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GENERAL BIOLOGY

On Possibility to Identify the Saiga Antelope (*Saiga tatarica*) on Very-high Resolution Satellite Images[1]

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Abstract—Analysis of high-resolution satellite images taken during the cold part of the year demonstrates that they can be used to reliably distinguish the saiga from domestic ungulates and also to determine the distribution of saiga herds over large areas. To achieve maximum reliability in differentiating animal species in satellite images, one should use a number of characteristics (including the color of animals, their size and shape, and herd structure) and prioritize those that are most prominently displayed in particular images. The results of this study can be used to develop a non-invasive and highly accurate method for saiga census.

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Censuses are an important component of monitoring the status of wildlife populations. Different techniques are used for different species, on account of their specific biological characteristics. The European population of the saiga antelope (*Saiga tatarica*) inhabiting northwest Caspian Lowlands (eastern part of the Republic of Kalmykia and south-western part of the Astrakhan Region) is in a critical condition. According to expert estimates, its size is no more than 5.000 individuals [1]. Past saiga censuses have typically relied on line transect surveys, either aerial (using mainly low-flying helicopters) or ground-based (using several vehicles). These methods have a negative impact either on the animals themselves or on the plant and soil cover of the areas they inhabit. Besides, line transect surveys of species that tend to move while being surveyed (as is the case with the saiga) are prone to substantial random error. In recent years, attempts have been made to conduct saiga censuses by means of aerial photography using drones. However, this method, albeit far less invasive than conventional line transect surveys, is still not adequately developed, and it also has certain inherent limitations.

Satellite remote sensing may offer a worthwhile alternative to the above methods. State-of-the-art satellite imaging systems are capable of providing highly detailed photographs that allow identification of relatively small objects, including certain species of mammals. Pilot censuses using high-resolution satellite images have already been undertaken for a number of Arctic marine mammals, including the polar bear, with promising results [2].

The aim of this study was to determine whether individual saiga can be reliably identified in high-resolution satellite images, with a view to developing a new non-invasive method for an accurate assessment of saiga population size. To that end, we analyzed three satellite images of the open-air enclosures of the Center for Wildlife Animals of the Republic of Kalmykia, which hold a known number of captive saiga, and three images of the sanctuary "Stepnoi" in Astrakhan Region, which is inhabited by free-ranging saiga. The images were taken by GeoEye–1, EROS–B, and Pléiades satellites (see Table 1). The images were processed and analyzed using ScanEX IMAGE Processor software. Distances between animal groups and between animals within groups were calculated using MapInfo Professional 8.0 SCP software. Statistical analyses were performed using Statistica 8.0 package.

First, we had to make sure that the resolution of the images was high enough to distinguish objects the size of the saiga antelope. For that purpose, we analyzed three images of animal enclosures at the Center for Wildlife Animals of the Republic of Kalmykia, obtained from different satellites at different times (Table 1, 1–3). We found that the number of saiga-like objects identified in each of these images was close to the actual number of saiga that were being kept within

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Table 1. Characteristics of satellite images used in the study

No.	Satellite	Date	Time, UTC	Resolution, pixel size	Sun's angle of elevation	Site
1	GeoEye-1, USA, DigitalGlobe	Oct. 27, 2009	08:05:00	0.5	30.14	Center for Wildlife Animals of the Republic of Kalmykia
2	Eros-B, Israel, ImageSat Intl. N.V.	Feb. 25, 2013	10:56:18	0.7	30.25	Center for Wildlife Animals of the Republic of Kalmykia
3	Pléiades, France, EADS-Astrium	Jan. 15, 2014	08:08:41	0.5	21.3	Center for Wildlife Animals of the Republic of Kalmykia
4	Eros-B, Israel, ImageSat Intl. N.V.	Nov. 22, 2012	10:55:05	0.7	17.2	Sanctuary "Stepnoi", Astrakhan Region
5	Eros-B, Israel, ImageSat Intl. N.V.	Dec. 12, 2013	10:52:33	0.8	40.49	Sanctuary "Stepnoi", Astrakhan Region
6	Pléiades, France, EADS-Astrium	Mar. 22, 2014	08:00:59	0.5	43.01	Sanctuary "Stepnoi", Astrakhan Region

enclosures at the time the image was taken, as reported by the Center for Wildlife Animals' staff (see Table 2).

