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# Technology-Based Fish Health Service Innovation for Sustainable Aquaculture Practices in Indonesia

**Fadlil Ferdiansyah, Irawan Habib Yulianto, Muhammad Zamrol Imada, Patricia Evericho Mountaines*, Erwin Adriono, Yudi Eko Windarto, Arseto Satriyo Nugroho**

Department of Computer Engineering, Faculty of Engineering, Diponegoro University, Semarang, Indonesia
* Corresponding Author: evericho@ce.undip.ac.id

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ABSTRACT

**Background:** Indonesia's aquaculture sector holds vast potential, yet many fish farmers, especially those in remote areas like offshore cages, face limited access to timely fish health services, leading to undetected disease outbreaks, mass fish mortality, and significant economic losses.
**Contribution**: This study introduces *Fish Doctor*, a scalable platform integrating fish species detection, disease diagnosis, and expert consultation. It bridges the gap between AI-based detection and practical aquaculture needs in developing countries, supporting sustainable practices aligned with SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production).
**Method**: The application was built using Next.js, Express.js, MySQL, and integrates computer vision and expert systems. Its core features include image-based fish species detection using YOLOv11, rule-based disease diagnosis through forward chaining, and an online expert consultation module. Designed as a Progressive Web App (PWA), the system offers offline-first capabilities, enabling its use in low-connectivity environments.
**Results:** The system was evaluated using test datasets of five fish species, achieving an average diagnostic accuracy above 80% and response times of less than 2 seconds per case.
**Conclusion:** The developed platform demonstrates potential for improving early disease detection and reducing reliance on chemical treatments in aquaculture. Future research will involve usability testing with more than 100 fish farmers across multiple provinces to assess scalability and generalizability.

## 1. Introduction

Indonesia is recognized as one of the world's mega biodiversity countries, particularly noted for its rich marine biodiversity. Approximately 37% of the world's coral reef fish species are found in Indonesian waters, highlighting the nation's critical role in global marine ecosystems [1]–[3]. This richness makes Indonesia a critical hub for fisheries and aquaculture development. The aquaculture sector, in particular, plays an increasingly vital role in meeting global protein demand, as capture fisheries face resource limitations. According to FAO, global aquaculture production reached 185.4 million tons in 2022, surpassing capture fisheries for the first time [4]. This milestone underscores aquaculture's importance for global food security.

Nevertheless, aquaculture productivity remains vulnerable to disease outbreaks. Disease outbreaks in fish can lead to mass mortalities, causing significant threats to the viability of aquaculture businesses and contributing to up to 20-30% of global production losses [5]–[7]. In countries such as China, India, and Vietnam, fish diseases cause significant reductions in growth rate, feed efficiency, and survival, leading to severe economic losses. Meanwhile in Indonesia, similar challenges threaten both farmer livelihoods and national food resilience [8]–[10]. These problems directly relate to Sustainable Development Goal (SDG) 2: Zero Hunger, which seeks to improve food security, and SDG 12: Responsible Consumption and Production, which emphasizes reducing excessive use of antibiotics and chemicals in aquaculture [11]–[13].

Digital innovations offer a promising solution to address these problems. Computer vision and artificial intelligence can support faster and more accurate disease detection, while expert systems provide structured reasoning for diagnosis [14]. Recent reviews also emphasize the growing role of AI in aquaculture, highlighting its applications, challenges, and future directions for scaling sustainable production [15]. Integrating these technologies has the potential to reduce reliance on antibiotics, improve early intervention, and promote environmentally sustainable aquaculture [16], [17].

However, farmers especially those managing floating cages in remote coastal areas—often lack timely access to fish health services [18]. The remoteness of aquaculture sites creates delays in diagnosis and treatment, resulting in higher mortality rates and economic losses. Previous studies have proposed digital tools for fish detection [19], [20] or disease diagnosis [21], [22], but these approaches are often limited to a single function, rely heavily on stable internet connections, or do not provide direct access to expert consultation.

In response to these gaps, this study proposes the Fish Doctor application, a Progressive Web App (PWA) that integrates three key features: YOLOv11-based fish species detection, rule-based disease diagnosis using forward chaining, and online consultation with aquaculture experts. Unlike previous systems, this platform was designed with offline-first capability, enabling use in low-connectivity environments. This article presents the system architecture, implementation, and evaluation, and discusses how such an integrated platform can contribute to sustainable aquaculture in Indonesia.

