UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT GROUP 14

DOCUMENTATION REPORT

Smoking Eel

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Chapter 0: Introduction

Introduction

Should we continue to build hydropower plants and dams, when we cannot effectively solve the problems that come along with them? According to a WWF study, “hydropower plants are one of the main causes for the decline of numerous fish species in the Mediterranean region” [1]. Specifically, these systems endanger fish species as it damages their habitats and blocks their migratory paths and prevents them from reaching their breeding grounds. For instance, currently, the European eel population is 2% of what it was in 1980 [2]. The major reason for the rapid decline of the European eel is the increase of water infrastructures that prevent them from entering breeding grounds. The European eel is only one of the many species that are critically endangered due to water infrastructures such as hydropower and flooding protection systems. To solve this, many water infrastructures have integrated systems such as fish ladders and fish cannons, which allow fish to move past these systems. However, these solutions might not fully resolve the issue. According to a study from Yale School of the Environment, fish ladders are not effective, as many fish do not choose to travel through these systems [3].

Since there is a lack of knowledge about fish migration patterns across water infrastructure systems and the effectiveness of fish ladders the research group, “Smoking Eel” from University of Twente are designing a fish monitoring system that can be placed near these water infrastructure systems. Specifically, this device will count the number of fish that are entering or leaving the system. In this way, the data will provide information about the effectiveness of the fish ladders, as well as monitoring the population dynamics of the fish. Additionally, this information can help determine the breeding season and can indirectly indicate pollution in the area. As a result, this data can be used to prevent fish populations from declining. This solution can be impactful, as there is a rising number of hydropower systems and dams, due to the high demand of renewable energy and more frequent floods. This solution could encourage scientists to innovate more effective systems for fish to migrate along these infrastructures.

Chapter 1: Literature Review

1. Dramatic global changes to the environment have wrought unprecedented reductions in biodiversity. The journal article "Wildlife conservation and management in China: achievements, challenges and perspective" is about how China deals with this problem by means of combating illegal wildlife trade, habitat protection, and raising awareness. And the challenges and achievements that come forth of those means [4].

2. The journal article, "Methods for wildlife monitoring in tropical forests: Comparing human observations, camera traps, and passive acoustic sensors" compares the three main methods for monitoring wildlife in tropical forests: Human observation, camera traps and passive acoustic sensors. Their advantages, and the limitations that come with each method [5].

3. The journal article, "Long-term monitoring of wildlife populations for protected area management in Southeast Asia" is about long-term monitoring of wildlife populations for protected area management in Southeast Asia. It's a study that presents abundance estimates and population trends for different species between 2010 and 2020 based on long term distance sampling surveys in Cambodia [6].

4. Precision wildlife monitoring using unmanned aerial vehicles.
   This article talks about how Unmanned aerial vehicles are starting to get more and more relevant in wildlife monitoring [7]. One of the biggest advantages of using UAVs is that especially when it comes to population counts they seem to be way more precise than traditional counting methods. Because of this more and more monitoring projects will transition to using UAVs. This transition will require knowledge about how UAV collected data compares to traditional counting data. UAV counting data is collected by taking multiple pictures of a colony after which these images get analyzed. This way researchers have more time to actually count while there is less movement from the animals then when they would be counting live. Because of this there is less room for errors and the count will be more accurate. On top of that when using UAV images the count can be divided into subsets and this way it can be done in multiple sittings. Examples in this article show that when using UAVs the amount of duplicate counts and missed out counts are less then when using ground count. Because the UAV count method is better it increases the power to detect population trends. However there are some small downsides to using UAVs, one of them being the costs of flying drones and the other downside is how the UAV data corresponds to historical data that was done using traditional methods. Because the UAV count is more accurate, it might give us a wrong image of what is happening to the population numbers compared to when the population was still counted using ground count. However after using UAV count for a longer time period this problem will solve itself because numbers will get clearer.
   The last part of the article describes the details of the example counts used in the article. It describes which camera settings were used, flight altitudes and the number

of people that did the counts. This gave a little bit more insight about how the numbers shown in the article were obtained and this might be useful for our future project.

5. Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa.
   When monitoring wildlife on a local level it is very important to keep close track of the quality of the monitoring. This research found that locally based wildlife monitoring projects often lack in tracking population numbers and because of this the numbers found do not represent the specific colony well [8]. Local Projects also seem to not have enough professionals ready to start monitoring often because of low funding.

6. Looking into the paper; "A review of UASs in wildlife monitoring"[9]. it appears to be a summary and investigation into the viability and potential future improvements/adaptations of using unmanned aircraft systems(UAS) for the purpose of tracking wildlife. Currently UAS are mostly used to track and count individual animals in small numbers as modern hardware used so far has shown to have difficulties when it comes to counting individuals in large herds, though tracking the movement of said herds still remains viable.
   secondly they talk about the limiting factors of UASs which include the following:
   - legislative restrictions on the use of airspace leading to:
     - less to no possibilities of short notice flights
     - less to no capacity to test new flying methods and techniques
     - less opportunity to train people
   - issues with the balance of flight duration, cost and sensor sophistication

7. Reading into "Acoustic localization of terrestrial wildlife: Current practices and future opportunities"[10] it is a paper about the use of autonomous acoustic systems to identify, count and locate different animals for the purpose of wildlife monitoring. They describe some of the methods used and the lack of standardisation in the fields of study and wildlife monitoring projects they are used in.

8. looking into "How biologists estimate populations of animals," [11] this article on the website of the Alaskan wildlife service explains some of the methods used to count and estimate animal populations in an area. These methods are used all over the globe and have proven to be very accurate.

9. This article is about detecting chemical contamination in the environment. The scientist believed that wildlife populations can act as sentinels for excessive chemical contamination[12].

10. The article is all about the method of acoustic monitoring wildlife animals. How to use it in practice, what are the pros and cons of this method [13].

