The Unique History of Two Recaptured Brown Trout in Roskilde Fjord

To supplement the existing brown trout population in Roskilde Fjord, fishing organisations such as ROLK and Foreningen til ophjælpning af fiskeriet i Roskilde Fjord stock thousands of brown trout."

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Many local Danish organisations, including *Roskilde og Omegns Lystfiskerklub* (ROLK) and *Foreningen til ophjælpning af fiskeriet i Roskilde Fjord*, support natural fish populations by restoring habitats used for reproduction (Figure 1). In addition, these organisations release thousands of juvenile brown trout (*Salmo trutta*) into Langvad Stream which drains into Roskilde Fjord, just 40 km from Copenhagen.

DTU Aqua carries out research in which trout are tagged with electronic transmitters and returned to the aquatic environment. The electronic transmitters allow scientists at DTU Aqua to track the fish as they are moving and foraging in Roskilde Fjord, providing detailed information about the location, temperature, depth, and activity of the individual fish. Occasionally, tagged trout are caught by fishers who return the transmitter to DTU Aqua, thus allowing DTU Aqua to identify which fish was captured. Here, we uncover the unique migration patterns, water temperatures, depths and activities of two tagged trout that were recaptured by fishers in spring 2020. The research reveals that, while temperature was similar for the two fish, their migration route, depth and acceleration often varied.

THE LIFECYCLE OF A BROWN TROUT

Brown trout is a species of salmonid fish that is native to Europe, North Africa and Western Asia. Within the brown trout species, there are types with varying life histories, including freshwater trout who spend their entire lives in rivers or lakes and anadromous trout who migrate to the sea and are termed sea trout.

Sea trout migrate to the sea to forage and return to freshwater to spawn. Spawning occurs between October-February (Figure 2). After the eggs are fertilised, the adult sea trout return to saltwater. The eggs hatch in March-May and the alevins (small trout) reside in the gravel banks. Some weeks later, the small trout leave the interstitial spaces between the gravel. After spending 1-8 years in the stream, the anadromous trout undergo a physiological adaptation to more saline water (Thorstad et al., 2016). During this smoltification process, the trout change color from a brown towards a silvery appearance. The small trout, now called smolts, typically migrate to the sea in spring. After foraging for 0.5-4 years in the sea, the sea trout return to freshwater rivers to spawn (Thorstad et al., 2016).

↑ Figure 1: These volunteers are adding gravel to a stream. Gravel bed streams are the ideal place for brown trout to spawn. The projects are carried out by local organisations, including *Fishing Zealand*. Photo: Kim Jørgensen.

LOCAL ORGANISATIONS ARE SUPPORTING FISH POPULATIONS

To supplement the existing brown trout population in Roskilde Fjord, fishing organisations such as ROLK and Foreningen til ophjælpning af fiskeriet i Roskilde Fjord stock thousands of brown trout. Fish stocking involves hatching and raising fish in a hatchery. After half a year or a full year, the trout are released to the natural environment to support the existing fish population.

Trout are caught in a trap in Langvad Stream around November-December (Figure 3). Female and male trout are stripped of their gonads to produce juveniles for stocking (Figure 4). After extracting the gonads, the adult trout are returned to the stream. The local organisations are producing about 80,000 small trout per year (Clemmensen, 2019).

