RESEARCH PAPER - WATERBIOLOGICAL RESEARCH CENTER - JAN PANHUIS
WATERBIOMES
HA 2024/25 Erfgoedlijn P5
TU Delft, Heritage & Architecture

Since the 1970s, the number of artificial rivers, canals has risen in newly constructed neighborhoods. The bloemkoolwijk is a good example of this in the Netherlands, aiming at a symbiosis between man and nature. “Het water zal vanaf het oosten langzaam de wijk in komen, en zo ontstaat een symbiose tussen natuur en mens”. (Dekkers, 2024) Nowadays, many neighbourhood plans include access to water for every dwelling to increase their appeal. In Popular media, the benefits of living on the waterfront stretch from physical, mental, to even spiritual health. (Kempen, 2020)
Regardless of the veracity of these claims, the appeal of surface water has increased since the 1970s, when water was primarily viewed as a functional tool for transportation or as a dumping ground for industrial waste. In many of the Netherlands' major waterways, this was the case. Industry could especially thrive here because of the favorable location, close to the sea, at the river's mouth. (Peters, 2017)

In the project area of the Sliedrecht, situated on the floodplain of the Heritage Line, Dutch expertise on water-related subjects like dredging and water management regulation has been a massive contributor to the region's industrial heritage. These fields of expertise mainly had the benefits of humanity in mind.

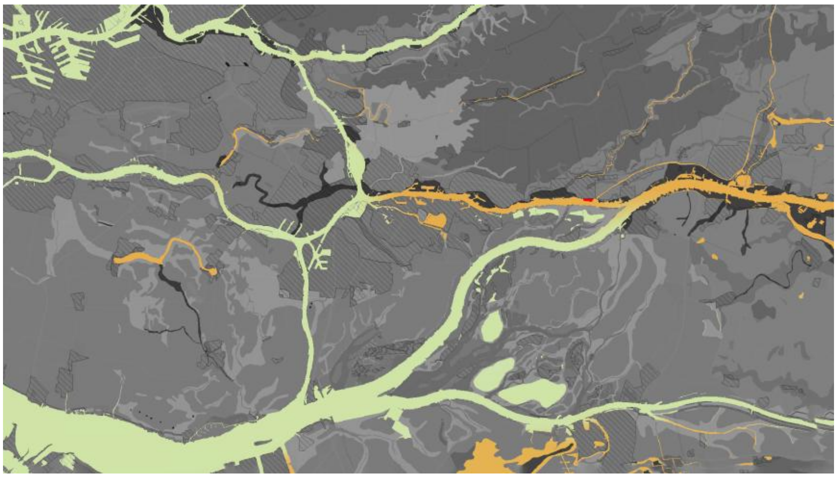

Fig. 1 Project location and water pollution in Heritage line

The problem is that this tendency to favor industry and safety largely disregards the water biology in these waters. The damming needed to deal with flooding after the 1953 watersnoodramp was executed with little regard for migratory fish. Even if the policies of the 1970s and onwards led to significant cleanup of the water quality, the increased use of fertilizers and manure in the agricultural sector and the growth of the national livestock on land have had a negative impact on the water quality of the river system around Sliedrecht. The river once used to be a major source of food for its inhabitants, but now, specifically, migratory fish are largely diminished in the area.

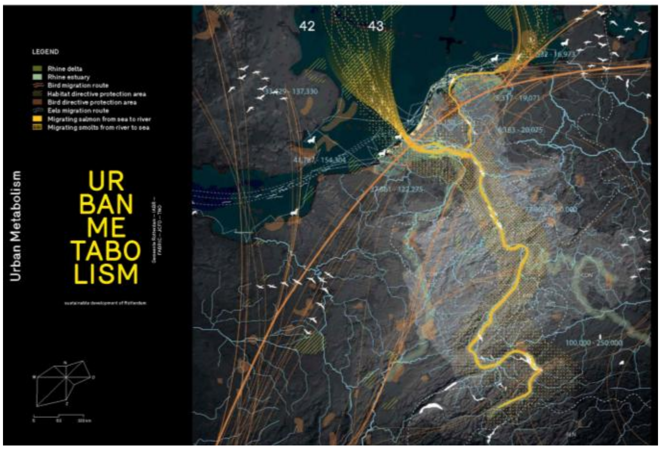

Fig. 2 Rhine Delta as a major migratory fish hub in Europe (Gemeente Rotterdam, 2014)

This paper focuses on the water biological conditions needed for migratory fish, and adds an understanding of their significance for the architectural and landscape architectural disciplines by formulating a program for a water biological center in the project area of the Sliedrecht Floodplain.

