REMY

INTELLIGENT MONITORING SYSTEM
FOR LIFE BELOW WATER

CBI A^3 powered by

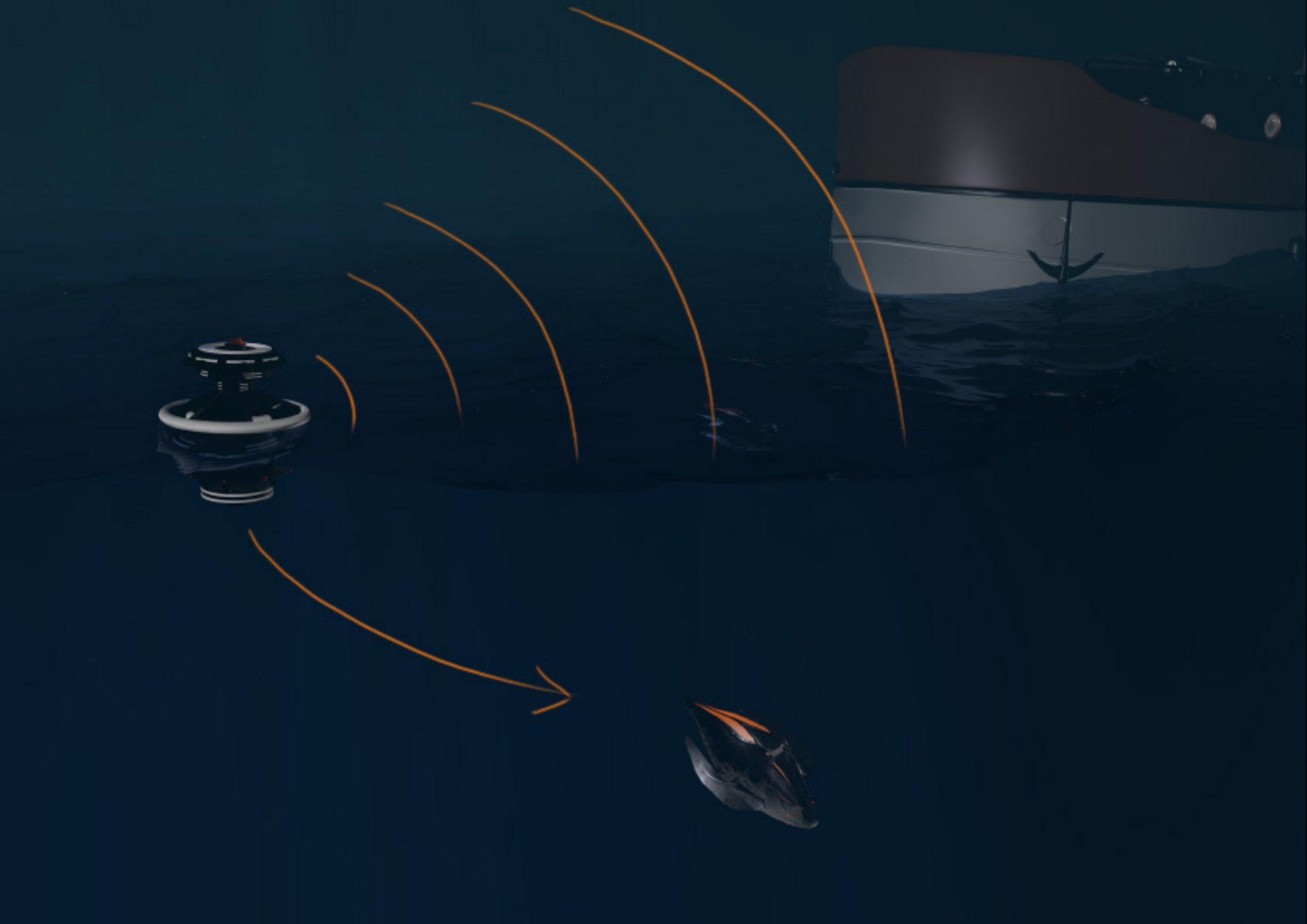
"YOU CANNOT ESCAPE THE RESPONSIBILITY OF TOMORROW BY EVADING IT TODAY."

ABRAHAM LINCOLN

ABSTRACT

The overfishing of our seas is more and more becoming an essential problem of our time. If we do not do anything about it, we will drift towards a dark future. ReMY is our concept to avert such a future. A Supervision, Control and Data Acquisition System (SCADA) is interconnected with drones and buoys all over the ocean. The system is based on CERN technologies and able to track and monitor life below water. ReMY enables us to save endangered species, boost science and research and push fishing industry towards sustainable methods.

Our concept is based on the UN Development Goal 14 "Life below water", which aims to protect marine life and face societal needs in this context. The UN Goals aim for a more sustainable world by 2030. In the CBI A^3 Challenge Based Innovation Program, we meet those UN Sustainable Development Goals with the support of CERN technology.



THE TEAM

Leo is studying Computer Science and is interested in user centered design topics like user experience and design thinking. He is inspired by the sustainable and open mindset of the CBI project.

Fabienne is doing her masters in medical engineering at University of Applied Sciences Mannheim. She is interested in electronics and sustainable and ethical development. She's excited about the CBI project because it teaches her to work in a multidisciplinary team and gives her many new ideas for developing solutions.

Vanessa is interested in design thinking and design based projects. She is doing her bachelors in communication design at University of Applied Science Mannheim. For her the CBI project is an opportunity to work in an interdisciplinary team and finding a sustainable solution which might bring a change to the future.

Bartosz is a Master of Science Software Engineering student in his first semester at University of Applied Sciences Mannheim, participating in the Challenge Based Innovation project (CBI). This project is an opportunity to grow, meet new people from around the world and work on a solution for an important issue of the future.

THE SOCIETAL CHALLENGE

For our challenge, we decided that the most important aspect of SDG 14 is the stabilization of the fish stock. Since humanity started industrial fishing, the fish population has been on a steady decline. According to the Food and Agriculture Organisation (FAO) of the United Nations [1], the average food fish consumption has grown from 9.0 kg in 1961 to 20.2 kg in 2015 (1.5 percent per year). This will be a problem in the future, not only because fish are needed for a stable ecosystem, but also because a lot of people rely on fish as their primary food source. For some, there are also traditional reasons to consume fish.

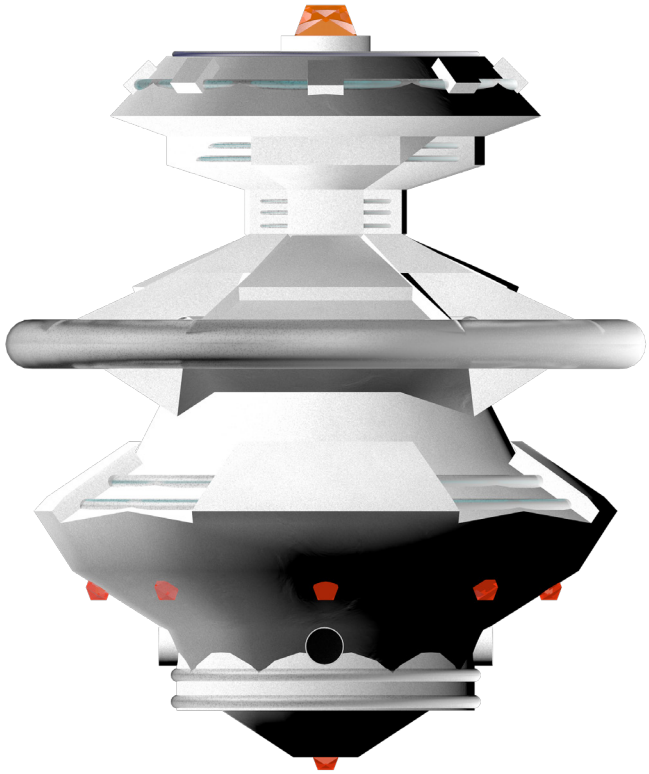
For example, the Maldives have a fish consumption of 166 kg per capita. [2] The population mainly relies on fish as their source of protein. At the same time they have an exceptionally high growth in population. The lack of sustainable stock management resulted in a decline of fish catch by 2011. This can lead to serious problems like malnutrition for the population of areas like the Maldives.

