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GENERAL BIOLOGY

Movement of a Female Polar Bear (*Ursus maritimus*) in the Kara Sea during the Summer Sea-ice Break-up

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Abstract—The polar bear movement trajectory in relation to onset date of the sea-ice break-up was studied in the coastal zone of the Taimyr Peninsula, eastern part of the Kara Sea, using as an example a female polar bear tagged by a radio collar with an Argos satellite transmitter. Analysis of the long-term pattern of ice melting and tracking, by means of satellite telemetry, of the female polar bear who followed the ice-edge outgoing in the north-eastern direction (in summer 2012) suggests that direction of the polar bear movement depends precisely on the direction of the sea-ice cover break-up.

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The life features of many arctic mammals depend on sea ice. For the polar bear (*Ursus maritimus*), early ice melting and late seasonal ice formation increases duration of the adverse period. Ice melting is accompanied by a shift of the ice—water boundary towards the deepwater Arctic basin, where food accessibility is lower and polar bears are forced to go to land.

In 1994—1997, female polar bear ice habitats in the western Russian Arctic, the Kara Sea, were studied using the Ocean-01 synchronous satellite to determine the ice type and concentration preferences of these animals [1]. The data of this report suggest that in the Kara Sea, in summer, polar bears are moving in the northeastern direction. The same is supported by the results of our interviewing in 2010 of the Cape Sterlegov station staff, who observed the polar bear movement along the Kara Sea coast from west to east. However, there is no comprehensive survey of reasons for such a movement of polar bears.

Much attention is paid to the polar bear strategy of space use, especially in connection with changes in ice habitats [2—4]. The polar bear female displacements during different seasons have been discussed in a number of reports [5—7] and even the average speed has been estimated for an individual female bear on the way from northern Alaska to Greenland [8]. But it is still unclear how migration of an individual animal depends on the ice break-up timing.

The object of this study was to determine the influence of the arctic marine phenology on the direction of the polar bear movement. A polar bear female has been tagged by a satellite transmitter and the trajectory of its movement was studied in relation to the sea-ice break-up onset date in the coastal zone of Taimyr Peninsula in eastern part of the Kara Sea.

In the framework of a project for the polar bear tagging by the satellite transmitters on the Pyasinsky Bay islands, the Kara Sea, an adult female and its yearling cub were immobilized on May 22, 2012, at 8:43 a.m. UTC. The search for a suitable animal was conducted on board of a Mi-8MTV helicopter above the stable fast ice 5 km away from its edge (to prevent that a polar bear gets into water after the drug administration). The animal was immobilized by a combination of medetomidine (Domitor preparation from ORION, Finland, 40 μg/kg body weight) and a mixture of tiletamin/zolazepam (Zoletil preparation from Virbak, France, 3 mg/kg), which were administered using a DAN-Inject JM-25 distant injector (DAN-INJECT, Denmark). After immobilization, the animal state monitoring was conducted permanently every five minutes up to restoration of motor activity. After completion of the procedures, the antidote Antipamezol was administered (Antisedan from ORION) at a dose of 10 mg per animal.

The collar of the Argos system from Es-Pas, Russia, which was dressed on the polar bear female, was operating until August 8, 2012. During this period, 1482 messages were obtained on the Argos system site (www.argos-system.cls.fr) with coordinates that were filtered by the Kalman Kalman Filtering algorithm. When studying the trajectory of the polar bear movement, some locations were evaluated as false and excluded from analysis. Using the remaining 1132 locations, a type II trajectory [9] was constructed with

