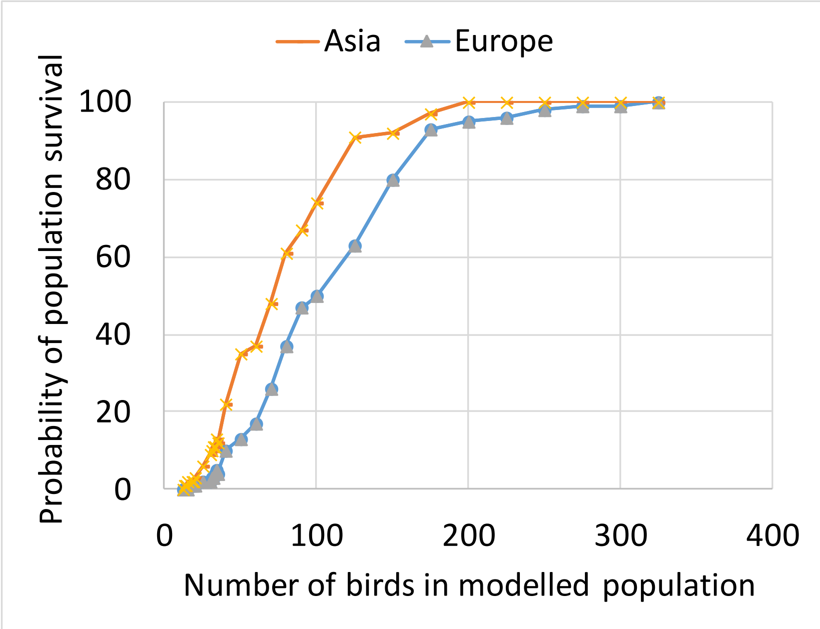
	Original Kazakhstan data	Europe (conservative survival)	Asia (conservative survival)
survival rate to 9 months	23%	36%	36%
survival rate 10-21 months	82%	58%	58%
survival rate 3+ year	82%	80%	80%
expected breeding rate for single adult	**64%**	**89%**	**65%**
young produced per pair that lay eggs	3.10	2.20	3.00
harvest rate of juveniles	0%	0%	0%



IV.3 Testing resilience to random and consistent changes

Higher productivity gives the Asian scenario greater resilience, as shown in two ways. Vortex has the ability to vary parameters stochastically (at random) in order to investigate the risks of extinction from annual variations, and this capability was used to investigate the population sizes that would be needed to avoid risk of extinction from stochastic events. We used the variability applied in previous modelling of Saker Falcons (Nagy & Demeter 2006). Although the Vortex model operates stochastic rules that are considered realistic, it takes no account of density dependent feedback effects that may compensate with increased survival or productivity at low population levels. It therefore over-estimates risk of extinction from chance events and provides a precautionary approach for modelling "safe" population sizes. Vortex modelling suggested that a compact Asian Saker population could be considered safe at 200 birds, equivalent to a compact (non-fragmented) breeding population of at least 50 pairs, while a European population would need 325 birds (at least 80 pairs) for the extinction risk to become negligible (Figure 1), because of the lower productivity. There is also a need to consider how large fragmented populations need to be to withstand harvest at the same level as more cohesive populations, such as have re-established in Europe.

Figure 1 The population sizes that Vortex models estimate to persist with the survival and breeding parameters shown in Table 3; the Asian populations would be stable at 200 birds, but 325 would be needed in Europe.



The relatively high resilience of the Asian scenario was further tested by varying the survival rates and applying harvest pressures in the deterministic matrix model. With the conservative survival rates, the Asian population could sustain a 22% harvest of juveniles with 85% of adults breeding (Table 4, column 2). This is the breeding rate considered practical in other raptor yield models (Kenward et al. 2007).

Table 4 Effects on maximum sustainable harvest, with 85% of adults breeding, of varying the basic survival rates. With the basic survival (36%, 58%, 80%) and productivity (3 young/pair) scenario in Asia, the maximum harvest sustainable with 85% breeding would be 22% (column 2). See text for other scenarios. Yellow shading shows when parameters were changed, green shows harvest sustainable at constant breeding rates of 84-85%.

	Asian productivity, conservative survival						
Column 1. (the text below explains the contents of columns 3-8 in more detail)	2. basic survival	3. adult survival up 3%	4. adult survival 3% less	5. mo 9-21 survival up 9%	6. mo 9-21 survival 7% less	*7.* mo 0-9 survival up 6%	*8.* mo 0-9 survival 5% less
survival rate to 9 months	36%	36%	36%	36%	36%	*42%*	*31%*
survival rate 10-21 months	58%	58%	58%	*67%*	*51%*	58%	58%
survival rate 3+ year	80%	*83%*	*77%*	80%	80%	80%	80%
breeding rate for single adult	*85%*	*85%*	*85%*	*84%*	*84%*	*84%*	*84%*
young produced per pair that lay eggs	3.00	3.00	3.00	3.00	3.00	3.00	3.00
maximum harvest rate of juveniles	**22%**	**33%**	**11%**	**33%**	**11%**	**33%**	**10%**

The effect on possible harvest of changes in survival rates is also examined in Table 4. A three percent addition to adult survival, from 80% to 83%, enables a 50% increase in harvest to 33% of young at an 85% breeding rate (column 3), whereas a decrease in adult survival of 3% halves the estimate for sustainable harvest (column 4). Greater changes in survival of juveniles (columns 7-8), and especially of sub-adults (columns 5-6) are needed for the same changes in sustainable harvest in juveniles. Accuracy of estimation of adult survival is clearly very important for this modelling, with estimates for second-year birds allowing the greatest leeway. A further conclusion, also noted in

Kenward et al. (2007) is that added losses of adults, whether through trapping , electrocution or other factor, is a much more severe threat to Sakers than harvest of juveniles. In effect, it is drawing on capital rather than interest.

The effect of disproportionate removal of one particular sex, such as females because this larger sex is better able to subdue large prey, was not investigated specifically. This is because, in the absence of any compensatory effect of removal (for which there is no evidence) or of polygamy, dynamics should be modelled for the least abundant sex. The resulting breeding rate for the minority sex will be limiting for the whole population and merely be offset by differential breeding rates between the sexes. This occurred due to reduced survival of juvenile male goshawks in an area with abundant rabbits, which are easier prey for females to subdue, and resulted in a higher breeding rate being estimated (and checked independently)for surviving males than for females (Kenward et al. 1999).

However, the potential for harvest from healthy Saker populations is probably higher than indicated in Table 4. Hungary also provides evidence of two types that 36% and 58% underestimated the survival of Sakers prior to breeding. Among 65 ring recoveries from Sakers found dead or injured, 25 (45%) were in the first 9 months, indicating a survival of 55% (Table 5). Even this estimate would be conservative, because many ringed adults would not have had time to die by the end of the project. However, it could also be inaccurate due to small sample size effects, and there is also the possibility that ring recovery rates are biased downwards by many first year birds dying outside Hungary. Therefore a final plausible modelling scenario used 50% survival for the first 9 months, with 80% adult survival and 65% interpolated for months 9-21. Another reason for considering these sub-adult survival rates more plausible is that they estimate 26% of adults alive to breed in their third year. Sakers in Hungary were observed generally to start breeding at that age and, in the decade when numbers were increasing from 31 to 82 pairs (before a lower rate of recruitment as natural sites became heavily occupied and artificial sites were introduced) the increase rate would have recruited 23% of 3-year-olds as breeders (Prommer, pers. comm.). This is much closer to 26% than to the 16% (0.36*0.58*0.80) estimate from conservative data.

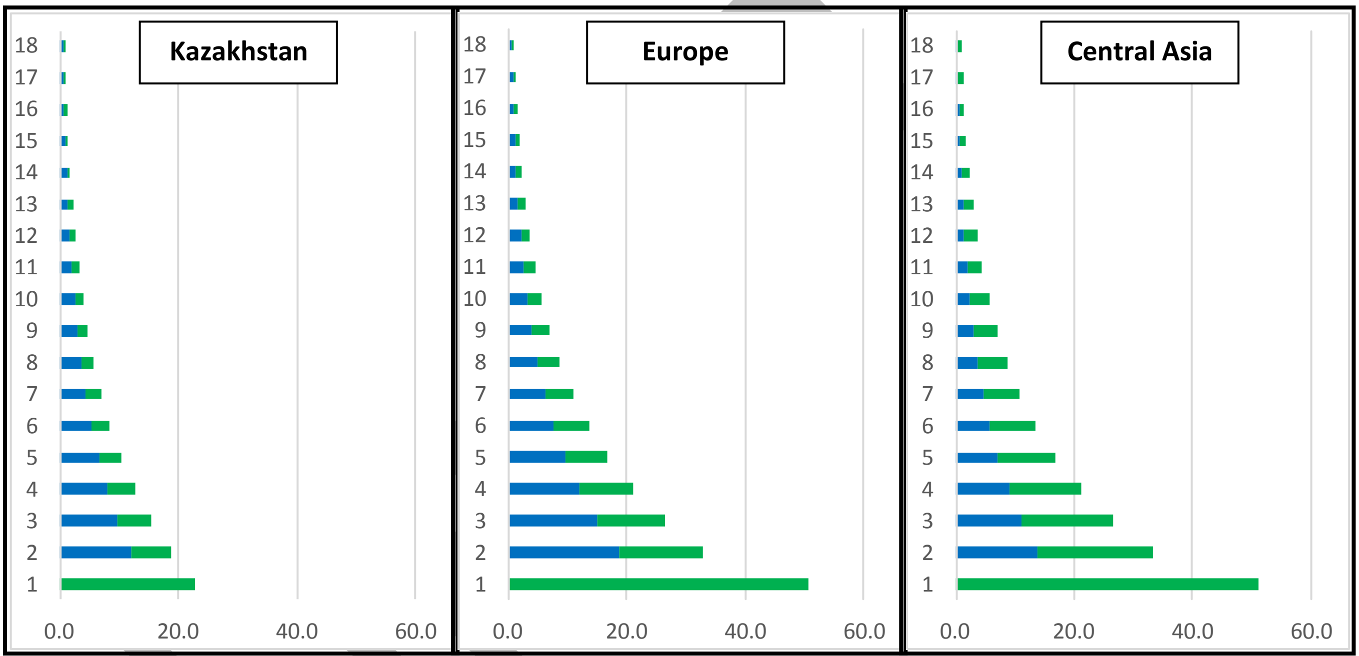
Table 5 Estimates of survival during the first 9 and 12 months of life from ringing of nestling Saker falcons in Hungary during 1951-2013 (data kindly provided by Birdlife Hungary).

