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GENERAL BIOLOGY

# Evaluation of Polar Bear Movement Patterns in Relation to Sea Ice Drift

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The polar bear inhabits mainly the Arctic sea ice, where it moves and hunts. The study of polar bear movements aimed mostly at determining the bear seasonal habitats [1] and evaluating the size of its home ranges [2]. However, the ice where the polar bear lives is drifting, and the ice drift have a substantial influence on the trajectory of animal relocations. The sea ice motion has been earlier assessed only qualitatively, but the rate and direction of sea ice drift should be measured quantitatively to evaluate correctly the animal movements on ice. A technique of quantitative measurement has been elaborated in this study.

To study the polar bear movements, a collar with a built-in radio transmitter of the Argos satellite system is usually mounted onto an adult female. The sea ice drift in Arctic is estimated using autonomous buoys, satellite images, and modeling. Data assimilation improves the accuracy of estimation.

The object of our study was one out of three female polar bears that we have tagged on the island Alexandra Land of the Franz Josef Land archipelago [3]. This animal moved throughout the Barents Sea, which is an area of high sea ice dynamics. The data transmitted from the satellite collar on the bear provided information about the accuracy of coordinates, which were used to plot the trajectory with a standard 24-h time step of vertices, which corresponded to the animal position at 12:00 UTC. Erroneous locations were excluded manually from the trajectory. Position coordinates were calculated using the weighted mean of locations (±12 h), accuracy class, and time interval from the noon. The resultant trajectory has been constructed using 165 locations from November 8, 2010 to April 21, 2011.

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Several datasets of ice drift have been used from OSISAF [4], CERSAT [5], and NSIDC [6] providers. To verify visually these datasets, an independent evaluation of ice drift used the data on the concentration and brightness temperature measured with an AMSR-E microwave radiometer [7].

The ice drift is evaluated from the satellite data by the method of maximum cross-correlation [3]. Each out of four 36 and 89 GHz channels of both polarizations is treated independently with different sizes of the search areas and with overview of the ice edge position, surface wind, and sea level pressure.

To localize the female polar bear, the vectors of sea ice drift have been constructed using spatial interpolation by the method of ordinary kriging [8] with a maximum distance of 200 km. Variogram is approximated by Bessel function yielding the least error values as compared to other functions.

The OSISAF dataset estimates ice drift for a 2-day interval, CERSAT reflects ice movement for 2, 3, and 6 days according to AMSR-E and for 3 and 6 days according to ASCAT, the combined ASCAT and SSM/I data for 3 and 6 days, and the combined QuikSCAT and SSM/I data for 3 and 6 days. The average daily ice drift is withdrawn from the original NSIDC set in the uniform grid.

To match the data on sea ice drift and the data on the polar bear movements, the animal locations were studied during the periods when it was possible to evaluate the sea ice drift. The vector difference of the absolute polar bear movements and the ice drift for a similar time interval is regarded as the relative animal movement. The vector amplitudes have been subsequently compared.

According to ASCAT data, the rate of sea ice drift in the locations of the female polar bear was low; therefore, parameters of the absolute and relative animal movements were similar. According to other datasets, the rate of absolute movement exceeded that

