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Development of the Rybinsk Reservoir by the Great Cormorant *Phalacrocorax carbo* in Russia, 1941–2024

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ABSTRACT

The Great Cormorant *Phalacrocorax carbo* is a long-lived, range-expanding fish-eating predator. Many populations across the species' extensive range today are show increased in abundance. This study provides new knowledge about the Great Cormorant colonizing the Rybinsk Reservoir, the northernmost of the cascade of reservoirs of Europe's largest river, the Volga, in the East European (Russian) Plain. The aim of the work is to study the historical and current distribution of the species in the Rybinsk Reservoir, estimate its abundance and identify the breeding status in the study area. The basis of the work is information from the beginning of the formation of the Rybinsk Reservoir in 1941 until 2024. Great Cormorants have visited the reservoir at varying intervals since 1946. Recordings of cormorants were sporadic and irregular until 2015, after which the birds began to be observed annually at the reservoir. In the fairway zone of the Rybinsk Reservoir in 2020 and 2021, the abundance of Great Cormorants and the share in the bird population (%) varied from 0.10 (3.22%) to 0.31 (6.34%) individuals/km², respectively. The current expert number of Great Cormorants seasonally inhabiting the reservoir is estimated at 100–150 adult and immature individuals. The Great Cormorant began nesting on the Rybinsk Reservoir for the first time in 2017. Both in the past and at present, cormorants migrate to wintering places, do not winter in the reservoir, and do not form sedentary populations. Current status: Rare, locally breeding, migratory species, seasonal resident with a positive trend in population growth.

Keywords: Fish-eating predator, Fairway, Volga

1. INTRODUCTION

The Great Cormorant *Phalacrocorax carbo* is a long-lived fish-eating predator, feeding mainly on mature fish. It has a wide range. Cormorants inhabit Eurasia, Africa, North America, Australia and many islands, including Greenland, New Zealand, Tasmania and others (Klimaszyk and Rzymski, 2016). In most European countries, the Great Cormorant population is growing and continues to grow as the birds colonize more inland areas near rivers and lakes where they were not previously found (Steffens,

2010; Steffens, 2011). Recently, the total number of subspecies *Phalacrocorax carbo carbo* and *Ph. c. sinensis* in Europe was about two million individuals (Steffens, 2010). In Russia in 1990–2000, the breeding population included 35,000–60,000 pairs.

On the East European Plain, not limited to the Volga River, the expansion of the species' range occurs across a broad front along remote water bodies rich in fish. An increase in the number of Great Cormorants can lead to an aggravation of competitive relationships with fishing. The essence of the conflict is related to the ability of cormorants to quickly populate new territories and develop new food resources, often obtaining and consuming food (for example, fish) in significant quantities (Boström, 2013). It is also able to successfully compete with other bird species for valuable breeding areas, displacing not only common but also rare, vulnerable, and Red Book species of birds, such as Pallas's Gull *Ichthyaetus ichthyaetus* and the Caspian Tern *Hydroprogne caspia*, into less valuable areas).

The Great Cormorant can transmit viral diseases to humans and animals. In the Rybinsk Reservoir in Russia, piscivorous bird species serve as definitive hosts for several parasite species, and the Great Cormorant has the potential to be, or already is, one of them. Of particular interest is the continuing development of the reservoirs of the Volga River by the Great Cormorant, which has become noticeable since the beginning of the XXI century. The Volga is the largest river in Europe and the sixth longest in the world. Before thecreation of reservoirs, its length was 3690 km. The Volga extends mainly in the latitudinal direction. It covers various landscape-geographical and vegetation zones – taiga, mixed and broad-leaved forests, forest-steppes and steppes, semi-deserts and deserts.

