Features of migration and nesting of waterfowl in the zone of influence of the Siberian Chemical Combine (SCC)

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Abstract The flyby of waterfowl (Anseriformes) in the south-taiga zone of the Tomsk Prioby is associated with the valleys of large rivers. In natural landscapes, the migration process is largely determined by the nature of spring and weather conditions of a particular year. However, there are many cases when birds in an anthropogenically-transformed habitat “receive certain advantages” in comparison with natural landscapes. The observations were carried out in 1995–2001 on the reservoirs of the Tom River floodplain and on the system of inter-river technogenic settling reservoirs (reservoirs-coolers of the Siberian NPP) in the sanitary protection zone of the SCC (SPZ) of the SCC and closed administrative-territorial unit («ZATO Seversk»). Changes in the timing and intensity of the spring flyby, nesting density and success of reproduction of ducks depending on various natural and anthropogenic factors are traced. The majority of the waterfowl spring flies in transit and does not often use the reservoirs of the Tom River floodplain for rest and feeding, but willingly lingers on the rich food warmer waters technogenic of the SPZ of the SCC. For the first time, significant differences were established in the species composition, abundance, biotopic distribution, and success of duck nesting in natural and man-made reservoirs: in years with early and late springs, in years with different water levels in reservoirs with regulated flow. For the first time, an assessment was made of the strict, “reserved” mode of functioning of the territory of the «ZATO Seversk», which determines the almost complete absence of disturbance factors on technogenic reservoirs during periods of flyby and nesting ducks.

1. Introduction
The anthropogenic transformation of natural landscapes is one of the main factors affecting the change in the composition and structure of natural ecosystems [1]. Along with the British Agency for the Protection of Waterfowl and Wetlands [2], technogenic reservoirs include reservoirs that are included in the technological cycle of enterprises in the energy, industrial, domestic, and agricultural complexes. These are septic tanks, cooling ponds, ash dumps, etc. [3]. On man-made reservoirs, birds find optimal conditions during nesting, migration, wintering periods [4-9]. Most of the works on man-made reservoirs contain only scattered information on the species diversity of birds, the biology of individual species, the fauna of rare bird species, wintering birds, etc. [10, 11] However, special multi-year studies of bird populations, spatial location, spatial-vremennoy dynamics of the avifauna of anthropogenic water reservoirs is very little [3]. But they do not affect at all the man-made cooling ponds of nuclear NPPs, except for a few works on the effects on the phyto, zooplankton and ichthyofauna of aquatic ecosystems [12] and on the winterings of waterfowl [13-15], and in closed areas with artificial reservoirs of the SPZ of the SCC, such work was not carried out at all.
The span of Anseriformes in Tomsk Prioby is closely related to the river valleys, where studies on the phenology of the span, the spatial and temporal heterogeneity of the migration flow, and the influence of landscape and climatic features were previously conducted [16, 17]. Visible span, as a rule, is estimated by passing transit flocks and poorly reflects the nature of the specific water bodies’ use of ponds during periods of migration and reproduction. The most complete studies of the dynamics of the Anseriformes on the lower key section of the Tom River were performed by I. G. Korobitsin in 1998-2003 [18], but in this work only the natural biotopes of the valleys of the Tom and Ob rivers were examined. A unique system of natural and man-made reservoirs is located in the sanitary protection zone of the Siberian Chemical Combine (SPZ of the SCC) in the territory of a closed administrative-territorial entity («ZATO Seversk»), including three large sedimentation reservoirs (RA, RB and RC), ash dump reservoirs and Lake Black. Of particular interest are the continental man-made sedimentation reservoirs (RB and RC), located in the forest industry zone with a strict border protection regime, with the complete absence of a factor of concern and economic activity in this territory. As a result, a diverse wetland ornitocomplex is formed here, and there is successful nesting of rare species listed in the Red Book of the Russian Federation [19].

Our research is devoted for the first time to the study of the species composition, abundance and productivity of waterfowl breeding in various natural and artificial water bodies in the vicinity of Tomsk (in the floodplain of the Tom River and in the technogenic reservoirs of the «ZATO Seversk»). The impact of climatic and hydrological conditions, including the water level in the RB and RC reservoirs, as well as disturbance factors on the biotopic distribution and abundance of waterfowl during periods of migrations and nesting is assessed.

