PRESENTATION : Fish Farming Water Monitoring

Summary. Marine fisheries and aquaculture are a fundamental resource in the livelihood and development not only of underdeveloped but also for developed countries. The monitoring of the environmental conditions of marine aquaculture allows targeted interventions to maintain the health of fish species and the marine environment. The containment of management and intervention costs can often be a strategic value. This work describes a component of a system created with Internet of Things technologies which, by monitoring the quality of the water through a simple and cheap LED spectrophotometer can identify the characterizing quantities of water quality. Actually studying water responsivity data can lead to building a Regression Model , for example by using Neural Networks, at the cloud level computing platform (AWS, AZURE, etc.). Of course this imply that the data can be transmitted from the edge to the cloud by a network , for example LoRaWAN. The sensor spectrometer here examined should be the component a buoy taking part to Internet of Buoys. Everything can be done using low-cost and low-impact technologies. The benefits that can derive from adopting water monitoring allow to know and intervene, where possible, on the living conditions of the fish in an immediate way and with almost zero costs both in terms of human resources and technological instruments This technology is especially designed for those countries that, despite basing their economies on aquaculture, do not have sophisticated and expensive technologies.
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Ocean Sustainability and Income value added as a percentage of GDP (OECD, 2020[1])

The ocean makes an essential contribution to the worldwide economy, offering jobs to hundreds of thousands of people. Nevertheless, pressures on the sea are mounting. We are witnessing sea-use alternate, persisted overexploitation of marine resources, intensifying pollution and, above all, weather alternate. The COVID-19 disaster is reworking our world, forcing us to alternate the manner we think, the manner we work, and the manner we produce and consume. Lower earnings countries, depend appreciably on their assets to expand their ocean-primarily based totally industries, and in a few instances essential stocks of their GDP rely upon those industries.

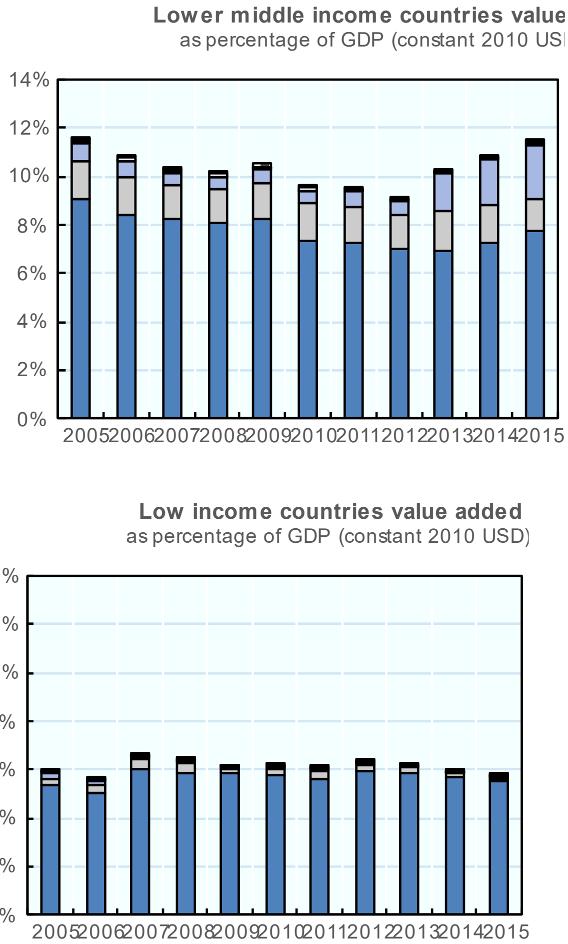


Figure 1: Income value added as a percentage of GDP

The Aquaculture

Aquaculture is taken into consideration to be one of the sectors with the most important capacity for growth (FAO, 2018[2]) and has extended drastically in latest years. In 2016, international aquaculture, inclusive of each inland and marine, changed into 110.2 million tonnes and changed into really well worth about USD 243.five billion (FAO, 2018[2]). At least 64.2% of aquaculture is inland and aquaculture in coastal regions consists of species farmed in saltwater ponds, species produced in cages and man-made systems both next to or at the coast. Developing marine aquaculture will be a possibility for growing countries, despite the fact that the control and tracking expenses can represent a barrier to access or working situations that aren't worthwhile or ecologically unsustainable. The coastal population are inclined due to the fact that now no longer continually can depend upon farming or fishing . This can help them with an extra supply of income.

The increasing demand for Aquaculture

Global demands for food from aquatic environments are expected to increase in future decades, because these foods will help to meet the needs and preferences of a growing human population. Aquaculture production is rising, wild-capture production has more or less stabilized, because there are few opportunities to develop new sustainable fisheries or to increase catch rates in existing fisheries.