	Dead	Injured (later dead or not known)	Injured (later released)	Dead + injured
up to 9 months	21	8	0	29
between 9 and 12 months	6	0	0	6
beyond 12 months	20	6	4	30
Total	47	14	4	65
Survived 9 months	55%	56%		55%
Survived 1 year	43%	56%		46%

On this basis, it can be estimated that Saker populations in Europe and Asia would be stable with only 58% and 42% of adults breeding (Table 6). These rates resemble breeding rates estimated for male and female goshawks, respectively, while a stable buzzard population in southern Britain had only 30% of adults laying. At an adult breeding rate of 85%, harvest rates of juveniles from such populations could be 32% with European productivity of 2.2 young per clutch and 50% for Asian productivity of 3.0. If these survival parameters apply, then the Saker populations studied in Europe and northern Kazakhstan were showing excellent resilience to harvest and other perturbations.

Table 6 The survival rates are increased from those in Tables 2-4 to accommodate the new estimate for juveniles from ringing in Hungary (in Table 5). The bar graphs show not only far more survivors from 100 birds fledged than in the original Kazakh scenario (left), but greater resilience at stability due to more non-breeding adults.

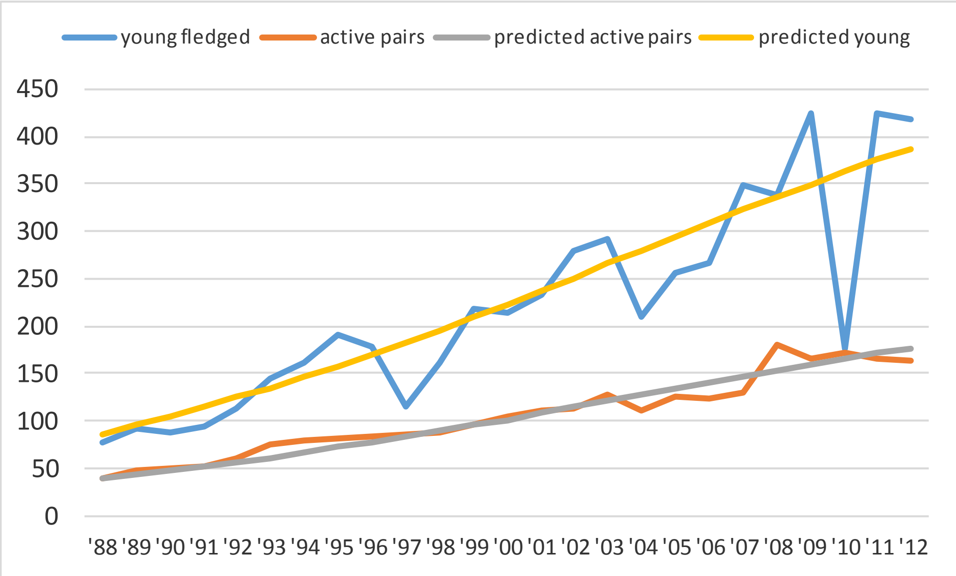
	Original Kazakhstan Data	European Plausible Survival	Asian Plausible Survival
survival rate to 9 months	23%	*50%*	*50%*
survival rate 10-21 months	82%	*65%*	*65%*
survival rate 3+ year	82%	80%	80%
expected breeding rate for single adult	**65%**	**57%**	**42%**
young produced per pair that lay eggs	3.10	2.20	3.00
harvest rate of juveniles	0%	0%	0%



IV.4 Implications from modelling growth of the Saker population in Hungary

Finally, it is instructive to use the IAF model to model the growth of a Saker population that has occurred in Hungary, where excellent data were collected during a period of Saker Falcon population recovery during the 25 years from 1988 to 2012. With the observed productivity in Hungary of 2.2 young per clutch (from a nest success of 67% and 3.02 young per successful nest), the survival parameters of 50%, 65% and 80% (as in Table 6) tended to under-predict initial growth and over-predict in the last decade. However a very close prediction of the population development (Figure 2) was obtained if an initial breeding rate of 95% of adults breeding fell steady to 70% breeding. Equivalent fits with a decline in adult breeding rate from 85% to 60% could be obtained with either 4% increases in adult survival or 4% increase in both juvenile and sub-adult survival. It seems likely that survival was actually slightly higher than the 50%, 65%, 80% scenario and that breeding rates were declining as the population tended towards environmental carrying capacity.

Figure 2 The numbers of active nests and fledged young observed in Hungary compared with models of breeding rates decline from 95% to 70%, or from 85% to 60% with 4% increase in survival



IV.5 Conclusions and recommendations from demographic modelling

The registration of productivity data for Sakers has progressed well in both Europe and Asian breeding areas. Although that is not equally true in all countries, experience in registering nesting pairs, their breeding success and brood sizes is available to be shared. One recommendation would be the effective recording of productivity, by checking for nest occupancy during incubation (which can be done from a distance with little disturbance but may stretch observer capacity), as well as during brood rearing, in order to detect early failures. For demographic modelling in general, the main shortfall is in estimation of survival rates. Whereas banding data are accumulating for estimating adult survival, for which minimum estimates can also be obtained from turnover rates, survival of first and second year birds badly needs further work.

The dispersive tendencies and relatively high philopatry of young Saker Falcons found when tracking by satellite (Prommer et al. 2012) shows that survival of young birds cannot easily be estimated either by VHF tags or genetic re-identification of young at nests in their natal area. Tags for tracking by satellite show promise, but are likely to underestimate survival if they impact wearers or cease transmissions prematurely. The most reliable tags are those with primary cells and not tags dependent on solar-powered rechargeable cells, so the most practical approach may be to use these with transmissions at relatively long intervals for the first 3-4 years of life. Tags sending once a week, synchronised to satellite passes, should give more reliable than solar-powered tags at low weight. Moreover, by not needing to protrude through plumage, they should reduce the risk of creating drag on the birds when in flight.

More reliable tags would also provide increased data on causes of death of Saker Falcons. It was noteworthy that one of two radio-tagged Sakers which attempted to over-winter in southern Kazakhstan was found dead (in good condition) under a powerline, and that two of the nine deaths recorded for birds for satellite tracking were caused by electrocution. Power-lines seem to be an appreciable mortality factor for Saker Falcons (Dixon et al. in press) and more data are needed to indicate whether losses to this threat are, at least locally, unsustainable.

However, even with two of nine losses on power lines, and a further two tags ceasing to transmit in circumstances that suggested trapping, and a relatively low productivity of young compared to Asia, the Saker population in Hungary has been increasing strongly. It seems likely that estimates of 50%, 65% and 80% are conservative baseline values for estimation of fledged Saker Falcon survival for, respectively, up to 9 months, during months 9-21 and as adults.

A matrix model in MS Excel is understandable for representatives of falconers, trappers, local land managers and government (with translation if necessary). The IAF model is also suitable for planning release of Sakers to rebuild populations, such as those in Kazakhstan, or to increase populations by provision of artificial nests (Dixon et al. 2011). A deterministic model can also be reduced to a few lines of computer code, which can be used for cellular spatially predictive modelling through use of remote imagery, both as an independent prediction of population sizes and to forecast possible effects of habitat change (due to agricultural intensification or global warning). In all cases, Vortex has a potential follow-up role for investigating uncertainty of measurements and setting safe limits on harvest (through sensitivity analyses).

There is a strong incentive for falconers to assist in gaining better data on survival and movements, because it can be used to justify harvest from populations with good productivity. It cannot be stressed too highly that adults should not be trapped in breeding areas, because this degrades the natural capital of this wildlife resource. Engaging with falconers and trappers to explain this would also open the possibility of sponsoring of radio-tagging which has proved successful in projects on a number of species.

Sponsoring of tagging could also very useful for encouraging biologists and local people to mark and gather genetic samples inexpensively from Sakers breeding in their areas, which would enable marker-recording estimates of population sizes and harvest levels. Marking with harness-based tags needs to be considered carefully, although survival to first autumn may not be greatly affected for VHF tags (Kenward *et al*. 2001), but methods based on rings, transponders and feather markers give rise to less concern. At the end of this report we outline a systematic approach to engaging falconers, trappers, biologists (including falcon-vets) and regulators with a system to facilitate monitoring of populations, and recording as well as regulating trade, through the use of such markers.

The matrix model used for the above analyses is in principle extremely robust and underlies all estimations of yield from animal populations. It can be rendered more sophisticated, for instance through incorporation of stochastic effects in Vortex, if likely variability is also measured (as it is through annual recording). It can also in principle be broken into cellular components to summate from geographic or genetic subpopulations, if the variables that define cells are understood. If the mechanisms by which genes and environmental factors interact to affect the survival and breeding parameters are also understood, further levels of spatial specificity can be added. Thus, although we have restricted our modelling to a basic level, we believe it provide a good foundation for further research as well as for applied management and judicious harvest of Saker Falcon populations.

V. Socio-economic modelling for conservation through use in falconry

Saker Falcons are a wildlife resource that has traditionally been harvested on migration by falconers for use by themselves and close colleagues (Allen 1980, Al-Timimi 1987). They have always been a very desirable acquisition, and with the development of modern transportation it became possible for supply chains to build and for trappers to move further from migration sites. With increasing wealth in Gulf States, there was also increase in the demand for falcons. This raised concern in the 1990s about the scale of future harvest of wild Saker Falcons (Riddle & Remple 1994).

Both matrix and Vortex modelling can in principle be used to estimate safe harvest quotas H from i different Saker falcon populations, giving a total harvest of ΣH_i. However, that begs questions about the size of those populations. Populations can be counted, as the total number of breeding pairs, but this is prohibitively expensive for widely spread species except in small areas. There can be merit in counting areas where populations are under severe pressure, but it is unreliable to gross-up to total numbers of breeders from the proportion of area covered by these samples, especially where attrition may be varying over small scales.

