ISSN 1067-4136, Russian Journal of Ecology, 2011, Vol. 42, No. 2, pp. 151–160. © Pleiades Publishing, Ltd., 2011.
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Routes and Intensity of Geese Migration over Northern Sakhalin and the Mainland Part of Tatar Strait

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Received March 26, 2010

Abstract—The intensity of geese migration has increased since 2005, and its routes have shifted eastward. The main migration route of the geese previously passed over the northwestern Sea of Okhotsk, far from the coast; since 2005, however, a major migration flow has been recorded over northern Sakhalin and the mainland part of Tatar Strait. A probable factor accounting for this shift is a change in weather conditions and, in particular, in the circulation of air masses over the northwestern Sea of Okhotsk.

Keywords: geese, migration, flight dates, numbers, northern Sakhalin, Tatar Strait.

DOI: 10.1134/S1067413611010139

Sakhalin Island is located on the East Asian–Australasian flyway. Its diverse and extensive wetlands and coastal biotopes offer a major resting and feeding stopover opportunity to numerous shorebirds and waterfowl. In particular, this concerns anseriform birds, which account for 63% of all birds recorded on the island. Due to the abundance and diversity of biotopes attracting hundreds of thousands of birds, almost the whole northeastern coast of Sakhalin, with numerous lagoon-type bays, is on the list of Russian wetlands of international importance according to the criteria of the 1971 Ramsar Convention (*Vodno-bolotnye*..., 2000).

Since the late 20th century, active development of natural resources in the Sea of Okhotsk shelf has been in progress, involving the construction of oil and gas pipelines, petroleum industrial facilities, etc. This situation stimulated scientists to pay more careful attention to the state of the biota in corresponding regions. Annual monitoring of nesting and migrating birds in northern Sakhalin and the mainland part of Tatar Strait has allowed us to trace changes related not only to anthropogenic impact (which is definitely strong in the region) but also to the cyclic pattern of natural processes and probable regional manifestations of global climate change.

MATERIAL AND METHODS

The material was collected in the course of long-term monitoring studies on the biology and abundance of waterfowl, which were performed on the northeastern and northwestern coast of Sakhalin from April to November of 1988–1991 and 1999—2009 and on the mainland coast of Nevelskoy Strait between the village of De-Kastri to the Tymi River on the north, mainly in autumn, in 2001–1008 (Fig. 1). Visual observations were made during the daylight period.

Data on winds were taken from three databases: ECMWF ERA-Interim (Berrisford and al., 2009), NCEP/NCAR Reanalysis 1 (Kalnay et al., 1996), and NCEP-DOE Reanalysis 2 (Kanamitsu et al., 2002). The first database contains provides data on the most complete set of meteorological and oceanographic parameters and also on parameters characterizing the ocean–atmosphere system over the period from 1989 to 2008. The spatial grid spacing in the database is 1.5 degrees latitude and longitude, and the time step is 6 h. The NCEP/NCAR Reanalysis 1 and NCEP-DOE Reanalysis 2 databases provide meteorological data over the periods from 1949 and 1979 to the present time, respectively, with a grid spacing of 2.5 degrees in either direction.

As a parameter characterizing the field of winds over the study region, we used space-averaged meridional (x) and zonal (y) components of the wind vector:

$$U = \frac{1}{S}\iint\limits_{S} u\,dx\,dy \quad и \quad V = \frac{1}{S}\iint\limits_{S} v\,dx\,dy,$$

where S is the area of the study region (integration is performed within its boundaries).

Attention should be paid to quantitative indices of atmospheric circulation, which are widely used in meteorological research. According to Kats (1959), these are values proportional to the average rate