We then calculated the average length, width, and length-to-width ratio for the 154 saiga-like objects identified in satellite image 3 (see Fig. 1): 0.91 ± 0.18 m; 0.54 ± 0.13 m, and 1.74 ± 0.37, respectively. These data served as the baselines for subsequent identification of saiga in satellite images covering the area of the Stepnoi nature reserve.

As the next step, we established a list of characteristics that could be obtained from satellite images and used to distinguish the saiga from other herd animals commonly present within its range—namely, sheep, horses, cows, and camels. This list includes: color, size (length, width, and height), and shape (ratio between size dimensions) of individual animals; and herd structure.

Color: The satellite images analyzed were taken during the cold part of the year (late October to late March), when saiga's white winter coats stand out against dark snowless steppe. Sheep that resemble saiga in terms of size have either white or black coats.

Table 2. Number of saiga-like objects identified in satellite images vs. actual number of saiga at the Center for Wildlife Animals of the Republic of Kalmykia

No.	Satellite	Date	Number of saiga-like objects identified in image	Actual number of saiga in enclosures
1	GeoEye-1	Oct. 27, 2009	52	56–58
2	Eros-B	Feb. 25, 2013	143	116
3	Pléiades	Jan. 15, 2014	154	153

Length and width: Table 3 provides measurements of saiga and domestic ungulates that occur in the same areas. Outlines of individual saiga in satellite images occupy fewer pixels than those of cows and horses (a saiga silhouette typically takes up 2 pixels, but can amount to 4 pixels with the shadow, depending on the angle of incidence of the sun's rays at the time the image was taken and the angle at which the image was taken).

Length–to–width ratio: In saiga, this characteristic exceeds 1.0 and typically reaches 1.5, whereas in sheep it is smaller than 1.0.

Height: The height of an object in a satellite image can be determined by the tangent of the angle of incidence of the sun's rays (which is recorded for every image) and the length of the object's shadow. Saiga are smaller in height than camels, cows, and horses.

Herd structure: We took every animal identified in a satellite image as a nodal point, and distances between the three nearest individuals as nodal point connections.

By using the above characteristics we were able to identify not only individual ungulate herds within the Sanctuary "Stepnoi" refuge, but also to distinguish saiga from sheep, camels, cows, and horses. Our identifications were confirmed by the field staff of this protected area by physically visiting herd locations obtained from the images.

To achieve maximum reliability in differentiating animal species in satellite images, one should use all the above characteristics, and prioritize those that can be most clearly assessed in each particular case.

Animal aggregations visible on an image taken from EROS–B satellite (4 in Table 1), which we identified as "saiga-less" (they include both sheep, which

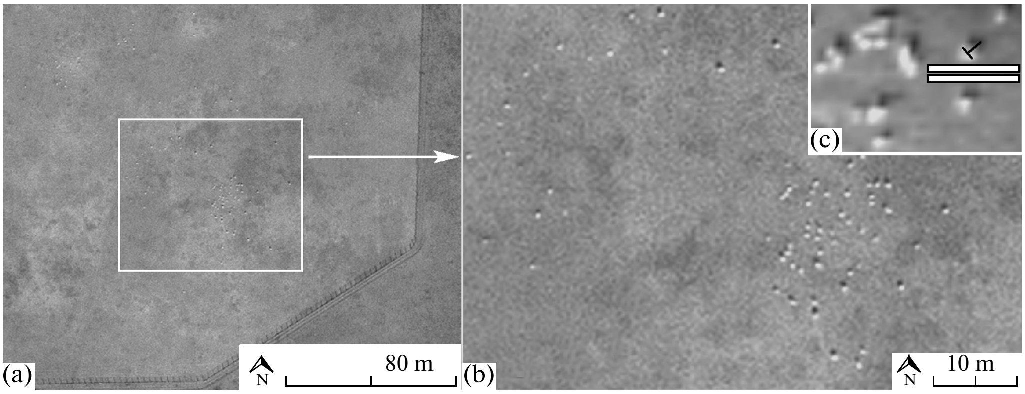

Fig. 1. Image of an open-air enclosure of the Center for Wildlife Animals of the Republic of Kalmykia with saiga, taken by Pleiades satellite: (a) saiga in the enclosure; (b) enlarged portion of (a); and (c) the scheme for the measurement of animals and their shadows used in this study.

are similar to saiga in terms of size, and other livestock), are easily distinguishable from saiga herds based on color (see Fig. 2). These mixed aggregations feature both light- and dark-colored animals, whereas all saiga had white winter coats at the time this image was taken. Besides, mixed livestock are made up of variously-sized animals.