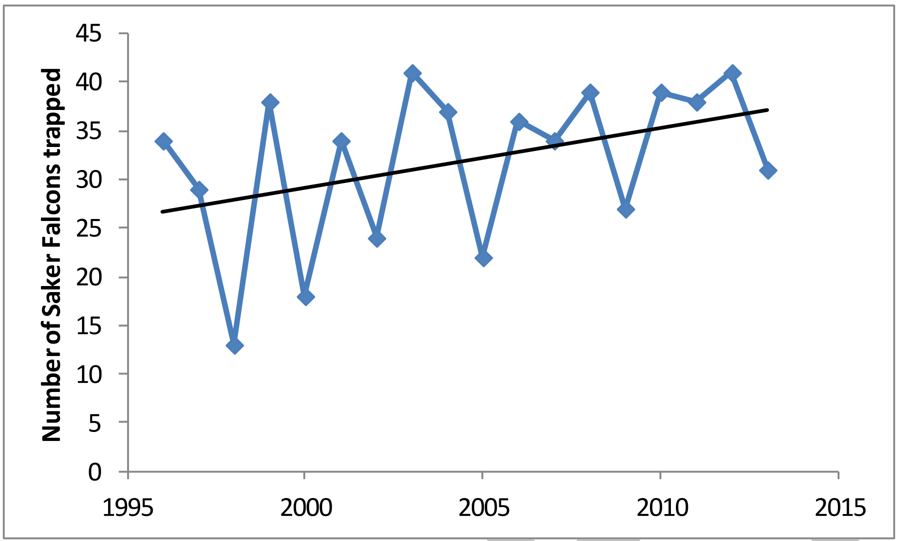
An alternative is to use marking-recording techniques (e.g. mark-recapture, mark-resighting), in which young are marked in the sample areas and then, on dispersal, are assumed to have a similar likelihood as other unmarked birds of being caught elsewhere. Their proportion among the total number trapped is used to estimate the total juvenile population of a catchment area and, from observed productivity, the number of pairs. With this approach, there is a role in conservation monitoring for trappers, and potentially also for local people to boost numbers marked across the Saker range, as well as for supervisory scientists, who become especially important if there are many sub-populations so that marking-recording estimates need to be adjusted by genetic markers for each sub-population. An advantage of this approach is that estimates made with data owned by trapping and falconry stakeholders could be cross-checked by other estimates, provided for example by the long data series from Hungary or more intensive radio-tracking, and if proved satisfactory could be less expensive than alternatives in the long term. There would be added costs of training observers, but also gains for community-based conservation through engagement of local people.

Moreover, if these stakeholders are prepared to cooperate for estimating population sizes and harvests, the resulting monitoring of trade could lead to guidance of trade and other potential benefits for wild Saker populations by voluntary actions based on peer-pressure and codes of conduct, with less cost than the need to promulgate and enforce restrictions. To investigate this possibility, we gained information on trapping and falconry in Saudi Arabia. However, for guiding the potential trade in Saker Falcons to ensure sustainability, other stakeholder groups must be recognised and their roles considered. These other stakeholders include the vets at falconry clinics, the breeders of falcons as an alternative to procurement from the wild, the governments and their institutions that act as regulators, the non-government organisations involved in conservation and the local people whose management affects habitats that are important for Sakers. For effective conservation, **all** these stakeholder groups need to be considered and encouraged to cooperate. Their roles will be identified in more detail through this section, and the potential for bringing them together then considered.

V.1 Trapping and the potential for monitoring through marker-recording

Sakers migrate along the Coast of the Red Sea and are trapped by falconers in small numbers, along with Peregrine Falcons, at a number of sites. The number of Sakers reported by Mohammed Al Khathlan, as a representative of these trappers is shown in Figure 3. There is considerable fluctuation between about 15 and 40 captures per year, but a rising trend despite an apparently similar annual effort. This would be consistent with a tendency for increase in the Saker Falcon populations on this migration route, which includes birds from steppes lying north of the most arid zones of central Asia.

Figure 3 The number of wild Saker Falcons trapped annually in Saudi Arabia since 1995 as recorded by Mohammed Al Khathlan



When the first research on wild Saker Falcons was commissioned by government falconers in Abu Dhabi in 1993, it was noted that veterinary hospitals were becoming widespread in Arabian Gulf countries and were using micro-transponders to identify falcons they were treating. Therefore, when wild Sakers were first being marked to investigate harvest levels, they were not only ringed but also tagged with micro-transponders for identification after capture in case rings were removed. By using rings from British Trust for Ornithology, and with excellent cooperation from the veterinary hospitals in the Gulf States (including Saudi Arabia) for recording transponders, 13 of 171 falcons marked in Kazakhstan during 1993-7 were recorded as trapped. That represents a minimum harvest of 8%.

Knowing also the productivity of young, such marker-recording by trapping provides data for an estimate of population size. The approach was used to estimate breeding populations of Northern Goshawks in Fennoscandia (from widespread trapping in Sweden during the 1970s) and on Gotland (from trapping for research in the 1980s). In both cases, tens of ring recoveries gave estimates very close to those obtained by extrapolating nest densities in study areas to the whole areas concerned (Kenward 2006). From records at veterinary hospitals, Riddle & Remple (1994) estimated that 2,750 falcons were being obtained in the Gulf States (including Saudi Arabia) annually in the late 1980s. With the 8% harvest rate, these would have represented about 36,000 young, or progeny from 12,000 laying pairs with 3.0 young per clutch.

However, that estimate assumes not only similar marking and harvest rates from all Saker populations concerned, but also the reporting of all markers. Neither assumption may have been valid. Eight rings were from 126 young Sakers ringed in northern Kazakhstan and reported by trappers in Saudi Arabia (4), Iraq (1), Syria (1), Turkey (1) and Yemen (1). Although Syrian trappers travel widely, seven birds had almost certainly migrated southwest (and five were on the Red Sea flyway). The other five recoveries were from 45 Sakers tagged in southern Kazakhstan. Not only were the recoveries in different countries (Pakistan, China and the UAE), but only two were notifications of rings while three more were detected in falcon hospitals after rings had been removed.

Clearly, the observed recapture rates have potential for estimating both harvests and population sizes. However, could monitoring become extensive enough through marking in breeding areas and through the trapper community to create large enough samples, and could attitudes of trappers and falconers become supportive enough to remove sources of error, such as tag removal? This was studied through a survey of falconers and trappers in Saudi Arabia in June 2013.

V.2 Falconer/trapper attributes and the potential for a management system

A questionnaire developed for falconers and trappers is shown in Annex II. It was designed by Dr Monif AlRashidi following a previous successful survey (AlRashidi 2004), and will when completed and analysed provide evidence of any changes from that earlier survey, plus comparable data from other countries where trapping and flying Saker Falcons is popular. The results presented here are from the first 37 responses, in Saudi Arabia, and are therefore preliminary. Nevertheless, the findings in Tables 7 and 8 are quite clear enough to indicate the extent and thoroughness of engagement that could be practical, and also what might not be practical. Both aspects are important.

Table 7 Attributes, experiences and value placed on Saker Falcons for the first 37 falconers and falconer/trappers surveyed in Saudi Arabia in 2013

	Region	Age	Why do you practice the sport of falconry?	How many years have you practiced the sport of falconry?	How many falcons do you have now?	And from which species are they?	If none, why?
Mean/ reply %		48.8		29% 10-20 years	2.3	52% of 61 are saker	27% (10) not active
Median/ majority	**78% Hail**	**49.0**	**100% Hobby**	**54% more than 20 years**	**2.0**	**8% are hybrid**	**Shortage of quarry (Houbara, Stone Curlew and Arabian Hare)**

How do you mark your falcon?	In the last 10 years, how many wild falcon have you had with CITES?	What is the longest period which a falcon has stayed with you?	From which species is it?	What happened to it?	Sort falcon species according to your preference	How many Saudi Riyals do you expect to pay for a wild Saker now?	How many falcons have you trapped (captured) by yourself in the last 10 years?
100% marked	100% reply	5.3 years	100% reply	**16% died**	100% reply	US$8313	18% of falconers also trap
96% ring +micro-chip	**10% had CITES**	**4.0 years**	**91% Saker**	**66% sold**	**91% Saker first choice**	**US$7500**	**Saker was 38/100 falcons trapped**

To summarise these results:

1. In a sample of 37 falconers, of which 78% from the Hail area, average age was 48 (range 29-75); 54% had practised falconry for more than 20 years and only 17% for less than 10 years.
2. The falcon preferred by 34 (91%) was the Saker, which was also the longest held falcon by them (up to 15 years, median 4 years), with most leaving due to sale (66%) not death (16%).
3. Ten (27%) were no longer keeping falcons, due in all cases to lack of quarry; the other 27 had a median 2 birds each (maximum 6), with 52% of the 61 falcons being Sakers.
4. Only 8 of the 27 active falconers did not have Sakers, and 3 of those had 3 of the 5 hybrid falcons recorded (8% of the total falcons possessed).
5. Seven (18%) of the respondents had also trapped 2-60 falcons in the last decade, Sakers being 38% of the 100 hawks trapped.
6. CITES permits would not be needed for falcons trapped and flown entirely within Saudi Arabia, and only 4 falconers had flown birds with CITES certificates.
7. All active falconers marked their hawks, in only one case without a ring as well as a microchip; however, 2 of 7 trappers did not want to mark trapped birds before sale even if paid to do so.
8. A wild Saker was considered worth about US$8,000 (range US$1,900-19,000).
9. All agreed that numbers of falconers had increased; only 3 disagreed that trapping was reducing numbers of falcons, with half considering prolonged possession to be a problem (Table 8).
10. Favoured solutions were more falcon hospitals, clubs, domestic breeding and certification, although falconers volunteered to pay only about 1% extra for certification by CITES (Table 8).