FISH TELEMETRY IS USED TO MAP THE MIGRATION OF ADULT TROUT

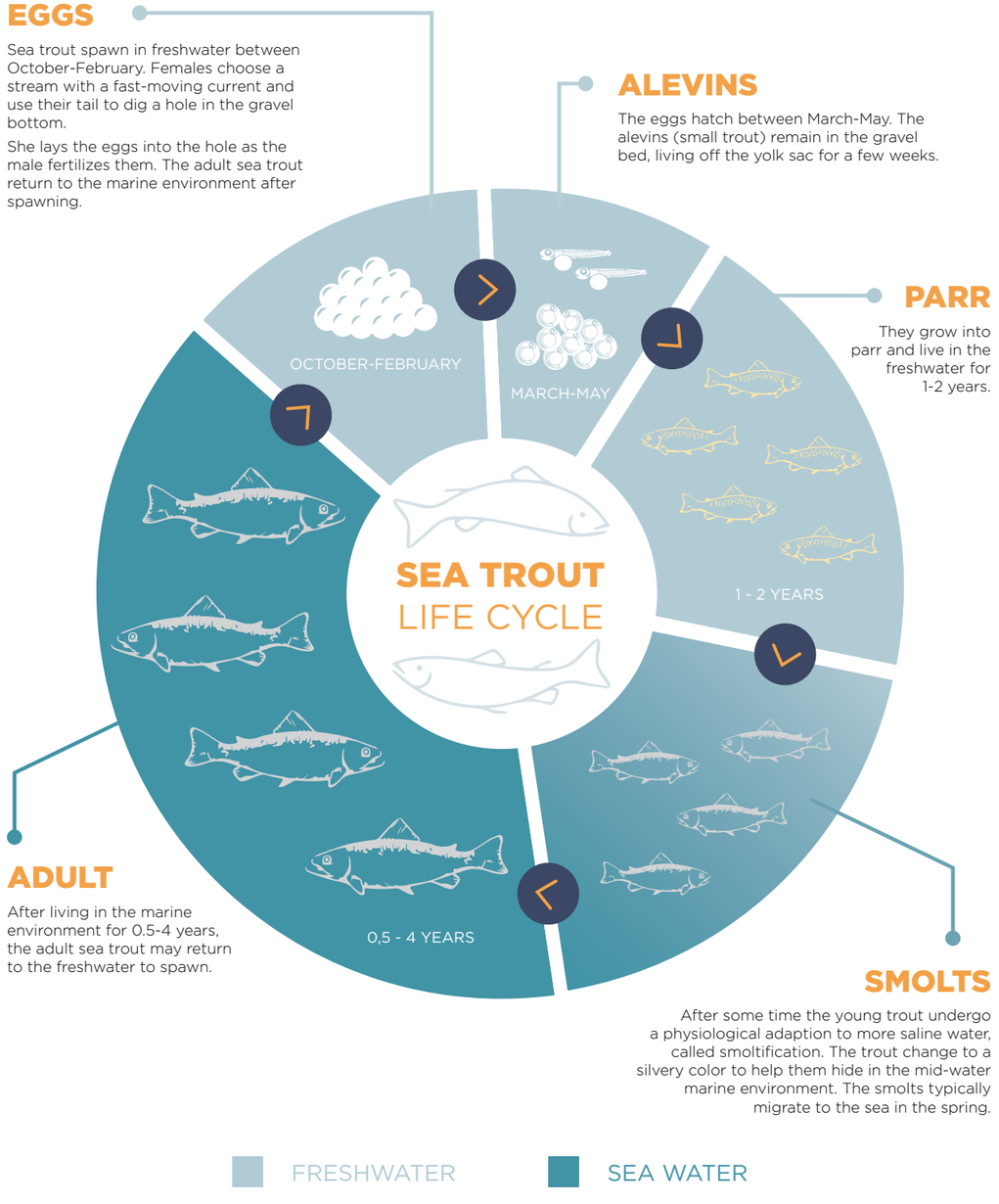
DTU Aqua uses fish telemetry to track adult brown trout in Roskilde Fjord. Fish telemetry enables researchers to track individual fish using electronic tags. After being captured in Langvad Stream, adult trout are tagged with acoustic transmitters (Figure 5). The signals from the transmitters are received by stationary receivers, called hydrophones (Figure 6), that are placed around the fjord (Figure 7). Each hydrophone can pick up signals transmitted within a radius of 500-600 m. These transmitters allow researchers to remotely track the trout in the wild. The Thelma ADT transmitters measure fish temperature, depth and acceleration in addition to the position of the fish.

↑ Figure 3: This sea trout was captured in the trap in Langvad Stream. Measurements of length and weight are taken before the fish are stripped of their gonads. The fish was 46 cm long and weighed 1080 g. Photo: Uffe Clemmensen.

↑ Figure 4: This is a portion of the 80,000 small trout that ROLK produces every year. Photo: Uffe Clemmensen.

↑ Figure 5: A Thelma ADT transmitter has a diameter of 13 mm and a length of 33 mm. The transmitter is inserted into the body cavity of the fish. Diagram credit: Mircea Herastrau.

SEA TROUT LIFE CYCLE



↑ Figure 2: The lifecycle of the sea trout including each major step in their life.