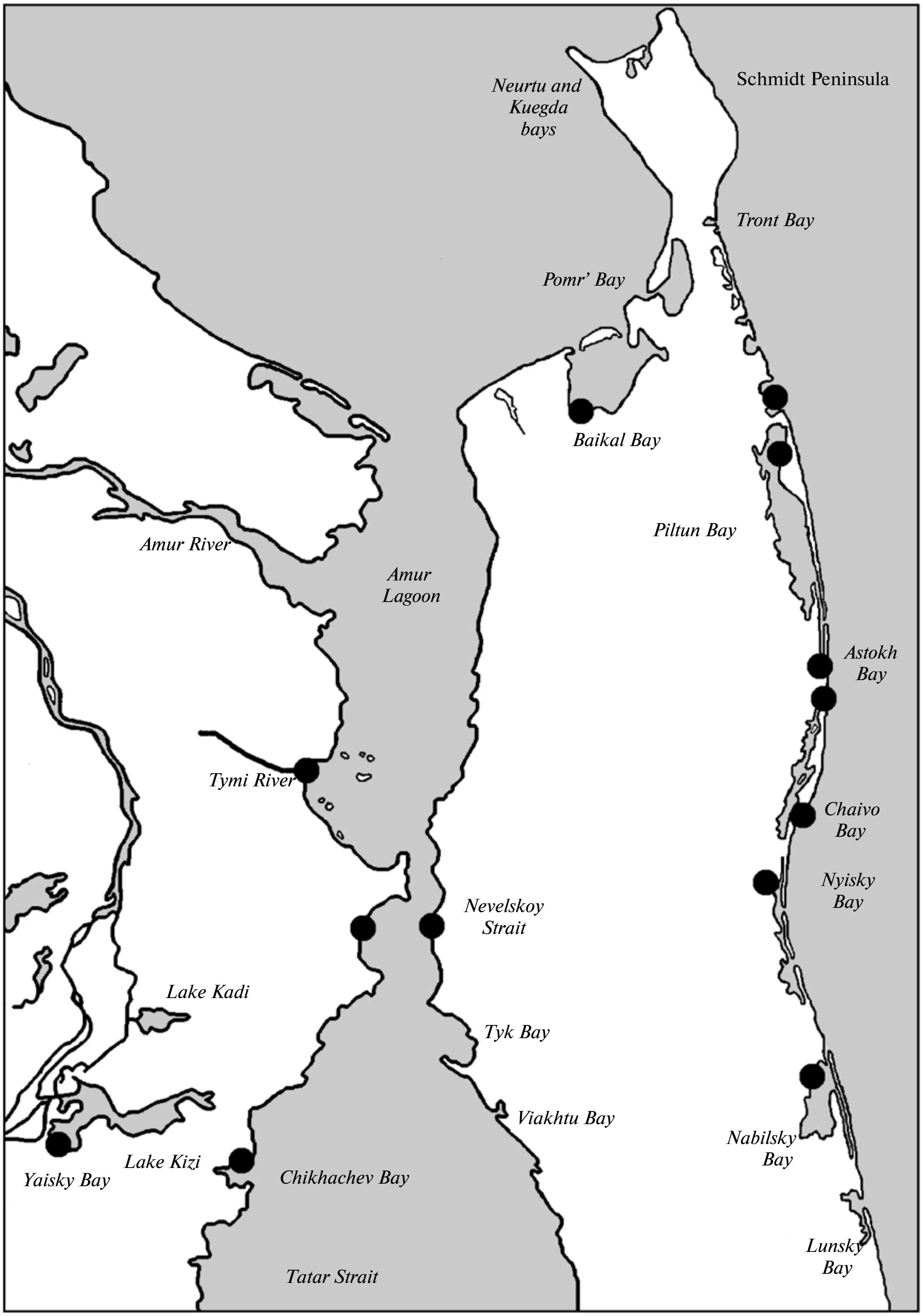

Fig. 1. Basic points of observations on geese migration over northern Sakhalin and Tatar Strait.

(per unit time) of latitudinal and meridional air mass transfer over a given area. Their advantage is that they may be calculated for an arbitrarily chosen region.

Under conditions of geostrophic movement in the region delimited by meridians x_1, x_2 and parallels y_1, y_2 (with the X and Y axes directed eastward and northward, respectively), the average zonal and meridional mass flows will be as follows:

$$M_\varphi = -\int_{y_1}^{y_2}\int_{x_1}^{x_2}\frac{1}{l}\frac{\partial p}{\partial x}\partial x\partial y \text{ и } M_\lambda = \int_{y_1}^{y_2}\int_{x_1}^{x_2}\frac{1}{l}\frac{\partial p}{\partial y}\partial x\partial y.$$

It is evident that, in case of geostrophic wind, these flows are equal to the zonal and meridional components of the wind vector integrated over the whole region of interest, i.e.,

$$SU = \iint_S u dxdy = -\iint_S \frac{1}{l\rho}\frac{\partial p}{\partial y}dxdy \text{ and}$$

$$SV = \iint_S v dxdy = \iint_S \frac{1}{l\rho}\frac{\partial p}{\partial x}dxdy.$$

Assuming that the region is small and density over it remains constant,

$$SU = \frac{1}{\rho}M_\varphi \text{ и } SV = \frac{1}{\rho}M_\lambda.$$

Thus, the Kats index in our case is equal, within the accuracy of the multiplier, to the space-averaged wind vector.

RESULTS AND DISCUSSION

Geese regularly occurring in northern Sakhalin in the period of spring migrations are as follows: the black brant *Branta nigricans* (Lawr.), greater white-fronted goose *Anser albifrons* (Scop.), lesser white-fronted goose *A. erythropus* (L.), been goose *A. fabalis* (Latham), and swan goose *A. cygnoides* (L.). On the Tatar Strait coast, this group additionally includes the greylag goose *Anser anser* (L.) and emperor goose *A. canagicus* (Sew.), the latter being a vagrant species.

The spring migrations of geese start in late April to early May, when ice-free areas begin to appear in the sea, bays, and straits. The appearance of such areas in the sea stimulates the onset of migrations, which, therefore, may be delayed for up to 10 days in northern regions of the coast. The earliest arrival of migrating geese in northern Sakhalin (Piltun Bay), as well as on the mainland coast (Tablo Bay), was recorded on April 25, 2008; the latest arrival, on May 17, 1991, in Chaivo Bay. Geese migrations in different parts of the study region come to an end almost simultaneously, the earliest and latest recorded dates of this event are May 8, 1990 and May 31, 2000 (both in Chaivo Bay). The duration of the spring migration (from the appearance of the first geese to the flight of the last flock) was the longest in 2000 (35 days, from April 27 to May 31) and in 1988 (27 days, from April 26 to May 22), averaging 16 days over the whole observation period ($n = 9$).