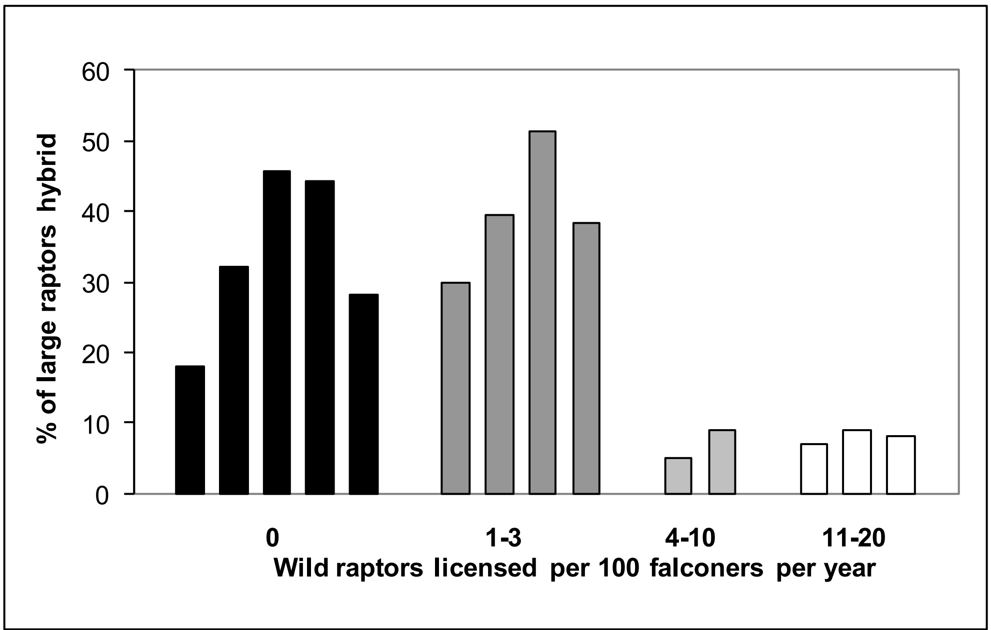
Table 8 Opinions of the first 37 falconers and falconer/trappers surveyed in Saudi Arabia in 2013, of which 100% replied to these questions.

Question	% who agreed
Do you think that the number of falconers increased or decreased in the last 10 years? Increase	**100%**
There are many falcons' trappers which decreases the number of falcons	**91%**
Maintaining a falcon in the captivity for a long time leads to decrease the number of falcons	48%
Increasing the price of falcons which leads trappers to seek them more to gain more of money	75%
There should be an Identification Card issued by the Wildlife Authority for the falconers that allows them to possess a falcon	**81%**
There should be an Identification Card for the falcons which allows that falconer to use it for hunting	**86%**
The price of the falcon should be set according to its species	37%
Setting a specified period for keeping a falcon	45%
Establishing breeding centres for falcons	**94%**
Establishing veterinary hospitals for falcons in the areas with high abundance of falconers	**100%**
Establishing falconers clubs in the areas with high abundance of falconers	**94%**
New regulations are making it harder to have wild Sakers	0%

A visit to Riyadh in June 2013 allowed useful discussion with falconers at a large communal moulting station and members of the Saudi Wildlife Authority. It became clear that ownership of falcons in KSA is at most levels in society, and that although the majority of falconers own few birds, some also have very large establishments and at these sites there can be a high proportion of hybrids obtained from domestic breeding. Motivations to own such birds are strongly competitive; catching wild Houbara is still an aspiration, but for this hybrid falcons (notable gyr-peregrine) are faster and stronger than pure Sakers. As hunting opportunities have decreased, falconry competitions (for racing as well as catching released quarry) have increased.

Among ordinary falconers, Sakers have remained popular during the last decade, keeping prices high, and wild birds are still sought after. It is likely that, with 7 trappers catching an average 10 birds per year among 37 falconers, there are more than 4 wild birds obtained by ordinary falconers per year. International survey by IAF for the European Commission showed that falconers in countries with this extent of access to wild raptors kept relatively few hybrids (Figure 4).

Figure 4 The proportion of hybrid raptors is low in countries where more than 4 wild falcons per 100 falconers are available per year (from Kenward & Gage 2008)



Falconers at a communal moult site, and in general responses to the survey, proved remarkably aware of conservation issues including pressure on wild stocks, and favoured solutions which included better care and information through falcon hospitals and clubs. Certification too was acceptable but other regulation less favoured. Initial suspicion of the survey team was overcome in discussion that showed strong links to international falconry: trust-building was important for cooperation. There were then reports that many Sakers are captured illegally in Russia and smuggled to the Arabian Gulf countries, with smuggling by impoverished Syrian trappers mentioned as cause of many falcon deaths in transit.

It is important to note that capture and flying of wild Sakers within a country has not been subject to CITES restrictions on international trade, and has therefore remained legal. Thus falconers have been able to answer surveys truthfully without fear of prosecution. Trappers in Saudi Arabia tend to be falconers, and have used the internet to report captures since 2005, albeit unsystematically. Once obtained, birds are checked and micro-chipped in falcon hospitals; this identification is used for their management, for example in communal moulting sites. Although 5 of 7 trappers would be prepared to marked trapped falcons prior to sale, there is reluctance to do so, presumably as this would raise suspicions about lack of wild origin.

However, it was felt that trappers could be motivated by payments to report captures on the site and provide a feather from trapped birds for DNA extraction, for genetic fingerprinting and investigation of origins. Adverse legislation and lack of contact would make this harder to arrange overseas, although there is benefit in use of Arabic as a lingua franca and it would be practical to gain trust by providing information and other benefits for trappers on a web-site. Although falconers were loathe to pay for certification, they pay high prices for birds and pay falcon hospitals to mark them, so DNA fingerprinting of feathers could be used to match birds at hospitals to reported trapping as an interim measure before establishment of a less analysis-intensive approach, of marking on capture and banking feathers for DNA analysis only if marker tampering is suspected.

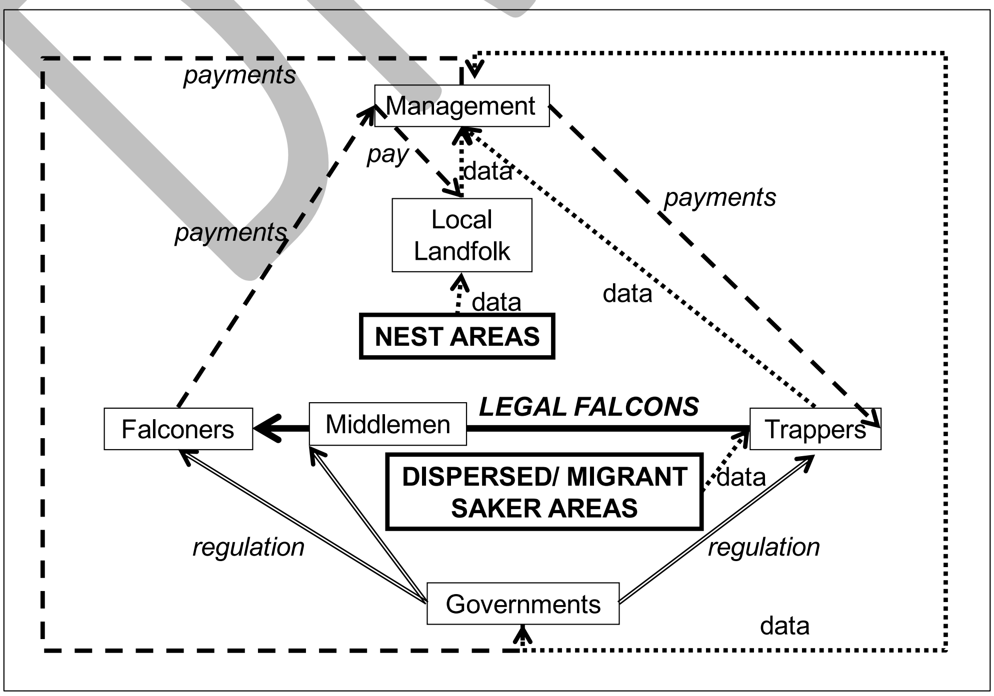
In conclusion, ordinary falconers in KSA keep relatively small numbers of hawks, retain a strong preference for pure, un-hybridised Sakers, and are prepared to pay good prices for them. They are cooperative enough with researchers for 37 to complete questionnaires at short notice. They have opinions on problems, are already getting their hawks marked by vets with implanted microchips and favour conservation solutions based on falcon hospitals and clubs and, but are not prepared to pay much for extra certification.

V.3 The conceptual model for a possible management system

CBD's Addis Ababa Princples and Guidelines make it clear that adaptive management, based on monitoring and then appropriate adjustment of the management, is a *sine qua non* for sustainable use of wild resources. A management system for conservation through use of the Saker Falcon, based on the reporting of trapping, could in principle enable monitoring of wild populations through marking in breeding areas and regulation of trade through marking or genetic fingerprinting of all harvested birds at capture.

To implement this conceptual model, several types of mathematical predictive model are required. One is for population demography to estimate harvests possible from different Saker populations. Another is to estimate sizes and trends recording markers on young falcons and sizes of harvests, possibly complicated by need to identify origins of birds trapped without markers. The first model will require expanded work in breeding areas, with survival parameters a knowledge gap to be overcome by improved techniques. The second model lacks important data on numbers of falconers and trappers, though survey indicates that these knowledge gaps too can be overcome if engagement of those stakeholders can be organised adequately. Models of a more socio-economic nature would be needed to optimise flows of information and payments in such a system (Figure 5).

Figure 5 An outline of the data and motivation flows (economic and regulatory) between actors that need to be modelled in a possible management system for Saker falcons.