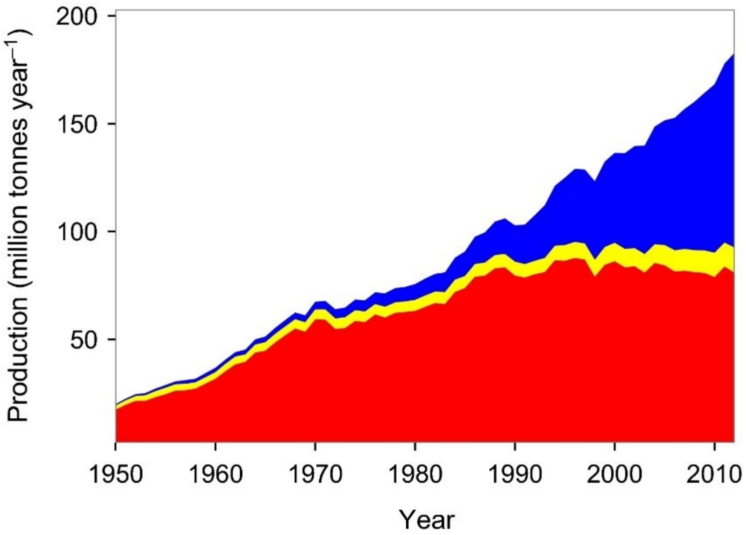


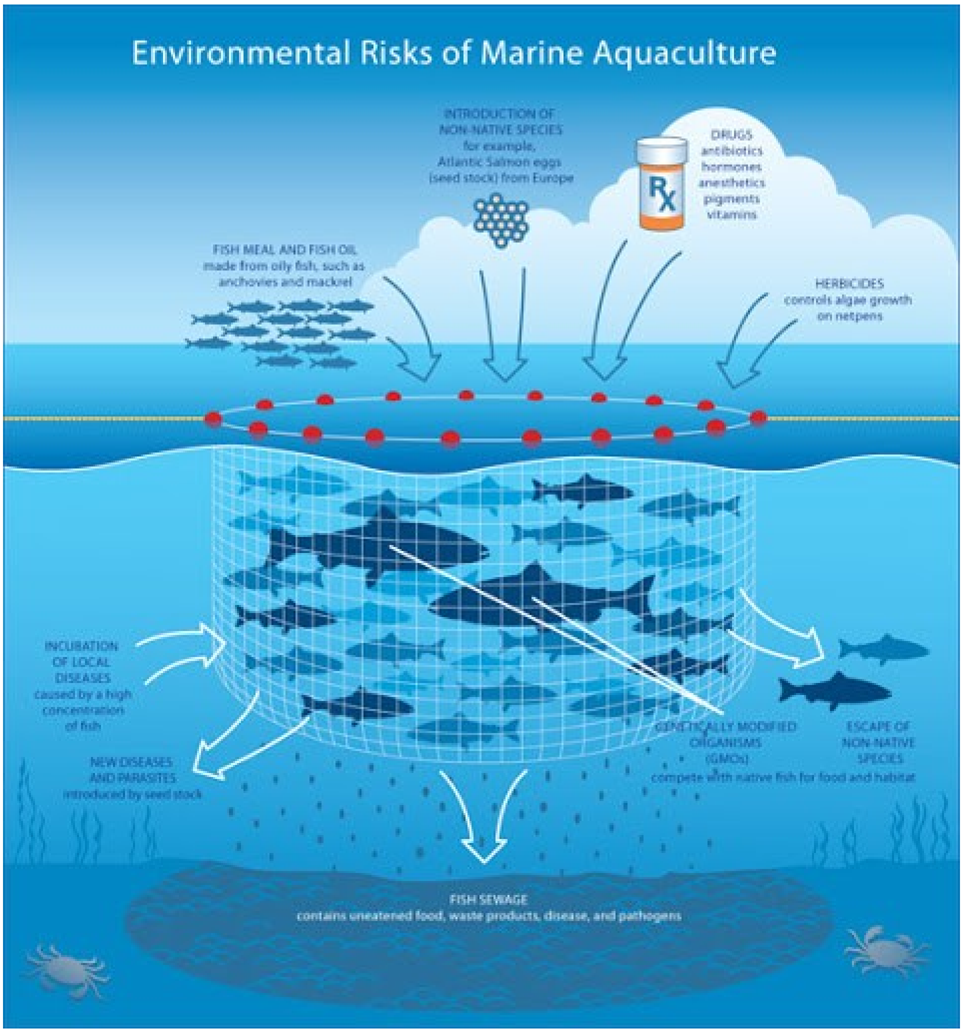
Figure 2: Trends (2016[3]) in global production from marine (red)- and freshwater (yellow)-capture fisheries and aquaculture (blue). Data from FAO FishStatJ (FAO 2015).

The need for better management

However, marine and aquatic ecosystems are under stress – from climate change, overfishing and unsustainable fishing and aquaculture practices in some areas, as well as pollution from various other human activities, which lead to ocean acidification and declining biodiversity. Global fisheries and aquaculture could be both more productive and more sustainable if they were optimally managed.

