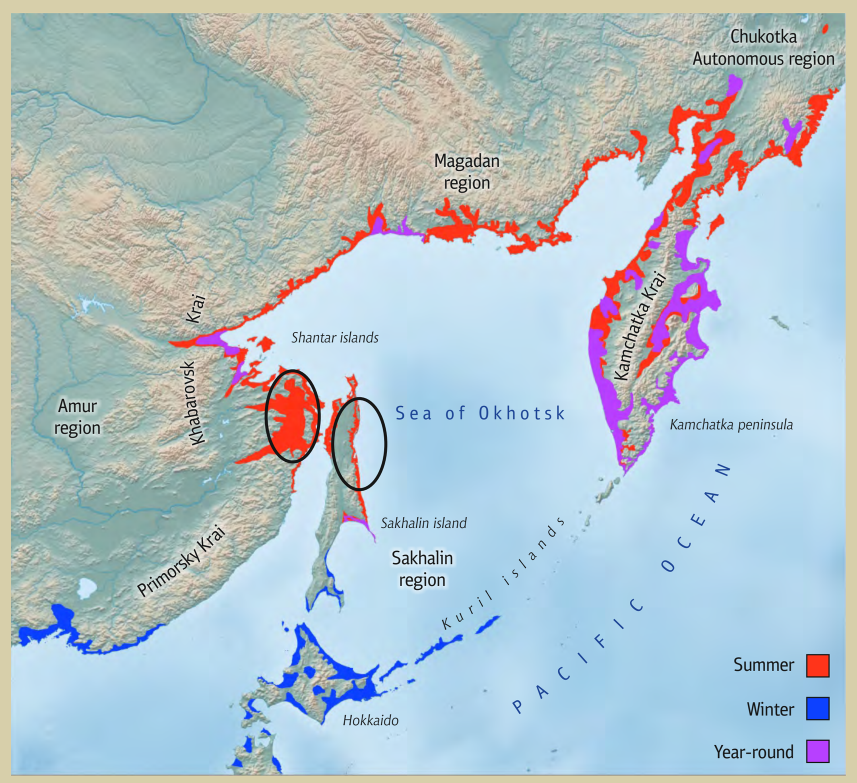
Performance of Steller's sea eagle population
in the northeastern Sakhalin and lower Priamurie

Earlier, a significant part of the Steller's sea eagle's range was located in remote areas of Russia, which protected these birds of prey from human intervention. However, the situation is rapidly changing. The demands for hydrocarbons necessitate the exploration and development of rich natural resources even in the most remote areas. On the shelf of the Sea of Okhotsk, large oil and gas fields were discovered, some of which are already developed. The breeding range of the Steller's sea eagle largely overlaps with the existing and prospective oil and gas areas.

On Sakhalin Island, oil exploration and production has been performed since the mid-1960s. Over the past period, the habitats of sea eagles in the northern part of the island have undergone significant changes. The coastal areas are now covered with a network of seismic profiles, access roads, and well sites. The coastal area suitable for nesting sites has considerably reduced. The construction of roads facilitated the penetration of population in formerly remote areas and led to an increase in the recreational pressure, disturbance by humans, and environmental pollution. Since the early 2000s, a large-scale development of offshore fields has begun. In the Lower Amur region, intensive nature management at the end of the XX century (primarily forestry and mining industries) has led to the degradation of rivers and substantial deforestation of the area, aggravated by catastrophic forest fires. This greatly reduced the environmental capacity for sea eagles.

STUDY AREA

The populations of the Steller's sea eagle in Sakhalin island and lower reaches of the river Amur represent about 1/3 of the World population of the species. Their total numbers is about 2200 individuals. At least 36% of Sakhalin birds spend winter in Hokkaido.



Range of the Steller's sea eagle and two study areas

METHODS

300 territories in NE Sakhalin and 280 territories in Lower Amur are subject to complex long-term monitoring. We visited nests, determined their status (active, occupied, or unoccupied). Status of territories was determined on the base of nest status with help of GIS analysis (it was very useful to detect territorial changes between pairs).

Population structure (proportion of age-and-territorial groups) was determined on the base of visual observations of sea eagles of different age and territorial status. In adults, their territorial status (territorial or floater) was determined on the base of their behaviour and verified with help of GIS-analysis: individuals recorded farther than 1 km from nearest known territory considered to be floaters.