This research paper answers how the levels of migratory fish can be increased through architectural intervention. To answer that question, we need a broad view of the significance of migratory fish economically and environmentally. After, the life stages of the migratory fish are discussed and determined which macro- and micro-interventions are necessary for their development. This includes both the physical features of the intervention, such as width, depth, soil types, water plants, and the molecular makeup of the water. In the fourth chapter, we make an inventory of the machinery that is necessary to influence the molecular and chemical conditions of the water in an experimental setting.

To achieve this, the research paper is divided into the following parts.

1. Relevance of the Sliedrecht Project location to migratory fish.
2. Ecological and economic role of the migratory fish in the food chain and its importance to the environment as a whole, and the challenges it faces today.
3. Details on the life stages of the migratory fish and the principal chemical and environmental demands they have.
4. The Architectural and spatial properties needed to supply this climate.
5. The Architectural conditions and machinery needed to study and improve habitat conditions

Scientific Framework

Most scientific sources on fish-cultivation mainly focus on optimizing industrial fish farming. A lesser number of sources are concerned with natural survival. Since this is the main goal of the intervention, I mainly focus on the expertise of the latter.
Another obstacle in the Architectural scientific literature is that there are not many sources directly concerned with fish habitats. The predominant literature again is about industrial fish

farms that may or may not have an ecological and sustainable label attached to them, yet serve in the end an economic goal.
For example, the common practice of sex-reversing male trout into female trout under great hormonal stress to reduce the fighting behavior of male trout is only one of the many practices used in fish rearing facilities across the world. These processes are not part of this paper, since they greatly disturb the balance of the existing ecosystem. Instead, the maintenance of the balance that the aquatic domain achieves in the broader ecosystem is a main aim of this paper. (Brown, 2009)
In order to stay close to the research topic, this paper uses scientific ecological research in order to establish a toolkit. This toolkit, in turn, can be used to inform how the building typology of an ecological center for water biology, as well as the tools needed for performing experiments, in gathering new data about the specifics of fish research.

1. Sliedrecht Project Location

The Selected project area is located on the Rhine River Delta, an outerdike mostly flat land with an old shipyard west and a water tower east. Located approximately 30 kilometers from where the River flows into the North Sea. For starters, in choosing a location for the Waterbiological center, certain environmental conditions had to be met. The terrain of the Delta Shipyard area had the unique advantage of being located outerdike, thus providing easy access to the river and the migratory fish so they can be studied.

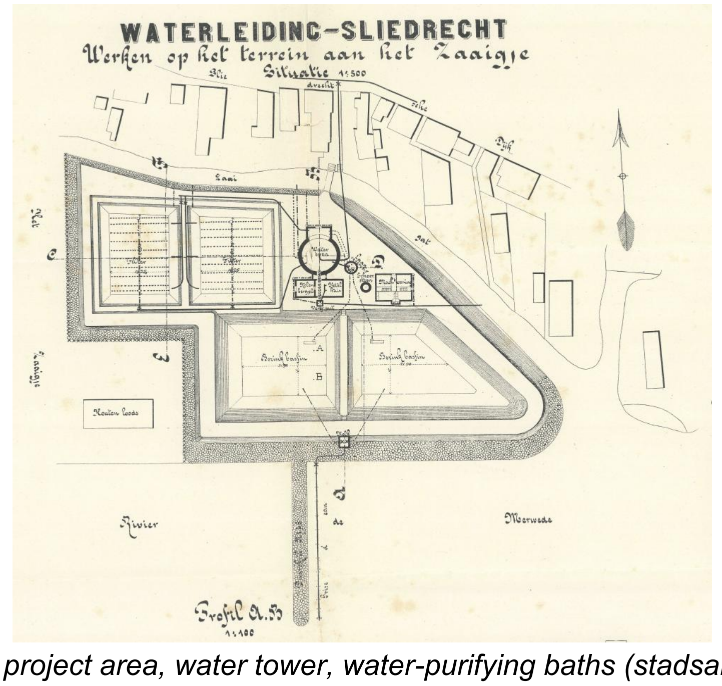

Fig. 3 Outerdike project area, water tower, water-purifying baths (stadsarchief Dordrecht)