11. Article about different aspects of wildlife monitoring. Like: gathering information, the purpose of the monitoring, and techniques. [14] It also describes different tools you can use for wildlife monitoring.

12. Paper about temperature measurement of bee colonies. They discuss different techniques for measuring the temperature. The information can be used for beekeepers to keep track of the behaviour of the bees and if needed to perform action. [15]

13. The book “bird ecology and conservation” emphasises the importance of bird monitoring, and the different techniques for monitoring them. For instance, they talk about breeding failure and how to research the possible causes. [16]

14. The online lecture, “Bird and Wildlife Monitoring: Integrating Proven Methods and New Technology to Monitor Wildlife” presents and evaluates the different methods for monitoring species [17]. Specifically, the following monitoring methods were discussed: calculating the location of birds through their bird songs, underwater and air drones, camera traps (they take photos of changes in the environment), capture -mark-recapture, satellite transmitters, GPS tagging, nest monitoring and apps that citizens can record their observations (such as eBird and iNaturalist). Additionally, it presents the type of information that can be gathered by monitoring species, such as the migration patterns, population dynamics, wildlife interactions and the number of offspring.

15. The news article “Hares, stoats and rabbits added to Dutch endangered mammals list” from the Newspaper “DutchNews.nl,” informs the readers about the rapid decline of rabbit and hare population size due to hunting [18]. The article also references other endangered species in the Netherlands that are on the Red Lists, such as the European hamster and the dormouse. Finally, it acknowledges the success of conservation strategies that managed to increase the population size of grey seals, otters, and beavers.

16. The web page, “Biodiversity” from the University of Twente website, presents UT’s action plan for increasing biodiversity in the campus [19]. Additionally, it states the types of species that can be found on Campus, such as squirrels, bats and more. Some of these species are endangered (European green woodpecker and spotted flycatcher). Bats are monitored in the bat house behind Westhorst.

17. The webpage “Animal welfare” from the Government of the Netherlands website, states that 500 species in the Netherlands are protected by law [20]. Specifically, protected animals cannot be controlled or hunted unless they have a licence from the government. However, some of these species (geese, hares, rabbits, pine martens, bats, birds, foxes) create problems. For instance, pine martens chew on electrical cables. Additionally, the article briefly mentions that wild wolves have returned to the Netherlands.

18. This is a study on beetle diversity on different tree species, specifically beetles who live in and from dead trees. Mainly the way of monitoring the beetles is relevant to us. The way they did that was by having logs from different tree species layed out in different locations. The beetles were monitored by placing an emergency trap on each log. Emergency traps are traps that catch insects as they transform to their adult stage. Monthly, the traps were emptied and evaluated. [21]

19. From this study we can learn how infrared cameras could be used to monitor wildlife. They show ways of positioning the cameras and how to process the data efficiently, since that can be hard with using cameras for monitoring wildlife. [22]

20. This is a study in which they used eDNA sampling as a way of monitoring wildlife in a river. They describe the methods and results, which can be helpful in our own project. [23]

Chapter 2: Identification of General Problems and Challenges

1. Capture and mark, GPS: How to make marking more animal friendly?
2. Protected animals can create problems:
    a. pine martens- chew on electrical cords
    b. damage of agriculture crops
    c. domestic animals could be killed (fox, wolves)
3. Reasons for species to be endangered
    a. invasive aliens
    b. pollution
    c. hunting/overfishing
4. Severe lack of standardisation in the equipment used/available.
5. It is hard to monitor small animals as they are small to observe. Estimation is done for them, but this can lead to inaccuracy. [5]
6. Sensors and cameras can damage parts of the habitat and can be expensive[5]
7. It is difficult to monitor animals in water due to the negative impact of water on electrical components.
8. Very expensive to track large animal migration patterns (drones).
9. Monitoring species long term without damaging their habitat.

Chapter 3: Identification of Relevant Problems

1. **Identifying invasive species.**
   The economic and environmental impacts of alien species invading are getting bigger in Europe. [24] To do something about this, it would be valuable if the invasive species are monitored.

2. **There are too many cats in Cyprus.** Specifically, according to Cyprus Mail, there are more cats in Cyprus than people [25]. Most of these cats are not taken care of, as there are too many. Since the cat population keeps increasing, it is crucial to be able to monitor the number of cats. Additionally, monitoring cats can help scientists know if a solution for reducing cat population is effective.

3. **Overfishing**
   According to WWF, overfishing is one of the main causes of the rapid decrease of marine wildlife [26]. Due to increase in population and more technologically advanced fishing methods, fish are captured at a rate faster at which they can reproduce. As a result, the population of marine life is decreasing. It is crucial to monitor the amount of fish in the water body, in order to help scientists calculate the sustainable yield more accurately.

4. **The lack of knowledge of fish migration patterns through fish ladders and water infrastructure systems (hydropower plants and dams).**
   Many fish species spend their time both at sea and in fresh water bodies (rivers and lakes. However, due to an increase in flood protection systems and hydropower plants, these fish struggle to move between freshwater and salt water, preventing them from reaching their breeding grounds, decreasing their population. Even though there are many dams and hydropower plants that are built, many of them do not monitor the environmental impact that these systems have on surrounding wildlife. Despite the fact that some organizations use systems such as fish ladders to make the water infrastructures more environmentally friendly, some scientific studies reveal that they are not so effective [3].
5. **Lack of awareness of Wildlife on Campus**
   We are aware that pollution of nature on campus is a big problem. Students just simply don’t care about how clean the campus is, and we think this might be because students don’t actually know about wildlife diversity on campus! Showing them what sort of plants and animals inhibit this campus might make them think twice before throwing plastic in the bushes again!

Chapter 4: Problem Selection and Motivation

Problem selected:
The lack of knowledge of fish migration patterns through fish ladders and water infrastructure systems (hydropower plants and dams).

