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The Danube at Dürnstein (picture: © Katrin Teubner)

Content

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WEPASS Project - Making the Iron Gate Dams passable for migratory fish

Smederevac-Lalić Marija[1], *Cvijanović Gorčin*[1], *Nikolić Dušan*[1], *Lenhardt Mirjana*[1], *Hont Stefan*[2], *Paraschiv Marian*[2], *Iani I. Marian*[2], *Baktoft Henrik*[3], *Gjelland Øystein Karl*[4], *Redeker Marq*[5], *Gatzweiler Julia*[5], *Milovanović Miodrag*[6], *Cvijanović Nevena*[6], *Hödl Edith*[7], *Masliah-Gilkarov Hélène*[7], *Gessner Jörn*[8], *Thorstad Eva*[4], *Økland Finn*[4]

[1] *University of Belgrade-Institute for Multidisciplinary Research (IMSI), Belgrade, Serbia, e-mail: marijasmederevac@imsi.bg.ac.rs, mitrandir@imsi.rs, dusan@imsi.rs, lenhardt@imsi.rs*

[2] *Danube Delta National Institute for Research and Development (DDNI), Tulcea, Romania, e-mail: stefan.hont@ddni.ro, marian.paraschiv@ddni.ro, marian.iani@ddni.ro*

[3] *Technical University of Denmark (DTU), Kongens Lyngby, Denmark, e-mail: hba@aqua.dtu.dk*

[4] *Norwegian Institute for Nature Research (NINA), Trondheim, Norway, e-mail: karl.gjelland@nina.no, eva.thorstad@nina.no, finn.okland@nina.no*

[5] *CDM Smith, Düsseldorf, Germany, e-mail: marq.redeker@cdmsmith.com, julia.gatzweiler@cdmsmith.com*

[6] *Jaroslav Černi Water Institute (JCWI), Belgrade, Serbia, e-mail: miodrag.milovanovic@jcerni.rs, nevena.cvijanovic@jcerni.rs*

[7] *International Commission for the Protection of the Danube River (ICPDR), Vienna, Austria, e-mail: edith.hoedl@icpdr.org, helene.masliah-gilkarov@icpdr.org*

[8] *Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany, e-mail: sturgeon@igb-berlin.de*

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Abstract

European rivers are obstructed by more than one million barriers that have resulted in excessive loss of river continuity (Belletti et al. 2020). On the main course of the Danube River there are 83 longitudinal continuity interruptions, out of which 65 dams are used for hydropower (ICPDR 2022a). The Iron Gate Hydropower and Navigation System is one of the largest river engineering projects undertaken in Europe, with the dams mainly built to provide hydropower and flood protection, and to facilitate navigation along the Danube. These infrastructures represent introduced barriers to fish migration. Hence, ensuring passage opportunities for fish at the Iron Gate dams is considered to be of major importance for the conservation of migratory fish populations in the Danube river basin. Restoration of river continuity at these sites would reopen an additional 900 km for migration up to the Gabčikovo dam, providing suitable habitats and spawning grounds along the Danube and its tributaries. Knowledge about fish behavior and movements in the vicinity of these river infrastructures is required to build effective up- and downstream passage facilities to allow the migration of fish species. To gain insight in the approach routes and aggregation areas a refined approach to acoustic telemetry is employed to support migration facilitation.

Introduction

The Danube River is the second longest river in the Europe (2,860 km) after the Volga. It crosses 10 countries and has an average multi-annual flow of 6,500 m^3/s before it reaches its delta and dewaters into the Black Sea (Hont et al. 2022). The Danube River is a biodiversity hotspot in Europe, inhabiting 2,000 plant and 5,000 animal species, including highly endangered sturgeon species.

The Iron Gate dams (IG I - rkm 943 and IG II - rkm 863) represent the first two impassable obstacles for fish migration along the River Danube from the Black Sea *(fig. 1)*. The construction of the IG I was completed in 1972 and IG II in 1984. The border between Romania and Serbia follows the

Figure 1. *Iron Gate I (rkm 943) on the left and Iron Gate II (rkm 863) on the right (Photo: Smederevac-Lalić)*

Danube in this area, and the two countries share the dams *(fig. 2)*. The Iron Gate system has transboundary effects; IG I created a reservoir of about 3.2 billion m³ and 270 km total length (up to Novi Sad, Serbia), trapping 20 million tons of sediment per year (Comoglio 2011).