The Volga Basin is inside Russia on the East European (Russian) Plain. Only in the east does it protrude towards the Ural ridge. From north to south, the Volga drainage basin lies between 61º55′ N and 45º35′ N. At present, the river flow of this river has turned into a cascade of reservoirs Avakyan and Iakovleva, (1998) and hydraulic structures (dams). The Volga reservoirs are large, flat reservoirs (Avakyan et al., 1987). Most were formed in 1930–1960 (Avakyan et al., 1987). Of the nine currently existing reservoirs of the Volga cascade, the Rybinsk Reservoir in the center of the Upper Volga is the northernmost artificially created reservoir. The history of its development by the Great Cormorant is documented by ornithologists from the initial stages of its formation to the current time (Nemtsev, 1988; Golubev, 2011).

Since cormorants can cause significant damage to fish stocks, fisheries, and aquaculture, the control of local populations remains relevant against the background of the rapid growth in the number of this fish-eating predator. In this regard, there is an obvious need to continue studying the species to control its numbers at a level that allows effective management of the size of local populations if necessary. This study provides new knowledge about the history of the Great Cormorant's development of the Rybinsk Reservoir. It complements the existing knowledge about its condition in the reservoirs of the Volga River. In the above key, I collected documented, compared and synthesized of facts, analyzed and interpreted thematic results. The objectives included (1) studying the historical and current distribution of the species in the Rybinsk Reservoir, (2) assessing its abundance, and (3) identifying the breeding status in the study area.

2. MATERIALS AND METHODS

Study area

The Rybinsk Reservoir is the largest inland lowland reservoir in Europe. This is a lake-type reservoir. The reservoir appeared due to regulation of the flow of the Volga, Sheksna and Mologa rivers. Filling the basin of the future reservoir with water began in 1941 and reached the design level (101.8 m a.s.l.) in 1947. The water surface area of the reservoir is 4550 km². The average depth of the reservoir is 5.6 m, the maximum is 30.4 m. The length of the reservoir from northwest to southeast is 100 km, and the average width from west to east is 40 km, the maximum width is 56 km (Figure 1A, B). The reservoir water level experiences significant fluctuations within a given year and from year to year. The minimum water level of the reservoir is observed in early April, the maximum water level – at the end of May or early June. Usually from November to May the reservoir is covered with ice.

Material and methods

I used historical publications and recent data found on the Internet, as well as my own original (published and unpublished) data. Thus, information about the Great Cormorant was collected and summarized from the beginning of the formation of the Rybinsk Reservoir in 1941 until 2024. The author's intermittent observations at the reservoir were carried out with varying levels of detail during all seasons from 1989 to 2022. The duration of observations in a particular field season varied from 1–2 days to a month or more.