To reveal long-term trends, we applied linear regression analysis,

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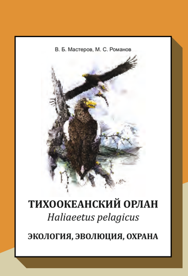


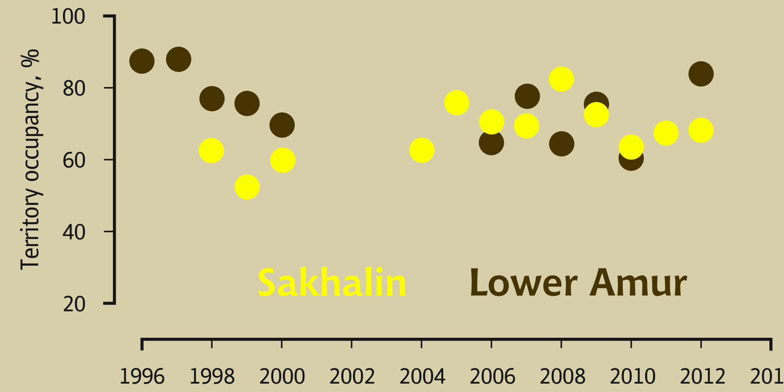
For more details see our book which is coming soon:

V. B. Masterov, M. S. Romanov. The Steller's sea eagle *Haliaeetus pelagicus*: ecology, evolution, conservation. Moscow: KMK Scientific Press Ltd. 2014. 372 p. [In Russian with English summary]

RESULTS: 1. Dynamics of population characteristics from 1990s to 2012

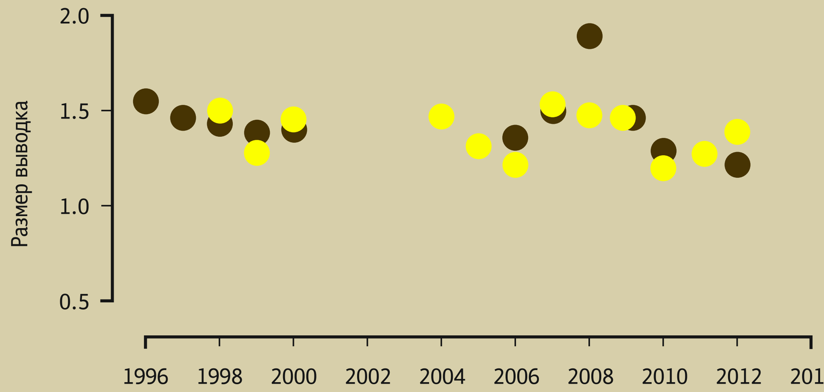
Occupancy ot territories

Occupancy (proportion of territories which are occupied by territorial pairs) did not change much. During 20 years it remains **more or less stable — about 70% at average.**



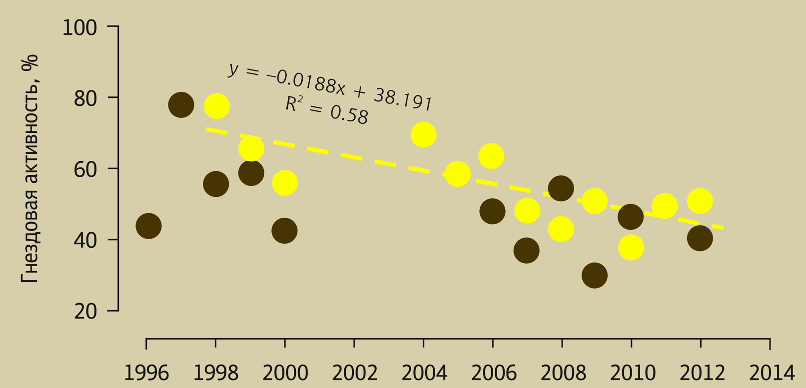
Brood size

Brood size remains relatively stable, fluctuating around 1.4 chicks per successful nest.



