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Exploring the Use of Precision Livestock Farming for Improved Fish Management and Production

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Abstract
Over the past few decades, the volume and economic yield of finfish aquaculture production have grown quickly, and it is now a major source of seafood. The possibility that the field can encounter new biological, economic, and social issues as the production scale grows also rises, which can have an impact on the sector's ability to continue producing fish in an ethically correct, fruitful, and environmentally responsible manner. For this reason, the industry must strive to keep track of and manage these issues' impacts to prevent potentially worsening issues when production is scaled up. We present the Precision Fish Farming (PFF) idea, the objective to make management-engineering concepts to fish manufacture, enhancing the farmer's capacity to observe, manage, and record biological activities in fish farms. PFF will help transition commercial aquaculture from the conventional dependent on experts to a knowledge-driven construction regime by applying multiple key concepts from Precision Livestock Farming (PLF) and accounting for the border settings & options which are specific to farming processes in the water atmosphere. The only way to do this is to use automated systems and develop technology more frequently. Additionally, we looked at current technology options which might be crucial elements in PFF uses in the future. To demonstrate the possibilities of such systems, we specified four case research that addresses particular issues with biomass tracking, feed delivery management, parasite tracking, and crowding operation management.

Keywords: Fish farming, Precision Fish Farming (PFF), Precision Livestock Farming (PLF), Atlantic salmon skill, Modelling sensors.

Introduction

Modern cattle ranchers are nevertheless under increasing economic constraints. Today, the majority of farmers are forced to make use of economies of scale to survive. Those who are still alive consequently frequently have a small opportunity to spend time with their pets. At the same time, concern for animal welfare has increased, and those involved in the livestock industry are more aware of the need to manage and butcher animals in ways that promote animal welfare (1). These new technologies have a lot of promise, but they also raise ethical questions about how they can affect the interaction between humans and animals, how they might objectify animals, how they might affect our understanding of care, and how farmers might come to see themselves as animal caretakers. A crucial factor that may affect both animal welfare and productivity is the interaction between people and animals. Animals' fear of humans is impacted by stock people's conduct is affected by their attitudes toward farm animals; pleasant handling results in a reduced level of avoidance, whereas poor handling results in higher dread of humans (2).

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The loss is a result of inefficient planting, harvesting, water usage, diminished animal contributions, and unpredictability regarding the weather, pests, customer demands, and other intangibles. The goals of precision agriculture (PA) and PLF are to maximize agricultural and animal productivity while reducing the aforementioned wastes and expenses. PA is a data-driven, technology-enabled method of managing agriculture that monitors, quantifies, and evaluates the requirements of specific fields and crops. PLF is another data-driven, technologies-enabled strategy for managing livestock production that makes use of technologies to objectively measure animal behavior, health, and efficiency. PLF manages livestock by continuous, automated, in-the-moment observation of (re)production, health, welfare, and associated impact on the environment (3).

Data and information are the essential components of smart fish farming. Making judgments dependent on science will be possible through the aggregate and advanced analytics of all or some of the information. Smart fish farming uses a tremendous quantity of information, which presents several difficulties, including different sources, different formats, and complicated information. Data on the tools, the fish, the setting, the breeding procedure, and the people are gathered from a variety of sources. Text, image, and audio are some of the different formats. Data complexity is caused by various mechanisms, phases, and species of cultures. Dealing with the aforementioned high-dimensional, nonlinear, and enormous data is a very difficult process (4). Fish farmers handle a range of duties, including disease management, fish-eating, and pond anomaly detection, to run a fish farm. Fish growers are obliged to continuously monitor those actions for extended periods because there is a chance that a human error could result in specific issues. Due to the speed at which fish move underwater and the overlap of those moves, counting and tracking fish can be difficult. The variety in the state and quality of the water makes counting much more difficult. Fish loss results from an absence of tracking, so automatically monitoring the fish farm would reduce the dangers of fish loss. Some fish actions reveal a requirement for something pertaining to their health, such as when a fish swims to the surface of the water to signal a need for oxygen. For fish, oxygen is a vital component that aids in breathing. Because of increased fish activity and respiration, ponds with too many fish have lower oxygen levels. Fish farmers may thus regulate oxygen levels in each pond by counting the number of fish in each pond (5).