Operation and modelling in such a conservation management system would need :
1. For population monitoring, local land managers in breeding areas to record nest productivity, mark young, and provide feathers (DNA) in exchange for payments ($\boldsymbol{P_m}$) from a conservation budget; local people could also benefit by providing information about illegal trapping.
2. For population monitoring, trappers to record and provide feathers (DNA) and other simple data from birds they capture, in exchange for payments ($\boldsymbol{P_t}$) from the conservation budget.
3. For trade control, falconers to require birds marked to certify legal-origin, for which ultimately a fee ($\boldsymbol{F}$) is contributed to the conservation budget ($\Sigma\boldsymbol{F}$).
4. For trade control, trappers to agree to supply data from trapped birds, ultimately in exchange for permission to trap and share the harvest quota ($\boldsymbol{H_i}$) from population $\boldsymbol{i}$.
5. For detailed population monitoring and social acceptance, for scientists to find geographic markers through start-up finding, supplemented later by a proportion ($\boldsymbol{s}$) of the conservation budget ($\boldsymbol{s}\Sigma\boldsymbol{F}$).
6. For social acceptance, governments in $\boldsymbol{j}$ countries to share payments for logistic or scientific support from a proportion ($\boldsymbol{g}$) of the conservation ($\boldsymbol{g}\Sigma\boldsymbol{F}$) supplemented initially by start-up funding.
7. **For start-up, an initial conservation budget and funding for socio-technological infrastructure**.

This approach has become progressively more feasible since 2000. Due to improvements in mobile technology, the otherwise rather intractable problem of dealing with trappers (2,4), exacerbated by the problems in Syria, is probably practical. Thanks to UAE efforts and KSA surveys, copied in other countries, falconers are now more organised and contactable too (3). Saker issues have generated funding leading to contacting of more and more local people (1) and relevant science (5), including the ability to deter tampering with markers on trapped hawks by banking genetic material at the time of marking for 'mark-bank' comparison with fresh material from a bird (Kenward & Gage 2008). Thanks to UAE efforts initially, and with IAF for the inscription by UNESCO (2012) of falconry as an intangible cultural heritage, many range-state governments are engaged (6), while socio-economic studies of resource use and technology have advanced substantially too. The socio-technological design needs to be based on mobile phone apps, which could provide a new infrastructure for central-local communication to provide instructions, collect data and deliver payments to trappers and local people (7).

For socio-economic modelling it will be especially important to understand:
1. Levels of reward for legal compliance (e.g. payments for marking to trappers, $\boldsymbol{P_t}$, and local land-managers, $\boldsymbol{P_m}$) at which compliance becomes more cost-effective for trappers than illegality. Such calculations must include hidden costs of compliance (e.g. costs of time for reporting) as well as hidden costs of non-compliance (e.g. detection probability and value of fines).
2. Whether the fees ($\boldsymbol{F}$) that are practical can combine with likely size of harvest (i.e. $\boldsymbol{F} \times \Sigma\boldsymbol{H_i}$) to cover the cost of running the system (including central administration, payments for marking and to a number ($\boldsymbol{i}$) of governments for facilities), to ensure long-term socio-economic sustainability and ideally enough marking payment for local people ($\boldsymbol{P_m}$) to motivate habitat conservation.

Promising results on costs and benefits which favour or deter illegal hunting are starting to come from studies of bushmeat procurement (e.g. Knapp 2012). A critical knowledge gap at present is whether falcon hospitals could contribute through marking to fees ($\boldsymbol{F}$) for a conservation budget.

Governments would be rewarded (by recognition, technology/skill transfer and possibly funding) for logistic and scientific support with regulations and data on populations. Collection of feathers at the time of marking is important, as it provides DNA as a control against marker tampering and for population genetics in mark-recapture estimation. Feather handling needs an envelope and foolproof system. Other serious knowledge gaps are whether governments would help with this in exchange for the payment in country $\boldsymbol{j}$ of ($\boldsymbol{g_j}\Sigma\boldsymbol{F}$), and whether CITES could approve transport of feathers, as a non-destructive sample, to approved institutions.

Whereas population modelling is a well-recognised process, the proposed socio-economic modelling is likely to evolve during implementation. The important thing is to recognise the need for such modelling and to plan processes within the management system for recording at least the above variables, whose possible interactions can again be modelled in MS Excel.

V.4 Technical design of a possible Saker Adaptive Management System (SAMS)

Annex III details a preliminary costing for a system to monitor Saker falcon capture and transportation across borders. It is a rough estimate of what is required, with Use-Cases listed to estimate the time required for programming, but not for initiating and testing the system. The cost would comprise about eight person-months of programming and four of administration and testing.

It must be noted that, although the administration team to manage such a system could be small (a single administrator is foreseen) the steering team needed to develop rules and protocols acceptable to all stakeholders would be much larger. Indeed, managing that steering group would require appreciable time from the administrator (or part-time administrators). The steering group would at the least need representatives of CITES, CMS and major stakeholders (e.g. falconers, other conservation interests). Whether the group should also include scientists (other than represented among those mentioned) and range states in another form than represented among the falconry and other conservation interests, would need decisions too. Rather than increase the size of core steering an alternative might be to have a separate science, technology and range states (STARS) group.

Application Overview

The following is an overview of the design for information technology which could be used to manage a system for monitoring raptor harvests and population sizes and trends on the basis of (nest-based) marking and (trapping-based) recapture, by exploiting new communications technology in mobile phones and the internet. The concept is based on the combination of rings and microchips used and recorded by biologists, trappers, falcon hospitals and falconers, which was used to demonstrate possible data flows in Kenward et al. (2001). Although such a system could work (and be motivated) on a voluntary basis, it could also double as an enforcement tool.

The Modelling for Conserving Saker Falcons project comprises six different areas of development, each a different interface to a central database. These are interfaces for System Administration, Biology Administration, Taggers, Falconers and Law Enforcement and a public-facing interface, known as the Access pages, to provide a point of entry to the browser-based interfaces, a description of the project to the wider public and an advertisement to falconers who wish to join the project.

Central to the application is a database. The database is accessed through web pages for all users except for law enforcement who will need non-browser-based software to control specialised tag scanning hardware. Taggers will be able to supply a small amount of data with their mobile phones as described below.

The system administrator interface will allow administrators to create and edit all the user accounts and give them access to the various areas of the application. Administrators have access to all areas of the application and can also manage payments and law enforcement institutions.
Biology admin manage the bird data, creating and managing bird records and history. Outside of the software they will send a tag and an envelope containing the code of the specific bird to a tagger.

Taggers trap birds and attach the tag sent by the biology admin. When they have attached the tag they will send an SMS text message which is received automatically by the system so the bird data can be updated automatically. They will also send a feather back to the biology admin in the provided envelop so that biology admin can update DNA data for the bird. Taggers also have their own web interface in order to view tagged birds and payments made to them.

Falconers can register their birds with the system and match their birds with individuals already recorded. They will be able to view the bird's history but they will have to make payments to use the system.

Law enforcement will have access to terminals, personal computers, tablets or smart phones, running Windows, iOS or Android, running forms-based software. They will scan bird tags as they come through customs; the scan data will update the bird record in the central database. They will be informed via the terminal if the bird is not legal and will be instructed to send a feather if a bird has no tag.

The application also includes a messaging system that provides pages for all users to contact other users, ask support from administrators, reply to messages and carry on conversations. Communications relating to the project are kept in a central place and can searched and referenced more easily than with disassociated email. Users are, of course, emailed when a message arrives but will link from the email back to the Saker system in order to reply.

V.5 Conclusions and recommendations from socio-economic modelling

Current harvest rates of Saker falcons are uncertain, but may be in the region of 5-10%. The best current estimate of the global population of the Saker Falcon is estimated at 6,400 to 15,400 breeding pairs (Birdlife International 2013). With annual productivity (young/pair, including nest failures) of 2.6 young (the mean of European and Asian values, but noting that Europe is a small part of the population), there would be 16,000-40,000 young. A 5% harvest of young would be 800-2,000 birds. A major gap in socio-economic knowledge is not only the actual harvest rates for different saker populations, and whether this is sustainable, but also the size of the total demand. The demographic models predict that a harvest much greater than 5% may be sustainable, but we do not know whether populations are actually being harvested at higher rates now. The decline in the southern Kazakhstan population was consistent with a harvest rate of 55% of adults, and adults are trapped in some areas (Kenward et al. 2007). This is clearly undesirable, and an early priority for the Saker Falcon Task Force should be to encourage appreciation of this among falconers and trappers. Falconers elsewhere have appreciated this and avoided trapping adult raptors in most other parts of the world.

If trapping is to continue within countries, it would also be in line with the precautionary principle (Cooney 2004) for local falconers and their authorities to be monitoring whether those harvest levels are likely to be sustainable. The apparent increase in harvests in Saudi Arabia (Figure 3) indicates that they may be sustainable, but knowledge of the total size and nature of the populations concerned is highly desirable.

The scientific capabilities, practical skills, attitudes and local knowledge appear to be available for running a system for adaptive management of Saker Falcons through sustainable use in traditional falconry. Such a system could control trade through quotas, with registration of harvest rates that are necessary for simple ecological modelling. Marking-recording techniques could be used to monitor sizes and trends of the populations being trapped. The required marking in breeding areas could in turn motivate local communities to conserve those areas in order to get payments-to-mark from the scheme. With such payments direct from the scheme to trappers and local communities, payments to central governments could be precisely and transparently targeted for required services/facilities. Scientists would be important too, for providing and handling genetic information and remote-sensed habitat data that would gradually fine-tune the system optimally to conserve sub-populations and the habitats they require.

The whole system, from which falconers, trappers, local communities, government officials, scientists, Sakers and their habitats would benefit, would require an Information and Communication Technology infrastructure to minimise costs, and a small management team. A contract for the programming of an appropriate system would require one person-year of technical work, plus further costs for implementation. Although such a system is virtual and can be run anywhere, a site would be needed for storage and analysis of genetic material, for which CITES administration would also be required. As the system involves a complex interplay of actors, data and motivation flows in ecological and socio-economic fields, development and management would benefit from appropriate complex engineering skills, such as are present at the Centre for Complex Engineering Systems of King Abdulaziz Centre for Science and Technology in Saudi Arabia.