Autumn migrations begin in September to October, depending on conditions of the season. The earliest records of autumn migrants were made in northern Sakhalin on September 9, 2000; the latest records, on November 10, 1990. The earliest and latest departure dates were September 25 (2004) and November 2 (1990 and 2001). The duration of the autumn migration reached 51 days (from September 6 to October 26) in 2005 and 48 days (from September 16 to November 2) in 2001 and decreased to only 9 days in 2004, averaging 28.5 days over the observation period ($n = 12$).

The altitude of geese flight depends on the weather, terrain topography, and disturbance factor. Low-flying flocks (at 10–30 m) occurred over water in windy and foggy weather. Over land, geese rarely flew below 50–70 m and above 500–700 m. The most common flight altitudes were 150–300 m

During the spring migration, geese flew singly (34 records), in pairs (29 records) or in flocks of 3 to 300 birds (360 records). In most cases, the flocks consisted of 3–20 (39.2%), 21–40 (20.3 %), or 41–60 ind. (13.3 %). The average flock size was 53.7 ind. In the autumn period, geese also migrated singly (26 records), in pairs (45 records), or in flocks of 3 to 300 ind. (2184 records). Most flocks consisted of 3–20 (45.2 %), 21–40 (27.2 %), or 41–60 ind. (12.7 %), with their size averaging 36.8 ind.

The greatest numbers of geese per season were recorded in the spring of 2007 (14 338 ind.) and in the autumn of 2008 (45 203 ind.). Peaks and lulls of migration activity (as a rule, one peak per season) took place both in spring and autumn. The highest intensity of spring migration was observed in May 11, 2007 in Nevelskoy Strait, where 13 880 flying geese were counted (96.8% of all geese recorded that spring in northern Sakhalin). On May 10 and 11, 2008, records of 2106 and 2792 migrants were made in Baikal Bay (21.9 and 38% of the total number of geese, respectively). The peak of spring migration in 1988, 2000, and 2005 was observed on May 8.

The autumn migration reached a peak in late September to early October. Thus, 85.4% of all geese recorded that season in northern Sakhalin (6220 ind.) were counted during the daylight period in Piltun Bay on September 30, 2006; 63.4% (9514 ind.), in Chaivo Bay on September 30, 2007; and 90.5% (23220 ind.), in Baikal Bay on September 29, 2008. On the mainland coast, the most active migration was observed in the south of the Amur Lagoon on September 29, 2008 and near the village of De-Kastri on October 5, 2005: 13580 and 1911 ind., or 69.4 and 31.3%, respectively. Peaks of autumn migration also took place on September 18 (1988 and 1989) and September 25 (2000).

Our long-term observation and analysis of published data on migrations of anseriform birds (Eremin

Numbers of migrating geese recorded in the study area

Year	Northern Sakhalin		Mainland coast	
	Spring	Autumn	Spring	Autumn
1988	1258	415	–	–
1989	130	596	–	–
1990	10	46	–	–
1991	2	322	–	–
1999	–	617	–	–
2000	824	1025	–	–
2001	120	103	–	82
2002	–	144	25	–
2003	–	36	–	–
2005	848	–	–	6096
2006	1689	7281	10	–
2007	14328	15008	10	6797
2008	9743	25638	605	19565

and Voronov, 1984; Nechaev, 1991; 1996; Blokhin and Tiunov, 2004) allowed us to reveal the main directions of geese migration.

Geese migrate over the whole northern Sakhalin, forming two main migration flows along the eastern and western coasts. The eastern and western flows intercross and augment each other, forming a network of smaller fluxes (Fig. 2). The eastern flow consists mainly of birds flying directly from Kamchatka to the region of northern Piltun Bay, where they join the flow of geese flying from Pomr' Bay on the northwestern coast (Fig. 3). Some geese then migrate directly across Sakhalin and the Amur Lagoon to the Tymi River valley and then to the Amur, while others travel south, to Chaivo and Nyisky bays. In the region of these bays, the majority of geese fly across the island southwestward, to Tyk Bay; then, some birds fly south along the southwestern coast, while others cross the Tatar Strait, arrive to the region of Chikhachev Bay, and move farther, to Lake Bolshoe Kizi and the Amur.

Geese migrating over the northwestern Sea of Okhotsk and approaching Sakhalin form the western migration flow, which is generally directed from Neurtu and Kuegda bays on the Schmidt Peninsula to Baikal Bay. In this segment, however, the birds may take some other routes leading to Baikal Bay. From this region, geese fly either to the Amur mouth or to the Tengi River mouth and then, across the Amur Lagoon, to the Tymi valley, joining the birds flying from Piltun Bay. In addition, some geese flocks migrate along the western coast, over Nevelskoy Strait to Tyk Bay and farther south and southwest, joining with eastern migration flow (Fig. 3).

The schematic map in Fig. 3 shows a generalized picture of migration routes, and it should be noted that the amount of traffic along each route or its branch naturally differ between individual seasons. Geese also may migrate along routes hardly accessible for direct observation, e.g., over the northwestern Sea of Okhotsk, far from the coast. We consider that such migration (away from observation stations) was a natural and regular phenomenon before 2005, when the recorded number of geese flying over Sakhalin during the daylight period did not exceed 1500 ind. per season. In addition, many birds could transit over northern Sakhalin at night. The situation began to change in the autumn of 2005, when more than 6000 migrating geese were recorded near the village of De-Kastri between September 21 and October 7 (table).