The Thelma ADT transmitters measure fish temperature, depth and acceleration in addition to the position of the fish."

→ Figure 6: A Vemco hydrophone has a length of 31 cm and a diameter of 7 cm. They are positioned across Roskilde Fjord (Figure 7). Diagram credit: Mircea Herastrau.

DTU AQUA IS TRACKING TROUT TO IMPROVE MANAGEMENT AND FISHING OPPORTUNITIES

The trout tracking project was started by local organisations (e.g. ROLK) and has several objectives. One objective is to reveal how much time the trout are spending inside the marine protected area (MPA) located in Kattinge Bay (Figure 7). When the trout are within Kattinge Bay, they are protected from gill netting and trolling with fishing lures all year round. Another objective is to track trout migration over multiple years to examine how the fish are responding to exceptionally warm summers (e.g. 2018). The project findings are used for improved fish management and to further support the vulnerable trout population in Roskilde Fjord. The overarching goal is to improve fishing opportunities in Roskilde Fjord.

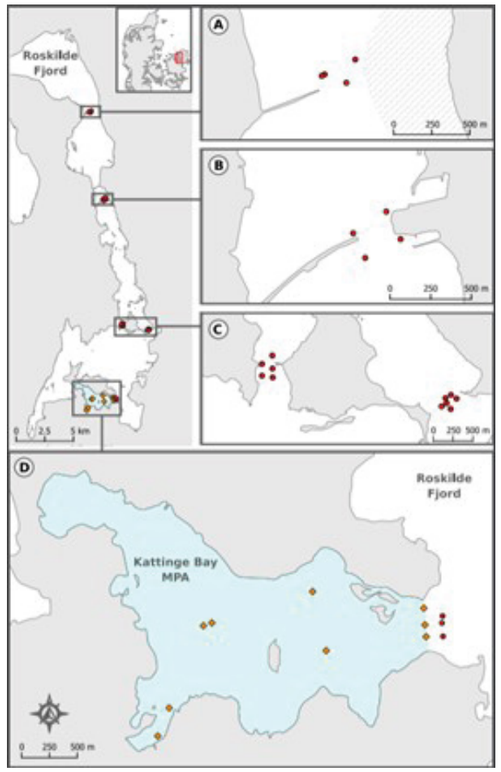
LOCAL FISHERS ARE RETURNING TRANSMITTERS FROM RECAPTURED FISH

In winter 2019-2020, 36 trout were captured by the trap in Langvad Stream. Together with the local organisations, DTU Aqua equipped the fish with acoustic transmitters (Figure 3, 5). In spring 2020, two of the tagged trout, fish A and fish B, were caught by local fishers.

Both fish were tagged on December 15, 2019. Fish A measured 60 cm and weighed 2.9 kg when it was tagged. Fish B measured 52 cm and weighed 2.1 kg when it was tagged. Both fish were male. Additionally, judging from the curled shape of their pectoral fins, both trout originated from a hatchery. These fish could have been from a previous stocking event carried out by ROLK and Foreningen til ophjælpning af fiskeriet i Roskilde Fjord.

UNIQUE MIGRATION PATTERNS OF RECAPTURED FISH

Fish migration is mapped using the hydrophones in Roskilde Fjord. For example, if detections stop being received in Kattinge Bay and the fish is next



← Figure 7: A map of hydrophone positions (red dots) in Roskilde Fjord. Diagram A shows four hydrophones positioned near Dyrnæs. Diagram B shows four near Frederikssund and diagram C shows hydrophones on the west side and east side of the island Eskilsø in Roskilde Fjord. Diagram D shows the hydrophones in Kattinge Bay which is considered a marine protected area (MPA). Diagram credit: Hugo M. Flávio.

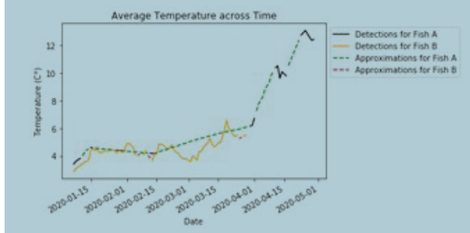
detected near Eskilsø, we can infer that the fish migrated from Kattinge Bay to Eskilsø (Figure 7).