Motivation:
Due to the high demand of renewable energy and more frequent floods, hydropower systems and dams are increasing. Therefore, more aquatic species are becoming more endangered [1]. As a result, it is crucial to be able to monitor the number of fish that can pass these water systems, to be able to measure the negative impact that these systems have on aquatic species. In return, this could be a catalyst for making these systems more environmentally friendly, protecting fish species from further decline.

Even though organizations implement systems such as fish ladders and fish cannons to make the system more environment friendly, another issue rises: The lack of data on the amount of fish that pass through these systems. Collecting this data is vital, as it can serve as an indicator of the effectiveness of the fish ladders and the fish cannon's ability to solve the problem.

Finally, if the fish ladders are effective, the number of fish that pass through these systems can help determine the breeding season and can indirectly indicate pollution in the area.

Chapter 5: Potential Solutions

1. **Monitoring system for detecting migration patterns for fish moving through water infrastructure systems (dams and hydropower plants)**
   A fish monitoring system that can be placed before or after fish ladders or water infrastructure systems (such as dams and hydropower plants.) The system could monitor the number of fish entering and leaving the water infrastructure and determine the type of fish based on their size and speed with two groups of IR emitters and receivers. A motion detector could be incorporated for more accuracy.
2. **Fish gate/capture trap**
   We could make a gate that prevents fish from continuing their path when the gate is closed. When a camera and program identifies the type of fish, it counts them and then the gate opens if the fish are not an invasive species.

3. **Automatic sampling system**
   A crane-like system could transport a bucket down underwater and collect fish samples. Then, the bucket could move up and a camera and program could be used to identify and count the type of fish. Finally, the fish are returned to the water body.

   This solution partially solves the issue, as it does not help the fish move over the flood protection systems. Additionally, there are risks, such as damaging the ecosystem further by placing machinery next to habitats and the machinery might require a lot of energy to power. This solution might be expensive as it has many requirements such as machinery, AI software, cameras, power energy and a bucket/container to catch the aquatic organisms. This automatic sampling system will most likely provide accurate data, as it will most likely collect sampling data faster than humans. However, this solution will most likely have negative consequences for the environment, as it requires a lot of energy.

4. **Fish ladder with infrared sensors.**
   One of our solutions is to make use of a fish ladder with a monitor system integrated in it. With a fish ladder, fish can move upwards and downwards, allowing them to move between the water bodies which are separated by water infrastructure systems (dams and hydropower plants). The basic principle of the fish ladder is as follows: to climb the ladder, a fish must swim against the current of water to reach a succession of climbing pools. When they reach a climbing pool, they can leap through the waterfall of flowing water and stop to rest in a pool, and after resting continue [28].

   To monitor the fish ladder, we could make use of an infrared and ultrasound sensor at the beginning and end of the fish ladder. With making use of these sensors, you can count the number of fish passing the fish ladder. We make use of two different sensors, so the results are more accurate. Infrared works well with more clear water and during daylight, and ultrasound is also usable at night and in muddy water. It could be a risk to make only use of one sensor per type, but you can solve that by

adding more of the same sensors. If the detecting system works as expected, you could add a camera to determine the species which passes the fish ladder. For this solution you need a fish ladder, something to save data on, a camera and ultrasound and an infrared sensor. If you determined the different types of species, it could be necessary to use a human for this. To test our system, we should make use of different types of water (like water flow and muddiness) and fish to check if the sensors work correctly. Depending on if we add a camera or not, we need to check the results in different types of water as well. For the demonstration, we will make a prototype of a fish ladder and fake fish, to show how the sensor works and what the outcomes are.

5. **Fish escalator-like system to prevent fish from getting crushed through the hydropower system.**
   This solution can be realized by having a large container being filled with water, and fish also get caught. The large container is being pulled up and dumped on the other side of the flood protection systems. This should not be a high maintenance system, because the water in the container will not stay there and so won't access plants and trash being caught. Monitoring can be done within the container quite easily. Pulling and dumping the container provides time to record or photograph the inside of the container. Recognition systems can do their job to monitor species that use the system. This should also be safe for the fish if done correctly, but there is no guarantee that fish don't get stuck in the opening of the container.

6. **Fish cannon and slide with infrared sensors.**
   The last solution we thought of was a fish ‘cannon’, this basically being a long tube that goes over a flood protection system, there are sensors at the beginning of the tube there are sensors that are able to determine if there is a fish nearby, if so the tube opens and the fish is able to enter, and then a camera will film the fish, so we can monitor the amount of fish that go through it. Then, the fish will swiftly be sent through the tube to the other side of the flood protection system, if a fish wants to go down the flood protection system, there is a slide that they can just go down from, at the beginning of this slide there are also sensors and a camera for monitoring the amount of fish that go through it. This solution is very friendly for the fish as it doesn’t harm them in any way. But it is quite hard to make a working ‘cannon’ that has enough force to let the fish go over the dam, but not enough to actually injure them.

Chapter 6: Solution Selection

Solution 1 has been chosen:
Monitoring system for detecting migration patterns for fish moving through water infrastructure systems (dams and hydropower plants).

Reasons for choice:
The main reason for choosing this solution is that it resolves the chosen problem (the lack of knowledge of fish migration patterns through fish ladders and water infrastructure systems) most effectively. Specifically, this monitoring system is designed so that it can be integrated in a variety of places such as fish ladders, dams, and hydropower plants. As a result, the device can collect more meaningful data.

Additionally, this solution has the least cost required, making it more desirable for organizations to implement. Furthermore, this monitoring system does pose danger to fish, as it does not occupy a lot of space and sensors are not harmful.

Finally, since this solution has the potential to collect a variety of different data, it leaves room for an ambitious plan. Specifically, one that involves AI and a system that could help detect and capture invasive species.

Modules
Table 1: *The modules and tasks involved.*

Module	**Tasks Involved**	**People**
Time manager	- Keeping track of everyone's progress and making deadlines for time plan. - Adapting to a new time plan, if problems are encountered.	Theoni
Circuit building	- Designing the circuit setup. - Building the circuit part of the sensor module.	Justen
Programming	- Arduino Programming: Collecting data about the number of fish entering and leaving the water infrastructure system. Additionally, collecting information about the size of the fish and - Processing Programming: Displaying the data. - Connecting Arduino data to Processing.	Rowan, Colin and Eva.
Designing	- Creating a water tank. - Building the setup for the circuits.	Eva, Yannick and Justen.

