Designing a biomimetic robot for aquaculture applications: first stages.

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***Abstract* – Aquaculture has become a key field for sustainable food production, fostering innovation in monitoring systems, fish welfare, and production efficiency. This study presents a bioinspired underwater robot for marine farm inspection and monitoring, designed to reduce stress on fish. The robot incorporates biomimetic features to avoid being perceived as a threat while enabling tasks such as net inspections, water quality assessments, and fish health evaluations. Preliminary testing has validated its underwater operation, and future work will focus on improving mobility, sensor integration, and real-world validation.**

***Keywords* -** *Aquaculture, robot-fish, robot biomimicry, biomimetic design*

I. MOTIVATION

Aquaculture, driven by the increasing global demand for fish [1], faces challenges related to animal welfare and production efficiency. In the early stages of aquaculture, fish are raised in indoor tanks, but they are transferred to sea cages for growth and fattening, where both the animals and the facilities are exposed to environmental fluctuations that can affect production and increase economic risks due to possible cage damage, infections, or predation. Therefore, large-scale aquaculture requires precise control, for which Advanced Aquaculture Technologies (AAT) are essential. These technologies include remote monitoring, behavior analysis, and smart management to improve safety and efficiency at aquaculture facilities [2].

So far, work in aquaculture has primarily been conducted manually, with expert divers facing the risks of the marine environment. To mitigate these dangers, teleoperated robots are increasingly used in aquaculture facilities to perform tasks in sea cages [3]. These robots reduce workers' exposure to hazards and enable tasks otherwise unfeasible for humans.

While effective, conventional underwater robots can stress fish due to their mechanical and aesthetic characteristics [4], prompting research into making robots more fauna-friendly [5]. In this context, bioinspired robots, mimicking fish swimming movements, have been developed to reduce their impact [6], but studies on fish behavior and interactions with these robots remain limited [7].

In this framework, and as a continuation of the ThinkinAzul project (GVA-THINKINAZUL/2021/037), the ARTEMISA project (CIPROM/2023/47) aims to develop an underwater robot for fish farms, focusing on fish welfare as part of a complex monitoring system complemented by other underwater, surface, and aerial vehicles. The goal is to design a robot that meets biomimetic criteria to prevent fish from perceiving the robots as a threat or stress factor, while being capable of performing tasks such as inspecting external nets, assessing water quality, and evaluating fish conditions. This will enhance aquaculture operations and reduce the need for human intervention in hazardous environments. This approach will contribute to the development of more efficient and safe aquaculture, with an ethical focus on animal and human welfare.

II. DEVELOPED WORK

The main challenge lies in developing an underwater vehicle that minimizes stress-inducing factors for fish while achieving the highest possible level of biomimicry and operating at depths of up to 20 meters. Furthermore, the tool is designed to be versatile, capable of operating in various situations to meet inspection, monitoring, and measurement requirements.

The vehicle has been developed using watertight components from BlueRobotics, along with custom-designed parts fabricated through 3D printing with filament and CNC machining (Figure 1a-b). It is propelled and maneuvered using caudal and pectoral fins powered by servomotors and is equipped with a frontal panoramic camera for inspection purposes (Figure 1c). Decisions regarding the biomimetic aspect were made based on the results obtained in [8]. In the initial phases of this work, a preliminary prototype has been developed whose teleoperation is achieved by varying the frequency and angles of the tail's oscillation via tether (Figure 1d).

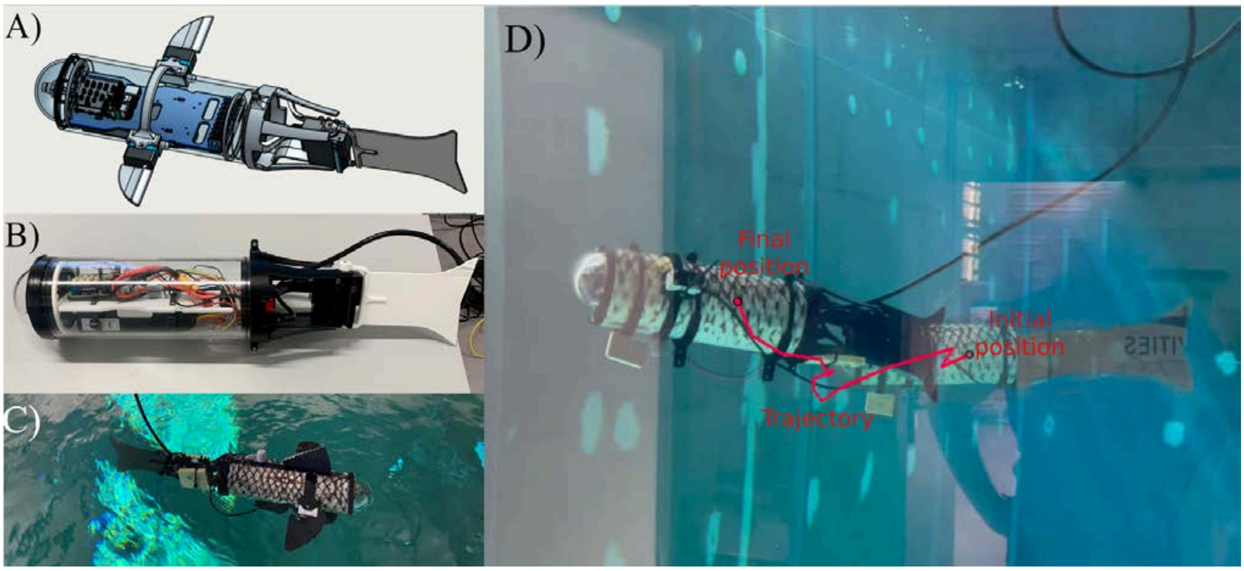

Fig 1. Prototype design evolution. A) 3D design using CAD tools. B) Initial preliminary prototype. C) First immersion and swimming test. D) Immersion and emersion test, evaluating trajectory, using AnimalTA v.2.3.1 software (http://vchiara.eu/index.php/animalta, accessed on 28 May 2024).

Although other works proposing biomimetic fish have been presented in the literature, the one presented in this paper presents some differentiating characteristics (Table 1).

	Proposed prototype	[9]	[10]	[11]
Exclusive use of fins/tail for propulsion	YES	YES	NO	YES
Immersion-emersion system	YES	YES	YES	NO
Environmental Sensors	YES	NO	NO	NO
Frontal and lateral vision	YES	NO	NO	NO
Depth (m)	20	1.5	18	Unknown

Table 1. Comparison of the developed robot with other fish-inspired bio-inspired cisterns already published.

III. FUTURE WORK

Future work includes implementing lateral fins to enable vertical movement of the robot, integrating all sensors and systems necessary for environmental detection, and improving communication capabilities. Additionally, a system for deploying and retrieving external sensors will be developed. All these improvements will be carried out with a focus on achieving a biomimetic integration of the system. To accomplish this, further mechatronic development of the prototype is required, leading to validation tests in both simulated and real marine environments.

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