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## 2. Method

The development of the Fish Doctor application followed a modular approach, combining computer vision, expert systems, and web technologies to provide a scalable solution for aquaculture disease management. The methodology is described in five subsections: system architecture, dataset, fish species detection model, rule-based expert system, and development process [17], [23], [24].

The application consists of two main components: a public interface for fish farmers and an administrative interface for aquaculture experts. This dual architecture was designed to support real-time interaction, data monitoring, and service management. Core features include image-based fish species detection using YOLOv11, rule-based disease diagnosis via forward chaining, and an expert consultation module. The system was implemented as a Progressive Web App (PWA) to provide mobile responsiveness and offline-first functionality, ensuring accessibility in low-connectivity environments.

### 2.1. System Architecture

The application was designed with two main components: a public interface for fish farmers and an administrative interface for aquaculture experts in Figure 1. The frontend, developed as a Progressive Web App (PWA) using Next.js, provides mobile responsiveness and offline-first functionality to support users in low-connectivity environments. The backend, implemented with Express.js and MySQL, manages authentication, data storage, and communication with the AI module (YOLOv11) and the rule-based expert system.

To ensure secure access, all client–server communications are protected with HTTPS and JSON Web Token (JWT) authentication. A cloud-based service is integrated for efficient handling of uploaded fish images, while database access is restricted through firewall configurations to allow only backend-mediated connections [25]–[27]. This architecture enables scalability, maintains data security, and supports the integration of AI-driven detection and expert consultation features within a single unified platform.

### 2.2. Dataset

The fish species detection model was trained on a dataset comprising 2.500 labelled images across five common aquaculture species: catfish, tilapia, gourami, tuna, and pomfret. Images were collected from open-access repositories and verified by aquaculture experts. The dataset was split into 70% training, 20% validation, and 10% testing. Data augmentation (rotation, brightness adjustment, and random cropping) was applied to improve generalization under variable field conditions.

For the disease diagnosis module, 120 representative cases of common fish diseases were compiled into a knowledge base from expert interviews and veterinary references. Each case included symptom sets, diagnostic rules, and recommended treatments.

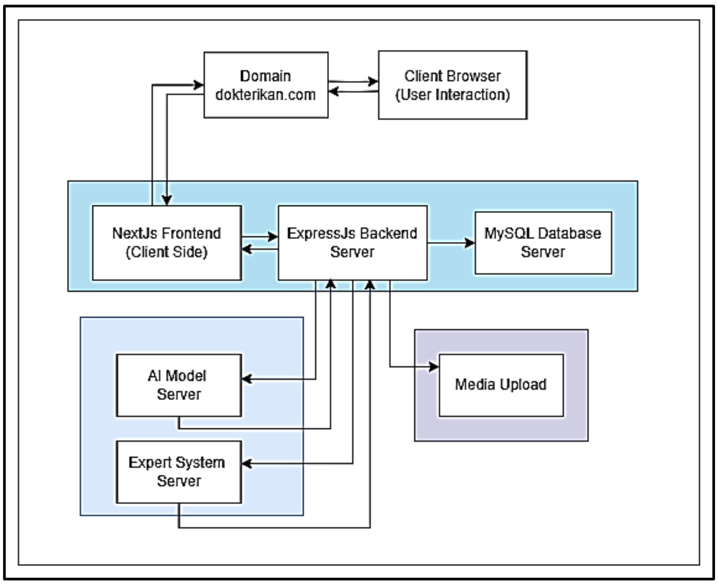


**Figure 1.** System architecture of Fish Doctor

### 2.3. AI Model for Fish Species Detection

YOLOv11 was selected for species detection because its single-stage detection framework balances accuracy and inference speed. Compared to earlier versions (YOLOv5, YOLOv8), YOLOv11 showed stable performance under constrained computational environments, making it suitable for browser-based deployment.

The model was initialized with ImageNet pre-trained weights and fine-tuned using transfer learning. Training was performed for 100 epochs with a batch size of 32 and a learning rate of 0.001 using stochastic gradient descent. The fine-tuned model achieved an average confidence of 82% across species classes on the test dataset. For deployment, the model was converted into ONNX format and optimized with Web Assembly, enabling client-side inference and offline execution.