Observations in northern Sakhalin were not performed that autumn, and changes in migration intensity in this region were detected only beginning from the spring of 2006, when more than 1500 migrating geese were recorded. Of greater interest is the autumn of 2006, when their number reached 7000 ind., exceeding the results of observations over the previous 18 years by a factor of four. In the subsequent autumn periods of 2007 and 2008, the numbers of geese recorded during daylight hours increased to 15000 and 26000, respectively. The numbers of these birds recorded in spring also increased, reaching 14000 in 2007 and 10000 in 2008 (table).

The causes of the abrupt increase in the numbers of geese recorded per season are not yet clear. One of the reasons why this phenomenon attracted our attention is that the authors of available reviews report a decline of geese populations almost throughout eastern Asia (Syroechkovskiy, 2006; Andreev, 2009). Apparently, there has been some shift in the choice of preferred migration routes, with consequent increase in the amount of traffic along those passing over Sakhalin.

A probable factor accounting for this shift may be a change in weather conditions and, in particular, in the circulation of air masses over the northwestern Sea of Okhotsk. To conform this assumption, we analyzed interannual variation in the field of winds over the region comprising the northern part of Sakhalin and part of the northwestern Sea of Okhotsk (140–150°E, 50–60°N). In the period of geese migrations, the summer monsoon changes to the winter monsoon and, hence, zonal winds over the study region are weak and unstable. The highest absolute values of wind velocity were 1.5 m/s (northerly wind) in 1995 and 2007, and 1 m/s (southerly wind) in 1996. Meridional winds were several times stronger but also unstable, with the highest recorded velocities being 3 m/s (westerly wind) in 1998 and 2004, and 2 m/s (easterly wind) in 1996.

Of special interest is the period since 2004, when the geese migration flow has increased. According to the diagram in Fig. 4a, this year also marks the beginning of the period with higher values of the meridional wind component, including the second peak of westerly winds. This period continued until 2007, when the values dropped abruptly. A comparison of data on winds from different databases showed their good