2. Materials, methods and study sites and years of observation
The study of the status of populations of waterfowl and near-water birds was carried out during periods of wintering, migrations and breeding in 1995–2001. Bird counts were carried out on permanent routes along the coastline of water bodies, as well as from observation points (NP). Particularly noted were flocks and groups of birds that are located directly on water bodies, in contrast to transit flocks. On the routes, all encountered birds and broods were recorded, with possible determination to the species and subsequent recalculation of abundance per 1 km of the route or on the square in individuals per 1 square km (individuals/km²)[20, 21]. In this case, flying birds are calculated using the formula where the number of birds encountered is divided by the route time in hours multiplied by the average flight speed of the birds, and the sitting birds are multiplied by the average detection range and divided by the length of the route. Additionally, during the nesting period, water bodies were examined from a boat with the counting of all nests and broods. The regularity of surveys was 4–6 times a month with averaging all the data obtained by months to analyze the seasonal dynamics of numbers. For six years of observations, the total length of the routes was more than 440 km, and the total time spent on the NP – more than 350 hours. In the observations involved A Dubovik and C Milovidov.

The RB and RC reservoirs (1995–2001) are reservoirs-septic tanks, where the cooling waters of the nuclear reactors of the Siberian NPP stopped in 2008. The total area of water bodies separated by a central dam is about 280 hectares. The level of reservoirs is determined by the constant inflow of waste thermal water, adjustable runoff between RB and RC and atmospheric precipitation. Part of the RC reservoir does not freeze all year round. The RA technogenic reservoir (1998, 2000 and 2001) is a wastewater treatment plant with a treatment area of 65–70 hectares, which does not freeze all year round. Regulated runoff is carried out along the drain channel and the Romashka River in the Chernilshchikovskaya channel. The deep continental Black Lake (2000 and 2001) with an area of 36–40 hectares is located among the taiga landscape on the boundary of the SPZ of the SCC.

Man-made reservoirs of the third stage of the ash dump (1999–2001) – a complex of artificial closed and flowing reservoirs, located between the first terrace above the floodplain and the flowed Chernilshchikovskaya. It is a system of deep and shallow lakes, dams and an extensive flooded hollow with remnants of woody vegetation. The total area of the flooded depression is more than 200
hectares. According to the morphology and structure of the vegetation, the reservoir is close to the floodplain landscape. The control were the sections of the river bed Tom, natural lakes and ponds on the left bank of the floodplain near the village of Black River, Kislovka, Timiryazevo (1997, 1999 and 2000), on the right bank – near the village Kolarovo (1998 and 2000–2001). In the winter, surveys were carried out on the Ushayka River within the city limits (1998–2000).

3. Results and discussion
Weather and climatic conditions of spring periods determine the timing of snowmelt, ice drift and the release of water from ice, which determines the number of waterfowl [16]. The observation period covered seven seasons, of which three “early” (1995, 1997, and 2001) were characterized by an early, warm spring with the opening of the Tom River until April 10 and the release of water from the ice by the end of the month. Three “late” seasons (1996, 1998, and 1999) differed in the long spring with late snowmelt, opening the river after April 20, and water bodies only in the first decade of May. In 2000 average weather events were observed. A significant factor is the artificial “heating” of man-made reservoirs RA, RB and RC due to the influx of thermal waters. The non-freezing reservoirs of RA and RB are places of annual concentrations of wintering mallards Anas platyrhynchos (L.). In the spring, the RB reservoir is completely free from ice 6–10 days earlier than RC and 10–14 days earlier than natural water bodies (Table 1). In the years with cold protracted springs, in the RB and RC reservoirs, the most massive accumulations of local and flying waterfowl were observed, when all other reservoirs were still covered with ice.