To enhance the management and production of livestock, particularly fish farming, PLF is a new idea that makes use of cutting-edge technologies and data-driven methodologies. PLF seeks to improve many fish farming actions, including management of the entire farm, environmental management, health monitoring, and feeding. To meet the extra difficulties of raising animals aquatic, we created the PFF idea, which depends on PLF and hence accommodates its peculiarities. We will explain the PFF concept and by initial limitations and opportunities of PFF in the water atmosphere. We will then provide a brief explanation of the PFF idea and examine where PFF is currently in terms of research and business. Before we finish and suggest future study directions we believe are crucial for the continuing

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development of the PFF idea. Since this area of commercial PFF has a greater knowledge phase and is developing quickly, which may be particularly open to PFF methods, we will focus mostly on instances from the farming of Atlantic salmon. The PFF uses we suggest, nevertheless, we believe will also be applied to other water-farmed species. The study (6) analyzed for swine veterinarians and specialists, contains a summary of methods and machine learning, a summary of recent research on pertinent sensors and sensor network systems, and an explanation of how these uses may be utilized to improve swine welfare and satisfy stakeholder expectations for present pork manufacturing. Swine practitioners may serve a wider part as advisors in the transition of PLF technologies and its consequences to their clients due to their roles as animal and client advocates, interpreters of benchmarking data, and stewards in regulatory and tracking applications. The study (7) examined how present livestock practices affect the environment and explores the benefits of PLF as a viable method for reducing environmental concerns. The study (8) investigated how current PLF technology might help with pig welfare evaluation. An online search for PLF for commercially available pigs turned up 83 technology. To find studies on the verification of sensor technology for evaluating animal-based wellbeing indices, a literature search was carried out by the systematic review criteria (PRISMA). The research (9) calculated the flow of energy used by buffalo farms, energy usage of indexes construction effectiveness.

The study (10) suggested an integrated end-to-end neural network. To identify anomalous fish behavior from beginning to end and to monitor individuals with abnormal behavior quickly and accurately, the detection method delivers the target's first value to the tracking method, which monitors succeeding frames. The research (11) synthesized current data and novel methods for evaluating these benefits to livelihoods and their significance in nations with restricted accessibility to aquaculture and ocean resources to demonstrate these benefits. Several economically, socially, and categories of individuals worldwide who are nutritionally at risk rely on inland fisheries, but it is difficult to fully grasp the scope of their contributions due to the difficulties in tracking inland fisheries. The study (12) analyzed this information in light of historic sea stage records and catch documents; we look at Indigenous oyster harvest over time. Local oyster fisheries persisted for at least 5000–10,000 years and were widespread throughout both space and time. Oysters were most likely handled and occasionally "farmed," and they are intertwined with larger cultural, rituals, and social traditions. The research (13) examined the physical characteristics of the pellets, development efficiency, feed acceptability, and usage of apparent protein content. The study included trials for digestibility, growth performance, feed acceptability, and feed quality evaluation. The impact of substituting fish meal (FM) and fish oil (FO) with BSFL is examined. The study (14) suggested a collection of data-quality indicator forecasting techniques for a fish pond intelligent management module that, after being compared to DBSCAN, first identifies and eliminates anomalous data utilizing the local outlier factor (LOF) technique. Then, utilizing the model tree method, the important fishpond data are analyzed, modeled, and predicted, enabling water-quality indicators to be handled beforehand and maintained within a safe range that conforms to regulations. The study (15) offered a qualitative governance

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evaluation of the regulatory solutions available to bring livestock production into compliance with the legally binding environmental goals. The study (16) highlighted the fisheries management data gaps which monitoring information may help close, which range from enhanced estimations of natural mortality and abundance to serving as the foundation for temporary restrictions of fishing and the protection of hotspots for biodiversity and migratory routes. Obtaining this information is difficult due to factors such as the enormous vastness of the seas, the incapability of GPS technology, & characteristics of marine fish life histories.

Materials and Methods

The main goals of PFF are to: 1) enhance the consistency, accuracy, and repetition of farming processes; 2) enable greater autonomy and continue biomass tracking; 3) offer additional trustworthy decision support; and 4) lessen the reliance on manual labor and arbitrary judgments, thereby enhancing staff safety. By using these methods, PFF will increase commercial intensive aquaculture production, yields, and environmental sustainability while also enhancing animal health and wellbeing. Aquaculture can be characterized as a set of four cyclical procedures in that bio-responses in the cage are noticed (Analyze stage), understood (Interpret stages), and utilized as the base for decision-making (Choose stage) on what actions to take (Act stage), which in turn causes a bio-response in the fish. Figure (1) denotes the PFF cycle of four stages.