VI. Conclusions for SakerGAP

Simple matrix modelling, of a transparent nature as demonstrated by the IAF implementation in MS Excel, has already shown ability to model declining and expanding Saker Falcon populations. Such models require productivity rates as observed by biologists in local breeding areas, combined with estimates of survival from which additional rates of attrition, for example due to harvest or mortality on power-lines, can be subtracted. Minimum estimates of 50%, 65% and 80% of natural survival for months 0-9, 10-21 and >21 post-fledging, respectively, seem likely to be conservative. These base-line estimates are below estimates for other raptors of similar size to the Saker falcon (e.g. of 58%, 65% and 81% for Northern Goshawk, 70%, 91%, and 88% for Common Buzzard 78%, 87% and 92% for Red Kite). Funding for increased use of reliable long-life radio tags to improve estimates to first breeding, and for adults, could involve sponsoring of marked Sakers by falconers. The relative importance of additional attrition for Sakers from mortality on power-lines, and of harvest for falconry, could also be defined by such tagging, provided that trappers cooperate to report tags.

There are now suitable human resources in terms of science and technology capabilities, and of attitudes and knowledge among local falconers, for a Saker Adaptive Management System to be run in the Gulf States to estimate harvest rates and, given cooperation with falcon trappers, sizes of trapped Saker populations. The increasing use of web-sites and mobile communications by falconers and trappers means that the internet could be used increasingly to engage with and build trust among these stakeholders, using Arabic as a *lingua franca*, and to provide useful information on falcons, falcon management, individual marked falcons (if a monitoring system is developed), surveys, survey results and other rewards for participation. However, it requires time to attract people to new sites and build their trust. International legislation which increases opportunity costs for trappers is a further complication for building a trusted system to monitor population sizes and harvests of Saker Falcons.

The engagement of scientists, governments and NGOs for the STF Stakeholders' Workshop is important if Multilateral Environmental Agreements (MEAs) are to have any chance of accommodating a complex system for managing conservation of the Saker Falcon through sustainable use. It is already recognised that the interactions of MEAs can create complications for conservation (Ivanova & Roy 2007, Kanie 2007). Although this recognition is leading towards synergies (UNEP-WCMC 2012), the immediacy of conflicting business models (in the triangular relationship of protection, cultivation and wild-resource use) does not favour the patient deliberation which is needed to inform and converge the thinking of all actors. Those genuinely wishing to conserve Sakers, and their important steppe habitats that were cradles of western civilization, must seek to keep the topic broad and avoid hasty decisions. Can they provide the time needed for other stakeholders to engage productively, or will they prefer to create conditions in which falconers and trappers find it hard to keep their roles legal?

To ensure legal procurement of a desirable commodity, it is necessary for end-users to require evidence of legal provenence; given that requirement, legality can be driven back up a supply chain. In this case it is falconers in Arab countries who are the recipients of the birds, and trappers who operate within their countries or abroad, together with falcon traders who are especially important components in the supply chain. Moves are already afoot to have at least one prominent falconer/trapper at the Stakeholders' Workshop, but a key challenge is to ensure that ordinary falconers and trappers become engaged in as many countries as possible. Representation of the falcon hospitals, as a major link between falconers/trappers and higher levels, is also essential. Key knowledge gaps are the time that would be required to engage falconers, falcon hospitals and, especially, falcon trappers in the effective operation of a Saker Adaptive Management System.

Although any management system for wild resources may ultimately only be socio-economically sustainable if it self-funds from contributions of the resource beneficiaries, funding the initial start-up budget and technology costs for a Saker Adaptive Management System is beyond the capability of individual falconers owning 1-2 birds. With wealthy falconers moving already along the road of breeding enhancement that characterises competition with domesticated animals, are any enlightened enough to see the ultimate social-sustainability benefits for their passion from environmental philanthropy?

If not there remains the possibility that an organisation representative of stakeholders could provide enough funding for a bottom-up approach, to run a trust-building portal and gradually build interest, trust, cooperation and funding from those involved. Whether that approach could work would depend not only on the extent of voluntary support from local stakeholders, but also on enduring tolerance of high-level stakeholders. It is not clear whether either would suffice.

VII. Recommendations, strategy and actions proposed

The data and techniques for monitoring of Saker Falcon populations in a generic way are reasonably satisfactory. However, they need refinement for falcon populations with different ecological conditions in terms of breeding, migration and wintering areas, and hence of food supplies, harvests, attrition from power-lines and other threats. Given data on productivity, from nest studies, a balance of natural mortality and other attrition factors needs to enable sufficient resilience, in terms of non-breeding adults, for populations to persist despite natural variations, which can also be added transparently to the IAF model to avoid relying on less transparent assumptions in other models. It is clear that good productivity data are needed from harvested populations, and also estimates of their size, which can conveniently come from marker-recording if trapping is permitted. Refinement of breeding area data may in due course enable cross checking, e.g. through modelling of nest densities across breeding areas. Marker-recording estimation of populations also involves harvest estimation, and engages stakeholders in breeding areas and in the falconry-interest community, including trappers and falcon hospitals. Such engagement of stakeholders is essential for building trust and developing a cooperative environment for management of the species and its habitats, especially healthy steppes that support many other important species.

On this basis, we recommend engagement of:

- Biologists to build networks of local land managers to mark and record productivity in breeding areas;
- Falconers and falcon hospitals to record marked birds and fund marking in exchange for information;
- Trappers to record all captures, but especially marked birds, in exchange for payment and information;
- Governments and international NGOs to support this cooperative approach to Saker management.

We also recommend work on:

- Radios that can give reliable long-distance signals from pre-breeding Sakers;
- Genetics to identify falcon origin areas (particularly the source populations of trapped falcons);
- Information Technology to facilitate recording data from local falcon markers and trappers;
- Ways to engage falconers and trappers in 'citizen-science' data provision in exchange for information.

We conceive a pathway for implementing these recommendations. The first stage of the pathway is practical rapidly through cooperation of UNEP-CMS with appropriate stakeholder organisations. The second phase has two options, for which the choice will depend on high level stakeholder decisions.

Saker Management Pathway Stage 1 involves agreeing with relevant stakeholders to:

- ❖ Immediately develop a portal in Arabic offering benefits to attract falconers and trappers;
- ❖ Run surveys and competitions for information on the site to build trust;
- ❖ Promulgate the idea of not trapping adults in breeding areas or buying such birds.

Saker Management Pathway Stage 2 involves either:

1. Funding for the portal to host a system for monitoring populations and regulating trade.

   or

2. Using the portal to promulgate exchange of data for information, bird sponsorship, etc, then using sponsorship to gradually equip the portal with tools to monitor populations and trade through trapping, and finally inserting a tool to monitor and, if necessary, regulate trade if Saker populations remain depressed.

Additional outputs of the contract

Two Powerpoint presentations based on its contents and the IAF model framework in MS Excel.

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Annex 1 Saker breeding data

	Average number of nestlings (/successful breeding)	Number of observed pairs	Number of successful pairs	Total number of juveniles	Region	Source of information
BULGARIA						
?	2.00		7	14		Baumgart (1991)
CZECH REPUBLIC						
1999-2010	2.90	92	72	(209)	all country	Beran. Unpublished
HUNGARY						
1980	2.00	13	2	4	all country	Bagyura et al. (2004)
1981	3.00	14	3	9	all country	Bagyura et al. (2004)
1982	2.86	17	7	20	all country	Bagyura et al. (2004)
1983	3.71	21	7	26	all country	Bagyura et al. (2004)
1984	2.91	26	11	32	all country	Bagyura et al. (2004)
1985	2.82	31	11	31	all country	Bagyura et al. (2004)
1986	2.83	33	12	34	all country	Bagyura et al. (2004)
1987	2.47	37	15	37	all country	Bagyura et al. (2004)
1988	3.12	40	25	78	all country	Bagyura et al. (2004)
1989	3.07	47	30	92	all country	Bagyura et al. (2004)
1990	2.49	49	35	87	all country	Bagyura et al. (2004)
1991	3.21	52	29	93	all country	Bagyura et al. (2004)
1992	2.73	61	41	112	all country	Bagyura et al. (2004)
1993	3.09	75	47	145	all country	Bagyura et al. (2004)
1994	2.89	80	56	162	all country	Bagyura et al. (2004)
1995	3.13	82	61	191	all country	Bagyura et al. (2004)
1996	3.18	83	56	178	all country	Bagyura et al. (2004)
1997	2.83	85	41	116	all country	Bagyura et al. (2004)
1998	3.00	87	54	162	all country	Bagyura et al. (2004)
1999	3.13	95	70	219	all country	Bagyura et al. (2004)
2000	3.00	104	71	213	all country	Bagyura et al. (2004)
2001	3.11	111	75	233	all country	Bagyura et al. (2012)
2002	3.49	113	80	279	all country	Bagyura et al. (2012)
2003	3.15	127	91	287	all country	Bagyura et al. (2012)
2004	2.61	111	80	209	all country	Bagyura et al. (2012)
2005	2.94	125	87	256	all country	Bagyura et al. (2012)
2006	2.91	124	92	268	all country	Bagyura et al. (2012)
2007	3.16	130	110	348	all country	Bagyura et al. (2012)
2008	2.97	180	113	336	all country	Bagyura et al. (2012)
2009	3.13	165	137	429	all country	Bagyura et al. (2012)
2010	2.59	172	68	176	all country	Bagyura et al. (2012)
2011	2.95	165	144	425	all country	Bagyura et al. (2012)
2012	3.19	164	131	418	all country	Bagyura et al. (2012)
KAZAKHSTAN						
1941	3.30				Naursum	Baumgart (1991)
1946	3.40				Naursum	Baumgart (1991)
1947	4.40				Naursum	Baumgart (1991)
late 1940s	2.33		21	49	Naursum	Baumgart (1991)