Quantities to take under control in water monitoring of aquacultures

As a matter of realistic hypothesis , since our proof of concept is focused on the potential advantages of using a spectrometer for water quality monitoring, according to existing and most accredited literature on this (see references) the most important quantities to take into consideration and under control have been determined as : the existence and percentage of **fitoplancton and zooplankton (food),** the percentage of **oxygen**, the presence of **nitrogen dioxide**, of **nitrogen catabolites**, of **ammonia**; the **droppings** (dejections produced by fishes), the percentage of **Ph** and of **salinity** and the bioaccumulation of heavy metals, **dioxins, polychlorinated biphenyls**. Let's see the greatest risk of aquacultures (see following image):



Motivation for quantities determination

There are many studies , all around the world, declaring that oxygen saturation stage had a high-quality impact at the boom and feed conversion ratio whilst it was set at 80%-120% saturation. Nevertheless sea temperature and different environmental parameters over current years have affected tendencies and distributions of toxins. Contaminants and veterinary residues chemical substances withinside the environment, which includes pesticides, heavy metals and chronic natural pollution, can increase in fish and shellfish and may pose a public fitness issue. Fish can soak up chemical substances in 3 ways: nutritional publicity via meals or feed in wild and cultured fishes;

veterinary merchandise used to deal with fish sicknesses in aquaculture; and uptake from the water column in wild and cultured fishes. Human nutritional publicity to bioaccumulative pollution which includes methylmercury, polychlorinated biphenyls and emerging contaminants can pose dangers to fitness; as a lot of those chemical substances act as. Groups of human beings ingesting excessive portions of a few fish species in a few regions may also be at chance from those bioaccumulative pollution.

Aquaculture 4.0

As it has been stated before , a key aspect aquaculture management is the quality control of water. Traditionally, farmers perform periodic onsite measurements of water so one can make sure the protection and adequacy of the residing situations of the fish. They have been identified the maximum vital appropriate parameters to be measured, however water temperature is likewise vital, together with turbidity , and hardness. These water parameters are traditionally measured through technical body of workers , veterinaries, chemists, biologists, using hand held instruments, taking a limited quantity of recordings at some stage in working hours.

The concept at the bottom of the technique of this paper is automation of duties to create unmanned aquaculture. In the conventional farm the variant of one of the key water parameters beyond a secure stage can arise out of hours, unseen through the farm technicians. This can result in unwanted results consisting of negative growth, undetected ailment symptoms. Moreover, the endurance of that undesired scenario for a long term can growth fish mortality – and what's worse, the farmer could now no longer recognize the variant of the water great indicator associated with the motive of the issue. It will be displayed how water quality may be constantly monitored using the spectrophotometer sensor located right into a sealed box, thus now no longer being affected through water, salt or every other corrosive element , that is immersed into the water inside a quartz casing.

This clever instrument can offer a high-quality deal of statistics at periods of seconds or minutes, permitting a greater correct planification of the farming activities, the triggering of alarms in case of hazardous water situations, the immediate correction in short time or depth in fish care duties; and additionally the creation of a complete database which could help body of workers employees and scientists perform particular and precise research so one can enhance the performance of the farm withinside the medium and lengthy run. The faraway visualization of the measurements on an internet-based platform is likewise of high-quality cost for users; mainly in marine farms, where the cages every so often can't be accessed quick and on the preferred time. The visualization of the parameters can take place in a workplace PC display or on a transportable tool anywhere.

The Spectrometer

The use of a single sensor instead of multiple ones under water, to measure almost all the quantities is the base of this project.
The spectrometer used here is a metrology technique based on the detection of the spectrum of a sample light (with a wide range of wavelengths) pointed against the surface to be analyzed and reflected by it, at least in part. This methodology allows to recognize the composition of a liquid mixture through the trend of the spectral response curve to a non-coherent light that is pointed against it and partially reflected. Spectrometry is based on the fact that when light hits an object that does not absorb it completely (it is the case of almost all bodies) a part of it comes back: this is an optical phenomenon commonly known as reflection. The ones reflected corresponding to the wavelengths not absorbed.
In the classical approach the spectrometer is used to infer the absorbance or reflectance of a given material, and infer the concentration of it , based on the Law of Lambert-Beer. Spectroscopy is used in physical and analytical chemistry to detect, determine, or quantify the molecular or structural composition of a sample. Each type of molecule and atom will reflect, absorb, or emit electromagnetic radiation in its own characteristic way. Spectroscopy uses these characteristics to deduce and analyze the composition of a sample.
The intention here is to use the spectrometer to analyze in vitro and immersed into the water, in real time , the quality of water samples by comparing the spectrum of the light reflection obtained by the instrument with already known reference spectra, in order to identify the quantities dissolved in the tested water. It is a question of taking the tests, that usually take place in chemical laboratories, directly into aquaculture site, thus avoiding the taking of water samples, the discontinuity of the measurements, the waiting times for the results and the costs associated with it. The interpretation of the results will be completed, in a further work, by a learning module based on AI algorithms.

The Triad Spectroscopy Sensor AS7265x

The SparkFun Triad Spectroscopy Sensor is a powerful optical inspection sensor also known as a *spectrophotometer*. Three AS7265x spectral sensors are combined alongside a visible, UV, and IR LEDs to illuminate and test various surfaces for light spectroscopy that can detect the light from 410nm (UV) to 940nm (IR.

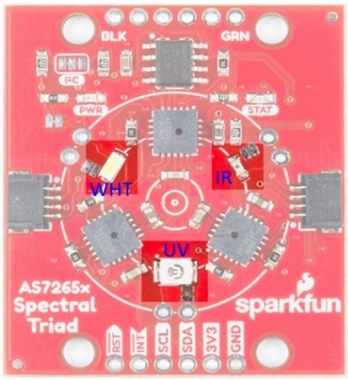


Figure 3: UV, IR and visible LEDs

The Triad is made up of three sensors; the AS72651, the AS72652, and the AS72653. In addition, 18 individual light frequencies can be measured with precision down to 28.6 nW/cm^2 and accuracy of +/-12%.