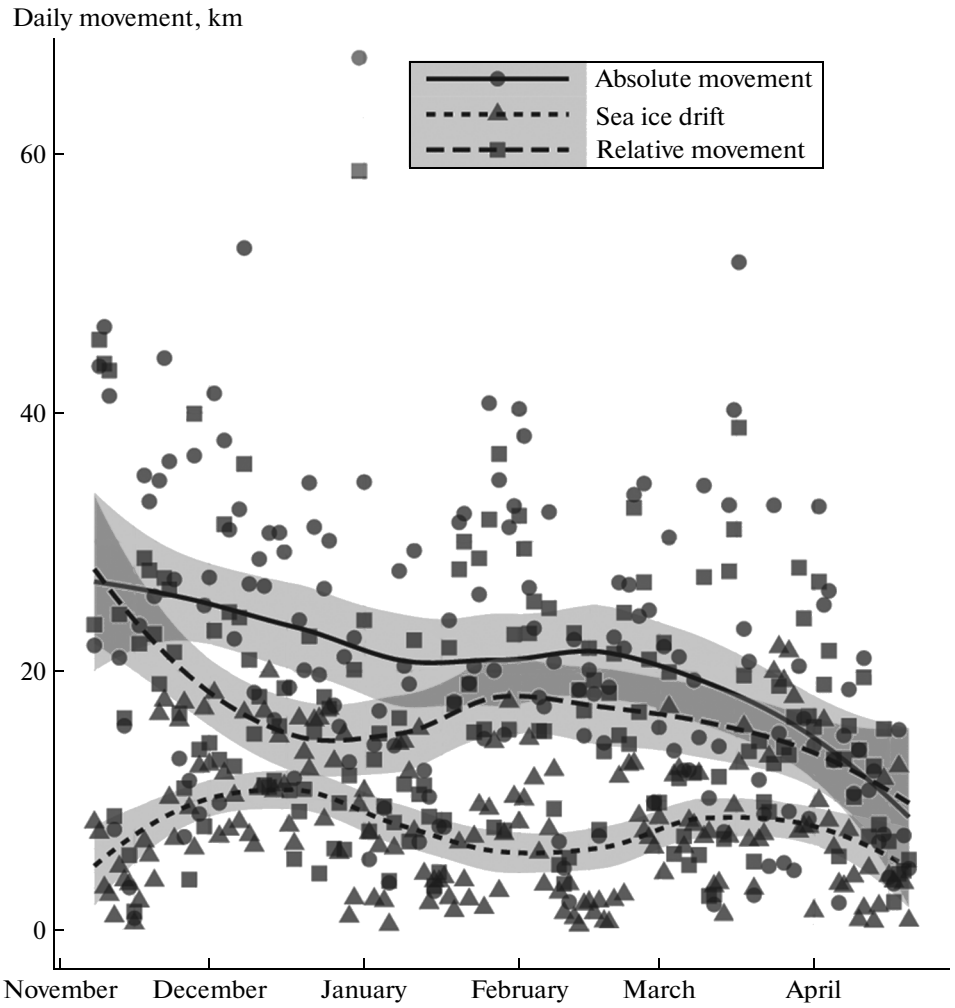


**Fig. 1.** Absolute relocations of the female polar bear during a day, the ice drift according to NSIDC, and movement of the animal in view of sea ice drift. The curves and shaded areas correspond to loess-smoothing [9] with a 95% level of significance.

of the relative movement, except for April 2011, when the female bear has reached the Spitsbergen archipelago, where sea ice dynamics is insignificant.

Figure 1 shows the absolute and relative movements of the female polar bear and the sea ice drift according to NSIDC data on the daily time scale. This is a general pattern of the female daily movements as determined from the data of other providers. The OSISAF dataset has been chosen for comparison with NSIDC data; the average daily ice drift was extracted with preservation of the coordinate grid.

The absolute and relative values of daily relocations of the female polar bear were similar at the beginning and the end of the period studied. When the sea ice drift was estimated, the rate of animal movement was 20.7 and 20.4 km per day according to NSIDC and OSISAF data, respectively. At the same time, the average daily sea ice displacement was 8.2 and 10.2 km per day according to NSIDC and OSISAF, respectively. The animal movement relative to ice drift was 16.7 and 17.5 km per day as determined using NSIDC and OSISAF data, respectively. The maximum absolute movement of the female polar bear occurred from December 31, 2010 to January 1, 2011; it travelled a distance of 67 km, while the animal movement relative to ice was as high as 58.7 km; the ice drifted over a distance of 9.6 km.

To estimate the size of the female polar bear home range, we used kernel (fixed contour) method [10] in an equal-area geographic projection to reduce the error values because of spatial distortions. From the geographical coordinates of the average daily locations, the absolute (geographical) home range of the female polar bear has been determined (in Fig. 2, this is the contour with a solid-color kernel [10]), while the relative area that is actually used by the animal was determined through correction of the animal movement trajectory with the sea ice taken into account (Fig. 3). It should be noted that, when assessing the actual home range of an animal (the area and shape),