1973	3.60		12	(43)	Naursum	Baumgart (1991)
1974	3.10		11	(34)	Naursum	Baumgart (1991)
1993	4.07	16	15	61	Naursum	Kenward et al. (2007)
1994	3.17	16	12	38	Naursum	Kenward et al. (2007)
1995	3.73	17	15	56	Naursum	Kenward et al. (2007)
1996	3.50	14	12	42	Naursum	Kenward et al. (2007)
1993-1996	3.33		12	40	South-central Kazakhstan	Kenward et al. (2007)
2003-2004	4.10		77		Caspian-Aral	Karyakin et al. (2005)
2003-2004	2.90		24	(70)	North (NW Kazakhstan)	Karyakin et al. (2005)
2000-2008	3.90		31	(121)	East Kazakhstan	Levin (2008)
2000-2008	3.70		156	(577)	East Kazakhstan	Levin (2008)
2005	4.50		4	18	Aral	Levin (2008)
MONGOLIA						
(2002-2006)	3.70		330	1221		Gombobaatar et al. (2007)
1998-2005	3.79		401	(1520)	all country	Gombobaatar et al. (2007)
1998-2005	3.34		401	(1327)	all country	Gombobaatar et al. (2007)
1998-2005	2.80		401	(1123)	all country	Gombobaatar et al. (2007)
2005-2010		75			Bayan+Darhan wild	Dixon et al. (in press a)
2005-2010	3.55	69	58	206	Bayan+Darhan grids	Dixon et al. (in press a)
ROMANIA						
2013	2.00	3	2	4	West-Romania	Prommer (unpublished)
RUSSIA						
1999	2.25	53	52	117	Altay-Sayan	Karyakin & Nikolenko (2011)
2000	2.38	20	20	48	Altay-Sayan	Karyakin & Nikolenko (2011)
2001	2.44	31	29	71	Altay-Sayan	Karyakin & Nikolenko (2011)
2002	3.00	46	45	135	Altay-Sayan	Karyakin & Nikolenko (2011)
2003	2.69	46	20	54	Altay-Sayan	Karyakin & Nikolenko (2011)
2004	2.24	51	34	76	Altay-Sayan	Karyakin & Nikolenko (2011)
2005	3.73	39	25	93	Altay-Sayan	Karyakin & Nikolenko (2011)
2006	2.69	19	16	43	Altay-Sayan	Karyakin & Nikolenko (2011)
2008	*2.48*	*108*	*55*	136	*Altay-Sayan*	Karyakin & Nikolenko (2011)
2009	2.50	34	20	50	Altay-Sayan	Karyakin & Nikolenko (2011)
2010	2.83	51	28	79	Altay-Sayan	Karyakin & Nikolenko (2011)

2011	2.86	46	22	63	Altay-Sayan	Karyakin & Nikolenko (2011)
2008	2.48	(65)	33	82	Altay-Sayan	Karyakin & Nikolenko (2008)
ex 2008		436	311	829		Averaged by RK from red data, excluding 2008
1999-2008	**2.63**	**413**	**243 (296)**	**639**	**Altay-Sayan**	Karyakin & Nikolenko (2008)
2003	2.90		10	29	Altay-Kray	Karyakin & Nikolenko (2005/2)
2004	2.86		7	20	Altay-Kray	Karyakin & Nikolenko (2005/2)
?	(1,63)		(3)	(~5)	Tula	Baumgart (1991)
?	(0,33)				Tula	Baumgart (1991)
2010	2.50		4	(10)	Republic of Altay	Vazhov et al. (2010)
2009	2.50		12	(30)	Altay-Sayan	Karyakin & Nikolenko (2011)
2010	*2.83*	*(42)*	*23*	*(65)*	Altay-Sayan	*Karyakin & Nikolenko (2011)*
2011	2.86		22	(63)	Altay-Sayan	Karyakin & Nikolenko (2011)
2011	*3.08*		*13*	*(40)*	*Republic of Tuva*	*Karyakin & Nikolenko (2011)*
2011	*2.17*		*6*	*(13)*	*Republic of Altay*	*Karyakin & Nikolenko (2011)*
2011	*3.33*		*3*	*(10)*	*Altay Kray*	*Karyakin & Nikolenko (2011)*
SERBIA						
1986	2.50	9	4	10	Sreme	Puzovic (2007)
1994	2.60	8	3	7	Sreme	Puzovic (2007)
2004	2.50	5	2	4	Sreme	Puzovic (2007)
SLOVAKIA						
1982	2.93	18	14	41		Baumgart (1991)
1983	2.70	18	9	24		Baumgart (1991)
1984	2.30	13	3	7		Baumgart (1991)
1976-2010	3.20	345	247	797	all country	Chavko. Unpublished.
UKRAINE						
late 2000s – early 2010s	3.09		64	198	Crimea	Myloboh (2012)
	3.90				Dnipropetrovsk	Myloboh (2012)
	2,7-3,2				Odessa	Myloboh (2012)

Annex 2 Falconer survey questionnaire

Date:…………….Country: …………….Name (optional):………………… Age: ………

1 - Why do you practice the sport of falconry? …………………………………………

2 - How many years have you practiced the sport of falconry?
1-5 years 5-10 years 10-20 years more than 20 years

3 - How many falcons do you have now? And from which species are they?

4- In the last 10 years, how many wild falcon have you had with CITES? …… without CITES from within your country? …… without CITES from another country?

5 - What is the longest period which a falcon has stayed with you? ……….From which species is it? ………………….What happened for it? ………………………….

6 – Which one from the species of falcons do you prefer? What is the reason?

7 – Sort falcon species according to your preference?

8 - If you are someone who traps (captures) wild falcons:
A - How many falcons have you trapped (captured) by yourself in the last 10 years?
- Saker…………. - Peregrine……………. - Barbary…………- Lanner……….
B – In which months of the year the trapping of falcons take place? And what is the most convenient time of the day to catch them?
C- In order to ensure a good supply of wild falcons for the future, would you be prepared to register and mark (e.g. with a ring) all trapped birds?
□ Yes, gladly □ only if paid to do so □ No

9 - Reasons for the decreasing numbers of falcons:
- There are many falcons' trappers. □ Agree □Disagree
- Maintaining a falcon in the captivity for a long time □ Agree □Disagree
- Increasing the price of falcons which leads trappers to seek them more to gain more of money. □ Agree □Disagree

10 - Methods that can be followed to reduce the diminishing numbers of falcons:

- There should be an Identification Card for the falcons which allows that falconer to use it for hunting. □ Agree □Disagree
- There should be an Identification Card issued by the Wildlife Authority for the falconers that allows them to possess a falcon. □ Agree □Disagree
- The price of the falcon should be set according to its species. □ Agree □Disagree
- Setting a specified period for keeping a falcon. □ Agree □Disagree
- Establishing breeding centers for falcons. □ Agree □Disagree
- Establishing veterinary hospitals for falcons in the areas with high abundance of falconers. □ Agree □Disagree
- Establishing falconers clubs in the areas with high abundance of falconers. □ Agree □Disagree

11- New regulations are making it harder to have wild sakers: □ Agree □ Disagree

12- How many dollars do you expect to pay for a wild saker now?.........................

13- In order to ensure a good supply of wild sakers for the future, how much above that price would you pay for a wild saker that was legal with CITES?
□ Nothing □ $100 □ $200 □ $500

Annex 3 Costing of use-cases for Saker adaptive management system

The costing takes into account the following requirements:

· A large part of the application is designed as a web application running through a suitable web server such as Internet Information Server (IIS) on a Microsoft server operating system or Apache on Linux.
· The application is to be developed in Microsoft .Net 2010 with ASP .Net written in C#, if running on IIS, or in PHP if running on Apache
· Application data are to be stored in a relational database, e.g. SQL Server or MySql. Database tables will be optimised with indexes and will be normalised as far as is sensible for optimal performance.
· XHTML, CSS and JavaScript are to be used to manipulate and display the application in the browser. This code will be written to W3C accessibility standards.
· The user interface is designed to run in Internet Explorer versions 8 and above, Mozilla Firefox, Apple Safari, Opera and Google Chrome. It will run on any computer that supports the above browsers e.g. Microsoft Windows, Linux variants and MAC OS. It is possible to develop the applications to run the pages in smart phones and tablets browsers though this has not been costed.
· The application is to use third party web services where necessary and available, for example to take and distribute credit card payment.
· To receive SMS text messages, a GSM (Global System for Mobile Communications) modem must be attached to the server, or to a remote computer that can communicate with the server, and suitable software, written in Java, C#, C++ or PHP, must be created to communicate with the modem, parse the received messages and insert the data in the database. Alternatively it may be pertinent, for example if a phone signal is not available, to use a third party service such as Twilio to send and receive messages and pass the message to our server.
· The law enforcement application controls an RFID scanner and it is unlikely that any provided developer toolkits can be run from a browser. This means this application will use a runtime that can access the native API and will be written in Java, C#, Objective C or C++ depending on the developer toolkit provided.

Actors in this costing include:	The developer: costed for Anatrack and its development partners System administrators: set up and edit all users and manage payments Biology administrators: manages bird data Taggers: tag birds and are paid for tagging Falconers: register birds, view bird history and make payments Law enforcers: scans bird tags, views birds info and is alerted to illegal birds

All except for the developer is considered an application user; each actor above has a proprietory interface. A design and preparation stage must be completed before the application is programmed.