### 2.4. Rule-Based Expert System for Disease Diagnosis

A forward chaining algorithm was implemented to match user-input symptoms with disease rules. Each rule consisted of symptom sets weighted by diagnostic relevance. If symptoms did not match confidently, the system notified the user and offered expert consultation. This hybrid design ensured diagnostic reliability while preserving user trust.

### 2.5. Development Process

The system was developed iteratively using Agile principles, incorporating feedback from aquaculture experts and fish farmers at each prototype stage. Security measures included JWT-based authentication and encrypted data storage. Fish farmers can detect fish species by uploading photos, processed using the YOLO algorithm, and diagnose diseases by entering symptoms analysed by a forward-chaining expert system. They can also read educational articles and submit questions or complaints for expert consultation. Experts can view and

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respond to consultations, provide diagnoses, and recommend treatments. The system uses session-based authentication to secure user data. On app access, it checks for an active session if valid, the user proceeds; if not, they must log in or register. A successful login creates a new session, granting access to all features, including consultation history. The business process Figure 2 includes registration, complaint submission, consultation, diagnosis, and prescription. The system then directs users to the payment menu, where the admin sets the delivery fee. Users choose a payment method, upload proof, and the admin verifies the payment, completing the consultation flow.

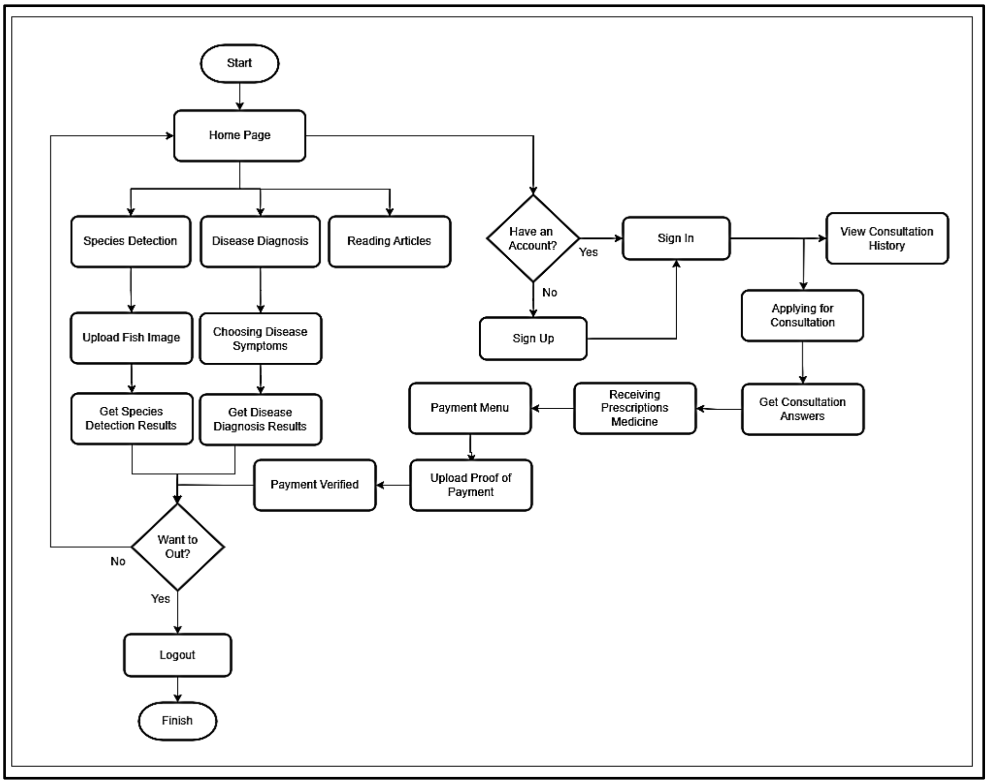


**Figure 2**. Fish Doctor Software Application Flowchart

The development of the Fish Doctor backend application utilizes the MySQL database management system. The database schema design process is shown in Table 1, which illustrates the creation and structure of relational tables.

### 2.6. Fish Doctor Software Application Interface

The *Fish Doctor* software application interface was designed to prioritize clarity, accessibility, and responsiveness, particularly for fish farmers in rural or low-connectivity environments. The interface consists of several key components, each designed to guide the user through the main services of the application in an intuitive manner.