Other people rely on the fishing industry since its the primary industry sector for lots of coastal areas.

During our research, we found that the solution to this problem is tricky, because there's many different factors at play. For example it wouldn't help to cease all fishing immediately, because the oceans have to be fished at a certain rate to ensure ecosystem stability. It's also important to use the resource "fish" as efficiently as possible because so many people rely on it.

CONCEPT

At this point it is necessary to highlight the main functions a bit more. The ReMY system is divided into three main parts, the fish drones, the buoys and the software.

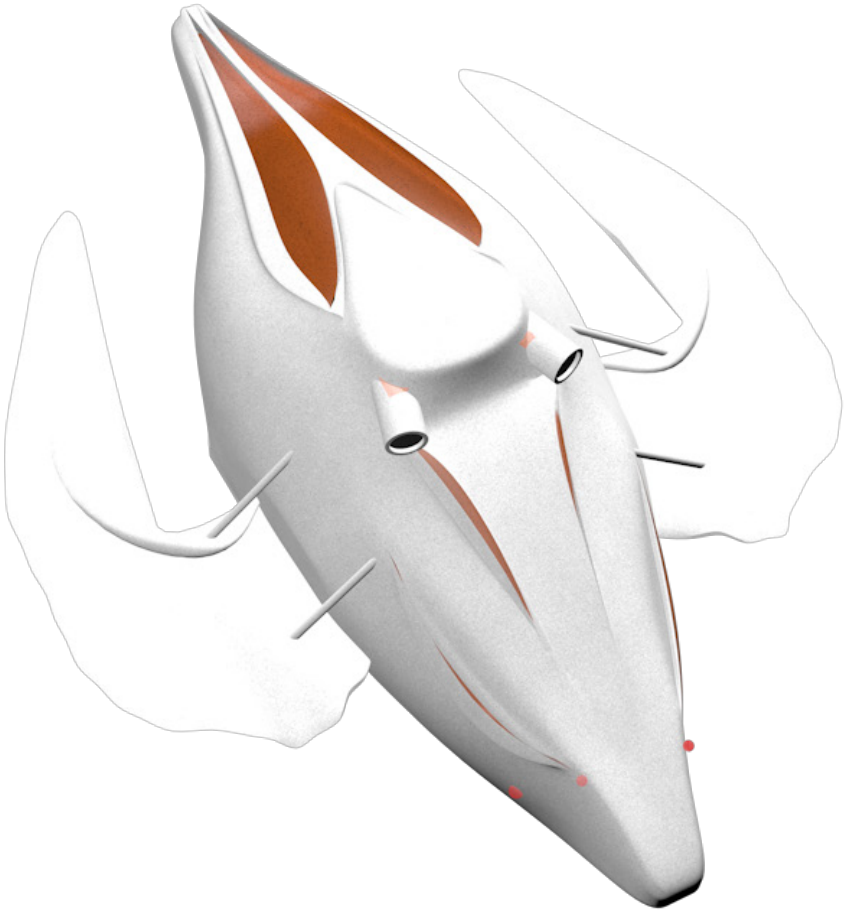


THE BUOYS

The ReMY buoys are smart and self sufficient ocean buoys. They have different sensors that collect data on biomass, weather, marine conditions and many more. 5G brings the possibility to send this data in nearly real time to a central data processing center. Solar and wind energy supply the buoy with enough electricity to deliver non-stop real time data collection. [3]

Intelligent placement of the buoys will form a big grid of buoys, which divides the surface of the ocean into triangular tiles. This grid is easier to handle and allows a modular and flexible deployment of the system. Depending on the needs, buoys can be added to change the scale of certain areas.

Sensor data and activities can be precisely aligned, as the individual tiles use specially tailored hardware. The buoys will be able to gather highly accurate data of what is happening within a specific tile. For example, in heavily fished areas, the buoys can be placed closer to each other to be able to track large swarms more precisely.

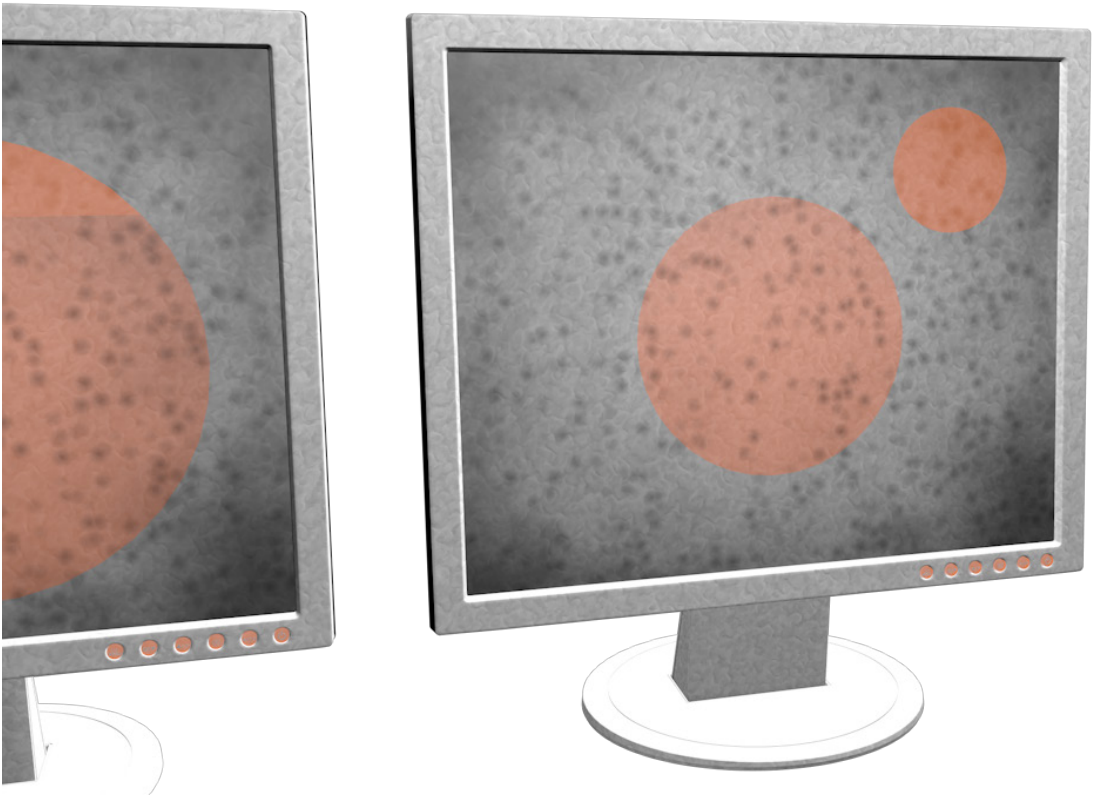


THE FISHDRONE

The autonomous fishdrones are used to actively intervene in marine life. Depending on the area of application, the drones can perform different actions. For example, they can act as a companion for endangered species and protect them from illegal fishing activities or separate large swarms of fish from unwanted by-catches.