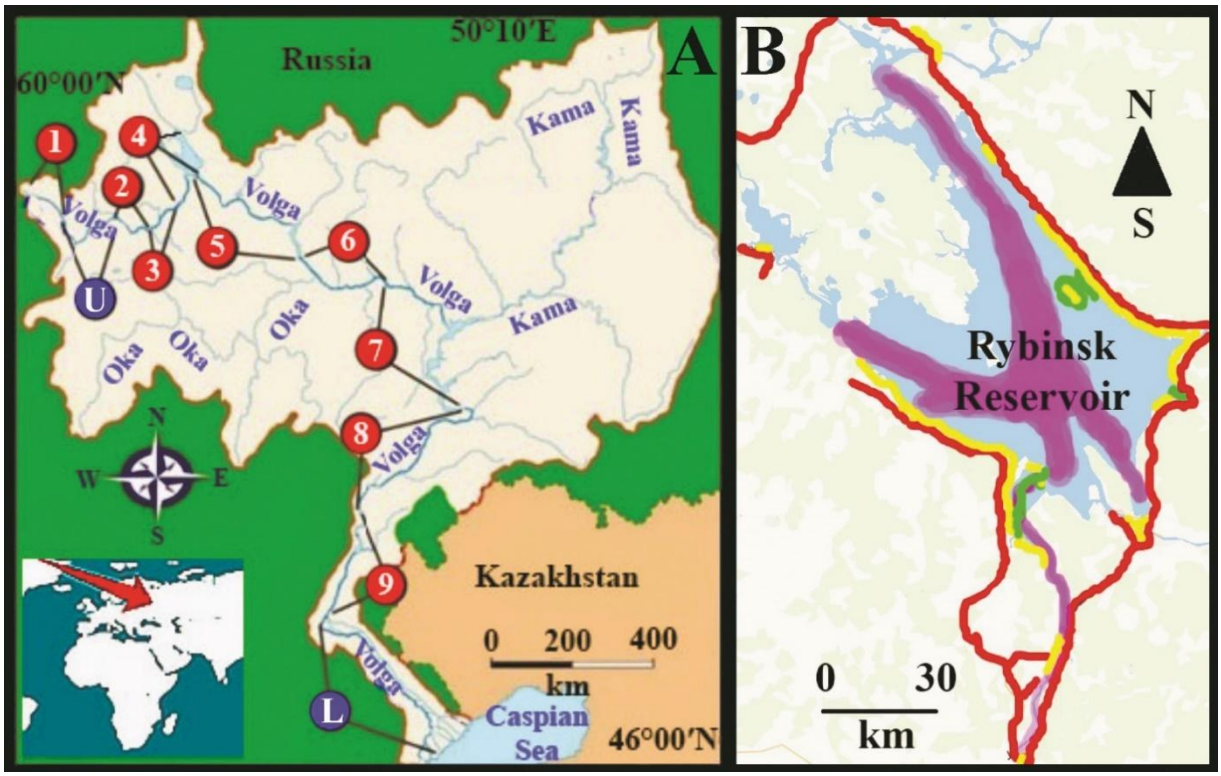

Figure 1 (A). Study area. Location of reservoirs and unregulated parts of the Volga River. The red arrow in the inset shows the location of the Rybinsk Reservoir. The Volga reservoirs are marked with red circles with numbers: 1 – Upper Volga; 2 – Ivankovo; 3 – Uglich; 4 – Rybinsk; 5 – Gorky; 6 – Cheboksary; 7 – Kuibyshev; 8 – Saratov; 9 – Volgograd. Unregulated sectionsof river flow of the Upper (U) and Lower (L) Volga are indicated by blue circles. (B). Land and water routes for ornithological survey of the Rybinsk Reservoir, its coast and islands (1989–2022). Red lines indicate automobile routes, yellow lines indicate ground walking routes, green lines indicate boat routes, pink lines indicateship routes.

Observations were carried out during walking routes along the shore of the reservoir and islands, as well as automobile, boat and ship routes (Figure 1B). Ultimately, most of the coast of the Rybinsk Reservoir was examined, excluding the territory of the Darwin State Nature Biosphere Reserve. I carried out surveys of the relative abundance of Great Cormorants in the fairway (navigable) zone of the Rybinsk Reservoir from board the research ship Akademik Topchiev in the summer and autumn of 2020 and 2021 (Table 1).

Table 1 Dates and length of water surveys of Great Cormorants *Phalacrocorax carbo* on the Rybinsk Reservoir in 2020 and 2021.

№	2020		2021	
	Dates	**Transect length (km)**	**Dates**	**Transect length (km)**
1	6 August	36.1	22–24 July	183.5
2	–	–	29 September	22.0
3	1–4 October	287.9	15–16 October	109.9

Observations were carried out on the bow deck of the ship at a height of ≈ 3 m above the water surface. Without bird counts, ehe ship moved at a speed of 14–18 km/h. The average vessel speed during bird counting is 14.6 km/h. The total length of routes where bird counts were carried out in 2020 was 324 km, in 2021 – 315.4 km. The duration of surveys in 2020 was 22 hours, and in 2021 – 21.4 hours. The total duration of ship expeditionary work in 2020 was five days and six days in 2021. The total number of individuals counted on the route in 2020 is 21 (20 sitting and 1 flying individual), in 2021 – 30 (19 sitting and 11 flying individuals). The timing of work on the vessel corresponded to the end of chick rearing and the summer-autumn migrations of birds.