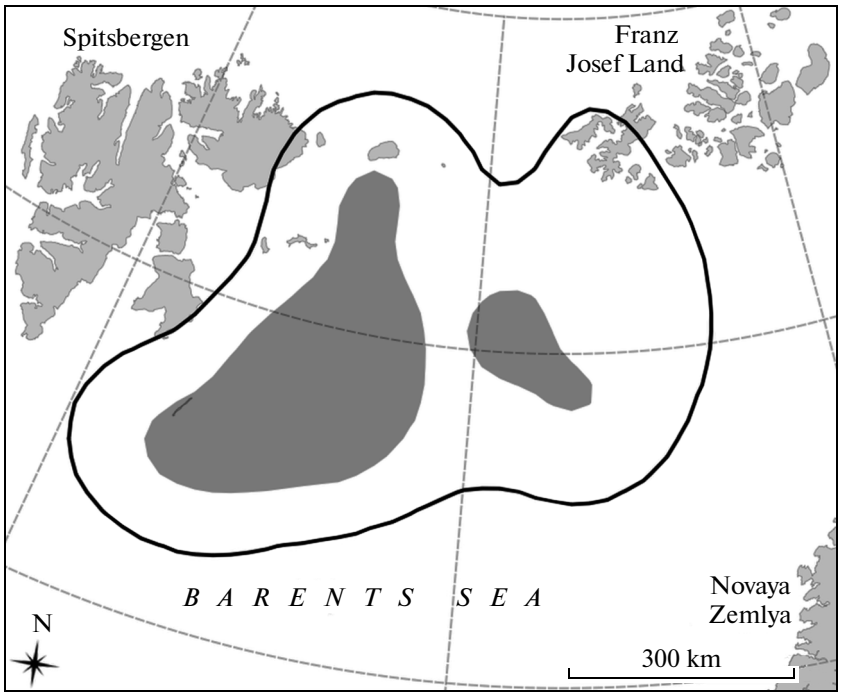


**Fig. 2.** Absolute home range (level 95%, contour) and kernel (level 50%, filled contour) of the female polar bear.

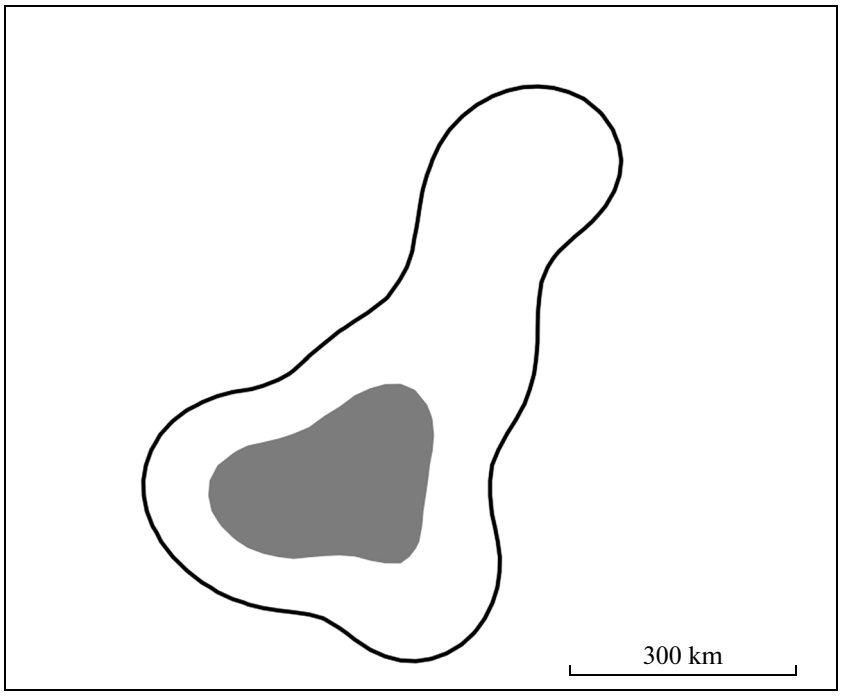


**Fig. 3.** The actually used home range (level 95%, contour) and kernel (level 50%, filled contour) of the female polar bear in relation to NSIDC sea ice motion data.

gridding cannot be used; nevertheless, the scale and direction of coordinate axes are retained.

The size of absolute home range (95% level) was 352 000 km$^2$, while that of the kernel (50% level) was 100 000 km$^2$. The relative area (with ice drift according to NSIDC data taken into accoujnt) covers 231 000 km$^2$, which is one-third less than the absolute home range. According to OSISAF locations relative to sea ice

drift, the relative area proved to be similar to the absolute home range (350 000 km$^2$). Relative to sea ice drift, the kernel area of the polar bear home range was 51 000 and 72 000 km$^2$ according to NSIDC and OSISAF data, respectively. In both cases, it was significantly smaller than the kernel of the absolute area, where there were two polygons, while in the relative area, there was only one.

The absolute home range is extended along the zonal direction and connected to the land on the north—the eastern Spitsbergen and western Franz Josef Land. The relative area is somewhat extended along the meridional direction according to both NSIDC and OSISAF data. Thus, zonal relocation of the female polar bear is a result of sea ice drift. Note that the animal preferred to stay near the ice edge in the autumn–winter period and to go away to the north at the beginning of the Arctic spring (April) [3].

Thus, the first quantitative data on the polar bear daily movements and the shape and size of its home range, in relation to sea ice drift, are useful for clarifying our notions about the animal movement patterns and home range.

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