The area contains one of the earliest water towers in the Netherlands, which was historically used to purify river water to make it potable for the inhabitants around it. It managed this by using two large baths, which removed sinking and floating material from the water, using the water tower as a pump between them, providing the needed water pressure. Soon after, in the 1930s, technical advancements made it possible to drill deeper, diminishing the importance of the water tower and the baths. These baths can be reused to experiment on the physical features of the fish in these waters.

The Netherlands, The Heritage Line, and the area of Sliedrecht specifically have a legacy of water management. The area used to be at the forefront of dredging technology, whose boats were built in the shipyards along the River. These innovations have since been upscaled and left the Netherlands in terms of production. Nonetheless, the know-how and innovation in maritime problem-solving are cornerstones of the Economy. Adding the innovation in fish migration and fish conservation can be a revitalising impulse for the area of Sliedrecht and the Dutch industries as a whole.

In the heritage line, these three factors make it spatially and functionally the most suitable location for a research center for migratory fish.

2. Ecological and Economic relevance of migratory fish along the Rhine

To know which factors need to be researched in the project area, first, a broad understanding of the importance of migratory fish is needed.

On the molecular scale, migratory fish are one of the only ways nutrients and minerals are transported from inland into the ocean and back. Migratory fish like salmon transport nutrients from the ocean to freshwater ecosystems. When they return to rivers to spawn and die, their bodies decompose and enrich river systems, benefiting plants, insects, and animals. By these means, they travel further upstream, reaching all corners of the ecosystem, not only the aquatic type, thus linking ecosystems together. Many migratory fish, like salmon and sturgeons, are predators and prey themselves and have a key role in the balance of the ecosystem. They serve as a crucial food source for a wide range of species, including birds like eagles and mammals like otters. At the same time, they feed on smaller organisms like plankton and invertebrates, helping regulate populations at lower levels of the food chain. (Closs, 2015)

Historically, migratory fish support commercial and industrial fisheries, on which millions of people rely for food and income. They are often central to local and global seafood industries, such as tuna, salmon, and herring. In recent years, widespread damming and other forms of water management have occurred. In the project area, mainly the migratory salmon population was an important source of food.
In the case of the Netherlands, the economic importance of migratory fish evolved over centuries, in sync with the country’s maritime history. During the Golden Age (17th century), fishing, particularly herring, cod, and whaling. The fishing industry supplied key industries like shipbuilding, salt production, and international commerce. Revenues from fisheries even helped finance the Dutch East India Company, reflecting the sector’s strategic importance.

Today, Dutch fisheries continue to contribute to the economy, shifting focus towards Sustainable practices, quota management, and technological innovation. The IJsselmeer illustrates the complex interplay between human exploitation and ecological limits. (NVWA, 2020)Overfishing led to sharp declines in key species, triggering scientific concern and conservation action. While opposition from fishers persists, collaborative governance is now attempting to reconcile tradition with ecological and economic goals. The water biological center in Sliedrecht can be an institute providing preservation data for the migratory fish in the Rhine River system.

3. Live stages of Migratory fish and the condition

To research migratory fish species, the natural environment in which fish rear and reproduce needs to be analysed. The Experimental setup inside and outside the water biological centers has to provide suitable conditions for the execution of this research.