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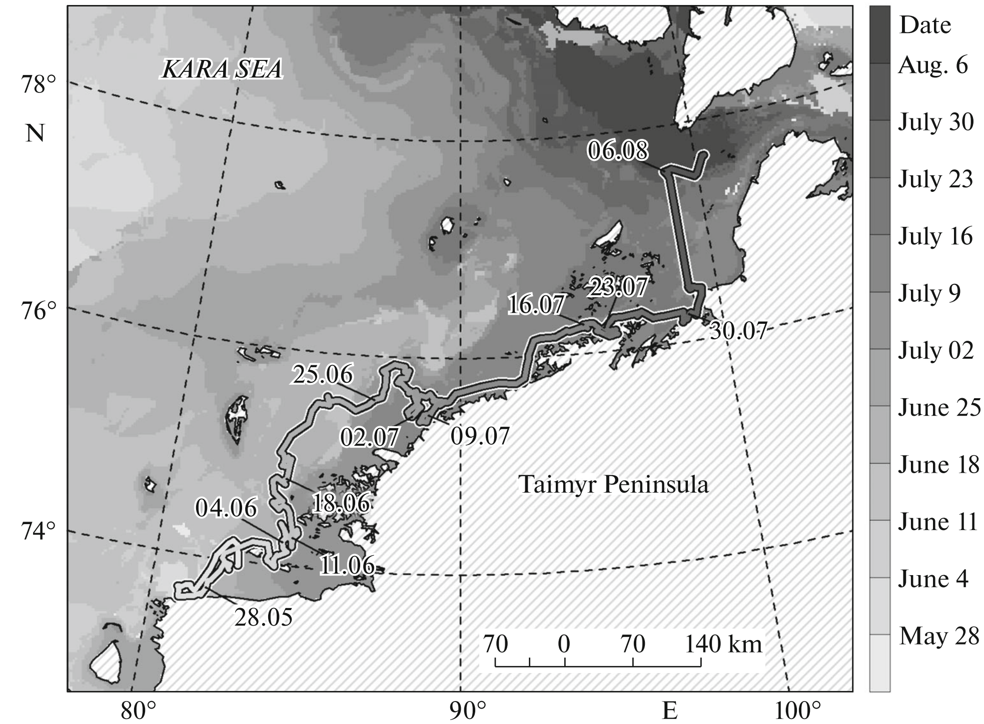

Fig. 1. Trajectory of the female polar bear labeled with a satellite transmitter and the sea ice-break-up dates. Grayscale of trajectory line and sea-ice melting map corresponds to a single legend on the right (in the DD.MM date format).

305 coordinates at 6-h time intervals, with time points at midnight, 6 a.m., noon, and 6 p.m. (unlike the *route* parameter, the *trajectory* parameter not only displays connected locations, but also includes information about the time of a given animal location). The distance covered by the female polar bear for 78 days of tracking makes up about 1730 km.

We were studying the female bear movements in relation to the seasonal ice state. To characterize ice phenology, we used the method developed by us to assess the ice break-up and formation onset dates throughout Arctic using the data on ice concentration and in accordance with ice charts. The ice break-up onset dates in the Kara Sea was determined with the search tools for structural changes in the time series of ice conditions developed for each node of the coordinate grid with a spatial resolution of 2.5 km on the ice charts of National Ice Center (United States) (http://www. natice.noaa.gov/), which are daily vector charts of the solid and scattered ice boundaries (concentrations of 80–100% and 15–80%, respectively). Based on these data, the ice concentration was reconstructed at three levels: 0%, open water; 45%, open ice; 90%, close ice. The abscissa value was taken as the date of ice melting when the fitted function concentration was lower than 22.5%. The long-term annual charts of ice disappearance with a resolution of 25 km have been constructed for the period 1988–2012 on the basis of data on ice concentration from the SSM/I and SSMIS microwave radiometers.

The resulting time series of ice concentration was approximated by a function with the minimum square error from a set of asymptotic functions (the piecewise constant function, Gompertz function) and the functions with a maximum (the piecewise constant function, asymmetric Gaussian function), which reduced an error of the ice melting terms as compared to the methods without approximation. To determine the female bear locations in time and with respect to ice and water, the trajectory of animal movement divided into segments according to the dates of their passing by, was superposed on the phenological ice chart, and an integrated chart was obtained where the female bear movement was synchronized with the sea ice spring phenology.