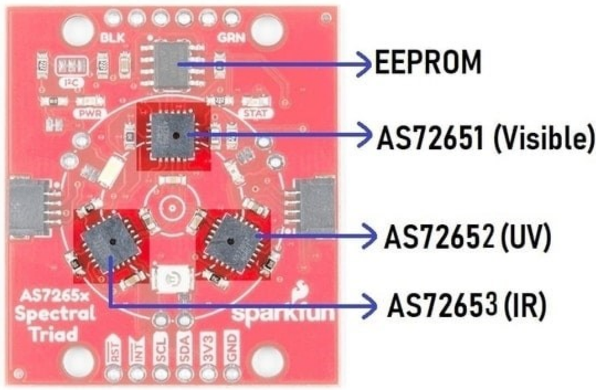


Figure 4: Three sensors of light: UV, IR and visible.

Wiring of Arduino BlackBoard with AS7265x Spectrometer Sensor

AS7265x has Qwiic connectors which provide a quick and easy way to connect the Triad over I^2C. However I have connected the 3.3V pin of AS7265x to the 3.3V pin of the Arduino BlackBoard & GND to GND. Also, connect the **Serial Data(SDA)** & **Serial Clock(SCL)** pin of AS7265x to A4 & A5 of Arduino BlackBoard respectively.

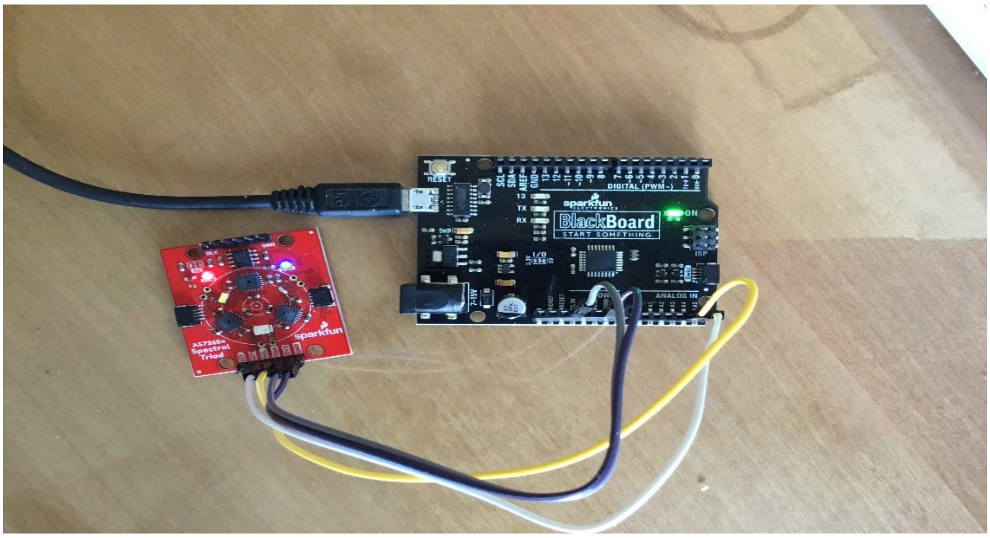


Figure 5: Wiring of BlackBoard to Spectrometer Sensor .

Set up of Triad Spectroscopy Sensor Test-Bed

In the experiment, the water sample is placed in a small glass jar and the spectrometer attached in direct contact with the glass. The glass allows visible radiations to filter but not completely those of ultraviolet. This experiment setup is an approximation as the ideal conditions are better described below. However, the results of this proof of concept are indicatively and qualitatively significant.

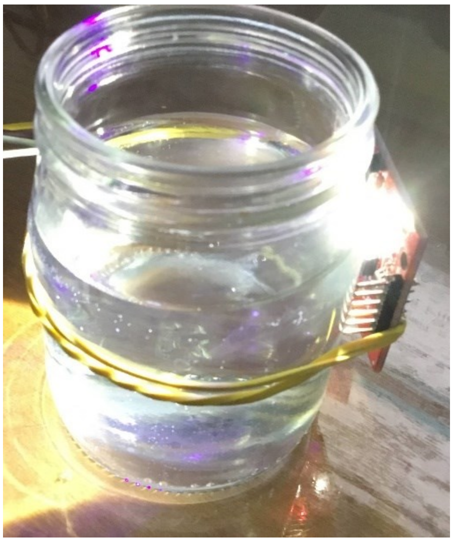


Figure 6: Spectrometer Scanning of Light Rays.

Generally the use of the spectrometer in the seabed for water quality monitoring has almost never been tried so far and constitutes the challenge of this work. In order to use the spectrometer immersed in water, the spectrometer must be suitably isolated in a container that can withstand the pressure of the water and with its walls that do not absorb the light radiation of interest for the experiment. To this end it should be inserted in a box with quartz walls, since quartz does not absorb UV light. Furthermore, considering that the AS7265x spectrometer is equipped with three LEDs that radiate light at three different frequencies IR, UV, and visible, and that the substance examined, in this case the liquid of water, must be placed at a distance of proximity to plus 1.5", the sensor should be encapsulated and in direct contact with the surface of the quartz casing and furthermore, in order not to disperse the reflected light rays, a small mirror should be inserted so that the liquid finds itself between the light source and the mirror. The mirror placed in front of the spectrometer should be manifactured with layers of metals which can reflect not only the visible light radiations but also the IR and UV ones. Usually visible radiations can be reflected by a layer of silver; UV by a layer of aluminum while IR can be reflected by a layer of copper and gold.