Eggs usually hatch in high-oxygen environments, which are the ones closest to the surface. Temperature is one of the most critical factors regulating embryogenesis. Optimal hatching temperatures vary by species, reflecting evolutionary adaptation to local environments. For instance, salmon develop best in water 6–12°C, whereas tropical species require temperatures ranging from 26–30°C. Deviations from species-specific thermal optima can result in delayed development, increased embryonic mortality, and morphological abnormalities. The pH level of the water should remain within the neutral range to ensure the stability of the egg and prevent toxicity. Elevated concentrations of nitrogenous compounds such as ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) are known to disrupt embryonic development and increase mortality rates.
Water movement plays a dual role in egg incubation: it facilitates gas exchange and reduces the accumulation of pathogens. In natural environments, flowing water ensures adequate oxygen delivery and disperses metabolic waste. (Wanjari, 2023)

Other than the initial hatching process, many essential features of the first weeks or so after birth need to be taken into account. For instance, the food the young fish eat differs per life stage and species and varies between plants, invertebrates, or other small fish and insect larvae. Second, the salinity of the water is important; transitional spaces between salt, brackish, and sweet water are important for the natural hormonal development of all types of migratory fish. For some species, this can be as precise as the difference in salinity of a 6-hour tidal shift.

Another important factor is the number of fish that can be raised in the same space. Trouts are known to spawn very close together, whereas salmon and sturgeon need a lot more space to develop. Another important factor to consider is the amount of protection the broodstock have from predators, especially in shallow waters, which is where most fish spawn. Mammals, Lizards, fish, and Birds all prey on small broodstock. In the wild, these protections amount to cracks in the rocks overhanging and underwater plants that make it difficult for these predators to reach them in tight spaces. (Buscher, 2016)

The Inside and outside labs of the Sliedrecht facility should accommodate these climatic variations in their experimental setups

Differences in migratory fish species:

The life cycles of salmon and eel to gain insight into the factors needed for their analysis and research, in the Sliedrecht waterbiological fish center. Both species are present in low numbers along the Rhine River and have been a focus of reintegration efforts.

Eel life stages:

Eels live most of their lives in freshwater or coastal brackish environments. They mature over twenty to thirty years until they return to the Sargasso Sea, a journey of over ten thousand kilometers. This is one of the longest migration routes in the animal kingdom. Once in the Sargasso Sea, they likely spawn at a depth of 400-700 meters. This has never been observed by cameras. Thus, a lot is still unknown about the reproduction of these species. The first live stage of the eel is the Leptocephalus larvae. These larvae drift with ocean currents for months to years. They then transform into glass eels (transparent juvenile stage). As they enter freshwater or estuaries, they become elvers, then yellow eels (their main growth stage). Finally, before migrating, they become silver eels, preparing physiologically for the oceanic journey. In the last stage of their lives, they return to their origin, incubate, and die. The many life stages, extreme distances, and depths of spawning make this one of the hardest fish to study or simulate in a laboratory setting. (Buscher, 2016)