The IG I dam has a total width of 1,278 m with symmetrical design. Both countries have an equal exploitation of the water for electricity production and navigation. The maximum design head and the range of water level variation both up- and downstream of the dam are important information for designing fish passes. At IG I dam the maximum design head amounts to 29.10 m; the water level fluctuations (fish pass operation ranges) total 4.45 m upstream and 2.0 m downstream.

The IG II is a system of two dams which exploits the ramification of the Danube River in two branches *(fig. 1, 2)*. The upper dam is located on the Romanian side, on the Gogoșu branch at rkm 875, with a total width of 509 m. The lower IG II dam is located on the main branch of the Danube River between Serbia and Romania, at km 863 with a total width of 1,009 m. The fish pass design head is 11.75 m and the operation results in water level fluctuations of 1.25 m upstream and 5.78 m downstream the dam.

The restoration of river continuity at the Iron Gate dams, being the 'doorway' to the middle and upper Danube river basin, has been classified as of 'utmost priority' in the Danube River Basin Management Plan Update 2021 (ICPDR 2022a). In 2022, Danube Ministers welcomed the progress made in the assessment of possibilities for opening fish migration routes at the Iron Gate dams and emphasized the need for ensuring the necessary financial resources for the implementation of technically and economically feasible solutions (ICPDR 2022c). Due to their substantial size and complexity, restoring fish passage at the Iron Gate dams is extremely challenging. There is no ready-to-use solution for fish passage facilitation considering the scale of the river, the size of the target species (sturgeons up to 7 m long), the dimensions of the dam structures and their morphological environments and the location on the border between two countries, and the hydropower and navigation utilization.

Fish migration routes can be re-established by building fish passages

The construction of dams has blocked upstream fish migration, impaired downstream passage survival and decreased available spawning, nursery, wintering, and feeding habitats (Lenhardt & Pekarik 2021). Additionally, the modification of riverbeds for navigation purposes caused negative impact on migratory species. The most famous fishes of the Danube, also recognised as flagship species by the International Commission for the Protection of the Danube River (ICPDR), are the sturgeons, which spawn in the river and spend the majority of their lives in the Black Sea. Sturgeons are among the most ancient fish families in the world, with some 80% of the sturgeon species globally being endangered to become

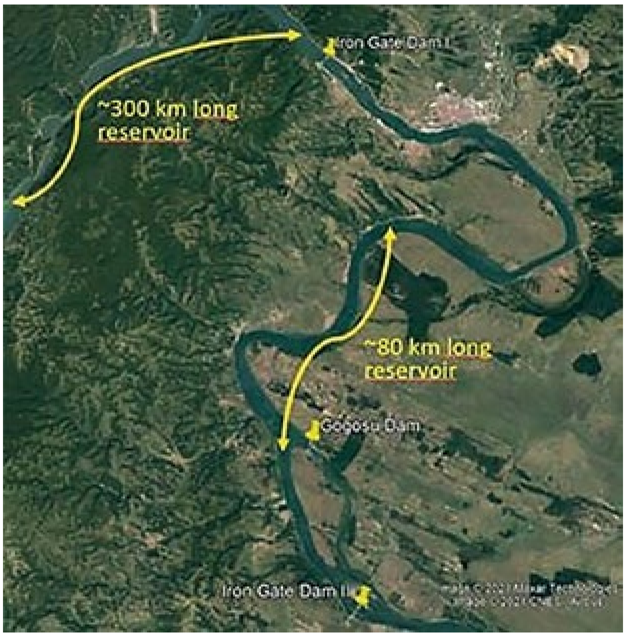

Figure 2. Study area, Iron Gate I and II and Gogoşu dams (Photo: Google Earth)

extinct (IUCN 2022). Before the construction of the Iron Gate dams, sturgeon migrated from the Black Sea as far upstream to Austria and Germany. The sturgeons in the Danube today are restricted in their migration to the Iron Gate II dam from the Black Sea (Paraschiv et al. 2021). Only one potamodromous (riverine) sturgeon species, the sterlet *(Acipenser ruthenus)*, is still common in the Middle and Upper Danube. Consequently, sturgeons are among the priority species for recovery measures, including the construction of fish passages. In addition to the sturgeons, there are numerous other migratory fishes that need to migrate up and down the