When analyzing an image from EROS–B taken under different lighting conditions (5 in Table 1), we found that animal size and herd structure provided the best combination of characteristics for identifying saiga herds (see Fig. 3). Specifically, the t-test revealed that the mean distances between animals in saiga herds (2.84 ± 1.3 m) and in sheep flocks (2.18 ± 1.51 m) were significantly different from each other ($t = 6.58$, $p < 0.005$).

For identification of saiga herds in satellite images covering large areas we relied primarily on animal size and color. If these two characteristics alone failed to clearly differentiate saiga herds from other ungulate aggregations, we used the entire set of characteristics described above. In the image of the Sanctuary "Stepnoi" that was used to test the possibility of distinguishing saiga herds based on the size and color of animals (4 in Table 4; Fig. 4), we identified 14 saiga herds and 3 "saiga-less" aggregations (including one flock of sheep and two mixed herds featuring sheep alongside cows or horses). An analysis of this image demonstrated the possibility of using satellite photography to examine the spatial distribution of saiga at a given moment over a large area (265.6 km^2)—namely, to determine the geographical coordinates of herds, the distances between them, and their sizes (ranging from 16 to 1.657 individuals in this image).

An analysis of another image of the Sanctuary "Stepnoi" (6 in Table 1; area covered: 226 km^2) using the entire set of characteristics described above identified eight ungulate aggregations made up exclusively of saiga, all of which were confirmed through first-hand observations by reserve staff.

We also found that satellite photography can reveal whether saiga were grazing or, rather, on the move at the time the image was taken. Grazing saiga are typically displayed as dense clusters, whereas saiga herds on the move have elongated shapes.

Overall, our analysis has shown that high-resolution satellite images taken during the cold part of the year can be used to accurately determine the location and size of saiga herds over large areas. For maximum reliability, identification of saiga in satellite images should draw upon a number of characteristics, picking out those that are most clearly displayed in the images under analysis. For example, if an image was taken under lighting conditions that make it possible to clearly recognize animal colors, identification of saiga should rely on this characteristic in the first place. If, however, animal colors are not clearly distinguishable in the image, then the size of animals within herds and the structure of herds (i.e., distances between individuals) should be used as the key characteristics.

Table 3. Measurements of saiga and domestic ungulates

Animal		Height, m	Length, m	Breast width, m
Saiga		0.6–0.8	1.04–1.46	0.4–0.6
Sheep	Kalmyk Fat-tailed*	0.75–0.84	0.74–0.83	0.9
	Soviet Merino*	0.65	0.75	0.95
	Karakul*	0.7–0.75	0.7–0.82	0.97–1.6
Cow**		1.28–1.52	1.5–2.4	1.7–1.9
Horse**		1.5–1.8	1.59–2.56	1.75–1.95

Sources: *—[3, 4]; **—[5].