Graphical Plot of a water sample measurements

The spectrometer sensor has the ability to measure and characterize how various types of materials absorb or reflect **18 different frequencies** of light ranging from **410nm** to

940nm. Each of the three sensors measures the intensity of light in six wavelengths (each wavelength is, therefore, a channel) well defined and we count on a total of 18 channels: there is enough to cover a wide spectrum of wavelengths and make an instrument usable in any analysis.

Device	Channel	Center λ (nm)
AS72653	A	410
AS72653	B	435
AS72653	C	460
AS72653	D	485
AS72653	E	510
AS72653	F	535
AS72652	G	560
AS72652	H	585
AS72651	R	610
AS72652	I	645
AS72651	S	680
AS72652	J	705
AS72651	T	730
AS72651	U	760
AS72651	V	810
AS72651	W	860
AS72652	K	900
AS72652	L	940

Figure 7: Channels and Frequencies of AS7265X.

By starting the spectrometer program it illuminates the liquid in the jar and scans the liquid under observation thus detecting the reflected light in the form of a vector of 18 floating point values representing the wave length of the light reflected from the liquid. The response is usually recorded as a **function of radiation wavelength**. This detection of spectrum is fingerprints in visible + near infrared spectrum. A plot of the response as a function of wavelength is referred to as a **spectrum**. The data measurements have been graphically plotted (see the following Figures).

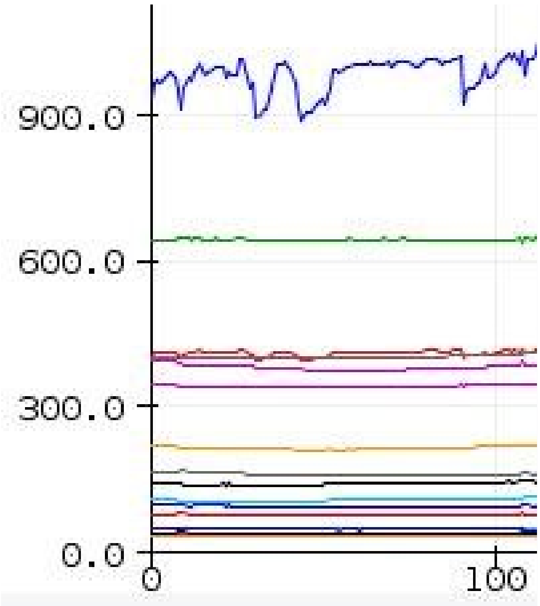


Figure 8 Sample of pure drinkable water

The ordinate axis represents the responsiveness or reflectance value, that is energy reflected on the given frequency. The value is normalized. For a given frequency the values are approximately 100 repeated measurements of the same liquid composition. It is observable that they are almost constant with less than some small variation. This assures us a certain stability of the device as well as reliability of the measurements. The small fluctuations around the average values are actually due to environmental disturbances or noise of the experiment.

The data relating to this sample are reported below in the form of a series of floating point numbers. For the sake of brevity, the first 4 measurements are shown.

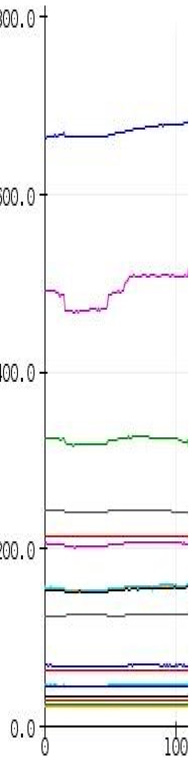
A,B,C,D,E,F,G,H,I,J,K,L,R,S,T,U,V,W

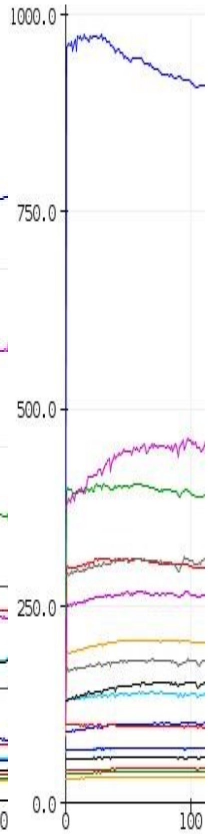
1054.53,405.61,676.10,198.37,343.88,435.63,107.24,140.40,86.75,34.79,32.33,28.21,347.31,155.94,43.59,37.58,42.00,74.59,