Figure 3. The St. Ours dam on the Richelieu River in Canada has one of the few proven efficient fishways for (lake) sturgeon (Thiem 2013)

Figure 4. First acoustic telemetry project 'Fish behaviour preparatory study at Iron Gate dams and reservoirs' (DDNI 2015)

Danube in order to fulfill their life cycles, such as common nase *(Chondrostoma nasus)*, barbel *(Barbus barbus)*, vimba bream *(Vimba vimba)*, asp *(Leuciscus aspius)*, Pontic shad *(Alosa immaculata)*, European eel *(Anguilla anguilla)* and other species.

A fish passage facility represents a structure that allows fish to pass over or around an obstacle. Worldwide, most of the fish passages were created for salmonids (strong swimming capabilities), and clupeids (generally pelagic). In contrast, sturgeons are bottom-oriented species with a lower swimming performance compared to salmonids (McElroy et al. 2012; Lenhardt 2021). Since the approach of sturgeons towards a barrier depends upon the morphology and hydrology of the river, detailed information must be available to ensure proper location of the entrances for fish passage facilities. The design of successful fish passage facilities for sturgeon for upstream and downstream migration is still in an experimental phase. There are some lessons learned *(fig. 3)* and particular success in this topic provides hope for reconnecting fragmented sturgeon populations (Lenhardt 2021).

In the past there have been some preparatory activities to make the Iron Gate dams passable for migratory fish species. The first assessment (FAO scoping mission) of possibilities to restore fish migration in the Danube River, following the legal requirements of the EU Water Framework Directive, was conducted in 2011 (Comoglio 2011).

Following the FAO mission, under a Dutch-Romanian partnership together with the ICPDR, the project 'Towards a Healthy Danube - Fish Migration Iron Gate I and II' was completed in 2014. The project report outlined possible technical solutions and provided a road map for further project implementation (de Bruijne et al. 2014).

Between 2014 and 2015 the European Investment Bank funded preliminary fish telemetry investigations down-

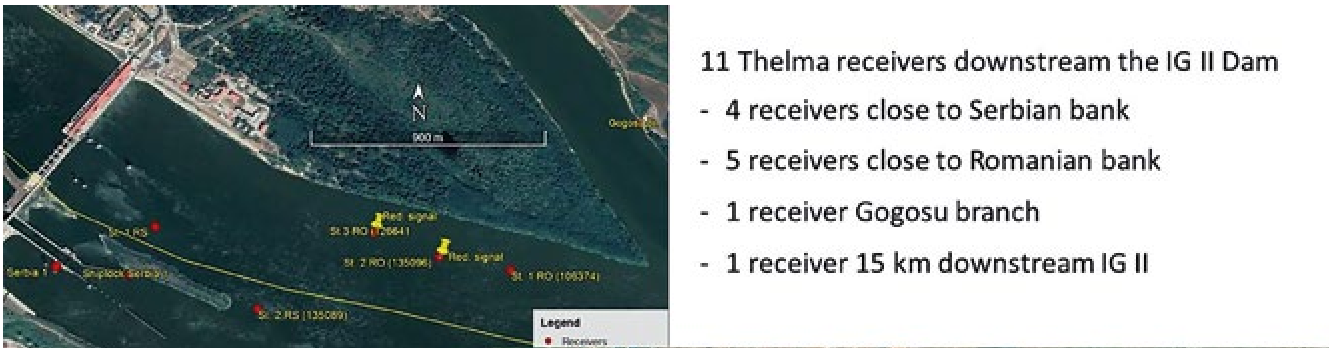

Figure 5. Restoration of fish migration in the Danube River at Iron Gate Dams in Romania and Serbia, Studies of fish behaviour in 2019 and 2021 (acronym: We Pass)