Fish A was detected every week in Kattinge Bay from the day it was tagged until the middle of February 2020 (Figure 8, blue no. 1). The following detections, after leaving the bay (blue no. 2), occurred on the eastern side of Eskilsø at the end of March (blue no. 3). The fish stayed there for some days. Afterwards, fish A swam to the western side of Eskilsø and stayed there for a few days in the middle of April (blue no. 4) before returning to the eastern side of Eskilsø (blue no. 5). The fish stayed on the eastern side until the end of April. Fish A presumably swam southward after April 29th as it was recaptured by a local fisher on May 2nd on the eastern side of Roskilde Fjord, south of Eskilsø (blue no. 6).

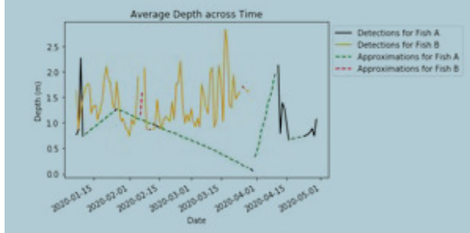
Fish B revealed a different migration pattern. After release into Langvad Stream in December, fish B was detected in Kattinge Bay almost every day until March 27th, 2020 (Figure 8, red no. 1). There are no other detections of fish B afterwards. This shows that fish B did not migrate north towards Eskilsø, as it would have been detected by those hydrophones. Instead, fish B remained south of Eskilsø and outside of Kattinge Bay throughout April and May and was eventually recaptured by a local fisher on May 8th (red no. 2).

← Figure 8: The map shows the paths that the two recaptured fish followed. The circles represent the groups of hydrophones and the numbered arrows represent where the fish moved. Fish A is represented in blue and fish B in red.

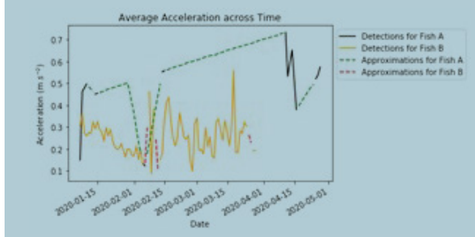
> **Both fish rarely went deeper than 2 m, showing that trout in Roskilde Fjord often are located near the water surface.”**



↑ Figure 9: The graph shows the average temperature for fish A and fish B.



↑ Figure 10: The graph shows the average depth for fish A and fish B.



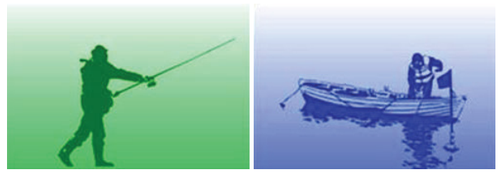
↑ Figure 11: The graph shows the average acceleration for fish A and fish B.

TRANSMITTERS REPORTING FISH TEMPERATURE, DEPTH AND ACCELERATION

The Thelma transmitters provide unique data on temperature, depth and acceleration. The transmitters reveal how the fish are reacting to environmental changes and indicate whether the fish are still alive. However, the tagged fish are only providing data when they are near hydrophones. The dashed lines on figures 9, 10, 11 show where the measurements were approximated (extrapolated) because data were not available.

The data set is limited, but some trends are revealed. The average temperature over time for the two fish was similar for the overlapping days (Figure 9). However, fish A revealed a rapid increase in temperature over the last month it was detected near Eskilsø. Increases in water temperatures could suggest higher growth rates for trout (Malmskov et al., 2019). Both the average depths and average accelerations for fish A and fish B varied substantially (Figures 10, 11). Both fish rarely went deeper than 2 m, showing that trout in Roskilde Fjord often are located near the water surface. Generally, fish A revealed higher accelerations than fish B, which might be related to the larger size of fish A. Furthermore, the daily variations in fish depth and activity may be explained by nearby predators or prey availability.

This study has been greatly aided by the return of the transmitters from local fishers. The study will continue to track trout and analyse the temperature, depth and acceleration data of the fish in Roskilde Fjord to provide useful information about trout populations for local organisations, improved management and better fishing opportunities in Roskilde Fjord.



↑ Figure 12: This is the logo of the fishing license system from the Danish Fisheries Agency.

ACKNOWLEDGEMENTS

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