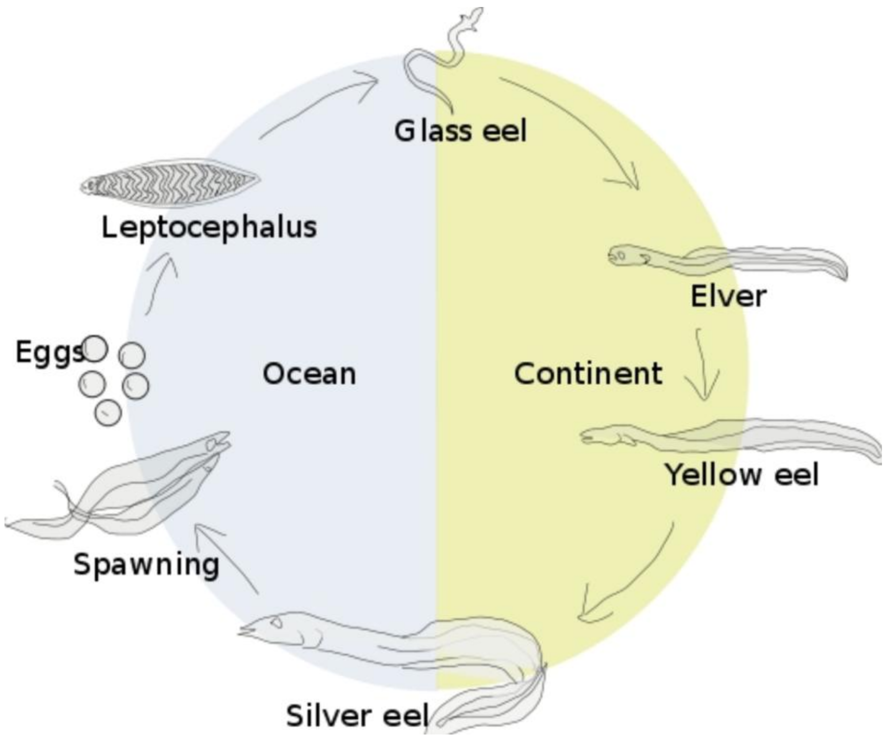

Fig 4: Lifestages of Eels (Gissarudotir, 2018)

Salmon Life Stages

Salmon spawn in Freshwater gravel nests called redds, laid by female salmon. The eggs are fertilized externally. This takes weeks to months, depending on the species and water temperature.
The Alevin stage marks a newly hatched salmon with a yolk sac attached. The yolk sac provides nutrients until they're strong enough to swim and feed. This takes another several weeks. As a fry, the salmon emerges from gravel into open freshwater (rivers or streams). Begins feeding on plankton and small insects. In this stage, they have camouflage to hide themselves from aerial predators.
As a Parr, they are actively feeding and growing, defending territories. This takes Several months to years, depending on the species. The next stage is the Smolt. This marks the point at which they transition from freshwater to saltwater (estuary). Now they undergo smoltification, a physiological change that prepares them for life in the ocean. Their bodies streamline and become "silver".
In the larval stage of the adult, the salmon undergoes rapid growth; feeds on fish, squid, and other marine life. This can last anywhere between 1–5 years, depending onthe species. Now they are ready to spawn once more. They return to their natal freshwater stream to spawn. Now they stop eating, change body color, and males develop hooked jaws (kypes). Reproduction: Builds redds, lays/fertilizes eggs, and usually dies after spawning.
it is evident that there is a big difference between species and a wide range of factors that go into the natural development of the fish. (Helfman, 2009)

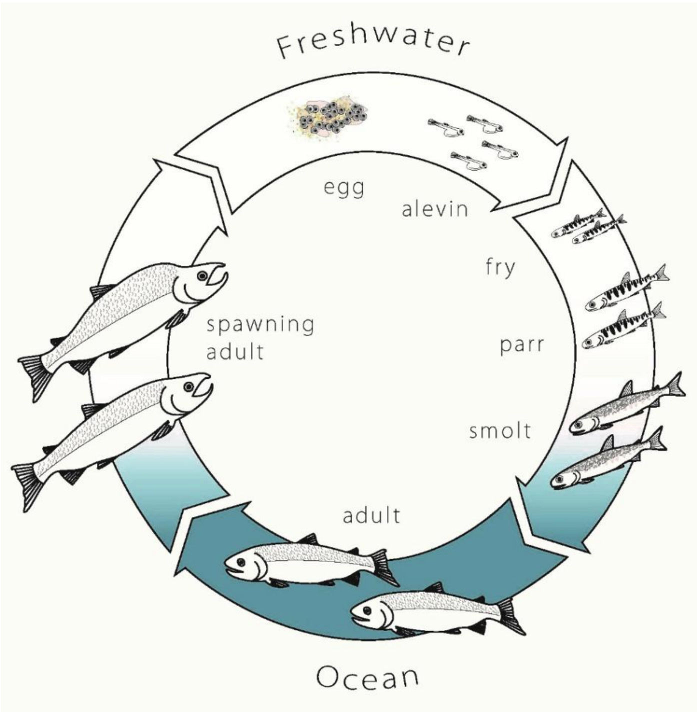

Fig. 5 Life Stages of salmon (NSEA, 2017)