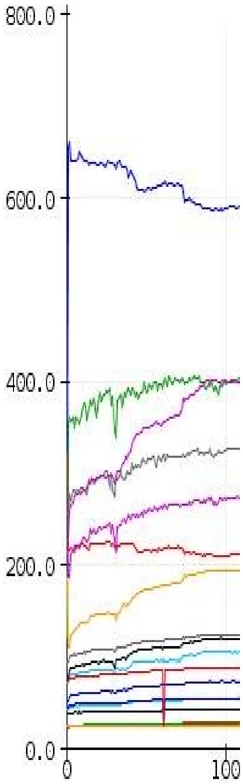
1049.59,403.66,675.12,198.37,343.88,433.27,107.24,139.87,86.75,34.35,32.33,28.21,347.31,154.96,42.75,35.94,42.00,73.48,

1054.53,404.64,675.12,198.37,343.88,434.06,107.24,139.87,86.75,34.35,32.33,28.21,347.31,154.96,42.75,35.94,42.00,74.59, 1056.50,405.61,675.12,198.37,343.88,434.06,106.69,139.33,86.75,34.35,32.33,28.21,347.31,154.96,42.75,35.94,42.00,73.48,

For the purpose of this work they have been collected the data of a number of water samples by adding pure water samples with additives in order to measure the responsiveness of the spectrometer to different organic or inorganic materials dissolved in water. You can see the plotted data in the following Figures.







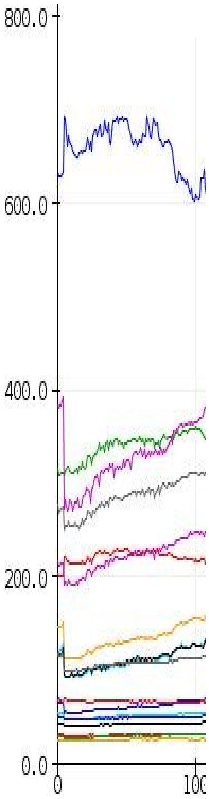


Figure 9 water with salt added

Figure 10 water with dejections added

Figure 11 water with oil, dejections, salt added

Figure 12 water with oil, dejections added

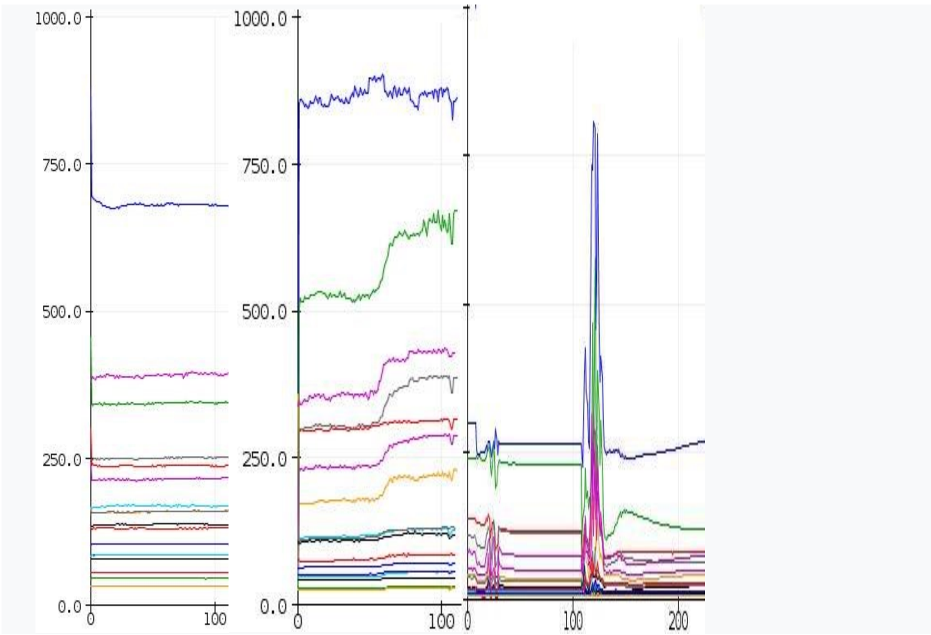


Figure 13 water with oil added

Figure 14 water with salt, dejections, bicarbonate added

Figure 15 with bicarbonate added during measurement

This is a preparatory activity for the next phase and future work, as if the target is to recognize an unknown sample of water, in order to determine the components dissolved in it, it should be build a machine learning model and therefore be collected a large number of samples.

For the sake of this proof of concept it has been used some additives present in our homes to alter the composition of water. For example, it has been used salt to obtain the salinity effect of the sea, it has been used sodium bicarbonate to simulate the pH of the water, or vinegar to check the rise of acidity pH , it has been used additions of gasoline to simulate pollution from combustion engines, and finally the manure of aquariums to simulate the situations of organic waste in the water. These are only few examples of the possible tests which have been used to ascertain the feasibility and significance of the data collection phases.

Each of these plotted graphs can also be exported to a data sheet and represented in a format as in the following Figure 16.
The data sheet can be interpreted as the reflectance response and is a useful tool to compare an unknown sample to a known one.