The ReMY drone is designed to seamlessly integrate into the ecosystem. By combining natural and biodegradable materials with natural movement, adjustable size and different types of sound they're able to perform their tasks in a environment friendly way.

The buoy act as a control and recharge station for the drone. From this home port the fishdrones fan out into the grid and act as a shepherd dog for fish. By following them and gathering data we can learn about their behaviour and get new insights. This information can help us to either guide the fishes to the next fishing boat to minimize their effort, or to protect them if necessary. For example we can scare them away from the fishing vessel if the swarm is not ready to get fished yet, or if it's an endangered species.



THE DATA PLATFORM

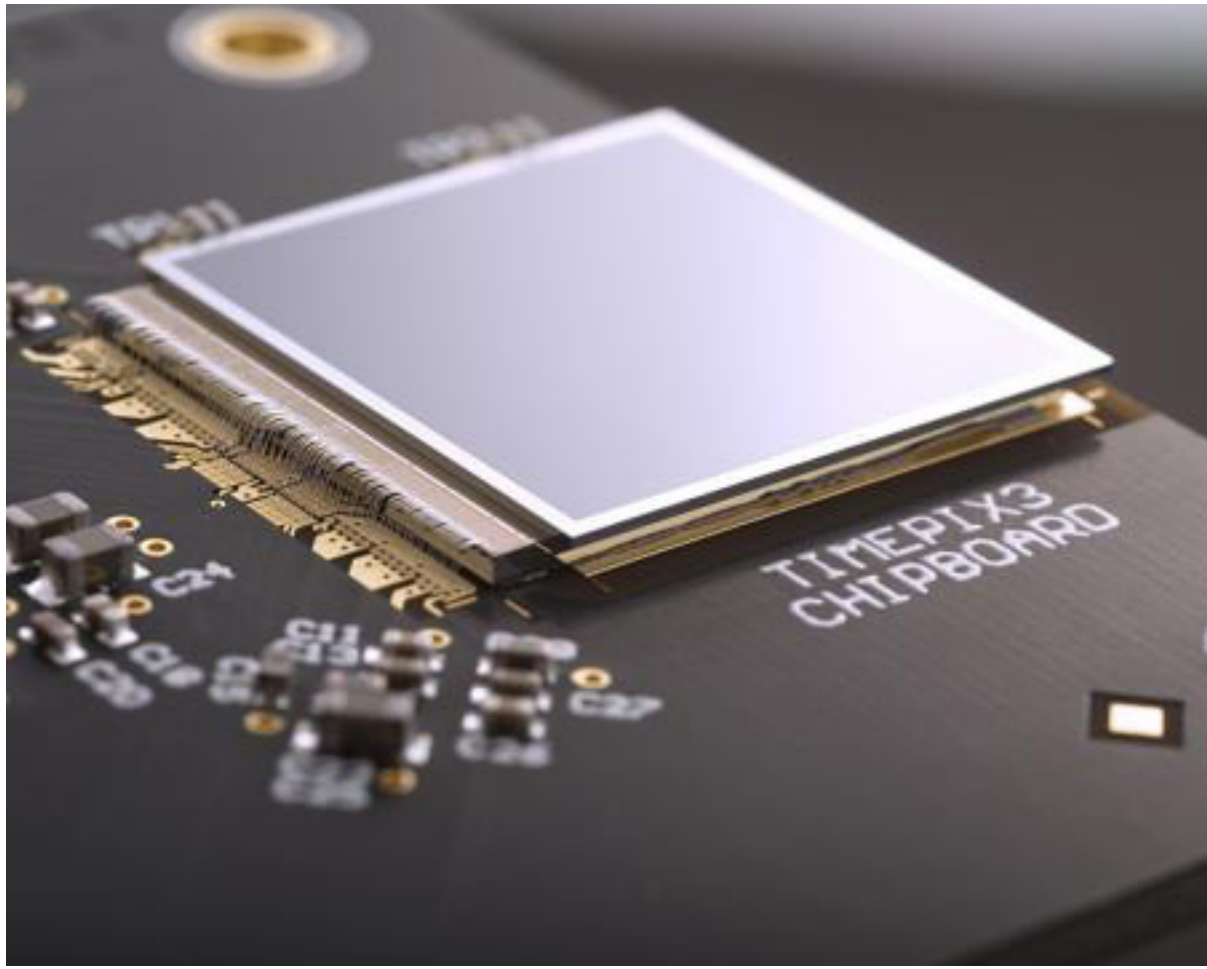
Processing the collected data from our buoys and drones is a crucial part in ReMY, not only for the features like fish stock monitoring and coordination of catch quotas, but also for continuous improvement of our equipment, algorithms and processes. Therefore the raw data transmitted by the buoys needs to go through a data cleaning and integration phase, before it can be stored in the data warehouses. From then on, we can perform different data mining techniques and gain new insights about the marine world. The decoding of the swarm behavior is not only important for the control of the drones, but also for research in general. Furthermore we can offer information for smarter and more target-oriented fishing methods. Other interested parties can access our databases over a public interface. Here, a distinction is made between commercial and non-commercial use and fees have to be paid accordingly.

CERN TECH

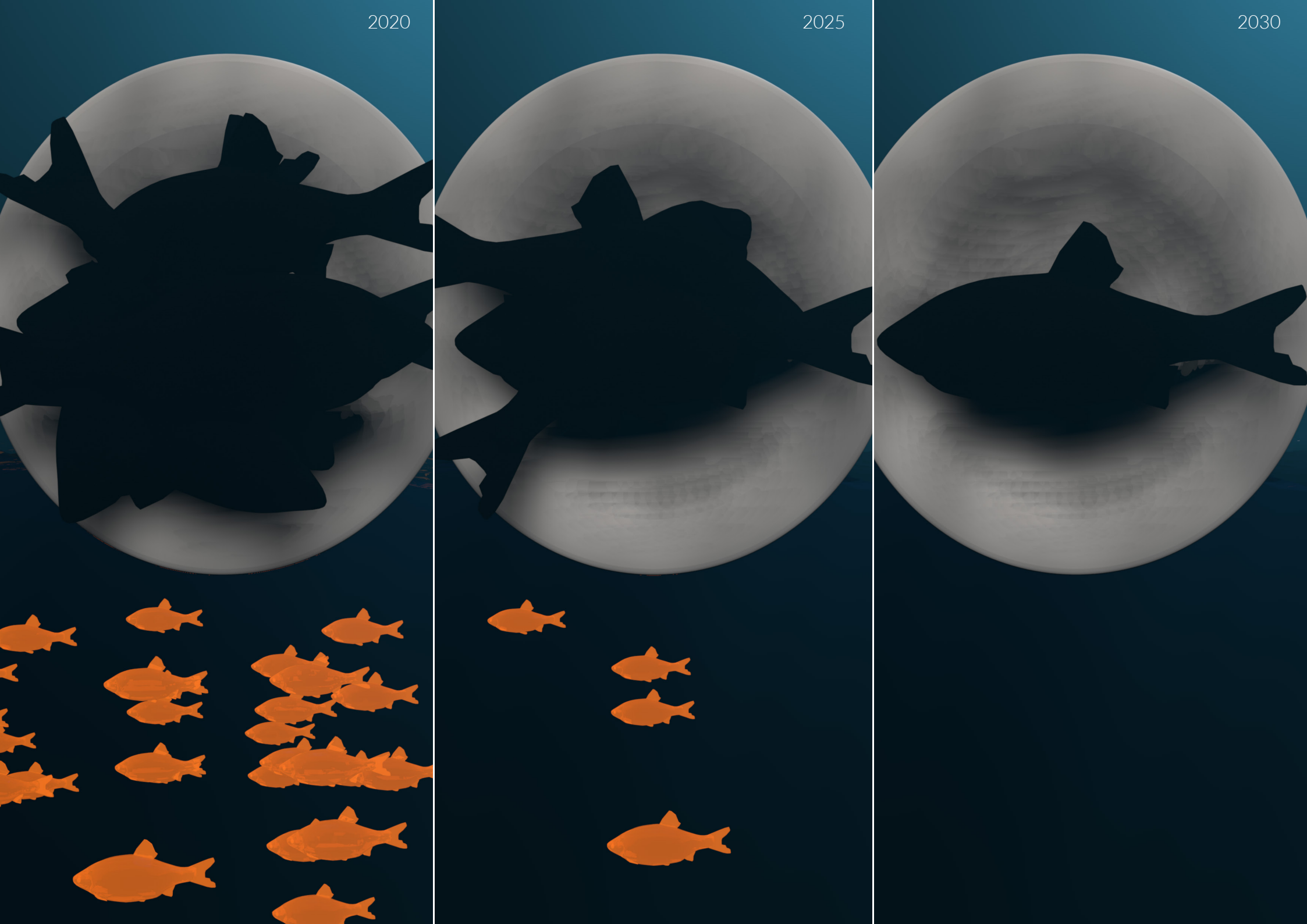
We will mainly use two CERN technologies, REMUS [4] and Medipix [5]. In the following paragraphs, the technologies and its usage in our design are explained.