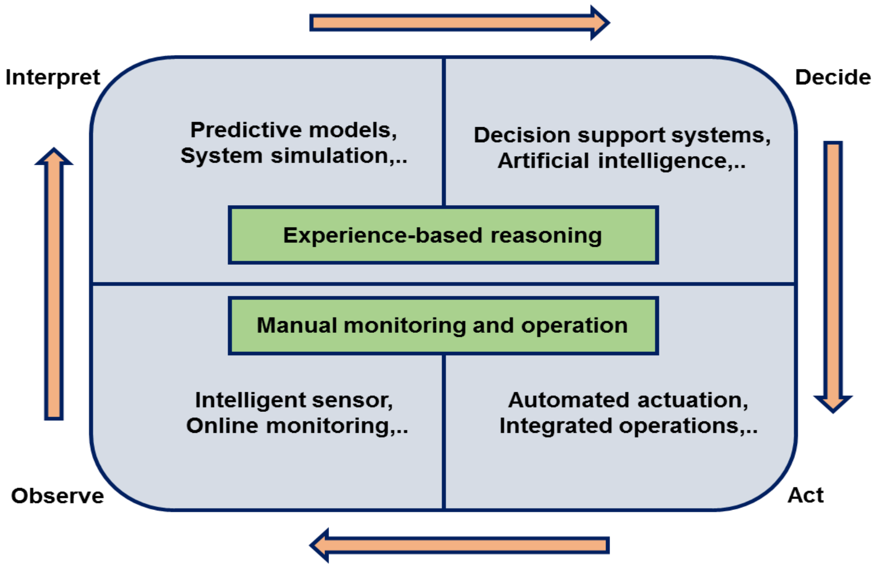

Figure (1): PFF cycle in which the four stages of observation, interpretation, decision-making, and action are considered to make up operational procedures

With manual operations and tracking, as well as interpretations and decision-making that rely on the expertise, the interior phase indicates the present state-of-the-art in production. The outer cycle serves as an example of how the introduction of PFF might affect the cycle's various stages. The fish is first seen by the farmer directly with their eyes or via data gathering instruments like cameras, to obtain qualitative or quantitative data on the fish's bio-reactions. The farmer then interprets this data mostly based on subjective experience, which results in an assessment of the fish's condition and state at the time. Following that, judgments about farming operations and management are made using these interpretations as a guide, and the cage is physically moved to put those decisions into practice. Such decisions can be depending on the expected current conditions or anticipated future conditions of the network, which constitute variations of the comment and feed-forward rules, accordingly, in controller engineering. PFF techniques can involve techniques and equipment for fish farming which uses technological advancements and automation ideas in some, all aspects of the farming process. The end outcome of implementing PFF to a specific process will therefore be the transition of that operation's components from an experience dependent on a data-driven regime for the several stages of fish farming processes.

Although the PFF idea has not yet been established, numerous study initiatives and tool advancements for the fish business might be measured elements for improving PFF techniques, and in some cases are PFF techniques in their own true. Here, we give a quick rundown of the current situation in this field, covering both commercial uses and ongoing studies. The majority of pertinent techniques or ideas discussed here focus on a particular stage of fish farming processes (Figure (1)). Fish producers already rely on electronic technologies to keep track of their animals because direct observation is typically insufficient to provide accurate evaluations of the individual and population states submerged in fish farms. The most frequent equipment used today in fish farms is submerged cameras, which are utilized to watch the fish as they grow while their behavior is manually and subjectively analyzed by the workers. By using computer vision techniques on the video stream, camera systems make useful tools for automated fish tracking. The potential of computer vision methods is growing quickly as a result of the advancement of supporting hardware, including cameras and computer systems, as well as the rising use of these innovations in the consumer electronics sector. Many distinct Animal characteristics, like clusters and movements, can be measured using computer vision techniques in a fish farm scenario. Despite the massive numbers of fish offered in current fish farming, evidence of every fish's actions can verify to be just as important to the sector as a group-stage animal parameter. Acoustic fish telemetry is an approach of remote sensing in which each fish is fitted with an electronic transmitter that contains sensors that identify some aspect of the fish or its surroundings and wirelessly transmit the raw or analyzed information to stationary receivers submerged in water. Acoustic telemetry is currently the sole practicable method for collecting continuous data series from every fish, which makes it an interesting option for further PFF techniques. In addition, the transmitter units are located inside or on the fish; acoustic telemetry can be employed to track fish physiology, such as heart rate and blood work, whereas other techniques for subsurface fish observations, such as cameras and sonars, are primarily restricted to obtaining animal variables depending on animal behavior. This makes farming operations at sea sensitive to the local natural conditions. Information on the native ambient surroundings is crucial for choosing farming locations for the construction of salmon because most of these characteristics have an impact on the development, improvement, and