Documentation	- Discussing with other team members about the topics in each chapter. - Making changed - Writing and editing the final report.	Theoni
Video creator	- Creating the video for the final demonstration.	Colin
Researching	- Researching about the different types of sensors that can detect motion underwater. - Researching where the equipment required for the circuit could be bought.	Eva, Yannick, Justen, Colin, Rowan and Theoni.

Chapter 7: Methodology

Table 2: *The data collection and analysis.*

Data Collection	Data use/Analysis	Sensors utilised
The number of fish that enter the fish ladders. The number of fish that exit the fish ladders.	Population dynamics of fish (This is the data that we will focus on.) Can indicate the efficiency of fish ladders Indirect indication of pollution in the area Can help determine the breeding season	LDR sensors and LED lasers Motion sensor (for more accuracy)
The size of the fish. The speed at which the fish are moving.	Could help determine the species of fish.	LDR sensors and LED lasers

1.How does our solution qualify as a smart environment?

This solution qualifies as a smart environment because it is context-aware (has sensors), and it is autonomous (does not need human interaction, to count the fish). Additionally, for the ambitious plan of this solution, this system would be intelligent, as it would utilize AI to distinguish different fish species more accurately.

2.Which equipment will be used?

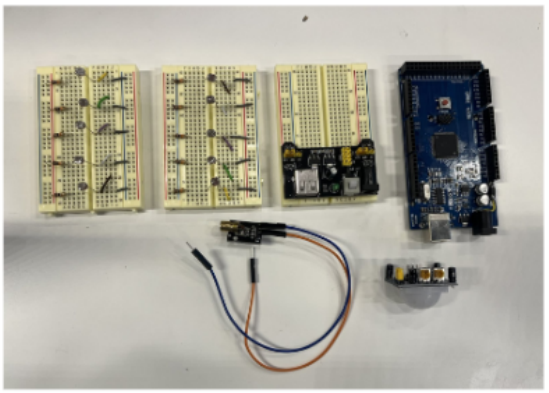

Figure 1: *The Equipment for the circuit.*

<u>Basic plan:</u>

- 10 LDR sensor
- 10 lasers
- Motion sensor
- Arduino (Omega)
- Plexiglass for the water container.
- Glue for the container
- Software: Arduino and Processing
- Container/see through PVC pipe
- 3 breadboards
- Cables
- 10k Ohm resistors
- Fish model: string, fish made by laser cutting plexiglass.

<u>Ambitious plan:</u>

- AI program that is able to distinguish different fish species.
- Underwater camera.

3.Would the sensors need calibration?
No.

4.Would the equipment be used in a controlled environment or not? In the latter, would a special casing be needed?
We do not need a special controlled environment, but because we use the equipment in the water, a special case will be needed, to protect the equipment from water damage.

5. and 6. How to collect data? When to collect it? How will the data be analysed?

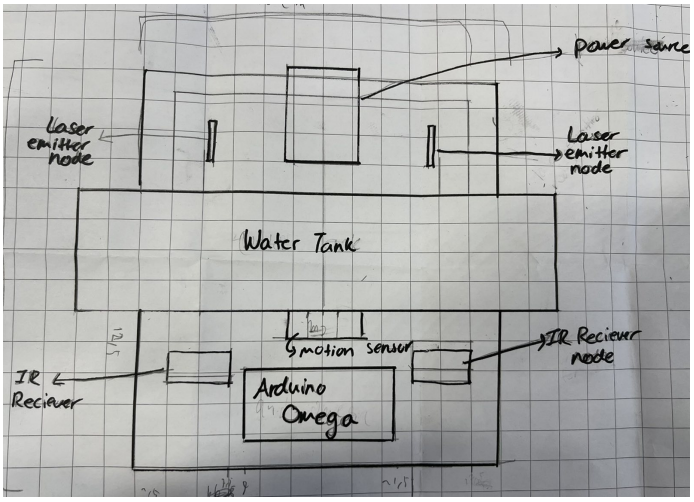

Figure 2: *Design of the Fish Monitoring System*

The data collection and use is presented in Table 2, but for more detail, read the following:. The design of the fish monitoring device is presented in Figure 2. Two groups of LDR sensors (instead of IR receivers) are connected to an Arduino Omega. On the opposite side of the water container, there are groups of lasers pointing at the LDR sensors. The data received from the LDR sensors will help determine if a fish is moving towards or away from the water infrastructure, depending on which group of LDRs is triggered first. For instance, if there is a change in resistance detected from the group of IR sensors on the right side first and then the group on the left side, it means that the fish is coming from the right side (entering). Vice Versa, the fish would be leaving the water infrastructure system.

Additionally, the amount of LDRs that have detected a change in resistance, will help determine the size of the fish. With the help of an internal timer in Arduino, the time it takes for a fish to move from one group of LDRs to the other group, will be employed to calculate the speed of the fish. It is important to note that if the solution were to be applied to real water bodies, IR receivers and emitters would be utilized instead of lasers and LDRs, to prevent posing danger to the fish.

As seen in the figure above, there is a motion sensor between the two groups of IR sensors. In the original plan, there would be a camera that would be connected to the motion sensor, so that a picture is taken when the motion sensor detects a fish. However, due to high costs and not adequate resolution for underwater, this was not possible.

Ambitious plan: A waterproof camera could be connected to the motion sensor. These photos could be then analysed by AI to determine the fish species. Therefore, the system could also count the number of fish species (richness) and the amount of fish in each species (evenness).

7.How to use data for automation/control/actuation?