Remus is a Supervision, Control and Data Acquisition system, able to monitor and control organizations' impact on their environment. We will use the CERN technology Remus to process collected data in real time.

Medipix is a chip for particle detection. It works like a camera and is able to detect particles in very bad light conditions. We will use this in the buoys and fish drones to monitor the fishes and ocean.



IMPACT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FUTURE SCENARIO

Due to our egocentric behavior, overconsumption of fish, non-stop pollution and unsustainable mindsets, the fish stocks in our oceans are on a steady decline. The FAO. 2018. State of World Fisheries and Aquaculture report shows, that over the last 40 years, the amount of overfished stocks is rising. Today, there are three times more overfished stocks than in 1975. While there are only 7% underfished stocks, the maximum sustainably fished stocks raised just about 9% to a total share of 59% in 2015.

On the one hand the majority of people take it for granted that they can have fish on their plates whenever they want. They don't feel responsible about the fishing methods and don't care about the origin of the fish. Scientific studies show that over the time of 36 years the the apparent consumption of fish products per capita raised about 9 kg to 20.3 kg in 2016. This trend is still continuing. With increasing consumption, the fishing industry is on a continues growth as well. By 2016, 59.6 million people were engaged in the primary sector of capture fisheries and aquaculture. [1]

On the other hand we have the fishing industry which is, like any other industry, profit based, trying to cover the demand for fish. It is not the goal of fisheries to pay attention to sustainability even if that threatens their business in the long term. Since depleted or overfished stocks need several years to come back to a useable level, the fishing industry faces a lot of problems by not coordinating the catch quotas within a sustainable manner. We assume that by 2030 we already lost a lot of diversity in marine life. The increasing demand leads to even more aggressive catching. The strong competition and the lack of coordination is unhealthy for the oceans and not sustainable at all. The article "Life history change in commercially exploited fish stocks: an analysis of trends across studies" points out that age and size at maturation have declined dramatically in many commercial fish stocks over the past few decades – changes that have been widely attributed to fishing pressure.

Since we need to ensure availability of fish for future generations, we have to take care of life below water and its habitat. We need to start supporting biodiversity, promote the health of fish stocks and establish sustainable fishing.

TOUCHPOINTS

ReMY as a system of multiple components and the benefit is especially visible in the bigger picture.

Some of the main user of the system will be fishing industry employees. They will use ReMY software which suggests nicely coordinated routes to optimize fish yield. ReMY supports fisherman on their daily work by providing them with insights and valuable data around their current tasks.

Politics can use the public interfaces and reports to base their legal requirements on. ReMY will keep track of overall conditions and changes so politics can evaluate the results against previous laws and decisions they made. Well-founded scientific knowledge is a key factor for political decision making.

Researchers are able to use ReMY's open data interface to run their own calculations and build new opportunities. We encourage them to spot coherent data, develop applications, or create studies that support the overall goal. By connecting comprehensive topics and supporting interdisciplinary research, ReMY will evolve to a strong research platform for future ventures.

These points of contact lead to new insights and by that to continuous improvement of ReMY.

IMPACT

Environment

The oceans play a big role in the whole ecosystem of the earth. Therefore, every animal, every human and every plant is directly or indirectly dependent on the health of the seas. [6] We need to understand them better and know how they are working if we want to ensure good life conditions for future generations.

Humanity has been acting selfish and unconscious and already destroyed and polluted very large amounts of our world's oceans.

Studies from the field of functional ecology show that every detail in a ecosystem plays an important role and it can cause a lot of trouble if single functions are missing. Functional ecology is a branch of ecology that focuses on the roles, or functions, that species play in the community or ecosystem in which they occur. [7] With ReMY, we want to find out about the roles and functions that life below water plays and how it's working and connected to our life. In this approach, every single detail is important and nothing gets left behind. We can measure the ocean conditions and behavior of marine life over large time periods in many places simultaneously. With this data we can see connections and relations between lifeforms and environmental conditions we didn't recognize yet. This enables us to be aware of malfunction and protect the ecosystem we all rely on.

Fishing Industry

Today, more than one billion people rely on fish as their primary source for animal protein[1][8]. The nutrients and micronutrients provided by fish are great for cognitive and physical development. Globally there are hundreds of millions of people who are directly involved and dependent on the fishing industry for their livelihoods.

Improving the productivity of fisheries and aquaculture is vital to reducing hunger and poverty for millions in the developing world. Sustainable, productive fisheries and aquaculture improve food and nutrition security, increase income and improve livelihoods, promote economic growth and protect our environment and natural resources.

A sustainable approach to fisheries and aquaculture will help to protect our natural resources and ensure that fish stocks are available for future generations. Currently, overfishing, ineffective management practices, industrial development and agricultural pollution have reduced fish stocks.

ReMY will push the industry towards sustainable manners. Scientific calculations and controlling of stock levels will increase efficiency and maximise profits which leads to much more economic acceptance.

IMPACT

Research

The oceans make up more than 70 percent of the earth's surface. Their depths have so far been a mystery. Only very slowly we reveal their secrets.

Revealing those secrets and changing our understanding of the oceans is ReMY's mission. If we want to save the oceans and life below water, we first need to understand. We need to find out how all the individual elements are linked and why everything is the way it is.

Since scientific community is rapidly moving forward with the adoption of the big data technology stack, we want to adopt these technologies to our system. With Big Data, the vast amount of data gathered by the system can be extracted, evaluated, and transformed into a source of valuable, factual knowledge that can be utilised to further enhance scientific research.

With ReMY we will build a great foundation for a international research community. By sharing insights and collaborating all around the ReMY data we can boost research and encourage entrepreneurs and scientists to explore the unknown parts of the ocean.