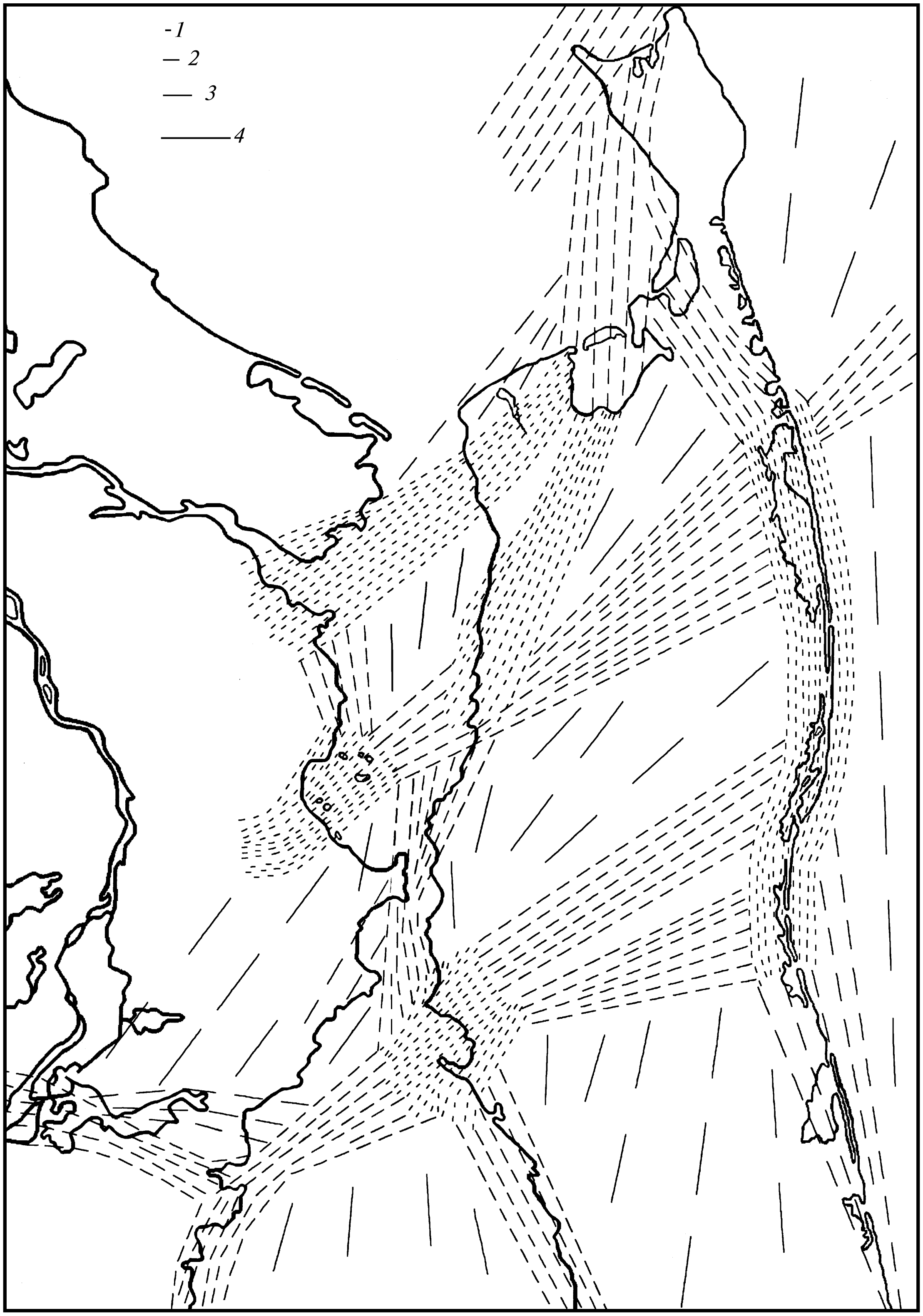

Fig. 2. Main fluxes of geese migration over the study area: (*1*) more than 10000 ind., (*2*) 1000–10000 ind., (*3*) 100–1000 ind., and (*4*) less than 100 ind. per season.

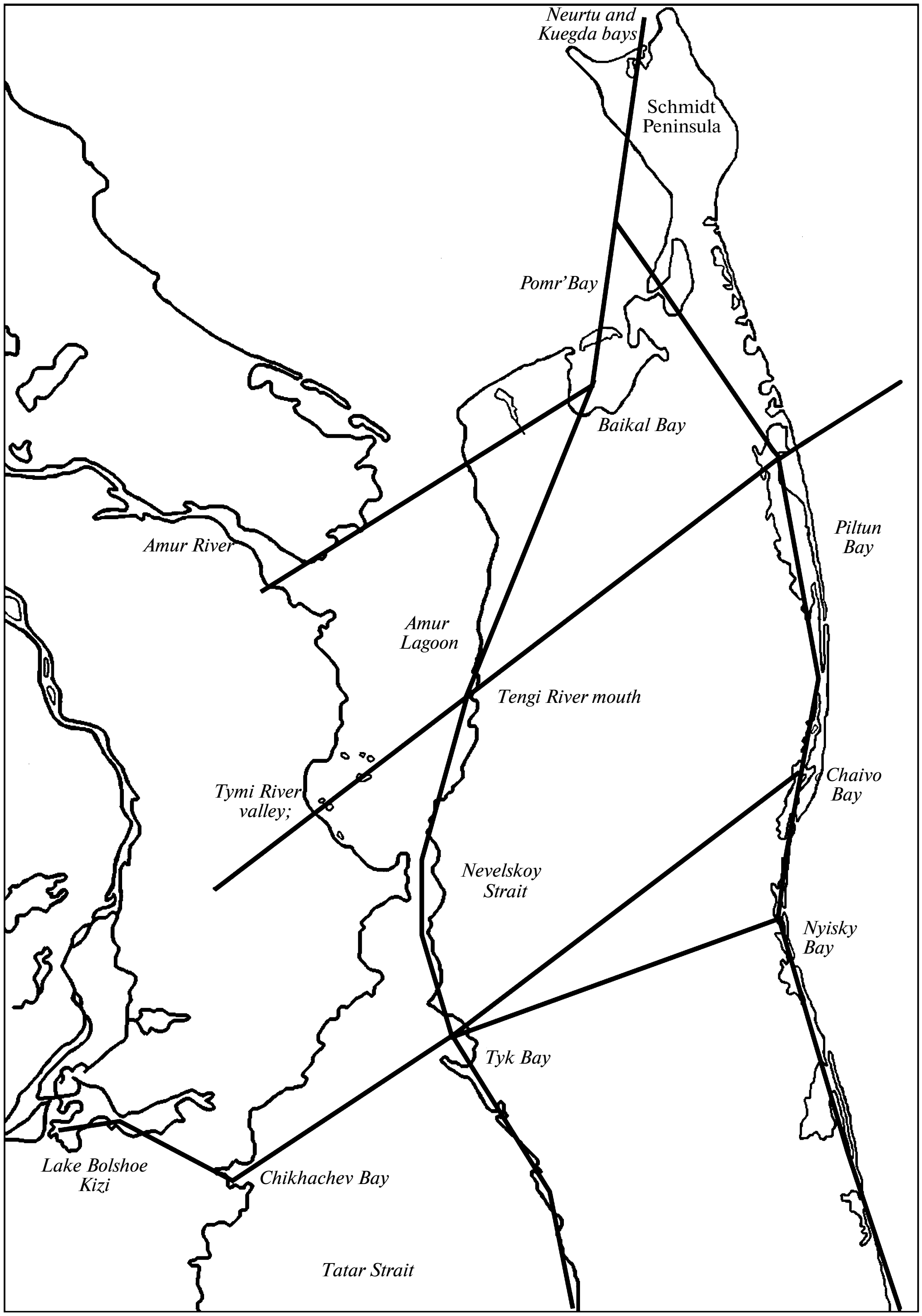

Fig. 3. Main routes of geese migration over the study area.