I counted Great Cormorants as the vessel moved along a transect with a fixed 200 m strip width (100 m in each direction from the vessel's bow). Seated and flying individuals were summed up and included in the calculation of the relative abundance of the species

on the transect in the fairway zone. Along with this, the type of interaction of birds with the water surface and the air environment (feeding, comfortable behavior, search flight, migration) was recorded. I counted birds during daylight hours. Bird counts were not carried out at vessel stops and moorings or during ichthyological trawl-hydroacoustic surveys, when the speed of movement was below than the average speed of the ship. I recorded birds usually on 30-minute transects.

Additionally, citizen science data was used – registrations of cormorants in the iNaturalist, Encyclopedia of Life (EOL), eBird, and Global Biodiversity Information Facility (GBIF) databases. If the observation locations, observation dates and observers were identical in the databases, then one observation location (one point) was displayed on the map. I estimated the abundance of bird species using the abundance scale: Numerous species (N) – 10–99 individuals/km²; common species (C) – 1–9 individuals/km²; rare species (R) – 0.1–1 individuals/km²; very rare species (VR) – 0.01–0.99 individuals/km².

Research equipment

Field observation data were stored and processed in the Microsoft Excel 2013, United States of America (USA) spreadsheet processor. While counting birds on the body of water, we used 8× binoculars, a Garmin eTrex Touch 35 Global Positioning System (GPS) recorder, and a Canon 60D digital camera with a 200 mm lens. I prepared the figures in Adobe Photoshop CC 2015.0.0 Portable Version (USA).

3. RESULTS

The distribution, abundance, and status of the Great Cormorant in the Rybinsk Reservoir have changed since the formation of this reservoir until recently. In the Upper Volga, the registration of Great Cormorants has exceeded the hundred-year mark. Thus, in the center of the Upper Volga, vagrant Great Cormorants have been observed since the beginning of the XX century. However, sightings of Great Cormorants in the Rybinsk Reservoir have occurred for more than 70 years. For example, in the Darwin State Nature Biosphere Reserve on the Rybinsk Reservoir, single individuals and pairs of Great Cormorants were recorded from August to October 1946, as well as in 1949 and 1985 (Nemtsev, 1988). I observed a pair of Great Cormorants in August 1989 at the reach of a reservoir near the mouth of the Ukhra River.

Subsequently, until the end of the XX century, cormorants were not recorded on the Rybinsk Reservoir. In the subsequent decades of the XXI century, registrations of the Great Cormorant at the reservoir and in the surrounding area became more frequent. Since 2015 they have become relatively regular and annual. During the historical period, the duration of seasonal use by the Great Cormorants of the Rybinsk Reservoir increased. Observations have established that non-breeding individuals began to use the reservoir in spring, summer, and autumn from April to October. In the above range, both migrating individuals and seasonal residents are recorded in the reservoir. For the first time on the Rybinsk Reservoir, the Great Cormorant began to breed in 2017, where several nests were identified.

In the fairway of the Rybinsk Reservoir, there were individuals of different age classes – from the first year of life to adult sexually mature birds. This is also supported by citizen science data. However, the quantitative ratio of individuals of different ages in the observed samples requires particular research. The observation results show that the spatial distribution of Great Cormorants on the large lake-like Rybinsk Reservoir, as mentioned above, was uneven. Great Cormorants avoided open waters at considerable distances from the shores and islands. The western and eastern coasts of the reservoir were also not inhabited by fish-eating predators. However, they visited them exceptionally rarely. The biotopic preferences of cormorants demonstrate a preference for the coast and coastal shallow waters, channel fragments of the reservoir, river mouths, bays and islands (Figure 2).

In such places, the depth of the water column did not exceed 10 m, and was more often within 1–5 m. Most sightings of Great Cormorants were made in the south of the reservoir. Basically, non-breeding individuals were recorded on buoys in the fairway and/or in shallow waters with stones in the middle of the water outside the fairway zone of the Volga spur of the Rybinsk Reservoir. Sporadic species registrations occurred further north, in the vicinity of this reservoir. Great Cormorants were recorded singly, in small groups, and in aggregations of resting birds (Figure 3), where concentrations of cormorants could exceed 40 individuals observed simultaneously.