Politics

Our data and control capabilities allow governments to create new laws that truly protect underwater life. The complete records of the activities of fisheries can be used as evidence in violation of the law. Sanctions against non-compliant fisheries can thus be made simpler and fairer. Furthermore, the states of the world can negotiate and control the use of the oceans on a common basis.

Being able to actively intervene in marine life with the ReMY Drone, governments and lawmakers get the possibility to enforce their rules and build a controllable association.

VALUE OF DESIGN

We believe that our concept will have a large societal impact on everybody, because we could revert the oceans to being a healthy habitat for marine animals. We also believe that with this change, the effects of global warming might be reduced, and that the environment will benefit.

Our concept could be beneficial to society for a variety of reasons. The most obvious one would be that by tracking the fishes, an effective usage of fish population can be ensured. This is important for a lot of the stakeholders that we identified, mainly the fishing industry, but also researchers, small-scale fishers and consumers. Making fishing more effective could also help with nourishment for people with limited access to food. Since the population numbers are rising, the need for food is increasing as well. By using the resource of fishes and the ocean more efficiently, the increasing demand for food could be met more easily. Another way that industry fishing will benefit is the decrease of bycatch, by managing the fish in a way that only the desired fish end up in the nets.

By implementing this system, researchers could find out more about fishes, the ocean and life below water because our concept will generate huge amounts of data. This data will help researchers to predict fish population even more precisely.

The entire society will benefit as well, because by tracking and managing the fishes, the biological diversity of marine animals could be ensured. The environment will also be protected, because when the fishing industry can fish more efficiently, the usage of ships will decrease, which is beneficial to the environment and life below water and on earth.

When a seal of quality is established by using our tracking and management system, consumers will have more control about what kind of fish they buy.
Lastly, NGOs and government organizations will benefit because they can effectively enforce the regulations and limits for maintaining a stable fish population.

SOCIAL LEAN CANVAS

The Social Lean Canvas extends the Lean Canvas with social aspects like purpose, impact, problem and solution. It is designed to structure and validate ideas with a positive environmental impact like ReMY and to understand existing risks and uncertainty.

The aspects purpose and impact have already been extensively discussed in the challenge and impact section, which is why we start directly with our customer segments.

SOCIAL LEAN CANVAS

Customer Segments

As already mentioned, we have three key customers namely the fishing industry, research and politics. The fishermen have to register with us if they want to fish. In return, we provide them with information on the selected species of fish, saving resources in their search for fish. Research institutes gain access to our collected data and can thus not only find out more about the underwater world, but also improve ReMY with new insights. Politics and lawmakers can use the ReMY data to enforce regulations and to stay informed.

Problem

Today we are confronted with many different challenges. The oceans are being exploited, resulting in a decline of fish stocks and decrease of the average age of fish.
There is also an imbalance in the availability of fish as food. While wealthy societies have an oversupply of fish products, poor people who rely on fish as their staple food have to look every day for where to get their fish. Small and traditional fisherman are at a disadvantage compared to large companies. The lack of awareness and knowledge about the condition of the oceans as well as an unsustainable mindset of too many people are also big problems that we need to consider.

Unique Value Proposition

ReMY allows fishing companies sustainable and efficient fishing methods. Our concept not only revolutionizes fishing methods, but also increases their transparency. Due to our open data philosophy, every consumer can check the origin of maritim products while buying. With our data, we also help in law enforcement against illegal fishing activities.

Solution

ReMY is an intelligent controlling, monitoring and data acquisition system for waters and marine life and consists of three main components:
Buoys for tracking and monitoring marine life and condition of waters.
The connected drone fleet acting like shepherd dogs to actively intervene and protect the fish and the ecosystem.
Data acquisition for the customer segment and for continuous improvement of ReMY.

In this combination we can secure endangered species, help the fishing industry in developing a sustainable business and boost research about understanding life below water.

Channels

With constant talk about the fishing industry, research and politics we forget the most important player: the ordinary people! We need to raise people's awareness of the acute problems of the seas and marine life. We want to use social media to achieve this goal. This includes information events, campaigns and challenges similar to the #trashtag challenges, but for waters and maritime products. Discussions and actions should follow, as happened for the bees. Influencers can support our agenda and help us to establish a sustainable mindset and lifestyle. Unsustainable products should lose their reputation and demand. What we want is positive social pressure regarding sustainability like the movement for organic food. This, in turn, will have a major impact on supermarkets, which will need to adjust their product range accordingly. Increasing the knowledge base of the population will help them make a more profound decision on the elections, which in the long term will lead to needed laws.

SOCIAL LEAN CANVAS

Revenue

We want to establish four revenue streams:
First, wenn implement license fees for the fishing industry. If fishermen want to go out fishing in the sea, they have to pay a license fee. In return, they receive helpful data on the position and quantity of the wanted fish. The ReMY label as an indicator for sustainable fishing methods will bring full transparency to maritime products. The data is not only sold to the fisheries, but also to research institutions and entrepreneurs to develop new ideas and applications. Our digital infrastructure allows other parties to collect their own data. We provide the infrastructure and other companies or research institutions can attach their own devices.

Cost Structure

Talking about finance, we determined four main cost drivers, namely parts and materials, deployment, IT systems and maintenance of the buoys and drones.

Since this is a lot to cover for a non profit based organization, we hope that we can build a community around the ReMY system which will help to fund the expenses. We can also imagine being funded by an international community, following the example of CERN.