4. Environmental conditions of the riverbank

The importance is not only in either the hatching or the reading, it is also in assessing the physical features of the habitat, and following up on investigating the degree of success of the implementations. First, the physical features that influence the migratory fish are specified. Second, the factors in successfully monitoring a migratory fish are explained through a case study on the current monitoring of migratory fish.
In the previous chapter, it was mentioned that migratory fish like salmon hatch in shallow waters at the spring of a stream. Here, they need protection from predators. This happens through rocks, plants, and other physical features. In the case of the Salmon in the alevin stage, they get to survive mainly through hiding and having a yolk stuck to their body that feeds them. The terrain should offer many such hiding places to give a chance of survival.
In the rearing of eggs and fish, the flow of water is another physical feature of great importance. This can be achieved through increasing the slope of the river, by making it narrower, or by increasing the amount of water. For young fish, water speeds are essential for escaping predators and maintaining proper temperature and oxygenation.
Features are all major factors in the rearing of fish. Physical elements should provide the right amount of Chemicals and PH levels for the fish, either passively through adding plant material or actively by adding other species to the chemical makeup of the stream. These factors can influence the time it takes to rear adults drastically.
Another physical feature is the transition between salt, brackish, and fresh water. Physically, this happens at the mouth of a river where it hits the sea or ocean. Particular interest should be given to the environment of these areas, the impact of tidal shifts, and the amount of new chemicals and food sources which are existent at this stage of the development.

Example of a well-monitored Life span for research

The first step is to assess physical features in habitat suitability: Evaluating the river's current conditions to ensure they support sturgeon life stages, focusing on water quality, spawning grounds, and migratory pathways. Second, the restoration and enhancement of the Habitats: Improving river habitats by removing barriers like dams, restoring natural river flows, and rehabilitating spawning and nursery areas. The particulars on the captivation breeding and rearing: raising sturgeons in hatcheries to produce juveniles for release, ensuring genetic diversity and health. The specifics on how Juveniles are being released in the wild: Introducing hatchery-reared juveniles into the river at appropriate life stages to maximize survival rates. The entire process should be monitored and researched in depth by tracking the released sturgeons to assess their survival, growth, and reproduction, allowing for adaptive management of the reintroduction program.

It is important to find ways to monitor successful physical adaptation in waterways, mainly this is done by marking the fish reared and over many years establishing the number of fish recaught after an adaptation. These adaptations can be due to changing the physicality of the river or by making fish more resilient to the current conditions.

In Northern California's Putah Creek, restoration efforts since 2000 have led to a resurgence of Chinook salmon. In the fall of 2024, 735 adult salmon were recorded spawning, a

significant increase from previous years. Notably, 11 of these were naturally spawned in the creek, indicating successful natural reproduction. This suggests that altered waterways, when properly managed, can support salmon populations.
Scotland has seen a revival of wild salmon populations in the River Caron due to restocking efforts initiated in 1995. Captive-bred fish were released into the river, leading to a significant increase in salmon numbers. Over 50% of the rod catch in some years comprised fish released as eggs or juveniles. Most importantly, the program emphasized breeding from wild-caught fish for a single season's hatchery cycle to maintain genetic diversity. This is a different approach from the one used in California, mainly focusing on the genetic diversity of the fish.
In the Zwalm River basin of Flanders, Belgium, juvenile brown trout were reintroduced starting in 2017. Monitoring indicated that the released juveniles survived and matured, suggesting adequate habitat conditions overall. However, natural reproduction was hindered by factors like heavy sediment load affecting egg survival. This pointed out the importance of addressing environmental factors alongside reintroduction efforts. (Boets, 2024).

These efforts highlight the importance of research hatcheries and reintegration centers. They show that the physical features of the river system also have to be considered if the reintegrations are to be sustainable. In the Sliedrecht Waterbiological center, I mainly seek to focus on improving hatching and rearing techniques and studying the impact of different physical features of the riverbed, the soil, the sediments, and water quality. The results of this research can only be useful if they are to be integrated into the existing water system: the physical features of the rivers and transitory areas.

5. Toolkit, mechanical and landscape architectural Sliedrecht:

In order to access the greatest variety in research setups concerning migratory fish in Sliedrecht, many domains need to be controlled and monitored separately, or in combinations. These domains are the physical, molecular, and genetic. In this chapter, an overview is given of the materials and machines needed to influence these factors. The combinations can be used to simulate existing conditions or experimental settings that do not occur in natural environments for research purposes. In Sliedrecht, the floodplain in between the Shipyard and the water tower will be used as an outside lab with the character of a park.