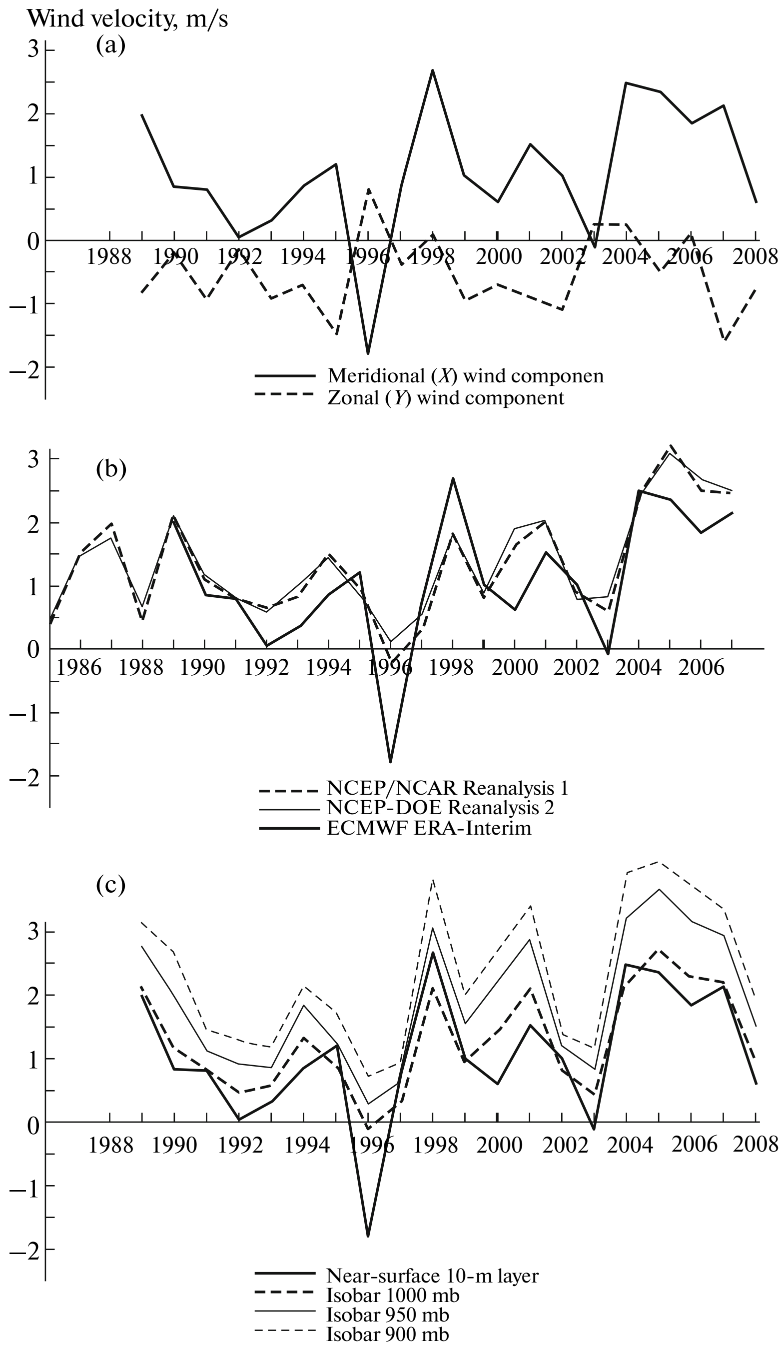

Fig. 4. Interannual variation in spatially averaged meridional and zonal components of the wind vector: (a) according to ECMWF ERA-Interim data, (b) according to different databases, (c) at different altitudes (according to ECMWF ERA-Interim data).

agreement with each other (Fig. 4b). To analyze winds at different latitudes, we calculated average values of the meridional component of the wind vector on different isobaric surfaces. In particular, we chose the 1000-, 925-, and 850-mb isobars (NCEP-DOE Reanalysis 2) and 1000-, 950-, and 900-mb isobars (ECMWF ERA-Interim), which approximately corresponded to altitudes of 100, 700, and 1400 m (NCEP-DOE Reanalysis 2) and 100, 300, and 800 m (ECMWF ERA-Interim) (Figs. 4c, 5a). A visual analysis of winds at different altitudes showed that wind velocity at 1 km is approximately twice higher than at the ground surface and, more importantly, insignificantly changes depending on wind direction. A noteworthy fact is that the peak recorded in 2004 is the global maximum over the whole observation period, which is clearly seen in Fig. 5b based on the NCEP/NCAR Reanalysis 1 data.