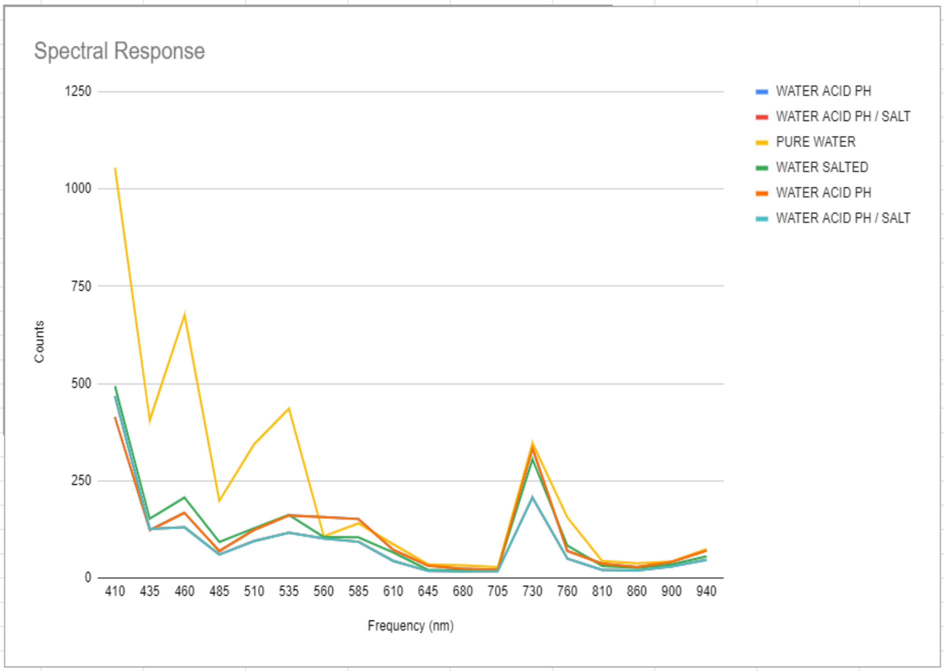
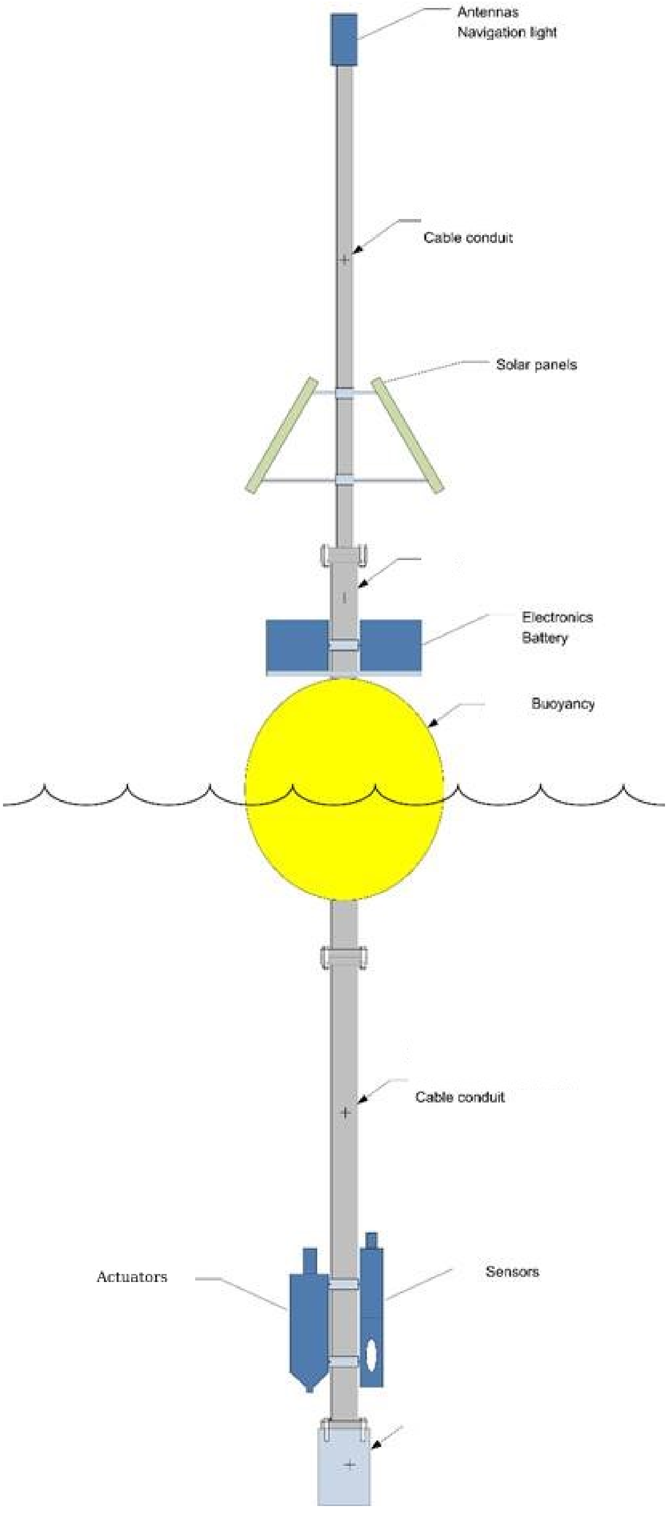