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wellbeing of fish. Additionally, farmers are becoming more interested in keeping an eye on these conditions at their location throughout production because this data may be utilized to inform management decisions for their farms, such as refraining from manipulating nets in the presence of strong currents or reducing feeding when temperatures drop. As it is frequently important to represent an observable fish variable to the current ambient settings to generate desirable feature variables, such information will be valuable auxiliary data for constructing PFF algorithms.

The amount of study being done to gain a better knowledge of the procedures taking place in farmed populations has expanded along with the production from the cage-based fish farming sector. The body of information about the various sub-devices and bio procedures taking place in commercial sea cages is thus fast growing. Before this knowledge may be organized to offer data pertinent to the processes taking place in the cage, though, it should be used for decision-making at the cage levels. By combining data from several subsystems into a comprehensive system depiction, calculated modeling of systems dynamics is a regularly utilized technique. A dynamic system's response to a given set of inputs may frequently be predicted using mathematics. Additionally, a mathematical representation of the system can estimate system characteristics which are challenging to test. Calculated methods are used in aquaculture studies to predict fish development and behavior. These frameworks can identify or evaluate fish attributes determined by observed inputs, making them suitable candidates for PFF methods targeted at interpretations. These inputs frequently consist of multiple kinds of auxiliary information necessary to drive the dynamics of the approach. A new investigation used simulations of sales strategy and plans along with a framework of sea bream development with temperature as input to determine the economic output of production operations.

Another illustration of this type of application of mathematical frameworks is the utilization of mathematical models to predict Features including fish feeding activities. Additionally, there are mathematical representations of environmental factors in production units that address issues like the geographical and temporal distribution of feed in sea cages. It is more challenging to measure the various phases and procedures effectively in the caged fish industry than it is in more technically oriented ones because the procedure is primarily biological. According to this logic, it is expected that significant utilization of estimations that depend on computational models will be required elements for creating the PFF techniques in the future, as PFF will need a richer basis for data than is provided by current observing techniques.

The lack of human existence necessitates at least some automation of decision-making procedures. Although there are currently no automatic decision support or decision-making systems in use in the aquaculture sector, information technology (IT) have allowed for the creation of decision support systems (DSS). A DSS is an automated device which produces compound output values for a specific issue by combining inputs and previous user experiences. These output values which are referred to as goal variables in the PLF/PFF

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language, are the DSS's starting point for suggesting a suitable option. Many sectors, such as oil and gas, banking, and medicine, adopt DSS techniques. Divers used to perform the majority of the required underwater tasks at fish farms. Remotely operated vehicles (ROVs) are now frequently used for similar jobs, significantly lowering the risk of employee casualties. Although ROVs are typically piloted by humans, a new study has shown that acoustic position techniques and computer vision-based systems may be used to enhance ROV navigation in and everywhere cages, enhancing the precision of remote processes. As a technology advances globally, commercially accessible fish farming equipment likewise improves in technological sophistication and capability to undertake more challenging tasks. Most of the technological concepts which could be employed as tools in the development of industrial PFF uses have already experienced some industrial and commercial use in other market sectors, including aquaculture. But for most of these, there are particular technical difficulties relating to the fundamental physics of the subsurface surroundings, characteristics of the chosen sensing techniques, or restrictions of interaction procedures when applied in a fish farm situation. Before aquaculture can take the next step toward commercial exploitation, these obstacles must be cleared. Implementing new product features, adjusting system settings, or strategically positioning equipment are all possible solutions to these problems.