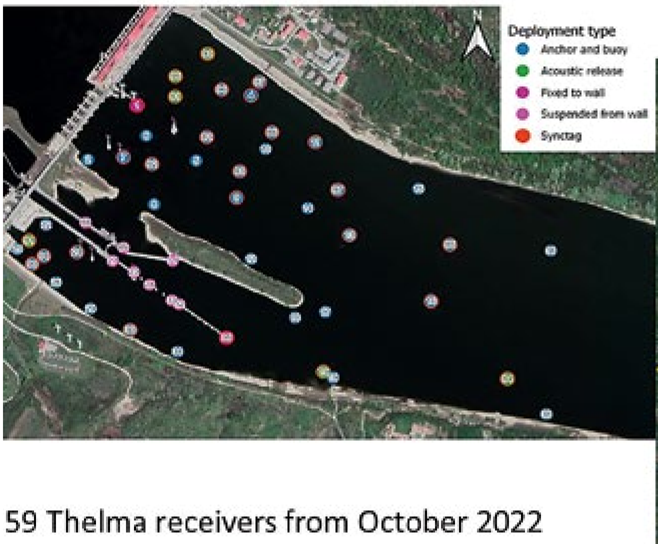

Figure 6. Receiver arrays in the WePass 2 project (left – 53 receivers deployed downstream IG II in October 2021, right – arrangement as from October 2022, downstream of IG I, between the dams and downstream IG II).

stream of IG II (Suciu et al. 2016; Lenhardt et al. 2021). As a continuation of the biological fish investigations, telemetry methods and equipment were used to work on the strategy for monitoring sturgeon behaviour/movements to ensure the function of future up- and downstream fishways *(fig. 4).*

The project named 'WePass' between 2018 and 2021 was funded by the European Commission (DG REGIO) (ICPDR 2022b). The objectives of the project were an analysis of the current situation and technical data gathering (Milovanović et al. 2021), a literature study on sturgeon behaviour and passage (Lenhardt 2021), fish movement monitoring using 2D hydroacoustic telemetry (Paraschiv et al. 2021), and preparatory engineering design works such as the development of a technical 3D model of the dams (CDM Smith 2021, *fig. 5*).

In March 2021 the European Commission (DG ENV) commissioned the 'Pilot Project: Making the Iron Gate Dams passable for Danube Sturgeon' (acronym WePass2) to conduct a feasibility study analysing the options to establish fish migration at the Iron Gate that includes (a) the study of alternatives for up- and downstream fish passage restoration at both Iron Gate dams, (b) a preliminary design of fish passes comprising all their technical elements, and (c) a cost estimate for the construction of the fish passes. The WePass2 project is still ongoing and will be finalised in September 2024 (CDM Smith 2023). The activities include substantial fish movement investigations using 3D acoustic telemetry *(fig. 6).*

Each of the aforementioned projects made a new contribution and a step further in order to find best solutions for making the Iron Gate dams passable for fish. In an international workshop in the WePass project experts including scientists and engineers agreed that fish passes are technically feasible at the Iron Gate dams. Yet, the site-specific application of appropriate solutions need to be assessed and their feasibility proven as one of the WePass2 objectives.

Monitoring of migratory fish in the Iron Gate area

Acoustic telemetry was used to track fish movements and migrations *(fig 7. left)*. The studies were performed by tagging fish with acoustic transmitters and releasing them downstream and upstream of IG II. The fish were tagged with a transmitter implanted into the body cavity *(fig. 8)*. The movements of tagged fish were recorded by receivers (hydrophones), deployed in preselected places in the river, when they were within the detection range of the receivers *(fig. 7 right)*. Receivers record the ID of the individual tag (fish), the time when the signal is recorded and swimming depth of the tagged fish. The movements of tagged fish were recorded by a combination of automatic tracking of fish passing receivers deployed in the river and by manual tracking from a boat.