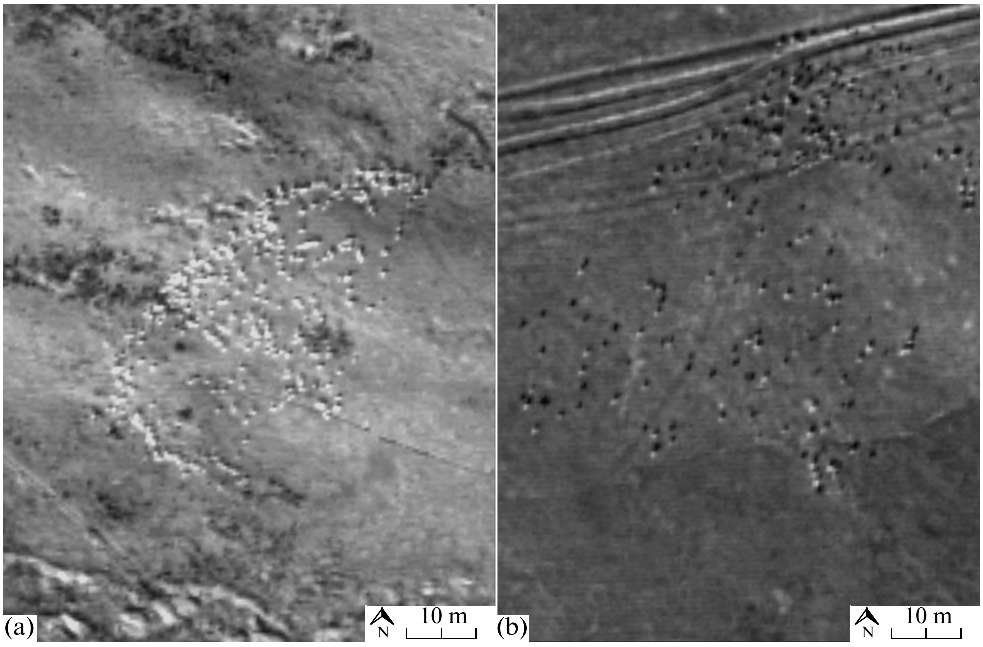

Fig. 2. Image of the Sanctuary "Stepnoi" area taken by EROS–B satellite (4 in Table 1). Animal aggregations visible in the image vary in color. In (a), all animals are white; therefore, it has been identified as a saiga herd. In (b), animals have different colors; therefore, it has been identified as a "non-saiga aggregation".

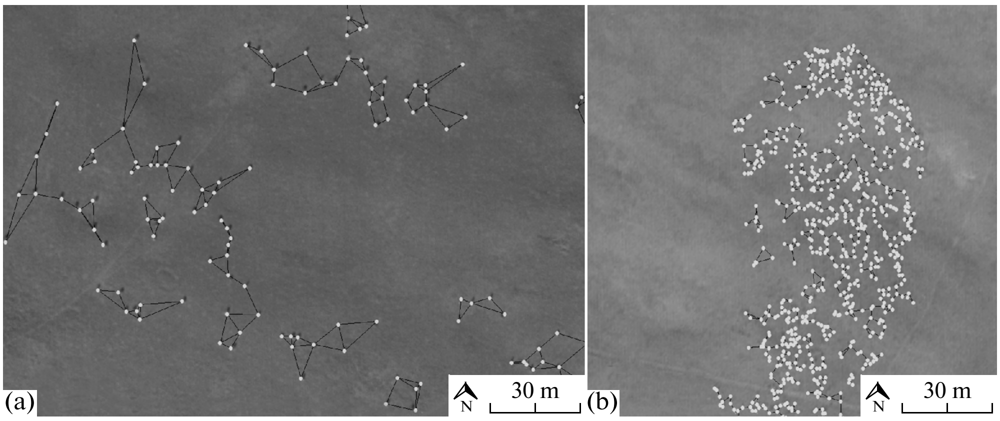

Fig. 3. Distances between animals—(a) in a saiga herd; (b) in a flock of sheep—can be used for species identification. When an image is used to assess herd structure, individual animals are marked with colored dots.

The results of this study demonstrate the possibility of developing a method for saiga census based on high-resolution satellite images. The proposed method has important advantages over current saiga survey methods: it is not prone to errors related to the movements of animals, and it does not disturb either animals or their habitat in any way. Its obvious shortcoming consists in the impossibility of choosing the exact date for image taking, which can affect the usability of some images for animal identification purposes (owing to weather conditions).

High-resolution satellite imagery opens new possibilities for surveying saiga populations and studying the spatial and temporal patterns of saiga distribution. If combined with satellite tracking studies, it can also help monitor individual saiga herds. Further, satellite images could be used for monitoring some of the major factors affecting the saiga, such as the numbers and distribution of livestock and the condition of plant cover in various parts of its range.