- This process was described in the answers of questions 5 and 6.
- This system is automated, as it can count fish entering and leaving the water infrastructure system and determine the fish species by determining the fish's size and speed, without human interaction. This is mainly done through two groups of LDRs. For accuracy reasons, there will be a motion sensor, to validate the results from the IR.
- Previous plan: For further accuracy, there could be a camera connected to the motion sensor. Once we have collected enough pictures, we can check the percentage of times the picture taken was actually a picture of a fish. Let us say that 90 out of 100 pictures are actually pictures of a fish, then we could count the amount of pictures, multiply it by 0.9 and have a calculated guess for how many fish have passed. The longer the system is active and thus, the more pictures are taken, the more accurate the percentage of fish passing is.

8.Validation?

<u>Test 1:</u>

- We have checked if the laser and LDR sensor works underwater.

<u>Test 2:</u>

- The first prototype will be finished on Thursday. The fish will be emulated by pulling a fish model through the fish ladder.

9.How does my methodology lead to a solution that solves the problem under study?

This monitoring system provides information on the number of fish that enter and leave the fish ladder/dams/hydropower plants. This information is important as it can measure the negative impact of dams/hydropower plants on aquatic wildlife and determine the effectiveness of the fish ladder. As a result, this data can estimate the fish population, can serve as an indirect indication of pollution in the area (based on the number of fish), and can help determine the breeding season.

Time plan

Weeks	Plan/goals
6 (Dec 19-23)	- Finalize the circuit diagram (Justen) - Researching the equipment needed (Whole team) - Finish purchasing the equipment (Justen) - Writing the Introduction (Theoni)
7 (Jan 9-15)	- Testing if the sensors work with the container of water (Whole team) - Creating the water container (Justen and Yannick) - Creating the model Fish (Eva) - Writing program for determining the direction of fish entering the dam (Rowan)
8 (Jan 16-22)	- Changing the method and timeplan (Theoni) - First prototype (Whole team)
9 (Jan 23-27)	- Connecting Processing to Arduino (Colin and Rowan) - Drawing the circuit diagram (Eva and Yannick) - Adding chapter 8 and 9 in report (Theoni) - Editing and finalizing the report (Theoni) - Demo Market (Whole team)

Chapter 8: Validation

Test 1: Checking if lasers, LDR and ultrasonic sound sensor work with water.

A circuit that had a buzzer that beeped whenever the laser was directed on to the LDR was created. When a container filled with water was placed between the laser and LDR, the function of the circuit continued to work.

The ultrasonic sound sensor did work as planned, as it collected many inaccurate data. As a result, we decided to use a motion sensor instead.

Test 2: First Prototype.
The first prototype, presented in Figure 4, could detect if a hand was moving right or left in the water.

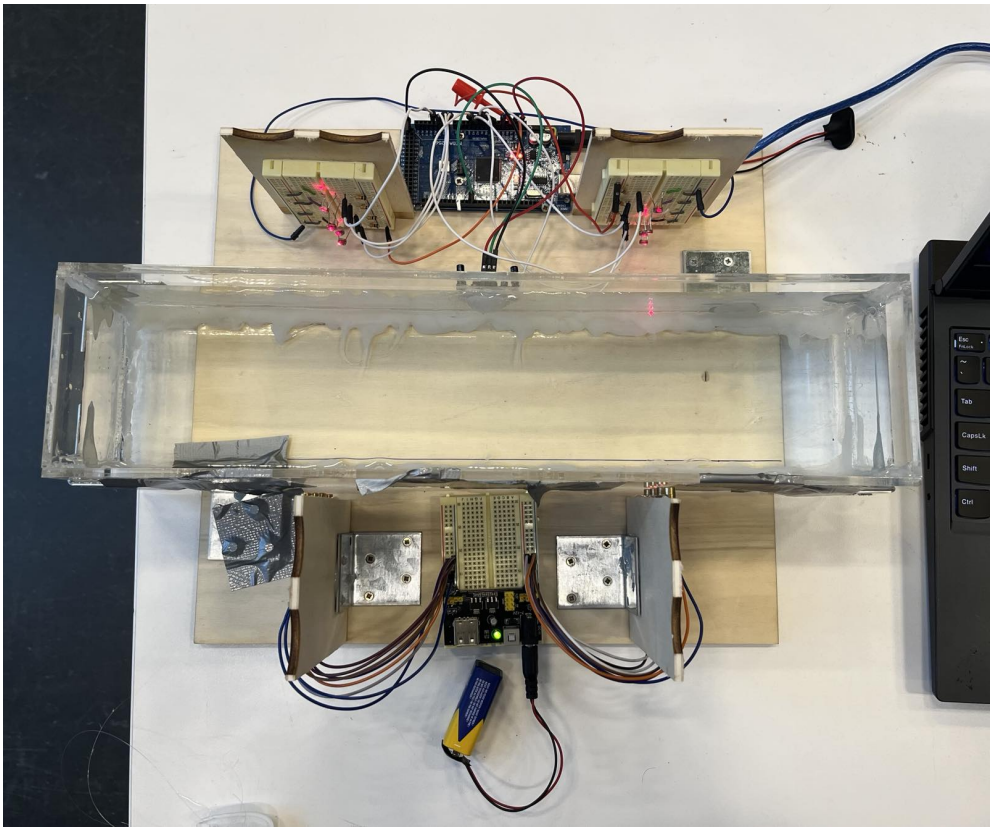

Figure 4: *Top view of the fish monitoring system*

Chapter 9: Results and Conclusion

Result: Final Fish Monitoring System

The Final Fish Monitoring System has the same setup as the first prototype, but has undergone many improvements. For instance, the system collects and analyses a greater variety of data (measuring the size and speed of the fish) and presents the data in a more aesthetically pleasing way by using Processing.

Since the lasers pose danger to real fish, we created fish models, which can be seen in Figure 4. These fish have a sting attached to them, so they can easily be pulled by someone when they are in the water. If this system is applied in real water bodies, the lasers and LDR will be replaced with IR emitters and receivers, so it is safe for the fish.