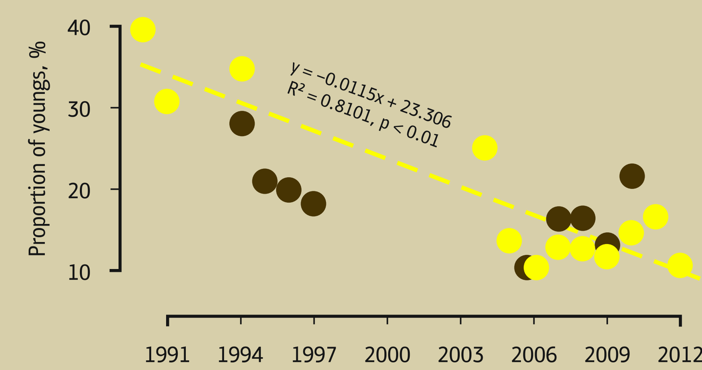
Nesting activity of territorial pairs

Nesting activity is the ratio of number of active territories to the number of occupied territories. It characterizes breeding activity of territorial eagles. In 20 years it decreased from 68 down to 54% in Sakhalin ($p < 0.01$), and from 60 down to 45% in Amur land (though trend is not significant).



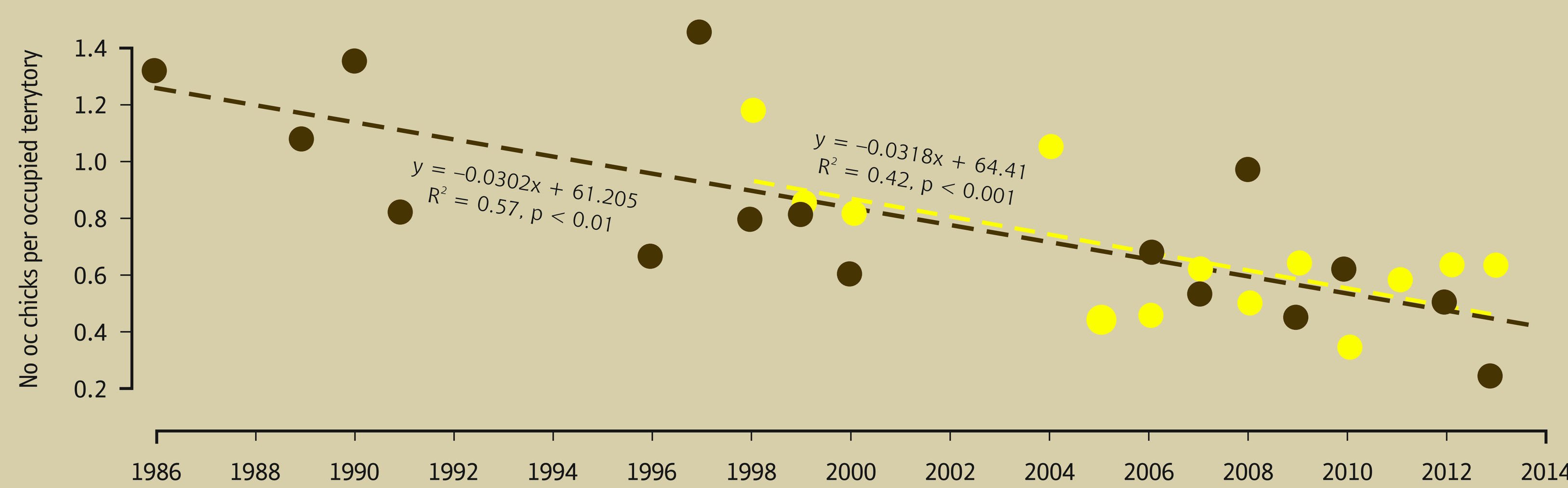
Proportion of immatures

Proportion of immatures decreased from 30.8–38.4 down to 14% in Sakhalin, and from 28 down to 17% in Amur region. In Sakhalin there is a significant negative linear trend (in Amur it is not significant).



Overall productivity

In both regions, productivity of sea eagles significantly lowered. In Sakhalin it decreased from 0.79 down to 0.58 fledglings per occupied territory, in Amur land — from 0.87 down to 0.64 fledglings. Among reasons are decline of nesting activity and predation of brown bears.