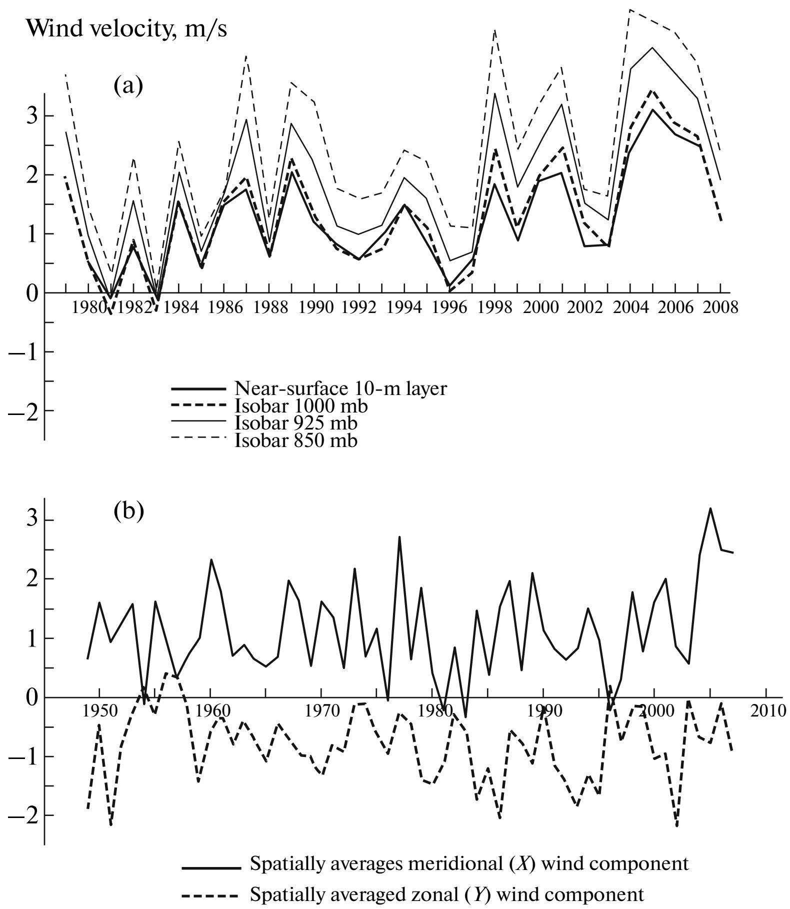

Fig. 5. Interannual variation in spatially averaged meridional and zonal components of the wind vector: (a) at different altitudes (according to NCEP-DOE Reanalysis data); (b) according to NCEP/NCAR Reanalysis 1 data.

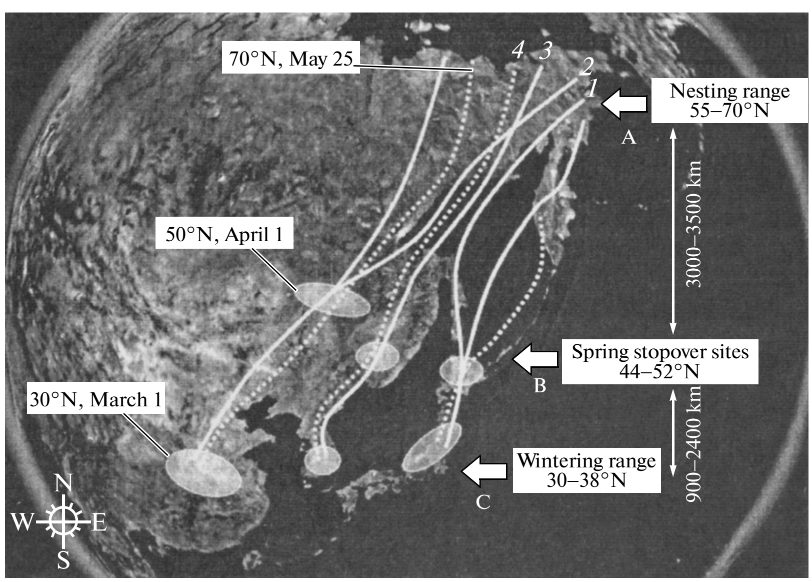

Fig. 6. Scheme of migration routes of the tundra bean geese (broken lines) and greater white-fronted geese (solid lines) in north-eastern Asia (according to Andreev, 2009).

The numbers of migrating geese accessible for observation began to increase in 2005, whereas the peak of the westerly wind was recorded in 2004, one year previously. Moreover, the drop of the meridional wind component in 2007 was also followed by an increase in the numbers of recorded migrating geese in 2008. According to the results of our observations in 2009, the number of recorded geese decreased again to 300 ind. in spring and 2491 ind. in autumn. Thus, geese appear to respond to changes in natural–climatic conditions with a 1-year delay.

In a recent study on geese migration in Asian Russia (Andreev, 2009), the author gives a scheme of migration routes of the tundra been geese and greater white-fronted geese in northeastern Asia. To illustrate events that have taken place between 2005 and 2008, we also present this scheme with necessary annotations (Fig. 6). It can be seen that the existing migration routes pass west of northern Sakhalin; therefore, strong westerly winds can displace these routes eastward, so that they would cross the northern part of the island, which is in good agreement with our observations.

Another probable factor accounting for the increase in the number of recorded migrating geese is the choice of a different wintering range and consequent changes in the migration routes of some geese that have wintered in Japan. It is known that the number of greater white-fronted geese wintering in Japan has increased since 1988 by a factor of more than seven, reaching about 110000 ind. in 2007 (Shimada and Mizota, 2008). At the same time, the number of geese wintering in China has decreased (Cao et al., 2008a), whereas that in Korea has increased (Han et al., 2003; Li and Mundkur, 2004). It is considered that the increase of the wintering geese population in Korea is accounted for not only by its natural growth but also by bird immigration from wintering grounds in China (Syroechkovskiy, 2006). This phenomenon is attributed to the influence of anthropogenic factors stimulating the change of preferred wintering area and also to global climate change, in particular, rise of winter temperatures in Korea, which has probably contributed to stabilization of the wintering geese population. It may well be that some geese have also migrated from their wintering grounds in Japan to those in Korea, but this assumption can be verified only by means of well-coordinated international censuses and large-scale color tagging of geese in the region.