Due to government regulations, limited time and high costs, we were not able to implement this in fish passageways.

Photographs of the Final Fish Monitoring System

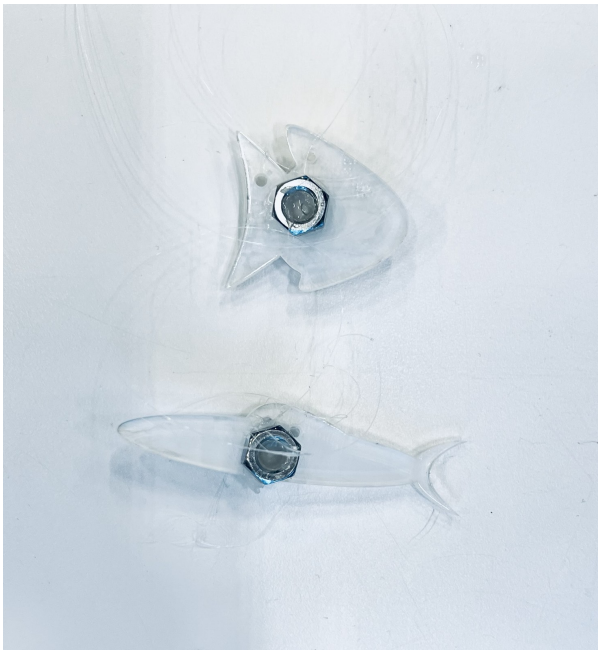

Figure 5: *Model fish.*

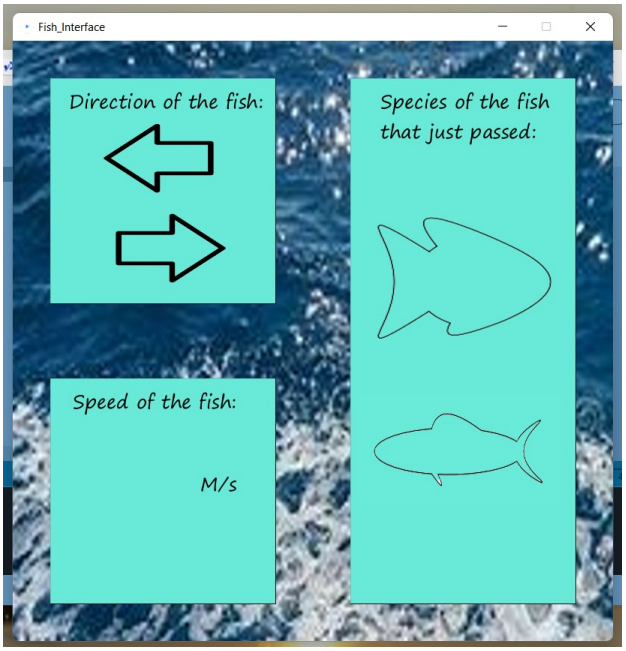

Figure 6: *Interface for presenting the data.*

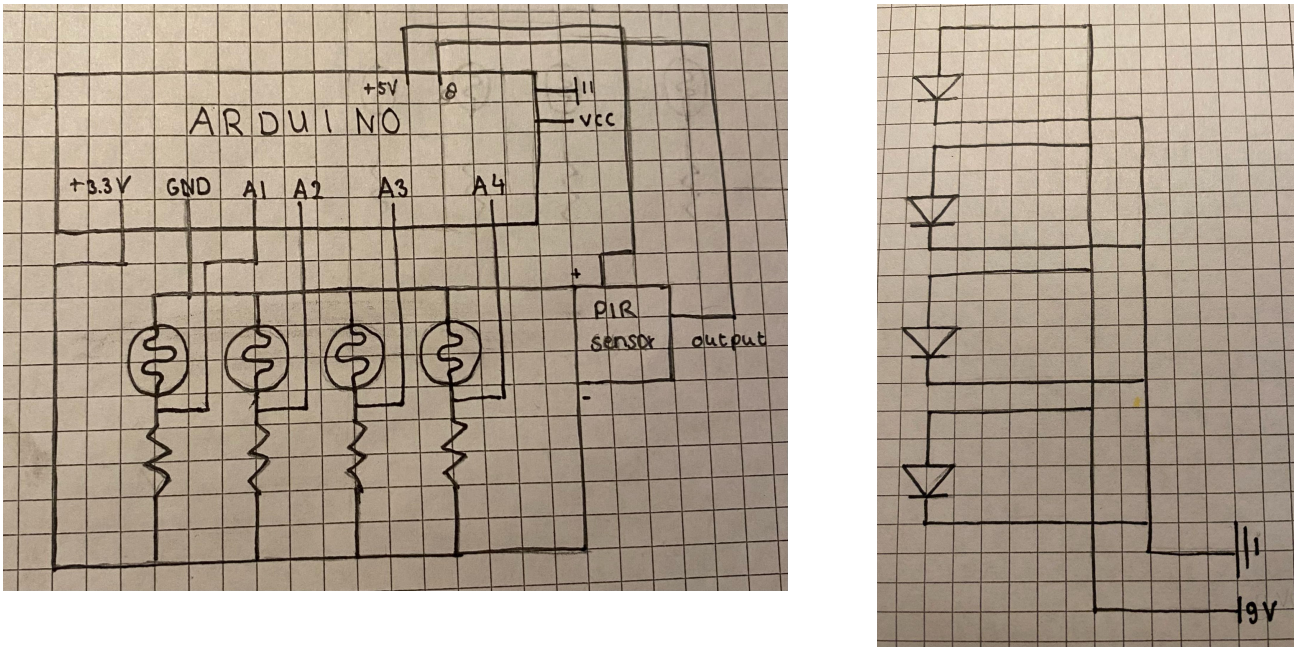

Figure 7: *Two circuit diagrams that present the main circuit components of the system. The left one represents the sensor setup (LDR and Motion sensors) and the right one is the circuit setup of the lasers.*