Therefore, both populations at the moment are characterized by relatively low nesting activity, decreased productivity, and small proportion of immatures. In Sakhalin population these features are more pronounced than in Amur population.

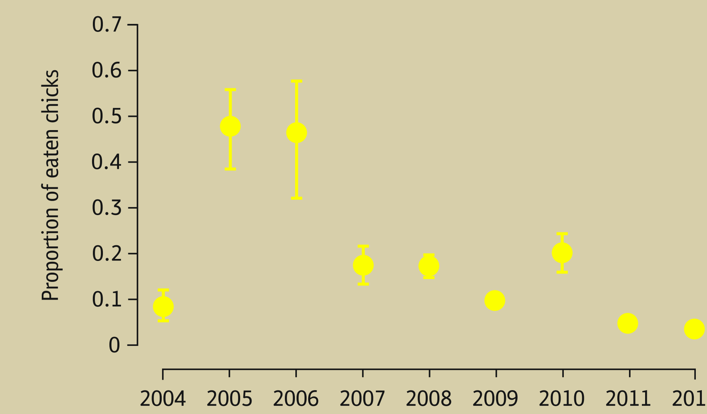
There is no obvious explanation of this. Among possible reasons are economic activity of regions which is followed by direct disturbance of birds. Also, construction of new roads gives to local residents access to previously remote areas. This in turn can lead to increased levels of disturbance and direct persecution of eagles (illegal hunting). In Sakhalin is it also high press of bear predation.

These results suggest that both populations might be possibly decreasing. To check this hypothesis, we developed matrix model for each population, and simulated various scenarios of their further development. To estimate population growth rate, we developed matrix population model ("Leslie model": see next section).

Photo of sea eagles by Igor Shpilenok

Predation of brown bears

In Sakhalin, one of negative factors for sea eagles is predation press of brown bears, which in some years is very high. Thus, in 2005-2006 bears have eaten nearly one half of all grown chicks. In other years it was lower — 10–20%. At average, in last decade bears exterminated 21% of sea eagle offspring. Conversely, in Amur land bear predation on sea eagle chicks is negligible.



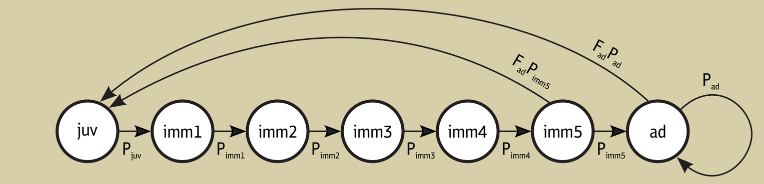
Bear press on sea eagles (proportion of chicks eaten): estimations ± confidence intervals.
Sometimes we could not ascertain fact of predation, or were not sure how many chicks were predated. That's why we put here 3 values: estimation, no. of chicks predated at least, no. of chicks at maximum.

Consequences of predation: eaten chicks and destroyed nests.

Mass-scale destruction of Steller's sea eagle's nests by brown bears on Sakhalin Island in the first decade of the 2000s required to take measures to protect them. A simple and reliable solution to this problem was to surround the trunks of nesting trees with metal belts, thereby preventing the predators from climbing the trees. On the protected trees, birds successfully bred and produced progeny. 94 vulnerable nesting trees were equipped with protecting facilities.

2. Leslie matrix population model

The model population consists of 7 age classes: juveniles, 5 classes of immatures (birds 1–5 years old) and unified class of adults. Probabilities of transition between classes form a transition matrix, which possesses some interesting features. The dominant eigenvalue, lambda (λ), represents population growth rate. The right eigenvector characterizes so-called stable age structure.



Graph of life cycle of the Steller's sea eagle. Circles — age classes, arrows — transitions between classes, P_x — survival of the age class x during one year. F_{ad} — fecundity of adults. Individuals reproduce in the end of simulation step, therefore adult fecundity is corrected with probability to survive during the year.

Input parameters of the model

The input parameters were fecundity of adults and survival probabilities of age classes. The former was based on the productivity which equals to 0.58 chicks per territorial pair in Sakhalin and 0.64 chicks in Amur land. However, fecundity used in the model is calculated per one adult bird, so we should take into account non-territorial adults ("floaters"), which consist 22% of adults in Sakhalin and 25% in Amur. Therefore, in Sakhalin **fecundity** equals to **0.22**, in Amur — **0.23** chicks per adult individual.