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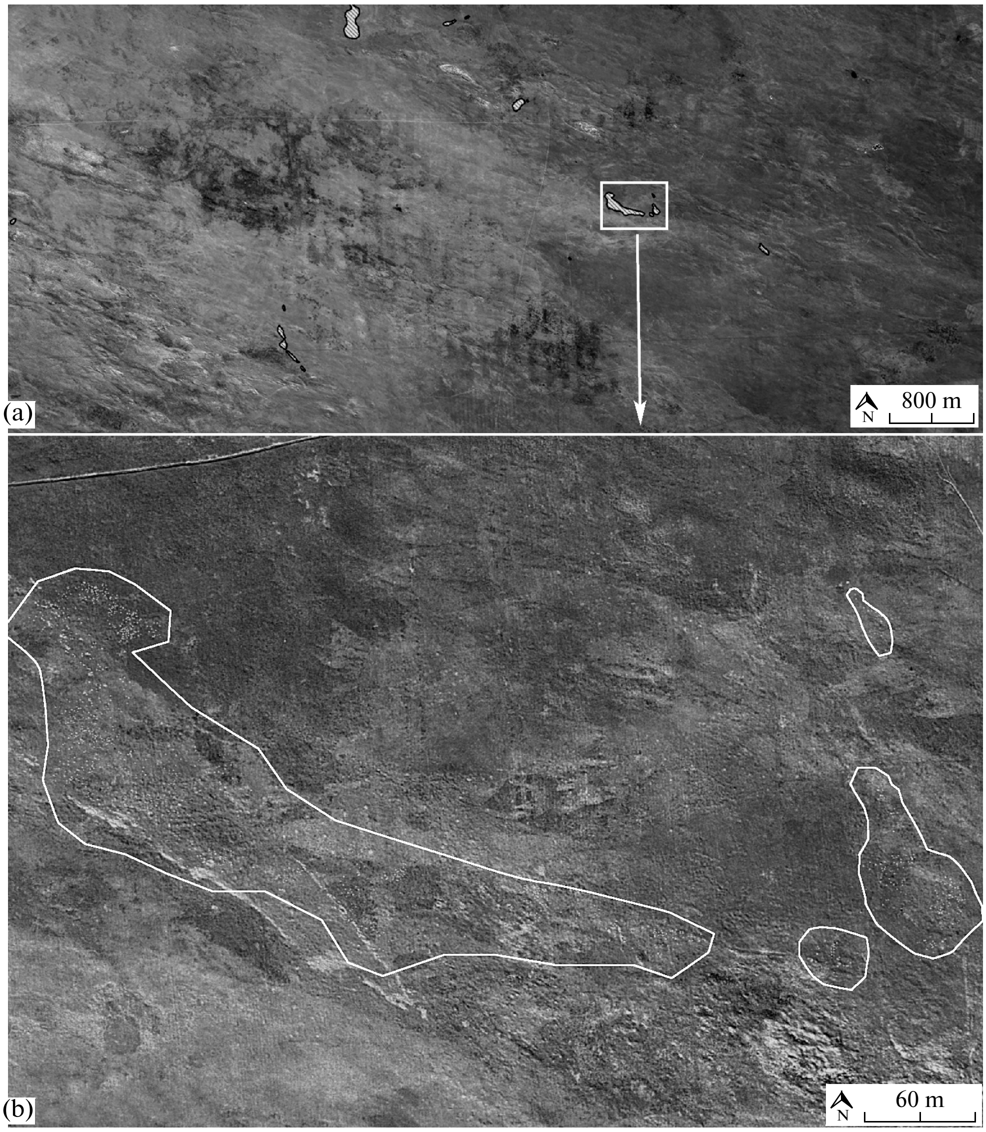

Fig. 4. (a) Distribution of saiga herds and other ungulate aggregations over a steppe tract; (b) Individual saiga herd in which the number of animals can be counted.

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REFERENCES

1. Neronov, V.M., Arylova, N.Yu., Dubinin, M.Yu., Karimova, T.Yu., and Lushchekina, A.A., *Aridn. Ekosist.,* 2013, vol. 19, no. 2(55), pp. 5–14.
2. Platonov, N.G., Mordvintsev, I.N., and Rozhnov, V.V., *Izv. Akad. Nauk, Ser. Biol.*, 2013, no. 2, pp. 217–226.
3. Erokhin, A.I. and Erokhin, S.A., *Ovtsevodstvo* (Sheep Breeding), Moscow: MGUP, 2004.
4. Shaidullin, I.N., Potokina, L.I., Feizullaev, F.R., and Bausina, V.L., *Zadaniya i metodicheskie ukazaniya dlya laboratornykh rabot i prakticheskikh zanyatii* (Exercises and Methodical Guidelines for Laboratory Classes and Practical Training), Moscow: Nosk. Gos. Akad. Vet. Med. Biotekhnol., 2004.
5. Kirina, L.I., *Zhivotnovodstvo* (Stock Breeding), Moscow: Kolos, 1985.

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