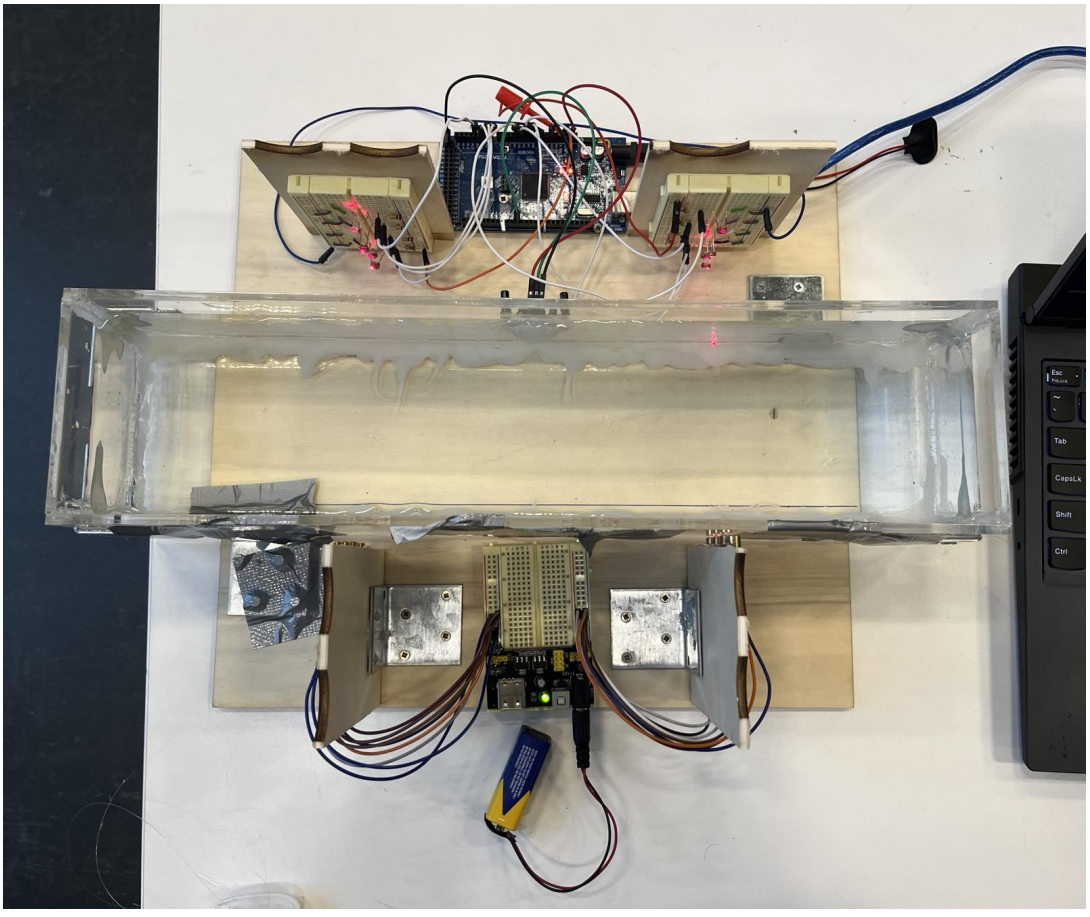

Figure 8: *Top view of the fish monitoring system.*

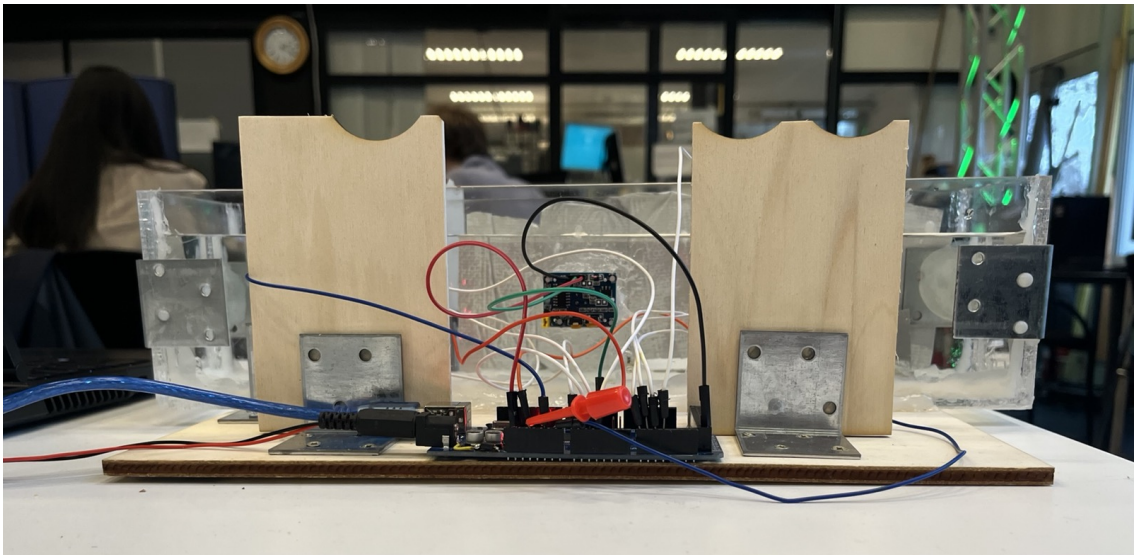

Figure 9: *Side view of the fish monitoring system.*

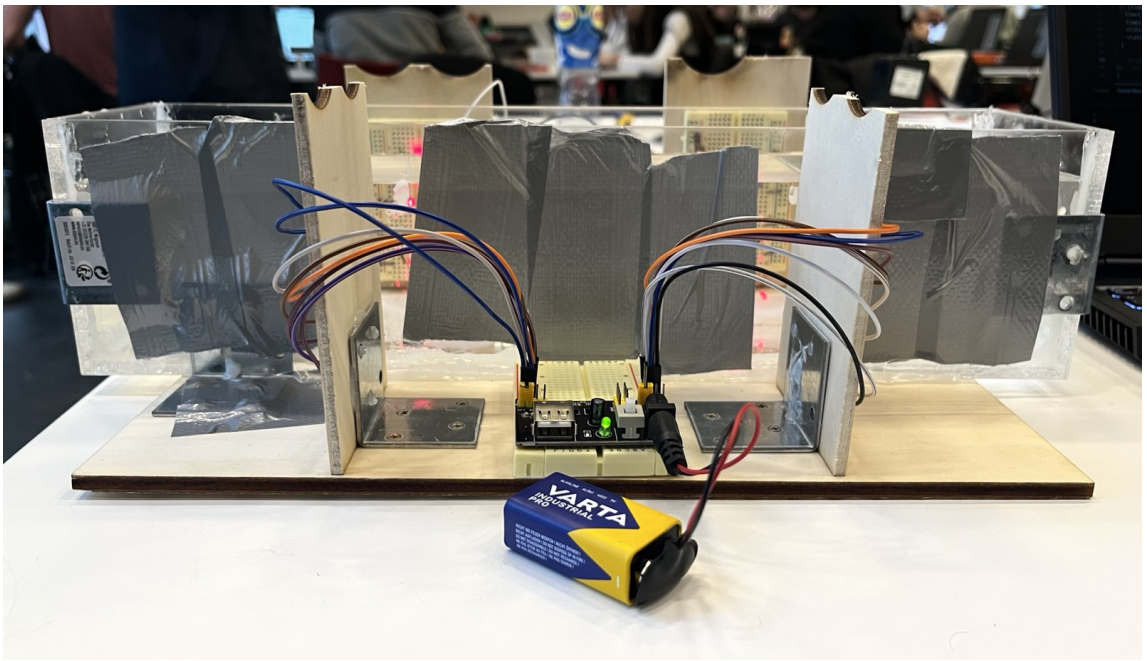

Figure 10: *Side view of the fish monitoring system.*

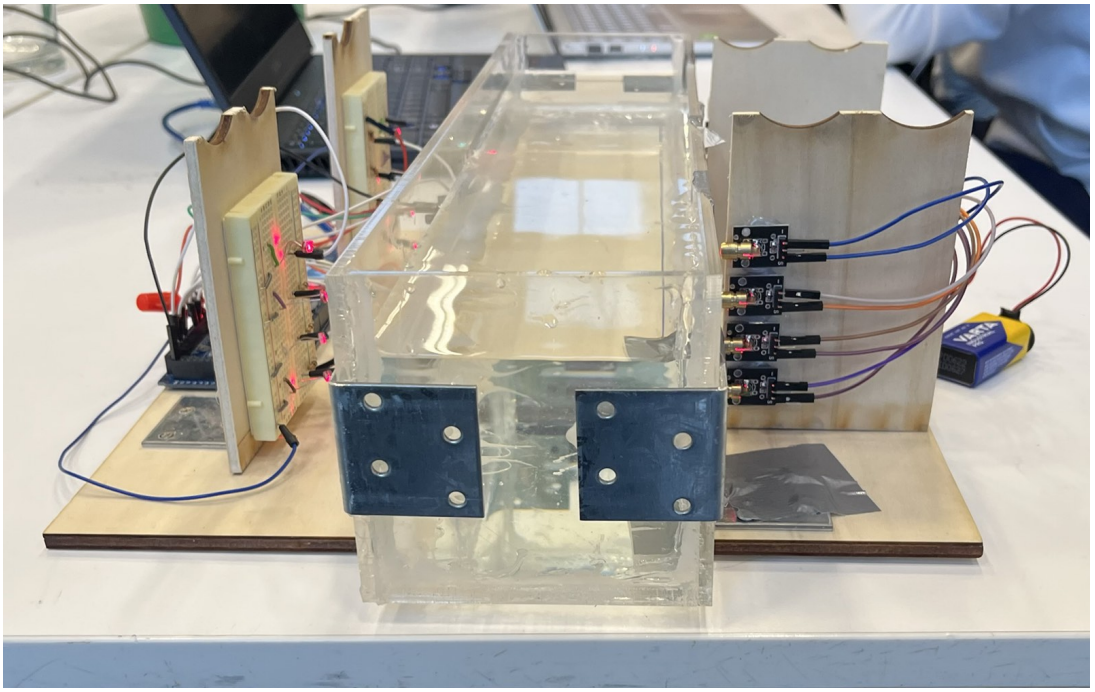

Figure 11: *Side view of the fish monitoring system.*

Conclusion

Even though this monitoring system was not implemented in nature, it is successful, as it is a new method for monitoring fish. Additionally, the data that it collects is very valuable as it can help measure the negative impact of dams/hydropower plants on fish populations and provide insight into the effectiveness of solutions such as fish ladders and cannons. This data is increasingly crucial, as there is a growing number of dams and hydropower plants, thus a greater need to protect fish species.

In addition, if this system utilized AI and was applied to fish passageways, it could effectively monitor the fish migration patterns, species richness, species evenness, breeding season and indirectly indicate pollution or depleting fish stock. Since the data provided by this fish monitoring system can be utilized for multiple purposes, it has a wide range of future possibilities.

Chapter 10: Future Possibilities

This chapter was added as we want to continue working and improving this fish monitoring system. However, we might change the purposes for this device.

Detecting and blocking invasive species
With the help of AI and a camera, this system could be utilized to detect and block invasive species from entering another ecosystem. The system could block the fish, by closing a gate when it is close by. This could be implemented in areas such as Panama and the afsluitdijk canal.

Children's Game
Furthermore, this monitoring system could also be turned into a children's game, to increase children's awareness and engagement with aquatic wildlife. The fish toys could be individually sold, to encourage children to collect as many fish toys that are different fish species. As a result, when the child moves the fish in the water tank, the digital screen will provide fun facts about this species such as its red list status, where it is found and more.

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