Working in a large river is challenging due to the variable environmental conditions. Studies of detailed behaviour of tagged fish can only be fine-scaled with an appropriate receiver deployment. Designing the array with a higher number of receivers then allows estimating tracks of tagged fish even if individual receivers are lost. Based on the experience from the WePass project in which a limited number of acoustic receivers was used, in WePass2, cutting-edge technology was applied allowing fish movement to be recorded in three

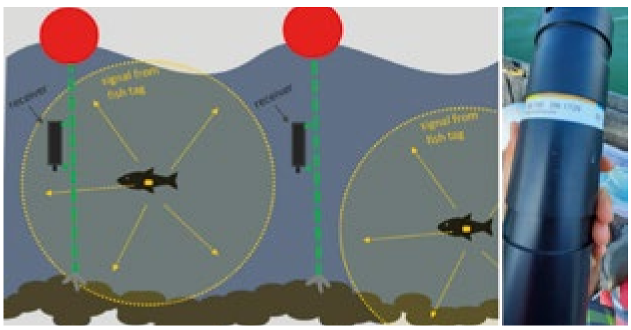

Figure 7. Illustration of two receivers that receive signals from tagged fish – left (Paraschiv et al. 2021), receiver ThelmaBiotel – right.

Figure 8. Tagging of fish was carried out by specially trained staff from the Romanian (DDNI) and Serbian (UB-IMSI) team members.

dimensions with more receivers deployed in the investigation area (*fig. 6*, CDM Smith 2022).

Studies of fish movement in 2019 and 2021

A total of 185 fish were tagged; 61 in autumn 2019 and 124 in spring 2021 (Smederevac-Lalić et al. 2023). Vimba bream, common nase, barbel and asp are known to be migratory species, which can perform long-distance movements. This was confirmed in our study, with many tagged individuals performing extensive movements, both below the IG II dam, in the Gogosu branch and in the reservoir. Several barbel, common nase and vimba bream moved upstream through the entire IG II reservoir to IG I, which is located 76 km from the release site in the reservoir. Barbel and vimba bream were the two species showing the most extensive movements. The study also confirmed that there is large individual variation in movement strategies and behaviour within these species.

Results helped identifying potential areas for fish passes downstream of IG II and in the Gogoşu branch, proved fish movements in/through the reservoir between IG I and II, as well as distribution of fish downstream of IG I (Paraschiv et al. 2021).

No fish released downstream of IG II were detected in the IG II reservoir, which highlights that the two ship locks do not represent viable routes for upstream migration past IG II (Paraschiv et al. 2021). There was also no clear pattern on which side of the river tagged fish preferred to move along.

Fish movement studies in 2022 and 2023

The correct location and functionality of a fish pass entrance (i.e., attraction) are key factors for fish pass efficiency. Even the best designed fish passes will not function if the fish cannot locate the entrance(s) or are not motivated to enter. This was the reason for further monitoring of migratory fish move-

Figure 9. Deployment of the receivers and range testing.

ment in the WePass2 project by increasing the hydrophone deployments at IG I and II, and in the IG II reservoir (*fig. 6*). 3D fish telemetry is being used to investigate the movement and distribution of fish downstream of IG II (2021 - 2022) and in the IG II reservoir (2022 - 2023). The results of the investigations are being used to (a) identify the best areas to place fish pass entrances that must work for the design flow/ water level regimes during the migration periods and (b) to determine appropriate concepts and/or strategies for downstream fish passage including technical facilities and their locations. A new mathematical approach is being applied to estimate highly precise tracks of tagged migratory fish (ca. 1 m accuracy) (Baktoft et al. 2017).

Fieldwork started in October 2021 with a survey of the areas for receiver deployment, range testing and receiver array installation. Expert biologists from Romania, Serbia, Denmark and Norway worked together (*fig. 9*), building on their experience gained in WePass in organizing and setting up the necessary telemetry infrastructure including catching and tagging migratory fish. In the first stage, 53 receivers were deployed downstream of IG II in October 2021. Additional receivers were added in spring 2022 to augment the array and improve tracking precision. In October 2022 the majority of the hydrophones were transferred and placed in the IG II reservoir. The latest receiver array has improved the accuracy of the tracks of tagged fish swimming between IG I and IG II (upriver and downriver movements) and security of data collection (*fig. 6*).

From October 2021 until November 2023 a total of 202 fish were tagged: sterlets, asps, barbels, vimbas, common nase, eel. From October 2022, with the new improved receiver array between IG I and II, all tagged fish were released in the IG II reservoir. Results of our detailed fish movement investigations showed that tagged and released fish in the reservoir can and will migrate up to IG I and back downstream to IG II.

Focusing on Iron Gate II, different migratory fish species used different areas downstream of IG II dam to aggregate. Based on the fish tracks, aggregation areas were identified. Figure 10 illustrates movement of 2 tagged fish (sterlet and vimba bream) under the IG II in 24 hours.