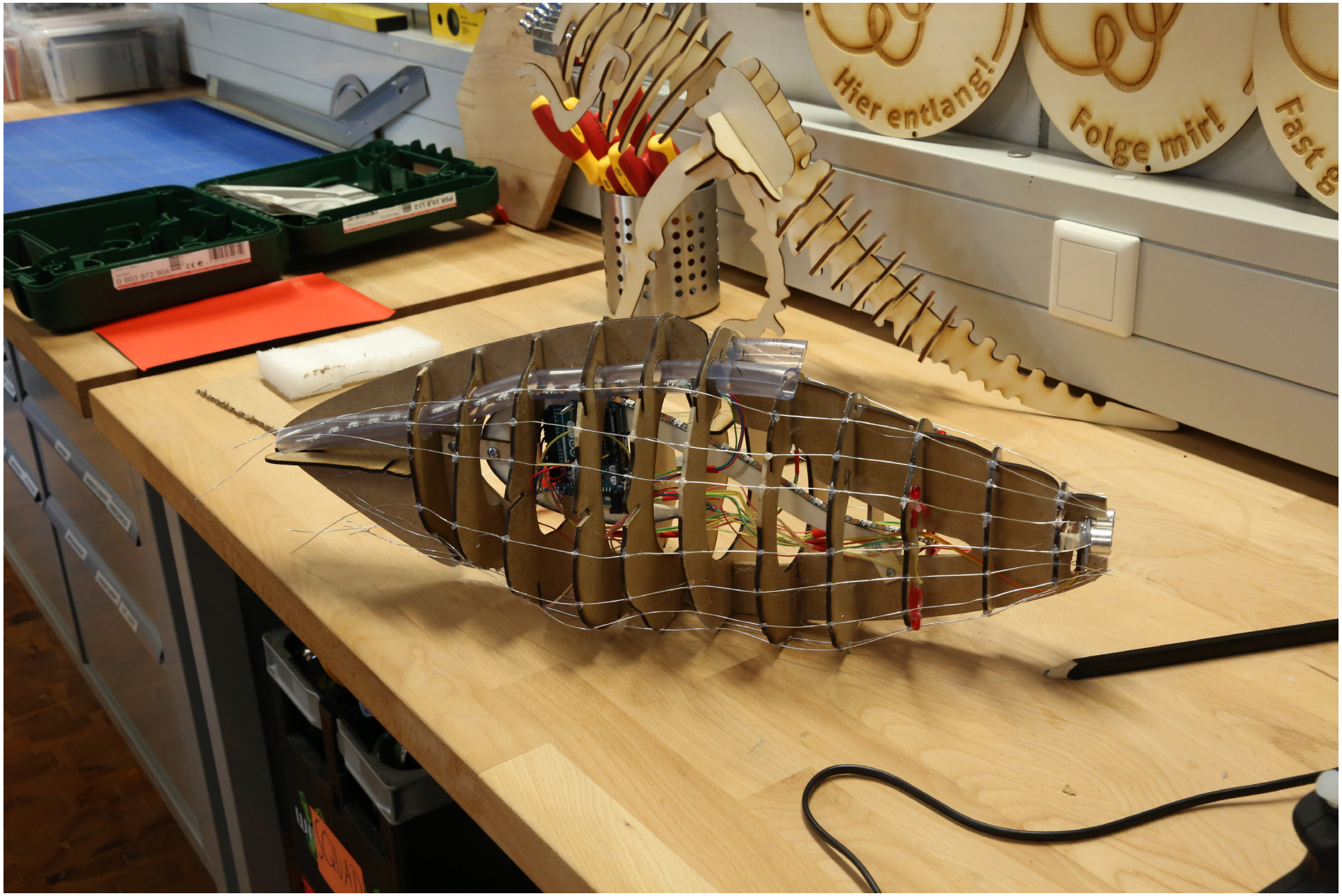
Key Metrics

We have an interesting and crazy idea, but how can we measure our success? During our research and interviews with experts we learned many interesting key insights. One of them is the sinking average age of fishes in general in the last decades due to overfishing. Measuring an increase in the future would be a good sign. In addition to the regeneration of endangered fish species, we also want to strengthen biodiversity. Marine life plays an important role in the food chain, not just for us humans, but for all living things. After all, the consumption of maritime products can be an indicator of whether things are moving in the right direction. When people change their shopping habits and buy sustainable products, we have achieved an important aspect.

Unique Advantage

There are already many ideas and projects that deal with SDG 14, but our focus lies on fishes in the first place and not on economy. Furthermore, with our buoys, drones and data centers, we provide a transparent possibility of monitoring activities in and on the oceans in real time. In the case of violations of international law, our data may be used as evidence against the accused.

PROTOTYPE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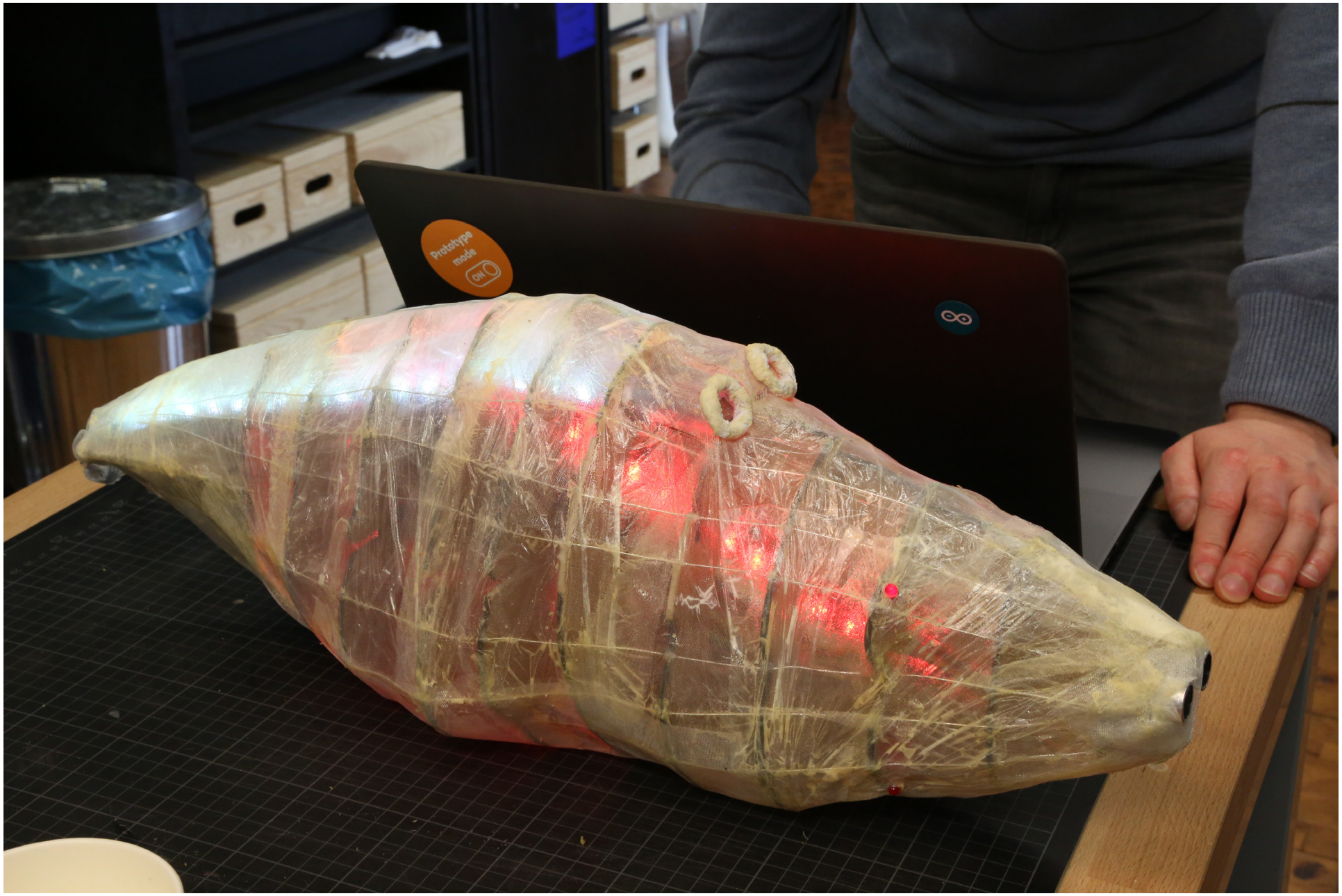
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PROTOTYPE

To get a better understanding how we would imagine ReMY in real life, we build a low fidelity prototype. We didn't care about technical specifications rather than getting a better visual anchor for transferring our picture of the ReMY drone. It's a small and agile drone in the shape of a fish. Since ReMY is a step towards a better understanding of ocean lifeform, we tried to make it look like one of them.

The propulsion of our drones will be inspired by the locomotion of cephalopods. Those marine animals use a sequence of consecutive cycles of inflation and collapse of their body to move forward, which we will adopt. This variant not only matches our remaining concept of inflation to control fishes, but is also very silent in comparison to other techniques and won't disturb living things underwater.