Action	Description
Design and Preparation	
Analysis and architecture	Build a requirements list, identify data objects and functionality and create formal designs based on these.
Specification document	Complete with costings and roadmap
Wireframe designs	To indicate GUI requirements (approx 60 pages @ approx 1 hour each)

Database design	Designing the database tables, fields, indexes and data relationships and scripting to SQL so it can easily be installed.
Graphic design	General graphics design for web page and form layouts of each application. This is crucial for a professional looking application though is as important for usability as for good looks.
Environment setup	Setting up a development environments (installing software, databases, creating paths etc)
Payment mechanism	Payment is critical and could be mixture of one-off and subscription payments, credit card and direct debit, automated and manual processes. A suitable payment engine should be selected. To avoid strict security compliance laws actual payment could be handled by the chosen engine's own payment pages but these would need to be integrated into the application. Note that the procedure for acquiring payment engine accounts often takes several months to complete.
Messaging mechanism	Users could be encouraged to communicate with each other through a web-based messaging system built in to each of the interfaces. As well as emailing the relevant users, the message would be stored in the database for a central record of conversations, to help solve disagreements and to log ideas/enhancements etc
System Administrator Interface	
The system administrator interface will run in web pages for remote access to the central database	
Template and navigation	Includes page furniture to appear throughout the administrator web pages with links to all pages in the administrator tool.
Login	Access to administrator tools must be restricted. Here he enters user name and password
Forgot password	Two pages and an email to allow user to reset his own password. For security, all system passwords are encrypted and cannot be read directly.
View/edit details	Allows for changing name, address, password etc
List users	List all users for editing. Filters and search tools help find events quickly.
Create users	Create other system users: administrators, biology admin, taggers, falconers and law enforcers
Edit users	Change their details, name, email address, password and role
Email users	Bulk email users from the application or email individuals
View user events	Provides the ability to quickly see user activity - log in, event creation etc.
Access to biology admin accounts	Use biology admin application as if the administrator had logged in as a particular biology admin user.
Access to tagger accounts	Use tagger pages as if the administrator had logged in as a particular tagger.
Access to falconer accounts	Use tagger pages as if the administrator had logged in as a particular falconer .
List law enforcement installations	A list of the law enforcement installations

View/edit law enforcement installations	Allows set up and logging of law enforcement installations recording where they are and providing an installation code to identify communications from the installation.
Delete law enforcement installations	Delete an installation record
List payments	View all payments made
Create payments	Make payments to users as required. So that all payments are recorded within the system, refunds must also be made through the interface.
Manage messages	As part of the databased messaging system, admin can view, filter and search all messages and conversations, create new messages to start a conversation or to reply to another message. Messages are emailed as well as stored in the database.
View user conversations	A specific list of conversations for a particular user. This would be accessed from the user's page and includes search tools.
Biology Admin Interface	
Template and navigation	Includes page furniture to appear throughout the biology admin web pages with links to all pages in this interface.
Login	Biology admin enters username and password to allow him to use these pages. As for system administrator.
Forgot password	As for system administrator
View/edit details	Allows for changing name, address, password etc. As for system administrator
List birds	List all birds currently registered. Biology admin can use filters and search tools to help find an individual bird quickly.
View bird	Allows the biology admin to view the bird details. This will include a generated bird code for sending to taggers for them to send back in an SMS text message. Images can be viewed.
Create bird	Creates a database record for a bird. This data in this record will populated by the biology admin and the other actors.
Edit bird details	Edit the bird data record such as the description, location caught, feather received, recognition code etc.
Add bird images	Photographs of the bird can be uploaded.
Delete bird	Delete a bird record only if it is not valid or a repeat.
Merge birds	It is possible that two separate records are created for the same bird for example, a facloner registers a new bird that turns out to be already logged. This functionality allows the records to be merged, keeping the events and, where possible, the details for both records.
Manage bird events	Bird events describe a history of a bird as it is initialised, one of its feathers is received and analysed, it is tagged, registered with a falconer, passed through customs, dies etc. The biology admin can see these events and may be able to create/edit/delete them as he sees fit. Events have a User, Type, Description and Date associated with them.
Create "Received feather" event	The biology admin will definitely create an event when he receives a feather from a tagger.
View bird alerts	Displays a summary of bird alerts and other reports

Contact admin/manage messages	As for other users, this provides a system-recorded way of contacting admin or other users with queries and continuing conversations. Includes the ability to view, filter and search conversations, create new messages and continue conversations.
Tagger Interface	
Receiving SMS text messages	Text messages received from the tagger must be parsed and the data for the relevant bird written to the database. There are two sensible ways to deal with the small amount of traffic anticipated: either connect a GSM modem to the server or imploy a third party such as Twilio to intercept messages and send them to our server. The SMS will parse for bird code and telephone number. A "tagged bird event" database record is created for the bird matching the code and tag user matching the telephone number. Repeat events and events with unrecognised codes and telephone numbers are also logged and flagged as alerts for the biology admin
Template and navigation	Includes page furniture to appear throughout the tagger web pages with links to all pages in this interface.
Login	Tagger enters username and password to allow him to use his pages. As for system admin.
Forgot password	As for administrator
View/edit details	Allows for changing name, address, password etc. Importantly, the tagging mobile telephone number can be changed in order to recognise the user sending the SMS
View/edit payment details	Depending on the payment mechanism utilised, the tagger and view and perhaps edit the details of the bank account/paypal account/credit card to which payments are sent.
View birds	View a list of birds tagged with a limited view of events
View payments	View a list of payments to date
Contact admin/manage messages	As for other users, provides a system-recorded way of contacting admin or other users with queries and continuing conversations. Includes the ability to view, filter and search conversations, create new messages and continue conversations.
Privacy Policy	What we do with collected data
Terms and Conditions	What a user can do with the application
Falconer Application	
Template and navigation	Includes page furniture to appear throughout the falconer web pages with links to all pages in this interface.
Signup	Falconers can sign up to the use the application. They enter username, password, contact details, etc.
Login	Falconer enters username and password to allow him to use these pages. As for system admin
Forgot password	As for administrator
View/edit details	Allows for changing name, address, password etc
List birds	List all birds currently registered to logged in falconer. Filters and search tools to help find an individual bird quickly.

View bird	Allows the falconer to view the bird details and its history.
Register exisiting bird	Falconer registers a bird by entering the provided bird code. This will create a bird registration event.
Register new bird	Falconer can add a bird he already owns to the system. This will create a bird registration event. Bio admin is alerted to send tag/envelope.
View payments	View payments made to the system
Make payment	Payments are made either on registering a bird or on sign up.
Privacy Policy	What we do with collected data
Terms and Conditions	What a user can do with the application
Law Enforcement Interface	
System startup	The software runs when the system starts. There is no login - system has been installed with a unique code to identify it.
Interface and navigation	Create the interface and buttons to different parts of the application
Test connection	The software regularly tests its connection to the central database and alerts the user if there is a problem.
Store data locally	If the internet connection is lost, store input data locally until it is restored.
Software update	The software is alerted to new versions and automatically updates itself.
Scan tag	RFID scanner is attached to the terminal. When it is used to scan a tag on a bird, the tag data and terminal id is automatically posted to the remote database to create a scanned bird event record for the bird.
View bird details	The server responds by posting back the bird details. This will include the legal status of the bird so that suitable action can be taken.
Report untagged bird	If bird is untagged, law enforcer and bio admin are alerted so that suitable action can be taken.
Access Pages	
Graphic Design	These pages are public-facing and need to be suitably styled and layed out.
Template and navigation	Site headers and footers for every page. Would include links to the various user applications.
Home Page	Introduction to the project. Photographs and screenshots
About	Describes the project in more detail.
Privacy Policy	What we do with collected data
Terms and Conditions	What a user can do with the application
Cookies policy	Provide explanation of cookie use and allow user to agree to their use (users cannot log in without cookies enabled)
Contact Us	Provides contact details and form to message the system administrator
Search Engine Optimisation and Registration	Site needs to reach the those who are interested

Other Application Tasks	
Help Files	Implementation of a help file system and integration with all the applications.
System Testing	The system will be comprehensively tested by the developer. It will also need to be tested by non-development staff or final users.
Encryption for secure data transferal	Displaying login and cc card pages over a secure socket layer (SSL) for secure data entry
Exception handling	Trapping exceptions and passing them to the developer whilst displaying a friendly message to the user.
Server specification and selection	Servers and a hosting solution need to be selected to run the applications and database with an eye to performance and on-going cost.
Law enforcement terminal and tag scanner specification and selection	Terminals for running the law enforcement software need to be selected along with the scanners for the tags
RFID tag specification and selection	Suitable RFID tags for attaching to birds must be selected.
Server patching strategy	Describes a mechanism to update the operating software (OS and databases) on the live servers with the minimum of downtime.
Load balancing and redundancy strategy	Describes a mechanism for adding new servers to the application in case the current hardware cannot support the user load (makes the application scalable). It also considers a database redundancy mechanism as emergency backup, possibly automated in case of primary database failure. This needs to be considered but there may be no work to be done as the user base, and server loads, will not be large.
Application installation and update strategy	Automated scripts to aid recompilation and database rebuild. Describes a mechanism to update to the live application with the minimum of downtime.
Backup mechanism design and development	Automated scripts to transfer compressed copies of the database to a remote location. In case of total server failure, the application can be reconstructed from these backups.
Staging setup	This is where updates to the system will be tested for user acceptance. It needs to run web and database server software, a GMS server and a firewall. The small-to-medium sized scale of the project suggests it will not need load balancing.
Live setup	This is where the final system resides after thorough testing. It needs the same hardware and operating software as the staging setup.
	TOTAL HOURS 1,090

Notes

Development documentation can be provided in as much detail as required but has not been costed.

As well as the time required for coding there are a number of architecture and design tasks as well as time required to specify server and terminal hardware and install the software. There is a approximately 140 days of development work for the application laid out but this might change as other requirements become clear.

There are a number of uncosted tasks including the costs of hosting the web applications and database, law enforcement hardware acquirement and software installation, system testing, training and support, use of a third party payment and/or SMS engine, content creation for some of the pages and system use. The cost of these elements cannot be estimated here. They include:

Hosting hardware and software	This is the cost of physical or virtual machines, owned or rented and hosted at a data centre. It includes the cost of licences for software required to run the database, receive SMS text messages and serve web pages.
Tag hardware	Each bird will need a RFID tag. A number of these will also be required for testing purposes.
Law enforcement terminal hardware	Law enforcement will need computers with an RFID tag scanners attached to each. Scanners, and in some countries also the computers, will need to be provided by project administrators.
Law enforcement terminal software installation	The law enforcement machines will need to be set up to run the software to scan tags and communicate with the central database.
System and acceptance testing	Crucial to guarantee a stable and functional web application. The more the application is tested, the better. This should not be completed by the developer.
Training, support and help page content.	Users, particularly taggers and law enforcement will need training in the use of their applications. Though this should be minimal, it should be factored in to project costs. Administrators will need to supply support to users, answering usage questions via email or on the phone. All applications will need comprehensive help pages. The better the written help, the less time will be needed to train users or supporting them.
Access page content	The marketing pages will need clear and to-the-point content - images and text to explain the content and to encourage falconers to participate.
Payment engine costs	The payment engine provider will specify a fee for use of its product.
Third party SMS service	If required, there will be a fee for this service
System administration	There is a cost involved with running the system, administration of users and payments and other tasks.