Physical dimension

Excavators are needed to reshape waterbodies to the desired size, depth, and width. They can also be used to install other features like boulders, stones, logs, etc. This is needed to vary the amount of shelters that can be made for young fish, influence the flow of the water, defend against predators, and change the molecular structure of the water biome. Different soil types can be tested for the nutrients they provide or the impediments they form for the rearing fish. These, in turn, provide the basis for the water plants and vertebrates that serve as food for the migratory fish. These are the physical elements used in a typical section at the Sliedrecht waterbiological center.

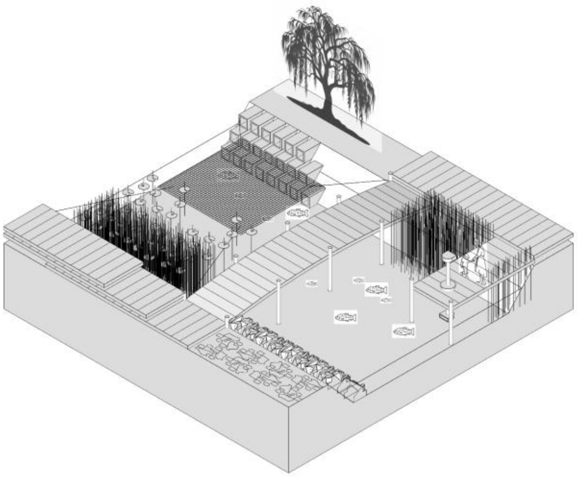

Fig. 6 Architectural Elements used in creating habitats in the Outside Lab

Other devices are needed to control conditions inside and outside labs.

- Machinery for controlling the molecular properties of the water is needed both for experiments and for keeping a stable condition of the water. Firstly, the water temperature needs to be controlled, facilitating adequate conditions for egg-hatching and fish raising. The temperature significantly impacts the duration of the life stages and hormonal development, which influence the behavior of the fish.
- Another machine needed is an automatic salination device which can simulate the transition of the migratory fish from salt into fresh water and vice versa. This again is vital for the research into the life stages of the fish and their rearing capabilities.
- The recirculation pumps are needed to simulate the flow of the river or the ocean. They can also simulate the seasons together with the temperature devices. When the river flows strongly and the temperature is low, it simulates the melting glaciers impacting the rivers during early spring. In turn, it can be used to simulate storms in the ocean in collaboration with the automatic salination device.
- pH levels need to be controlled; this mainly happens through chemical means, but can also be done naturally by using specific types of light. PH levels can be used in experimental setups; however, it is mainly expected to be used in a regulatory way. PH levels impact the duration of egg hatching and fish rearing. (Wanjari, 2023)

Genetic control

The inside lab of the research center in in-depth research on the genetics of the fish. In the case study concerning the Scottish river, it became evident that different genes within a species can make a huge difference to which one survives in the wild. It is thus informed practice to have a control group in any research setting of species with different genetics. Genetics interacts with all sorts of ecological, chemical, and physiological factors and can give important insights into what species are more fit for each situation.
In the introduction, it is demonstrated that it is equally important not to utilise genetic modification to work around the environmental problems. The genetically modified specimen can infiltrate entire ecosystems and have a severe impact on the balance of the species within. (Wanjari, 2023)

Conclusion

The lessons learned in this research paper can be applied at a variety of locations along the Rhine River to monitor and research the well-being of migratory fish throughout their transit. The specific case for the Sliedrecht location is the ability to have the research directly be part of the river system by introducing the river onto the floodplain. This makes it unique since most of the quays in this river system are high and industrial.

The expertise in the Netherlands in water management, maritime industries, and innovation is well-suited for such a center in the Sliedrecht area. Fish have had a variety of economic and environmental impacts throughout Dutch history. The introduction of a sustainable focus on fish life can create a sustainable center providing jobs for the residents of Sliedrecht, and a park that can be freely accessed by the public.