Applying the results of our fish movement analysis and 2D hydro-numerical modelling, various different upstream fish passage options were developed and their optimal locations were identified. Since an effective fish pass should work for all migratory species, multi-species passes are considered. The options include permanent structures (e.g., pool-type and nature-like fish passes, fish locks and fish lifts), operational changes (e.g., to the ship lock operation) and interim solutions (e.g., so-called trap & barge).

Restoring fish migration can only be effective if safe downstream passage is provided, too. Therefore, an assessment of the downstream passageways of fish and turbine survival was conducted and options for downstream fish passage (i.e., different fish protection technologies and alternative

Figure 10. Movement of the one sterlet (orange line) and one vimba bream (green line) in the area under Iron Gate II dam. Red dots are location of acoustic receivers.

hydropower management approaches) were identified. Using the outcomes of the recent fish movement investigations in the IG II reservoir, suitable fish protection and downstream passage possibilities will be detailed further.

The up- and downstream passage investigations and options were presented at a stakeholder meeting in May 2023 to the EU Commission, representatives of both dam owners/operators and international experts.

Conclusion

The status of migratory fish is a parameter of the ecological condition and key indicator of the habitat quality of the entire Danube River Basin. The Danube River connects all tributaries in the basin for migration. Since the Iron Gate dams represent significant migration barriers for fish, migratory fish, such as sturgeons as flagship species but also shad, nase or barbel are particularly affected, since they are prevented from moving up- or downstream between their historic spawning grounds and their feeding and wintering habitats. The implementation of measures enabling sturgeon migration across the Iron Gate dams would make large areas of the Danube River Basin accessible for the migration of the Danube fish species again and would reinstate the river continuum. As such it will contribute significantly to the recovery of the Danube sturgeon populations and long/medium distance migrating fish species as well as reverse the genetic drainage that is caused by the outmigration of the fish below the dams.

At the same time, legal obligations according to relevant EU legislation – such as the EU Water Framework Directive with its objective to achieve good (ecological) status of all waters in Europe and the Habitats Directive aiming to ensure that species and habitat types are maintained, or restored, to a favourable conservation status – are met by contributing to EU environmental objectives including the sustainable use of protection of water and marine resources, as well as the protection and restoration of biodiversity and ecosystems. The Danube countries have a strong commitment to bring the Danube River back to a better ecological status and to establish and preserve self-sustaining fish populations, which includes the restoration of the longitudinal connectivity of the river necessary for fish.

The location and site-specific design of the entrance(s) to any fishway are crucial features of their functionality. Therefore, information on the movement and (horizontal and vertical) distribution of fish trying to pass the dams is a prerequisite to ensure that the fishway entrance(s) will be located in an area where it/they can be detected by as many up- or downstream moving fish as possible. Sturgeon conservation activities including passage facilitation to Iron Gate dams and further upstream, are prominently addressed in the updated guiding Danube River Basin Management Plan Update 2021 of the ICPDR, endorsed by Danube Ministers in February 2022.

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Climate change in the Danube Delta and its consequences

Viktor Vyshnevskyi[1], Serhii Shevchuk[2]*

[1] National Aviation University, Liubomyra Huzara Ave., 1, Kyiv, 03058, Ukraine

[2] Central Geophysical Observatory, Nauky Ave., 39/2, Kyiv, 03028, Ukraine

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Abstract

Climate change in the Danube Delta, as well as changes in water temperature, evaporation from the water surface and the ecological state of wetlands have been identified on the basis of available observational data and satellite images. It was determined that during the last six decades, the air temperature in the Danube Delta has increased significantly, by more than 2 °C. Simultaneously the precipitation slightly decreased. As a result, the climate in the studied region became drier than it was at the beginning of the observation in the 1960s. According to the air temperature increase is observing the water temperature increase and the increase of the evaporation from the water surface. It is important, that dependence between evaporation and water temperature is nonlinear. This means that even a small increase of the water temperature causes an essential increase in evaporation. In turn, such changes concern the Danube wetland. During the last years, several fires were observed, which comprised a large area. At the same time, some shallow lakes fell dry and were transformed into salt marshes.