Results and discussion

A PFF approach should have a favorable impact on the current state of farming to be an industrial worth. Therefore, before implementing novel activities with the intention of commercialization, PFF techniques should be assessed to see how much they can improve fish welfare and health, reduce fish losses, increase manufacture performance and product quality, and reduce the conservational effects of farming operations. Additionally, as fish farming activities are often carried out outdoors, any system or piece of equipment situated at the farming location will be subject to the components. PFF techniques must therefore undergo durability testing to avoid equipment failure when applied to commercial settings. We provide four specific instances of PFF uses which are practical to execute provided the current state of technological preparedness and have the potential to have a significant influence on industrial fish farming to demonstrate how PFF approaches can be applied. The cases address crucial sectors of the salmon sector, from parasite control to feeding and biomass control. The examples also show how PFF concepts can be used for continuous-time scales, regular time scales, or transient time scales.

The features of cage populations, including the whole biomass, the quantity of fish, and the distribution of fish dimensions within a cage are essential data to several critical choices in the construction procedure, containing the computation of the overall profit when selling the fish before slaughtering. There are technologies to establish each fish's size and fish size distribution, these only offer information pertinent to their placement in the cage and cannot offer information that is typical of the overall population of fish in the cage. Therefore, rather than relying on an objective, knowledge-driven source, judgments that include the biomass distribution, number of fish, or overall biomass in a cage as inputs must in part depends on estimations made by farmers who have relevant expertise. The capacity to forecast and define such population features in sea cages has turned into a "holy grail" in the salmon farming business due to their significance in central farm controlling choices. Finding the pertinent Feature variables first is one way to apply the PFF ideas to this problem. The overall biomass in the cage, the overall sum of fish, and the population's spreading of individual sizes are potential feature variables in this scenario. The figure (2) denotes the output of a computational model during biomass frame and manual sampling.

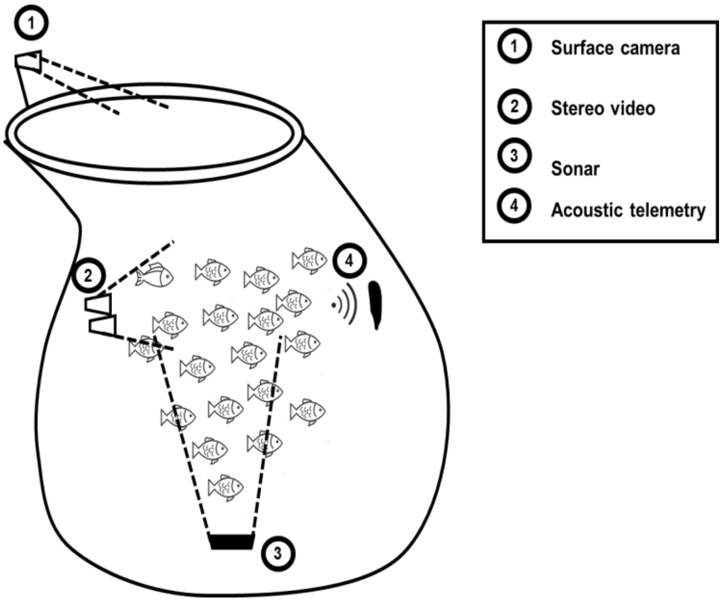

Figure (2): An illustration of the output of a computational model and experimental information gathered using a biomass frame and manual sample

Even though this plan would reveal new information regarding population differences in dimension and vertical differences in biomass both of which are valuable characteristics in and of themselves no combinations of these two fish variables may be utilized to directly determine the overall sum of fish. Using mathematical representations of the behavior and development dynamics of salmon in an estimator framework could be one method of obtaining such data. A closed-loop PFF use would largely need additional studies into new techniques to combine information from various sources with simulation data because some of the managing and implementation technologies necessary analyze and Interpret stages. It is not necessary to link feature variables that describe features of the biomass to specific Target variables because they provide data that is pertinent for a wide range of farming uses.