In the fairway zone of the Rybinsk Reservoir in 2020 and 2021, the abundance of Great Cormorants and the share in the bird population (%) varied from 0.10 (3.22%) to 0.31 (6.34%) individuals/km², respectively. Still the status of the species in both cases was consistently rare. Both in the past and at present, cormorants migrate to wintering areas, do not winter in the reservoir, and do not form sedentary populations. The phenology of the main biological events of the annual cycle, wintering sites, and diet and breeding details require additional research.

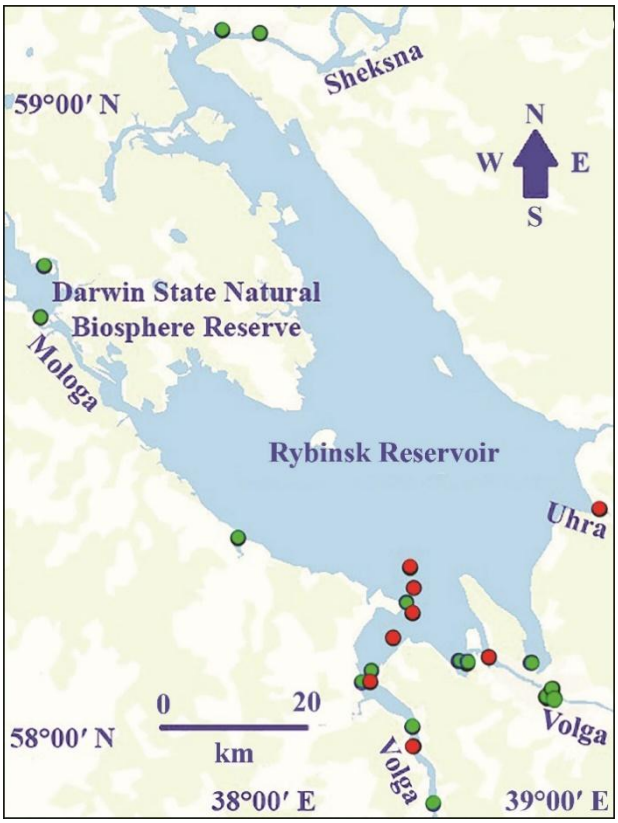

Figure 2 Registrations of Great Cormorants *Phalacrocorax carbo* in the Rybinsk Reservoir and its surroundings, 1989–2024. Red circles – registrations of cormorants in the water area of the reservoir (1989, 2020–2021, author's data). Green circles are citizen science records of cormorants on islands, coasts, and coastal habitats from the iNaturalist, EOL, eBird, and GBIF databases (2002–2024).

Figure 3 Great Cormorants *Phalacrocorax carbo* sitting on a buoy in the fairway, 15.10.2021. South of the Rybinsk Reservoir. Photo by the author.

4. DISCUSSION

At the end of the XX century, in the inland parts of the European part of the former Soviet Union, the breeding range of the Great Cormorant reached the 48th parallel. Currently, the distribution boundary of the species on the Volga has shifted to the 58th parallel, moving north by more than 100 km. At the same time, in the Volga basin, the spread of the Great Cormorant occurred on a broad front, and for the Volga reservoirs, the longitudinal direction of the spreading individuals was the main one. In my opinion, the expansion of Great Cormorants into previously undeveloped reservoirs of the Volga River over the past few decades occurred due to the following reasons: climate warming; availability, accessibility, and relative abundance of food in developed water bodies; ability to compete with other fish-eating predators; absence or weak pressure of natural predators; no or weak direct pursuit by the person; development and growth in the number of trout, carp and sturgeon fisheries.

In the near future the above reasons may contribute to the further spread of the species to the north and east and an increase in its registrations in undeveloped or poorly developed territories of the Upper Volga. Until the end of the XIX century, the distribution of the Great Cormorant in the Volga region was limited only to the Volga valley (Bogdanov, 1871). In the XIX century, in the middle reaches of the Volga River, it bred annually up to the Samara Luka but was much less numerous than in the lower reaches of the Volga. Cormorants were also found higher along the Volga – up to the Kazan province and on the Kama River, but there was no evidence of breeding (Bogdanov, 1871). Without going into historical details, according to some ornithologists, only during the first two decades of the XXI century were Great Cormorants able to move up the Volga to the Gorky Reservoir, and their most northern breeding was recorded at the Kuibyshev Reservoir.