It is known that the phenology and intensity of the spring flight of birds is associated with the timing of the opening of the rivers and the air temperature [18]. In the “early” years, the most intensive visible flight of ducks is observed in the floodplain of the Tom River, as a rule, with two peaks of increasing numbers (Figure 1a). The first peak of the span falls at the end of April – the beginning of May (up to 270 or more individuals per 1 km²), when the reservoirs are already mostly without ice, and the second (146–190) is observed in mid-May. By the end of the month after the flyby of the northern duck, the abundance of waterfowl decreases by 3–4 times and at the beginning of June is 20–42 individuals/km². In the “late” years, when most of the reservoirs are still covered with ice, the spring span passes sluggishly, stretches over time and is single-peak. April peak is not expressed (10–40), and the maximum intensity is noted in the middle (145) or at the end of May (118). In June, as in the “early” years, the abundance of ducks reached 8–32 individuals/km² and remained at this level until broods appeared. In 2018, with an extremely cold and lingering spring, after ice drifting on the Tom River, which took place in the middle dates (14–17 April), the temperature from mid-April to May 29 did not exceed 6–8 °C. Spring flight of, in fact, was not expressed at all. The number of ducks in the flood plain at this time (20–48) was the lowest in the last 40 years of observations.

In the “early” years in April, the number of ducks on the technogenic reservoirs of RB and RC is lower than in the floodplain (40–160), but the second peak of the northern duck flight is more pronounced at the end of May (129–170) (Figure 1b). In the “late” years, the reservoirs of RB and RC due to the discharge of thermal waters are freed from ice much earlier than other reservoirs, and mass accumulations of waterfowl were noted here at the end of April (270–482), and at the beginning of May the number of ducks reached 605 individuals/km². All May and June in these reservoirs in the “late” years there were 2–4 times more ducks than in the floodplain. It should be noted that the number of geese in the floodplain of the Tom river was mainly due to transit flocks (more than 60%), rarely stopping for rest and feeding, and on reservoirs RB, RC – taking into account birds directly feeding on water bodies (more than 90%). At the same time, large flocks of river (Anatinae) and diving (Aythyinae) ducks (up to 200 or more individuals) fed here for several days, and the total number of birds recorded on certain days reached 1,200 or more people/km².

After the end of spring migration at the beginning of June, the abundance of waterfowl in the floodplain decreases by 3–5 times (to 12–42 individuals/km²), and on man-made reservoirs – by 2–3 times (to 60–100), and the whole season remains high breeding. In June–July, the nesting population density of ducks in the control reservoirs of the Tom River floodplain and in the RB and RC reservoirs
was comparable in ordinary years (35–65 on average), and in years with cold long springs (1998 and 1999) in RB and RC reservoirs there were 2–4 times more ducks than in the floodplain (up to a maximum of 110–126). This is confirmed by the results of counting broods.

In late July – early August, when the main part of the ducklings rises on the wing, the birds migrate from the reservoirs RB, RC to natural reservoirs, and their abundance decreases almost twice (to 30–40), and in the floodplain increases to 70–80 individuals/km² (maximum up to 140–160). In September, local ducks almost do not occur in the floodplain, the span is weak, and the number is reduced to 10–20. On the man-made reservoirs of RB, RC, at this time, migratory flocks more often stop, and the total abundance of ducks is 2–3 times higher.

Table 1. Terms of the snow-free period in water bodies in the vicinity of Tomsk 1995–2001.

| Seasonal phenomena | 1995¹ | 1996² | 1997³ | 1998⁴ | 1999⁵ | 2000 | 2001 |
|--------------------|-------|-------|-------|-------|-------|------|------|
| Ice drift on the Tom river | 06–08.04 | 20–25.04 | 19–22.04 | 15–17.04 | 10–13.04 | 22.04–30.04 |
| Melting ice | 20.04 | 24.04–03.05 | 23.04–1.05 | 03–09.05 | 03–09.05 | 02–11.05 | 03–09.05 |
| on water bodies floodplain | 22–28.04 | 03–08.05 | 23.04–1.05 | 02–11.05 | 03–09.05 | 22.04–30.04 |
| on RB | 25.04 | 23.04 | 22.04 | 19.04 |
| on RC | 06.05 | 03.05 | 30.04 | 20.04 |
| Tom river | 19.11 | 21.11 | 20.10 | 23.11 |
| Freezing | – | – | – | – | 24.10 | 11.11 | 14–18.10 | 17–22.10 |
| on water bodies floodplain | 22.10 | 21.11 | 20.10 | 23.11 |
| on RB and RC | 14.11 | 26.10 | 22.10 | 21–26.10 |
| ¹ “early” years |
| ² “late” years |

Figure 1. Dynamics of population density of waterfowl on floodplain reservoirs (a) and on RB, RC reservoirs (b) 1997–2001.