Moreover, changes in weather conditions, including wind direction and velocity, may have an influence on the diel activity of geese, stimulating them to migrate during the daylight period and thereby producing an effect on the number of birds recorded. It is apparent that all factors considered above can complement each other.

Thus, the most probable factors accounting for the increase in the number of geese migrating over northern Sakhalin are as follows:

(1) Changes in the circulation of air masses over northern Sakhalin and the northwestern Sea of Okhotsk. The causes of this phenomenon is even more difficult to explain than its consequences, and we can only assume that this is a manifestation of global climate change.

(2) The choice of a different wintering ground and shifts in the migration routes of some geese that have wintered in Japan.

REFERENCES

Andreev, A.V., Geese in Northeastern Asia: Individual Energetics and Population Dynamics, *Kazarka* (Moscow), 2009, vol. 12, no. 1, pp. 11–32.

Berrisford, P., Dee, D., Fielding, K., et al., The ERA-Interim Archive: Technical Report, *ERA Report Series*, 2009, no. 1, pp. 1–16.

Blokhin, A.Yu. and Tiunov, I.M., Monitoring of Nesting and Migrating Game Birds in Northern Sakhalin, *Vestn. Okhotoved.*, 2004, vol. 1, no. 2, pp. 186–194.

Cao, L., Barter, M., Lei, G., and Yang, Q., Anatidae in the Yangtze Floodplain in Winter 2004 and 2005, *Kazarka* (Moscow), 2008a, vol. 11, no. 2, pp. 146–160.

Cao, L., Wang, X., Wang, Q., and Barter, M., Wintering Anatidae in China: A Preliminary Analysis, *Kazarka* (Moscow), 2008b, vol. 11, no. 2, pp. 161–180.

Eremin, Yu.P. and Voronov, G.V., Autumn Migration of Anseriform Birds over Northern Sakhalin, in *Ekologo-fenologicheskie issledovaniya Sakhalinskoi oblasti* (Ecological and Phenological Studies in the Sakhalin Region), Vladivostok: Dal'nevost. Nauchn. Tsentr Akad. Nauk SSSR, 1984, pp. 136–138.

Han, S.-W., Yoo, S.-H., Lee, H., et al., A Study on the Wintering Population of Geese in Cheolwon, Korea, *Proc. 2003 Int. Anatidae Symp. in East Asia and Siberia Region*, Seosan, Korea: Hanseo Univ., 2003, pp. 95–101.

Kalnay, E., Kanamitsu, M., Kistler, R., et al., The NCEP/NCAR 40-Year Reanalysis Project, *Bull. Am. Meteorol. Soc.*, 1996, vol. 77, pp. 437–471.

Kanamitsu, M., Ebisuzaki, W., Woollen, J., et al., NCEP-DOE AMIP-II Reanalysis (R-2), *Bull. Atmos. Meteorol. Soc.*, 2002, pp. 1631–1643.

Kats, A.L., The Circulation Index As an Indicator of Zonal and Meridional Synoptic Processes, *Meteorol. Gidrol.*, 1959, no. 5, pp. 23–31.

Li, Z.W.D. and Mundkur, T., *Numbers and Distribution of Waterbirds and Wetlands in the Asia–Pacific Region: Results of the Asian Waterbirds Census, 1997–2001*, Kuala Lumpur, Malaysia: Wetlands International, 2004.

Nechaev, V.A., *Ptitsy ostrova Sakhalin* (Birds of Sakhalin Island), Vladivostok: Dal'nevost. Otd. Akad. Nauk SSSR, 1991.

Nechaev, V.A., Specific Features of Geese Migration over Sakhalin Island, *Kazarka* (Moscow), 1996, no. 2, pp. 268–275.

Revyakina, Z.V. and Zykov, V.B., Migration of Anatidae over Lunskoi Bay, Sakhalin Island, in *Ptitsy presnykh vod i morskikh poberezhii yuga Dal'nego Vostoka Rossii i ikh okhrana* (Birds in Fresh Waters and Sea Coasts of the Russian Far East and Their Conservation), Vladivostok: Dal'nauka, 1996, pp. 170–178.

Shimada, T. and Mizota, C., Temporal and Spatial Changes in Foraging Distribution of an Increasing Population of Wintering Greater White-Fronted Geese over One Decade (1997/98 to 2007/08): A Case Study for an Area around Lake Izunuma-Uchinuma, *Jap. J. Ornithol.*, 2008, vol. 57, no. 2, pp. 122–132.

Syroechkovskiy, E.E., Jr., Long-Term Declines in Arctic Goose Populations in Eastern Asia, in *Waterbirds around the World*, Boere, G.C., Galbraith, C.A., and Stroud, D.A., Eds., Edinburgh, UK: The Stationery Office, 2006, pp. 649–662.

Vodno-bolotnye ugod'ya Rossii (Wetlands of Russia), vol. 3: *Vodno-bolotnye ugod'ya, vnesennye v Perspektivnyi spisok Ramsarskoi konventsii* (Wetlands Listed as Prospective Sites under the Ramsar Convention), Krivenko, V.G, Ed., Moscow: Wetlands International Global Series, 2000, no. 3.