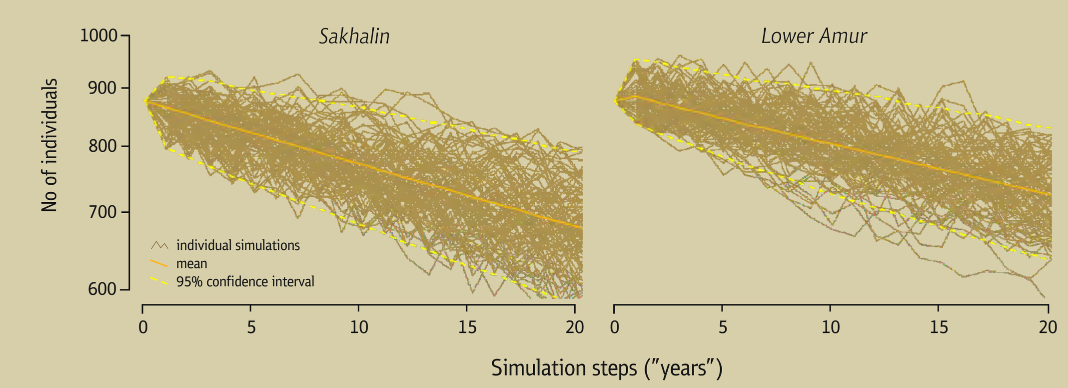
Unfortunately, our study lacks direct estimations of survival of age classes. For **adult survival** we used theoretical value of **0.952**, obtained from data on bald eagles and models of ageing (Ricklefs, 2000). Note that this value corresponds to biological potential of the species in natural conditions, to which it is evolutionary adapted. The actual value can be lower due to influence of anthropogenic factors (like poisoning, persecution, habitat alteration *etc.*).

Survival of young age classes was calculated from their proportions in the populations. Proportion of immatures (5 classes) to juveniles was quite low (0.75 to 1 in Sakhalin and 0.84 to 1 in Amur) that implies high mortality during first year of life. Also we assumed that after 1st year it is high. According to our calculations, **survival during 1st** year is **15.7%** in Sakhalin, and **22.9%** in Amur. Thereafter it equals to **0.981** per year up to the age of 6.

Model results

Matrix model showed that the Sakhalin and Amur populations are gradually reduced at a rate of 1.6 and 1.0 % per year, respectively. If these negative growth rates remain, the Sakhalin population of Steller's sea eagles will reduce twice in 44 years, and the Amur population will halve in 70 years.

To verify the results of matrix model, we constructed also a stochastic model which allows years to be more or less productive (generating random sequences of year productivity from real data). Even in this case, vast majority of 10 000 simulations show negative trend.



Results of stochastic modeling of population dynamics. 100 of 10 000 simulations for each region are shown.

CONCLUSION

The tight confinement to the coast and dependence on the "optimal prey" makes Steller's sea eagles especially vulnerable to environmental changes. The habitation in areas with harsh climate and sometimes unpredictable situation with food determined the existence strategy of these birds of prey that focuses primarily on the survival of mature individuals capable of reproduction. The high mortality of immature birds, late onset of sexual maturity, and slow reproductive rates reduce the chances of a rapid recovery of the population in case of a critical decline in its abundance.

Therefore, finding a compromise between the objectives of industrial development and conservation of vulnerable components of coastal ecosystems is the basis for creating favorable conditions of sustainable development of the region.

An effective method to protect birds is to create protected buffer zones around nests, perches, and hunting grounds. In some cases, to optimize and increase the capacity of habitats, it is recommended to build artificial nests and perches. The use of these tools makes it possible to purposefully influence the territorial behavior of birds, change the spatial configuration of boundaries of nesting sites, and shift the center of territorial activity to the desired direction. This approach opens up the possibility of solving the conflicts arising during the construction of industrial facilities in the habitats of sea eagles and attracting birds to new territories. Successful experience of such events proves the effectiveness of these conservation measures.

Our model implies low survival during the first year of life. Further research is needed to obtain estimations of survival probabilities of age classes.