The processes for feeding fish in sea cages used for commercial salmon are intended to ensure that each fish gets enough food to sustain set development degrees and reduce feed waste to the surroundings. In the sector, there is a constant trade-off that affects both fish welfare and the farm economy because these two goals frequently conflict (e.g., overfeeding may provide strong growth rates but increase feed spillage, and vice versa for underfeeding). When it comes to salmon production, feed expenditures are the biggest individual expenditure, making up around 50 percent of all production costs from the egg to the marketable fish. Salmon production techniques heavily rely on feeding tables that prescribe

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feed levels to population size and temperatures. Furthermore, to manually observe the feeding activities of the fish, fish farmers typically employ submersible cameras pointing at the feeding location. If they see that the fish appear less sensitive to the meal or otherwise exhibit decreased hunger, they will usually change the feeding rates appropriately. Although the relationship among feed deliveries and the biological activities in the cage is now better, the clarification of the fish reactions is still reliant on experiences and so is dependent on the knowledge and abilities of the single farmers. The results will differ greatly among operators and sites, however, it has been shown that this approach can occasionally result in decent development rates and feed alteration features. Additionally, it might not be practicable for employees to be on-site every day for places in distant or exposed (to wind, current, and waves) regions. Fully automated managed feeding is essential for farm process in such places. Improved precision and tracking technology employed in the feed dispersion to salmon cages would enhance the expected & observed feed intake in the fish population which could lead to a decrease in construction expenses and conservational effects while increasing development. To change the feeding control strategy from being mostly experience-based to being more knowledge-driven, the PFF principles could be implemented. Figure (3) denotes a Vertical placement (a, b) vertical motion speeds (c, d) 2 distinct fish during feeding are shown in the following example data from acoustic telemetry. Gray bars indicate feeding times.

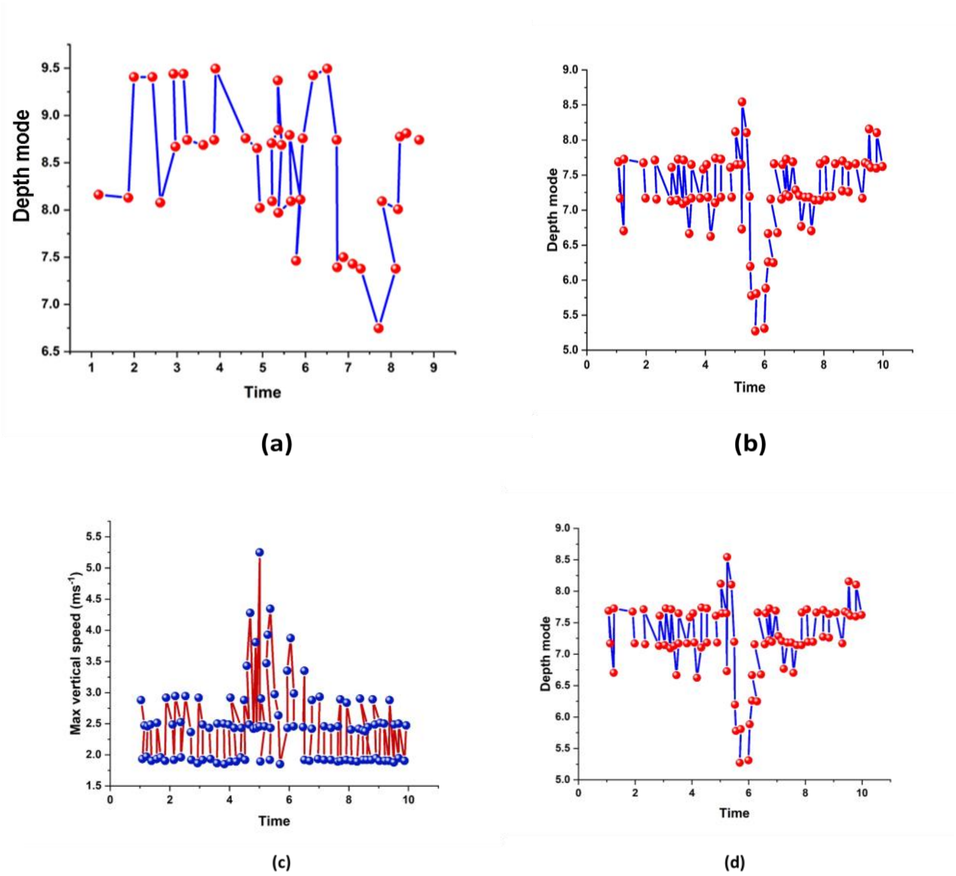

Figure (3): Vertical placement (a, b) and vertical motion acceleration (c, d) of 2 distinct fish during feeding