Visible prewinter flyby of waterfowl in the floodplain of the river Tom practically does not happen. Only in the years with a long autumn and late freeze-up (1999 and 2001) regular migrations and meetings of ducks were observed on the reservoirs and the river Tom until the beginning of November, but their abundance did not exceed 10–32 individuals/km². Transient flocks of ducks stop on the water bodies of RB, RC in October-November. The total density reaches 60–70, and in some years 150–160 individuals/km². At the same time, clusters of up to 100 or more birds of different species were recorded. In 2000 as a result of very early frosts and freeze-up in other reservoirs, by October 20, early concentrations of wintering mallards were observed on RB in October (up to 50-150
individuals). The flocks of mallards on the Ushayka River (10–30 individuals) noted in November–January were already wintering populations and, at full freezing washouts, moved to the technogenic reservoirs of RA and RB, where the number of mallards in January reached 50–80 and 300–400, respectively. Similar territorial distributions of hibernating populations of mallards, associated with the presence of non-freezing water bodies as a result of the discharge of thermal waters, were observed in different cities [4, 8 and 22]. After the shutdown of the reactors of the Siberian NPP in 2008, the discharge of thermal waters, in fact, stopped, the reservoirs began to freeze completely in November; wintering mallards began to concentrate on the Ushayka River. So, according to Bazdyrev on the bird accounting in the framework of the action "Gray neck" in January 2015–2017 on a route of 3.5 km along the Ushayka River, from 290 to 350 wintering mallards were registered.

The overall seasonal dynamics of the number of waterfowl on natural water bodies of the floodplains is very similar to the data of other authors collected on the lower Tomy site in 1998–2003, when the abundance of ducks in April–July averaged 30–200 individuals/km² [18], but such mass clusters of anseriformes on passage and nesting, like on technogenic reservoirs, they also did not observe.

The use of different landscapes by ducks during the migration and breeding seasons is associated not only with the opening, freezing of water bodies and air temperature, but also with the water level and the total water content of the territory. In the “late” years with a very high water level in the Tom River, when the entire floodplain was flooded (1998), the number of ducks in the spring migration was 1.5-2 times lower than in years with a low level (2000), when many small lakes, old riverbeds and temporary reservoirs were formed (Figure 2a, 2b).

![Figure 2](image-url)  
**Figure 2.** Dynamics of waterfowl abundance and water levels in the floodplain (a, b) and on technogenic reservoirs RB and RC (c, d).

In the settling basins of RB and RC with adjustable runoff, the population density of the waterfowl is related to the water level during the whole spring-summer period. This level is supported by the discharge into the reservoirs of thermal waters of the enterprises of the SCC, atmospheric precipitation
and regular descents. Fluctuations of levels in the reservoirs of RB and RC reached one meter between years and up to 30-40 cm between months. So, in 1998, during rainy summer (more than 180 mm of precipitation fell in June–August), the water level was highest during the years of observation, and the area of flooding of reservoirs increased by 20–30%. As a result areas of shallow water, small islands and bays were hidden under water, and the number of ducks during the whole season was 2–3 times lower than in years with low water levels (1999) (Figure 2c, 2d).

Despite the seasonal fluctuations, the number of pairs of ducks nesting on the technogenic reservoirs of the RB and RC remained very high compared with the natural reservoirs of the interfluvial and floodplains of the Tom River. Up to 40–100 broods from 8 species of ducks were noted annually, while in the control area of the Tom River floodplain only 20–30 broods of 5 species (Table 2). In the “early” years, the number of couples nesting on the RB and RC reservoirs is lower than in the “late” ones, but in any case 1.5–3 times higher than on other reservoirs in the vicinity of Tomsk and Seversk. This tendency was also noted for artificial reservoirs in the Moscow region, where the density of nesting waterfowl is twice as high, and for diving ducks it is several times higher than on natural reservoirs and in floodplains of rivers [23].

According to our estimates, taking into account possible undercount and repeated meetings of broods, about 100 pairs nested in 1995, in 1996 and 1997 – about 50, in 1998 and 1999 – about 80 pairs, and in 2000 – at least 60 pairs. In the whole area of water bodies it breeds at least 20–30% more ducks. Predominant in terms of the number of breeding pairs and the number of broods, river ducks were wigeon Anas penelope (L.), gadwall A. strepera (L.), teal A. crecca (L.), garganey A. querquegula (L.) and mallard, and goldeneye Bucephala clangula (L.) and tufted duck Aythya fuligula (L.). In the floodplain of the Tom River among the 20–30 nesting pairs of ducks there is a small proportion of diving, but pintail Anas acuta (L.) and shoveler A. clypeata (L.) were common, which were rare in the RB and RC reservoirs.