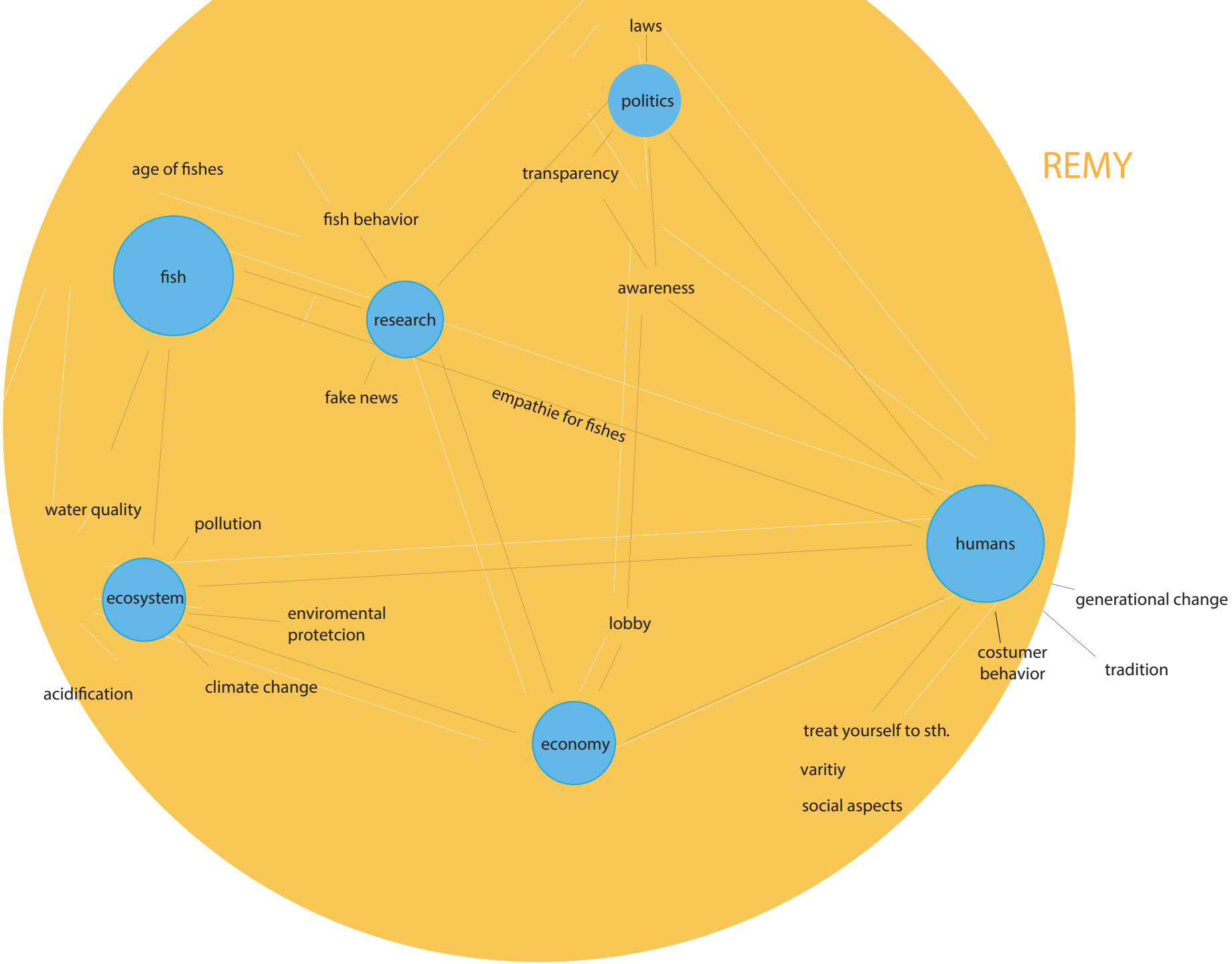
Renda, Federico, et al. "Structural Dynamics of a Pulsed-Jet Propulsion System for Underwater Soft Robots." International Journal of Advanced Robotic Systems, June 2015, doi:10.5772/60143

Therefore we integrated a pipe system with LED stripes in our prototype, which visualize how water is taken in at the front and ejected at the end, creating the boost. This propulsion can be combined with the inflation.

Of course, we must be careful not to pollute the oceans with our buoys and drones. In order to avoid that, we want to focus on new developments in the future, which are still in their infancy. One of them are biodegradable electronics that are already being researched today. This way, lost drones will disintegrate and won't pollute the waters.

[Kim DH, Kim YS, Amsden J, et al. Erratum: "Silicon electronics on silk as a path to bioresorbable, implantable devices" [Appl. Phys. Lett. 95, 133701 (2009)]. Appl Phys Lett. 2009;95(26):269902. doi:10.1063/1.3274132]

SYSTEM THINKING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SYSTEM THINKING

Since we are operating in a lot of different fields and need to cover a broad spectrum of contexts we designed a system thinking map. In System Thinking we perform problem solving in complex systems. One of the fundamental principles is that everything is interconnected in a biological way. Essentially, everything is reliant upon something else for survive.

We covered all stakeholders and environments we're interacting with and visualized the connections between them. This helps to be aware of chain reactions and side effects. When we're talking about serious and complex problems, it's important to be prepared for any unexpected game changer.

We can also use the interconnection to expand the variety of possibilities to approach different topics. For example we can put pressure on politics and governments by winning social influencers for our cause, which will then have an impact on the decisions people make at the elections.

THE FUTURE OF REMY

With ReMY we will start understanding the oceans and life below water as it is. To establish sustainable methods in fishing industry, we need to fully understand the fishes and their ecosystems. Investigating and observing is the first important step in building that knowledge.

While keeping economic benefits in mind our system will be easy to implement. ReMY will push the industry to act on a sustainable level by improving critical processes.

Connecting multiple actors from politics, society and industry will enhance cooperation at all levels, enhancing the capacity to solve problems in future crisis.

The future of our ocean life will no longer be random. Humanity will be aware of what is happening on 71 % of this planet's surface - and underneath.

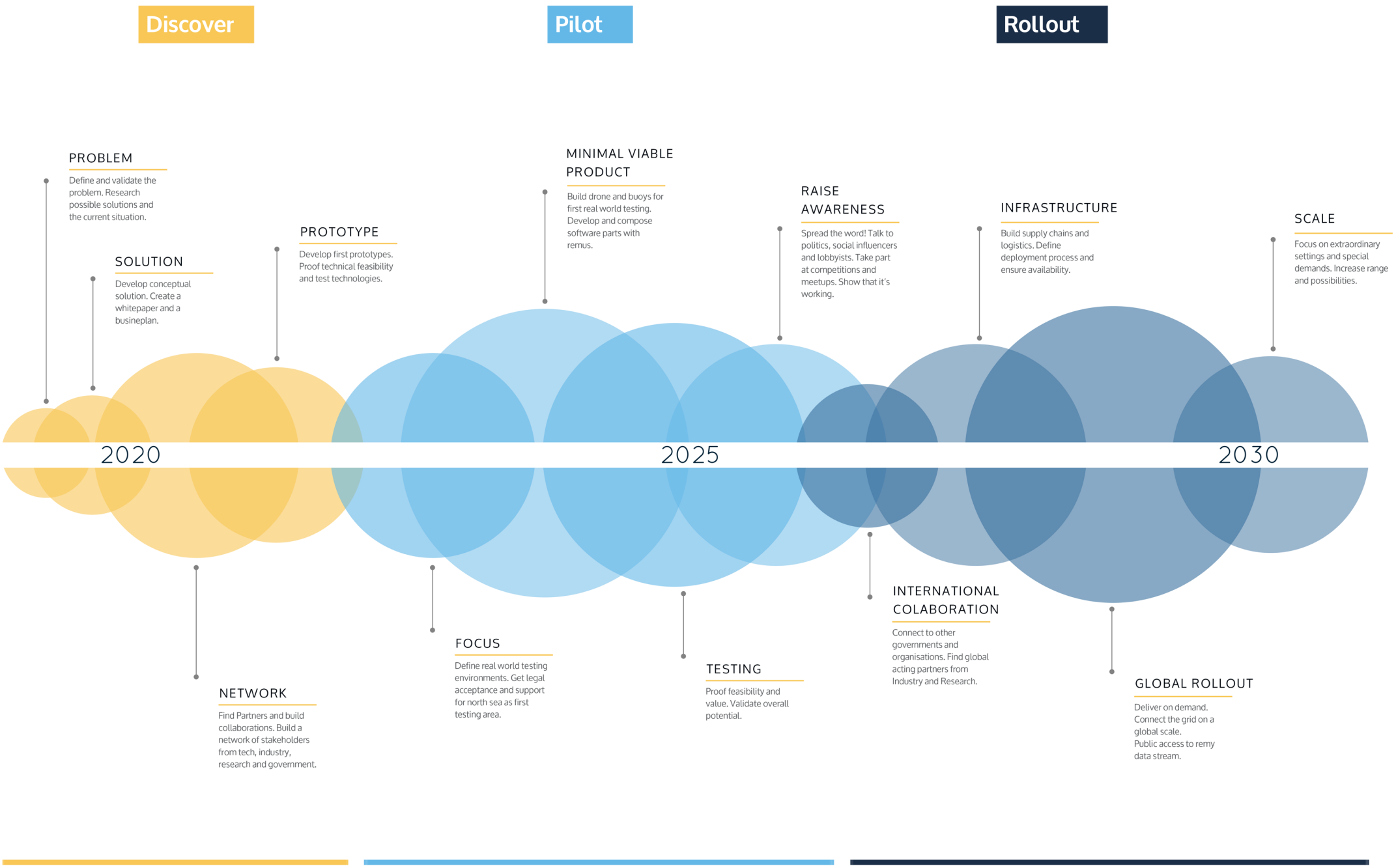
But what else holds the future for ReMY? Our whole concept can adapt to different kind of purposes.