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Vertical distribution and mobility, as well as individualized swimming behavior that are both driven by the fish's motivation to feed, are suitable animal variables for this use. The information given by all of these devices can be used to construct feature variables that represent the fish's hunger or eating motivation, but it's feasible that a more accurate and exact indication would include data from different technologies. Furthermore, given the significance of effective feed utilization for complete effectiveness, it is worthwhile to make the additional investments necessary to create a feature variable that integrates multiple animal variables from various causes, provided that the improved precision results in higher benefits or fewer negative externalities. It is necessary to gather information for the specified feature variables throughout both feeding and non-feeding times to construct an automated system that employs them to advise on whether or not the current feeding regime must be modified. Since several of the sensor solutions needed to gather the data necessary for this case study in the Observe stage already exist, developing a closed loop use would primarily entail researching new techniques for combining data from various sources into compound Feature variables and novel strategies for determining the right Target variables from these. Feed positioning could be spatially optimized using obtained Feature variables as feeding systems get more complicated. Feeding could then be positioned more upstream to decrease feed losses and enhance accessibility for the fish based on the animal's current location in the sea cage, the route, and the speed of the water travels. The daily presence of aquatic life in their cages must be noted. The average price of the various counts is estimated after sea-lice people are manually tallied on samples of each fish retrieved from about half of the cages on the location. The farmer should immediately delouse the farm if the mean number of sea lice per fish is higher than the permitted level. The louse assessment method affects some fish since fish must be trapped, handled, and sedated before the actual counting, in addition to being labor-intensive and expensive. Smaller sea lice phases are hard to see; hence it is assumed that they will be undercounted greatly in these counts because manual counting is vulnerable to changing climate factors, subjectivity, and numerous additional factors. The requirement to capture the fish to add them to the dataset also begs the query of represent ability: are the fish that are pulled up close to the surface depiction of the entire people contained in the cage. Due to recent evidence showing which salmon with more sea lice move greater, present lice count methodologies are likely to underestimated lice stages. By performing manual sea-lice evaluations concurrently with the technological uses, the gold standard needed to verify this procedure might be acquired. The primary difficulties in implementing closed-loop PFF use for this research would be in creating accurate and suitable approaches for assessing lice people dependent on the current sensor devices and in adjusting various delousing techniques to the resultant objective variables.

Effective delousing of salmon cages is essential once the sea lice count exceeds legal restrictions since unchecked outbreaks of sea lice can seriously affect the welfare and health of fish as well as wild salmonids in the area close to the farm. The employment of cleaner fish that consume sea lice, the use of medicated feeds, and immersing the fish in closed or semi-closed volumes are all common delousing techniques. However, the severity of the treatment regimens has recently increased along with the amount of sea-lice infestations. If the fish's conditions indicate that the process of crowding is putting them under excessive stress or physical strain, this approach could provide alarm signals to the farmer. Choosing the skills to employ in the Detect stage would be the first step in building the technique. This might be accomplished by raising the bottom of the net during crowding with automatically operated winches. These winches may be designed to crowd fish according to a predetermined schedule, gradually reducing the volume accessible for them.

Conclusion

Manufacturing PFF is a major source of aquatic protein used in food for humans. The sector strives to provide seafood to satisfy the growing need for it brought on by the extending worldwide population. Most likely, it cannot be able to solve this issue by just increasing construction volumes and adhering to the current manufacturing regimes because of factors like the declining availability of feed raw materials, the restricted number of farming places appropriate for current levels, the growing emphasis and requirements for eco-friendliness, and space usage conflicts with other businesses. As a result, to achieve greater efficiency, fish farming methods will require becoming more efficient and intelligent in the future. This will require a shift from experience-driven to knowledge-driven methods. Present market patterns indicate farms providing more food and improving efficiency per employee on every fish farm, which highlights the need to monitor and manage the production processes. To fully realize the capacity of PFF in commercial aquaculture, further research on technology applications within each of the four levels of fish farming is required. These techniques are more case-particular than generic and are based on practical study. Additionally, every phase might be concentrated on individually to handle technical issues, which includes advancing sensor technology for superior animal factor monitoring, industrialized calculated simulations, improving automated DSS approaches, and improving autonomous devices for adjusting cages. It is an important to carry out some fundamental investigation to better comprehend biological systems in fish. By setting the foundation for the development of novel approaches, this will have a greater long-term influence even if its immediate commercial appeal isn't as strong.

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