Figure 16 Spectral response of water samples

The Smart Buoy

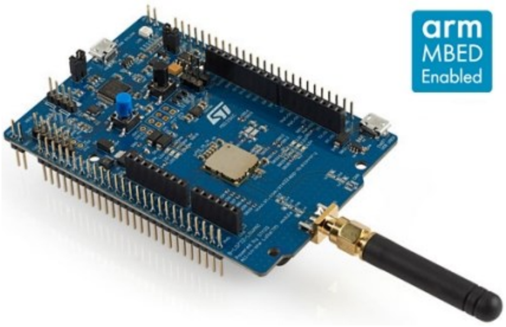
A spectrometer in the sea could not be operational without a structure such as the buoy which not only allocates the instrument but also prepares the wiring, the connection to the network (LoRaWAN), the 2200 mAh battery power supply connected to a photovoltaic panel to be able to power itself of energy from the sun. In the sea there is total absence of the gsm signal, and of any other network. For this, terms of the Internet of Buoys were coined. In our case, the aquacultures must be kept at a maximum distance of a few kilometers from the shore in order to be able to connect to The Things Network via an available gateways. If a gateway does not already exist nearby, a LoRaWAN concentrator must be installed.

A possible prototype of the smart buoy will be as the following:


Antennas
Navigation light
Cable conduit
Solar panels
Electronics
Battery
Buoyancy
Cable conduit
Actuators
Sensors

The LoRaWAN network

Our smart buoy will therefore be equipped with a LoRaWan communication module based on the ST B-L072Z-LRWAN1 board.



This can connect directly to The Things Network if the distance from the closest gateway on the coast is at most 6 km. If the site is further away, a gateway must be installed on the nearest coast by installing an iC880A-SPI concentrator board.

Therefore on the map point A represents the aquaculture site and point B in this case represents the installation point of the LoRaWAN concentrator.

The future work: the data collection for regression modelling

Sustainability is a growing demand for Aquaculture 4.0 and European Green Deal targets. The future work will collect water full-samples to estimate those determinant quantities, in the absence of pre-treatment or chemicals addition to the samples, resulting in a reduction of the duration and cost of analysis. Different regression models can be developed to estimate the determining factors for the quality of the water from the spectral response of sea water samples measured at 410–940 nm through multivariate linear regressions and machine learning genetic algorithms. An in-depth study will be carried out to determine how many of those quantities it will be possible to estimate starting from a water sample, and with what error rate.

References

1. OECD (2020), Sustainable Ocean for All: Harnessing the Benefits of Sustainable Ocean Economies for Developing Countries , The Development Dimension , OECD Publishing, Paris https://doi.org/10.1787/bede6513-en
2. FAO (2018), The state of World Fisheries and Aquaculture 2018, Food and agriculture Organization FAO (Rome) , http://www.fao.org/3/i9540en/i9540en.pdf
3. Wiley Online Library (2016), Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment, First Published 2016 https://onlinelibrary.wiley.com/doi/10.1111/faf.12152
4. Yovita John Mallya Kingolwira National Fish Farming Centre, Fisheries Division Ministry of Natural Resources and Tourism Tanzania. : THE EFFECTS OF DISSOLVED OXYGEN ON FISH GROWTH IN AQUACULTURE, United Nations Educational, International Centre for Capacity Development – Sustainable use of Natural Resources and Societal Change, Final Project 2007 https://www.grocentre.is/static/gro/publication/58/document/yovita07prf.pdf
5. Cheng Chun Chang, Chien-Ta Wu, Byung Il Choi, and Tong-Jing Fang, MW-PPG Sensor: An on-Chip Spectrometer Approach, Sensors (Basel). 2019 Sep; 19(17): 3698., MW-PPG Sensor: An on-Chip Spectrometer Approach (nih.gov)
6. Sergey S. Golik, Yuliya S. Tolstonogovaa, Dmitriy Yu. Proschenko, Alexsander Yu. Mayor, Anton V. Borovskiy,Michael Yu. Babiy,Natalia N. Golik,Tamara M. Agapova,Elena I. Makogina,Vladimir V. Lisitsa, Underwater LIBS spectrometer for analysis of sea water and bottom sediments on the continental shelf, 18 December 2019, Proceedings Volume 11208, 25th International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics; 1120868 (2019), https://doi.org/10.1117/12.2542434
7. Yulia Tolstonogova;Dmitriy Proschenko;Sergey Golik;Alexander Major;Anton Tolstonogov;Anton Borovsky, Development of the Underwater Spectrometer for In-Situ Chemical Analysis of Seawater by Laser Induced Breakdown Spectroscopy, Publisher: IEEE, Published in:2018 OCEANS - MTS/IEEE Kobe Techno-Oceans (OTO), https://ieeexplore.ieee.org/document/8559080
8. Miguel Castillon, Albert Palomer, Josep Forest, Pere Ridao, State of the Art of Underwater Active Optical 3D Scanners, Senso 2019,19(23), 5161; https://doi.org/10.3390/s19235161
9. N.Benoudjit, F.Melgani, H.Bouzgou, Multiple regression systems for spectrophotometric data analysis, Volume 95, Issue 2,15 February 2009, Pages 144-149, https://www.sciencedirect.com/science/article/pii/S0169743908001937
10. https://www.hackster.io/robotics-bangladesh/aquaculture-monitoring-system-powered-by-helium-network-9fb2c6
11. https://www.inmarsat.com/en/solutions-services/enterprise/solutions/aquaculture-management.html
12. https://link.springer.com/content/pdf/10.1007/s10499-019-00443-w.pdf
13. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9229190
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