The polar bear locations determined via the satellite transmitters are usually used to outline the polar bear habitats and for modeling the resource selection function [10–12]. In this study, we have evaluated for the first time the relationship between the polar bear movement and spring phenology of the Arctic sea ice.

Figure 1 shows the trajectory of the female polar bear movement according to the data of satellite telemetry in summer 2012 in the Kara Sea. The basemap showed the spatial distribution of the ice break-up dates in the eastern part of the Kara Sea. Sea opening continued mostly from southwest to northeast. The female bear stayed initially on ice, but after its break-up, it moved overland in the northeastern direc-

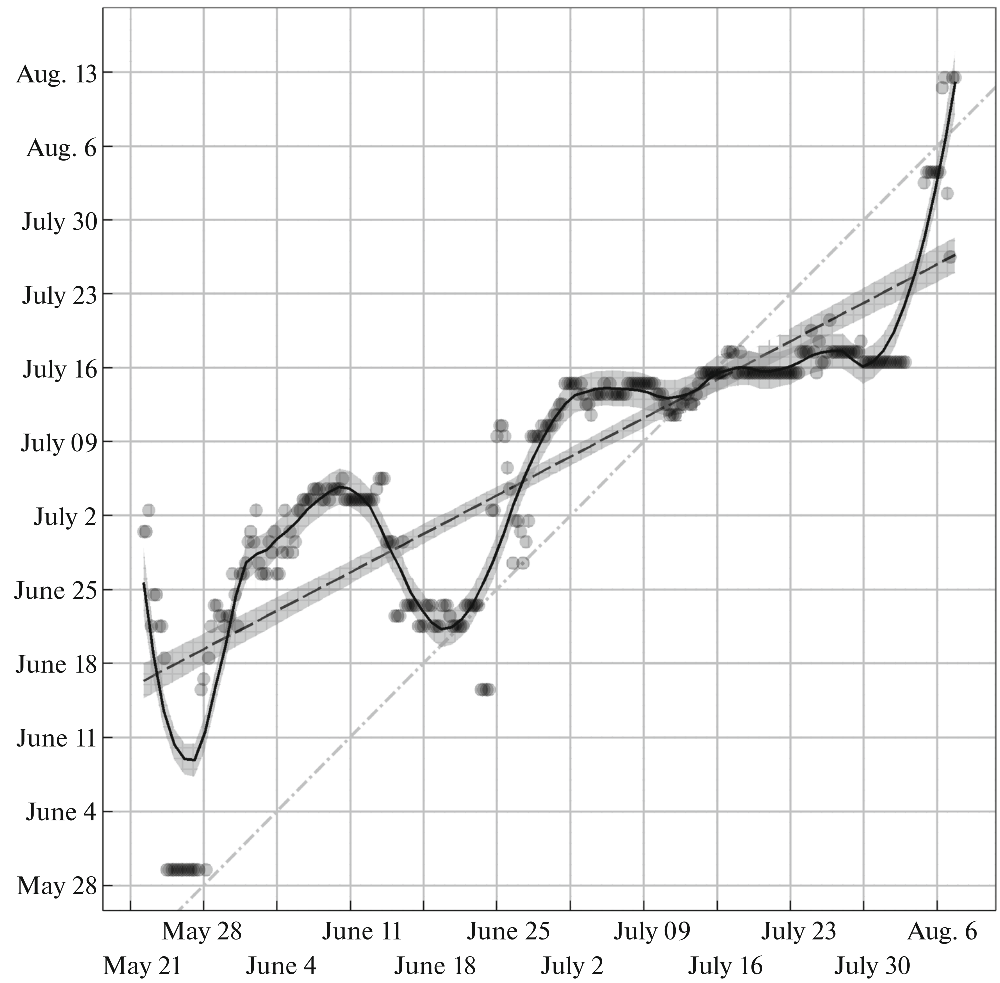

Fig. 2. Correspondence between dates of the female bear locations and the ice break-up dates. *X* axis, dates of the female bear locations; *Y* axis, dates of the ice break-up on the sea region nearest to the female polar bear location. Continuous line and dotted line indicate non-linear and linear approximation of the point distribution, respectively; the dash-dotted line, date equality on both axes. Shaded areas along the approximation lines correspond to 95% confidence interval.

tion; in early August, the animal made a swim off the coast towards the north to reach the remaining ice in the Vilkitsky Strait.