Migratory fish in the Rhine go through a whole lot of developmental stages that vary completely per species, and steps in this process are still unknown. An effort to understand all of the steps and provide experimental setups for this research is paramount. Some of the most important factors to control are temperature, molecular composition, genes, shading, flow speed, hiding places, soil types, and water plants. This accommodate to be able to do most of this research either inside or outside the facility

The future aspiration of this center is to form a network of these centers that can have an increase in its specialisation on the reintroduction of the migratory species. To do this, it is necessary to observe the current reintegration efforts and to experiment with different physical interventions along the river. The center aims to be able to run experiments throughout all phases of the fish's development, and on a variety of fish species that would benefit the area if reintroduced. Other facilities in the network may focus on a subset of the applications of the Sliedrecht one.

The building blocks of the outside lab have implications for the field of architecture and landscape architecture broadly. In my research, I could not find a single example of fish habitats specifically aimed at increasing the sustainable well-being in the architectural library at the TU Delft. I find this a missed opportunity because in the field of architecture and beyond, sustainability, well-being of animals, and water quality are all topics at the forefront of current-day innovative practice.

Sources

Intro

Dekkers, P. (2024) *toekomstvisie voor bloemkoolwijken in de hollandsche delta* **https://www.tudelft.nl/bk/onderzoek/research-stories/toekomstvisie-voor-bloemkoolwijken-in-de-hollandse-delta**

Kempen, T(2020) *Bewezen: mensen die aan het water wonen zijn gezonder en gelukkiger* https://www.margriet.nl/gezondheid/wonen-aan-water-gelukkig~b7571cd1/?referrer=https%3A%2F%2Fwww.google.com%2F

Peters, S (2017) *Hoe schoon is ons oppervlaktewater? https://edepot.wur.nl/338543*

Brown, K. H., Schultz, I. R., & Nagler, J. J. (2009). *Lack of a heritable reproductive defect in the offspring of male rainbow trout exposed to the environmental estrogen* 17α-ethynylestradiol. Aquatic Toxicology, 91(1), https://doi.org/10.1016/j.aquatox.2008.10.009 P 71–74.

Ecology

Closs, G. P., Krkosek, M., & Olden, J. D. (Eds.). (2015). *Conservation of freshwater fishes*. Cambridge University Press. P 324–360

Buscher, E., Olson, A.M., Pascoe, E.S. et al. David H. Secor: *Migration ecology of marine fishes*. Rev Fish Biol Fisheries 26, 609–610 (2016). https://doi.org/10.1007/s11160-016-9423-4 P82

Sportvisserij Nederland (2011) *Stop de overbevissing ijselmeer en markermeer.* https://www.sportvisserijmidwestnederland.nl/actueel/4296/stop-de-overbevissing-ijsselmeer-en-markermeer.html

NVWA Rijksoverheid (2020) *Toezicht op de visketen* https://www.nvwa.nl/onderwerpen/visketen-in-beeld/toezicht-op-de-visketen/schubvisvisserij-ijsselmeer-markermeer-en-ijmeer?utm_source=chatgpt.com

Live-stages

Helfman, G. S., Collette, B. B., Facey, D. E., & Bowen, B. W. (2009). *The diversity of fishes: Biology, evolution, and ecology* (2nd ed.). Wiley-Blackwell. P47 - 51 P86 - 91

Physical features

Boets, P., Dillen, A., Auwerx, J., Zoeter Vanpoucke, M., Van Nieuwenhuyze, W., Poelman, E., & Goethals, P. (2024). *The reintroduction of brown trout* (Salmo trutta fario) in the Upper

Scheldt River Basin (Flanders, Belgium): Success or failure? Water, 16(4), 533. https://doi.org/10.3390/w16040533 P 1 P 6-7

Machinery

Wanjari, U.R., Mukherjee, A.G., Gopalakrishnan, A.V., Murali, R., Kannampuzha, S., Prabakaran, D.S. (2023). Factors Affecting Fish Migration. In: Soni, R., Suyal, D.C., Morales-Oyervides, L., Sungh Chauhan, J. (eds) Current Status of Fresh Water Microbiology. Springer, Singapore. https://doi.org/10.1007/978-981-99-5018-8_20
P13 P29 P135-140

Immages