### Table 2. The number of broods of waterfowl in the floodplain of the Tom River and on technogenic reservoirs RB, RC 1995–2000.

| Вид                              | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|----------------------------------|------|------|------|------|------|------|
| Anas penelope L.                | 38   | 16   | 18   | 21   | 1    | 20   | 9    |
| Anas platyrhynchos L.           | 11   | 3    | 6    | 4    | 7    | 2    | 4    |
| Anas strepera L.                | 9    | 14   | 4    | 5    | 14   | 2    |
| Anas crecca L. and A. querquegula L. | 9   | 10   | 13   | 7    | 17   | 12   | 19   | 11   |
| Bucephala clangula L.           | 8    | 2    | 2    | 5    | 4    |
| Anas clypeata L.                | 2    | 3    | 2    | 1    | 2    |
| Anas acuta L.                   | 3    | 8    |     | 5    | 8    |     |
| Aythya fuligula L.              | 3    | 2    | 2    | 3    | 1    | 2    |
| Anas sp.                        | 14   | 4    | 2    | 11   | 4    | 2    | 14   | 7    |
| Total                           | 97   | 54   | 32   | 53   | 21   | 79   | 27   | 80   | 37   |

1 no data on the floodplain of the Tom River.

The occurrence of broods during the summer on the RB, RC reservoirs was 5.0–8.1, in June (on average 6.64), in July – 5.7–13.3 (8.98), in August – 0.7–3.8 (1.9) broods per 1 km of the route. The average number of ducklings in broods for all the years of observations was, respectively, in June – 6.18, in July – 5.3, in August – 3.44 (Figure 3a, 3b). The average breeding performance in all species for three years of observations in the floodplain of the Tom River was 5.66, and in the RB, RC reservoirs - 4.52 chickens per pair. In other words, the survival rate of chicks at the technogenic reservoirs of the SPZ of the SCC was 25% lower before the ascent to the wing, than at the control
reservoirs in the floodplain of the Tom River, where, according to other authors, in 1998–2003 the average breeding increment was 6.3 chicks per pair [18]. Thus, the total breeding efficiency in the floodplain was more than 64%, and on the technogenic reservoirs RB, RC did not exceed 45–50%.

![Figure 3. Seasonal occurrence of broods (A) and the dynamics of the average number of ducklings in brood (B) of waterfowl on RB, RC reservoirs 1995–1999.](image)

4. Conclusion

Thus, significant differences were established in the timing and intensity of the spring flight of waterfowl in different years of observations. In the natural waters of the floodplain of the Tom River, they are associated mainly with the course of spring, the timing of the opening of rivers and the establishment of positive temperatures. In the years from early spring, the massive intensive flight of ducks passes with two peaks of growth in numbers in late April and mid-May. In the years with a late protracted spring, the first wave is not pronounced, and the entire span is one-peak in nature with a gradual increase towards the middle and end of May. The level of water in the river and the area of the flooded floodplain have a significant impact on the number of ducks.

On the inter-river technogenic settling reservoirs, where the ice disappears 6–14 days earlier than on natural reservoirs in the floodplain, mass accumulations of migratory waterfowl species were noted in the “late” years exactly at the first wave of flyby. And in the fall, the flying flocks of ducks linger here even after freezing rivers. In addition, on these bodies of water throughout the spring-summer period, a significant impact on the number of migratory and nesting ducks is exerted by the absence of a disturbance factor and the water level regulated by thermal water discharges by the SCC enterprises and atmospheric precipitations: in years with high water levels, the overall abundance of ducks is lower; than in years with low levels. The total number of breeding waterfowl, the number of broods annually here is 2-4 times higher than in the floodplain. But due to the higher mortality of ducklings, breeding success is lower than on natural water bodies. In this way, man-made reservoirs on the territory of the SPZ of the SCC are places of large concentrations of waterfowl during periods of migration and wintering, as well as a reserve for nesting of many species of birds of the wetland complex.

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