On ice, the polar bear was mostly moving along the coastal zone and transited small islands. Only once did it go away a considerable distance from the coast (at least 20 km) in the period from June 17 to June 28. From June 15 to 20, the bear turned out on the small ice floes because of rapid ice melting, but it went up again on the solid ice. On July 15, the female bear appeared for the first time on the coastal land, where it was mostly staying later. When moving over the land, the bear was sometimes swimming across the ice-free areas; in particular, on July 25–26, it crossed the Taimyr Strait. By the end of July, it reached the Oskar Peninsula, and on August 3–4, the bear moved towards a range of non-melted ice by swimming across 110 km (on August 1 to 6, the wind speed weakened and the animal was swimming in the northern direction under the western cross wind).

Figure 2 shows the correspondence between dates of the bear locations and the dates of ice break-up. Separate time intervals of the female bear trajectory with the local range size of 0.2 were studied by the Loess method [13] using approximation of point distribution (Fig. 2, solid line). The slope of each segment of the trajectory indicates either leading or lagging of the female bear movement in relation to the moment of ice melting. The point position relative to the date equality line (Fig. 2, dashed line) reflects the presence of either ice or open water in vicinity of the female bear: the higher the point position relative to this line, the more time the bear has until the moment of ice melting; the lower the point position, the larger the female bear lagging relative to this moment. Periods of better and worse ice conditions for the female bear can be seen: on June 23–24, the animal was catching up the melting ice, on July 10–14, the animal was in the melted ice area, and after July 17, it was staying mainly on land and fast ice. The regression straight (Fig. 2, dotted line) reflects a straight tendency of the entire period of observations; the slope angle indicates that the female bear movement was slower than the ice melting; i.e., the animal was lagging: an increase in the distance between female bear and the melting ice that started in July 14 (intersection of the regression curve and the date equality line) forced the animal to landfall. From the August 3 to 4, the female bear was moving again towards the preserved ice and reached it.

Comparison of the female bear trajectory and the ice phenology in the Kara Sea showed that the northwestern direction of animal movement coincided with the direction of the sea-ice cover break-up. In 1988–2012, the prevailing sea-ice break-up occurred in the northeastern direction, as estimated from the many-year mean annual chart of ice vanishing: the northern points of the compass (NW, N, NE) account for 53% of the water range; the eastern ones (NE, E, SE), for 44%. This is consistent with the radio-collared polar bear displacements studied by us in summer 1994 and 1995 [1] as well as with the results of interviewing in 2010 of the Cape Sterlegov polar station staff. In 2012, the sea-ice break-up also occurred mostly in the eastern and northern directions (NE, E, SE points of the compass account for 55%; and NW, N, NE points, for 54%) which is in accordance with the average data of the many-year observations.

Matching of the ice melting direction and that of the polar bear movement extends the time of animal's staying on ice and may help to avoid their landfall in the ice-free period.

Thus, the data of satellite telemetry of the female bear movements in the northeastern direction, following the outgoing ice edge, in summer 2012, as well as the many-year pattern of ice melting, support the results of our analysis of the polar bear movement in summer 1994–1995 [1] and the data of interviewing (in 2010) of the Cape Sterlegov station staff. Hence, it is the direction of the sea ice break-up typical of the Taimyr coast that determines polar bear movement in the same direction.

Note that it is important to know the directions of the polar bear movements in different seasons as well as the reasons for choosing of certain directions in order to understand animal adaptation to the varying ice conditions, and to develop measures for preventing the human–animal conflicts, which become more frequent with expansion of the human presence in the Arctic.

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