ReMY can be used in the deep sea research, so that on one hand no human being is harmed during explorations, and on the other hand it can be an asset to observation and documentation.

Furthermore, ReMY can also be used to protect fishes from dams and hydroelectric plants. Many fish die trying to overcome these structures. ReMY could prevent them from swimming too close, which will also minimize the damage to the buildings.

In addition, the adaption of the system could detect waste in waters, which will also help preserve life below water and on land.

ROADMAP


Discover
Pilot
Rollout
PROBLEM
Define and validate the problem. Research possible solutions and the current situation.
SOLUTION
Develop conceptual solution. Create a whitepaper and a businesplan.
PROTOTYPE
Develop first prototypes. Proof technical feasibility and test technologies.
MINIMAL VIABLE PRODUCT
Build drone and buoys for first real world testing. Develop and compose software parts with remus.
RAISE AWARENESS
Spread the word! Talk to politics, social influencers and lobbyists. Take part at competitions and meetups. Show that it's working.
INFRASTRUCTURE
Build supply chains and logistics. Define deployment process and ensure availability.
SCALE
Focus on extraordinary settings and special demands. Increase range and possibilities.
2020
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NETWORK
Find Partners and build collaborations. Build a network of stakeholders from tech, industry, research and government.
FOCUS
Define real world testing environments. Get legal acceptance and support for north sea as first testing area.
TESTING
Proof feasibility and value. Validate overall potential.
INTERNATIONAL COLABORATION
Connect to other governments and organisations. Find global acting partners from Industry and Research.
GLOBAL ROLLOUT
Deliver on demand.
Connect the grid on a global scale.
Public access to remy data stream.

Since the CBI project end in mid 2019 we thought about how the project could move on and what would be the best way of bringing it to our oceans. After doing profound research all around the topic of life below water, defining the problem space and converting down to the keymetrics our solution should cover, the next step in our journey is to build a network of innovative and like-minded people. We need to activate and connect different communities and organizations to chain more expertise and expand our perspective.

Collaboration and knowledge transfer is an important role when we move on to build the first functional prototypes. The modular concept allows us to unlink the components and develop each on its own. For the data processing we can use various kinds of data like AIS (Automatic Identification System) from fishing boats, oceanographic data and satellite images. This data is already accessible and we can use it for early stage development.

For the physical components, we need to validate the technical feasibility. By cooperating with offshore plants and ocean research institutes, we can share expertise and boost our progress. Our underwater drone needs to be autonomous and should adapt to the ecosystem in a natural way – which is a big technical challenge. We have to research many new materials and technologies that are not yet on the market or in an early stage of development.

With our first functional system we will then start to focus on specific application areas. By setting up Minimal Viable Product tailored to target smaller good condition areas we can test the whole system in its final composition. With this setup we can run real world tests and evaluate potential and functions.

While running those real world tests, we can use first outcomes and insights to promote our publicity. By showing the concept and proving its value, we want to make governments and organizations aware of the issues. For the next steps, not only collaboration between industries and governments, but also building communication and associations on international level is important.

After building a well organized infrastructure with logistics, deployment, IT-systems and maintenance processes, we are ready to roll out ReMY right on demand. We can start connecting local and national ReMY grids and build a global system. Organizing and managing the global fish catch and monitoring ocean conditions as well as marine life on a global scale enables us to care for life below water and future generations.

PAUL ELLEN

"I BELIEVE IN THE POWER OF SHARED DATA AND TECHNOLOGY TO HELP BUILD A BETTER FUTURE."

APPENDIX

[1] FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome.

[2]Food and Agriculture Organization Maldives Country Programming Framework

[3]https://www.liquid-robotics.com/wave-glider/how-it-works/

[4]https://kt.cern/technologies/remus

[5]https://kt.cern/technologies/medipix3

[6]The Impact of Climate Change on the World's Marine Ecosystems, By Ove Hoegh-Guldberg, John F. Bruno, Science18 Jun 2010 : 1523-1528

[7]Schmid, Bernhard. (2003). Die funktionelle Bedeutung der Artenvielfalt: BiodiversitÃ¤t. Biologie in Unserer Zeit - BIOL UNSERER ZEIT. 33. 10.1002/biuz.200310236.

[8]Tidwell JH, Allan GL. Fish as food: aquaculture's contribution. Ecological and economic impacts and contributions of fish farming and capture fisheries. EMBO Rep. 2001;2(11):958–963. doi:10.1093/embo-reports/kve236

https://www.scientificamerican.com/article/ocean-fish-numbers-cut-in-half-since-1970/

https://www.worldfishcenter.org/why-fish

https://sustainabledevelopment.un.org/sdg14

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Cummins, A. (2004), The Marine Stewardship Council: A multi-stakeholder approach to sustainable fishing. Corp. Soc. Responsib. Environ. Mgmt, 11: 85-94. doi:10.1002/csr.56

Sharpe DM, Hendry AP. Life history change in commercially exploited fish stocks: an analysis of trends across studies. Evol Appl. 2009;2(3):260–275. doi:10.1111/j.1752-4571.2009.00080.x

Kim DH, Kim YS, Amsden J, et al. Erratum: "Silicon electronics on silk as a path to bioresorbable, implantable devices" [Appl. Phys. Lett. 95, 133701 (2009)]. Appl Phys Lett. 2009;95(26):269902. doi:10.1063/1.3274132

Kuparinen, Anna & Garcia de Leaniz, Carlos & Consuegra, Sofia & Merila, Juha. (2009). Growth-history perspective on the decreasing age and size at maturation of exploited Atlantic salmon. Marine Ecology Progress Series. 376. 245-252. 10.3354/meps07789.