Historical data indicate that Great Cormorants have been visiting the Rybinsk Reservoir with varying frequency since 1946, when the design water level of this reservoir was approaching its final stage. This study also showed that in the Rybinsk Reservoir in the XX century, rare vagrant, non-breeding cormorants were not recorded annually (Golubev, 2011). Until 2015, registrations of individuals were sporadic; after 2015, Great Cormorants began to be observed annually by naturalists at the reservoir. The uneven distribution of Great Cormorants on the Rybinsk Reservoir resulted from the occupation of its southern half, where the optimal quality of ecosystem services for this piscivorous predator probably exists. Feeding conditions most likely play a leading role in the spatial distribution of cormorants. Moreover, the places where they feed are determined only by the concentration of fish.

On other reservoirs of the Upper Volga, such as the Ivankovo and Uglich reservoirs, Great Cormorants were recorded many times from 1980 until recently for example although I did not observe them at the Upper Volga Reservoir. Information collected during long-term monitoring of the coast and water area of the Rybinsk Reservoir indicates that the ecosystem services of this reservoir are most optimal for maintaining the existing population of the Great Cormorant in comparison with other reservoirs of the Upper Volga, and the Rybinsk Reservoir apparently leads in the abundance of birds of this species. The current expert population of Great Cormorants, seasonal residents inhabiting the Rybinsk Reservoir, is estimated at 100–150 adult and immature individuals.The increase in the number of Great Cormorants in the reservoirs of the Volga River, including the Rybinsk Reservoir and other reservoirs of the Volga basin, will most likely continue in the coming decades.

We should expect the appearance of new breeding colonies on the coast or islands of this body of water. The sites of existing or previously existing Gray Heron *Ardea cinerea* colonies may be promising for placing cormorant colonies on the Rybinsk Reservoir. It is possible for nests or colonies to appear in places where this species has not previously bred. The environmental regime of the Darwin State Nature Biosphere Reserve can contribute to the emergence, growth, and preservation of colonies of Great Cormorants in the north of the Rybinsk Reservoir. A favorable place for the emergence of new colonies appear may be the south of the Rybinsk Reservoir, especially its Volga spur. Bays at the mouths of small rivers flowing into the reservoir and islands meet these goals.

5. CONCLUSION

Over more than 80 years of existence of the Rybinsk Reservoir, the status of Great Cormorants on this reservoir has changed from rare vagrancy to seasonal residence with minimal breeding. Current status is a rare, locally breeding, migratory species, a seasonal (spring–summer–autumn) resident of the Rybinsk Reservoir with a positive trend in population growth. The development of the Upper Volga reservoirs by the Great Cormorant continues. However, the overall process of its development of the Volga reservoirs is not complete.

Considering the trends in the expansion of the species' range and the positive trend in its numbers in many breeding populations within its extensive range, the Great Cormorant does not require special conservation measures in the Rybinsk Reservoir at the present time. I do not recommend including dispersing Great Cormorants in the Red Data Books of the regions surrounding the reservoir. The

small number of cormorants does not require population regulation by invasive methods. There is no need to include them in the list of hunting objects. To control the "Rybinsk" population of Great Cormorants, it is necessary to continue monitoring this potentially important fish consumer in the transformed aquatic ecosystems of the Upper Volga.

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Author's contribution

The research plan, fieldwork and manuscript writing were carried out by the author.

Ethical approval

Observations of wild birds and their identification in the field were carried out in compliance with ethical principles regarding animals as per the animal ethics followed in Fish Ecology Laboratory, Papanin Institute for Biology of Inland Waters, Russian Academy of Sciences, Borok 152742, Russia.

Conflicts of interests:

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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