On the Fish Species Detection page, there are two methods that users can use to upload fish images. The first method is to select an image from the device storage, while the second method is to open the device camera directly to take a photo in real-time. The fish images uploaded by the user have been analyzed by the system, and the species identification results are displayed in detail on this page. The purpose of this page is to provide complete information about the detected fish species, so that users can understand the characteristics of the fish in more depth. Fish species detection page image can be seen in Figure 3.

**Table 1.** Fish Doctor Database Design

| Relational Table | Items |
|---|---|
| Consultation table | This table stores user consultation records, including symptoms submitted by the user and diagnostic feedback provided by the expert. Columns include user_id, user_consultation_id, and fish_expert_id |
| Fish Disease table | This table contains data related to various fish diseases, including disease_name, description, and disease_image |
| Fish Type table | This table holds information on different fish species, including fish_name, description, and fish_image |
| Medicine table | This table stores data on available medications. Columns include medicine_name, contain, dosage, and medicine_image |
| Prescription table | This table records treatment recommendations or prescriptions issued based on consultations. It includes consultation_id, fish_expert_id, and instruction |
| User table | The data of user is saved from signing up. Columns include user_id, name, email, password, phone_number, address, and role |

The Fish Disease Detection page is designed to assist users in identifying possible diseases experienced by fish based on the symptoms that appear. The system provides two categories of symptoms that can be selected by the user, namely physical symptoms and behavioral symptoms. Physical symptoms include signs that can be observed visually, such as changes in body color, wounds on the skin surface, or swelling. Meanwhile, behavioral symptoms include changes in fish activity, such as abnormal swimming, frequent surfacing, or loss of appetite. Users can select one or more symptoms from each category according to the actual conditions observed in the fish. Fish disease detection page image can be seen in Figure 4.

The consultation page is a feature that allows users to submit complaints or questions related to fish conditions to fisheries experts. To be able to access this page, users are required to login first to ensure that only verified users can use this service. After successfully logging in and opening the consultation page, users will be presented with important information related to the terms of service. This information includes consultation fees, instructions for filling out forms, estimated response times from experts, and applicable terms and conditions of service. The submission of this information aims to make users understand the flow of consultation and the responsibilities of each party during the process. Consultation page image can be seen in Figure 5.

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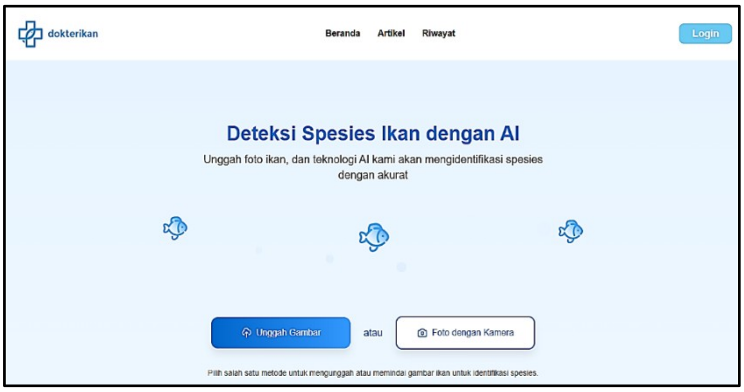
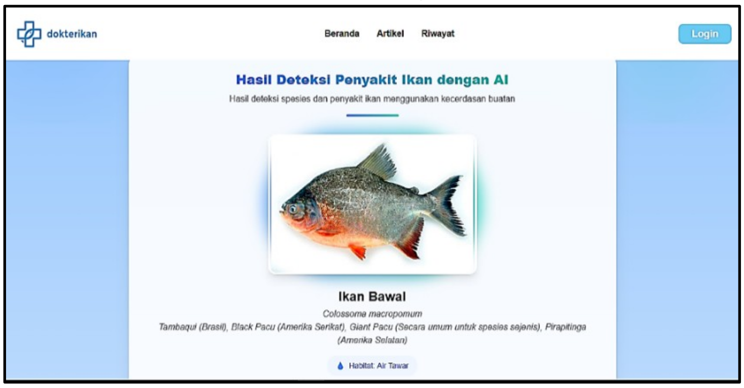


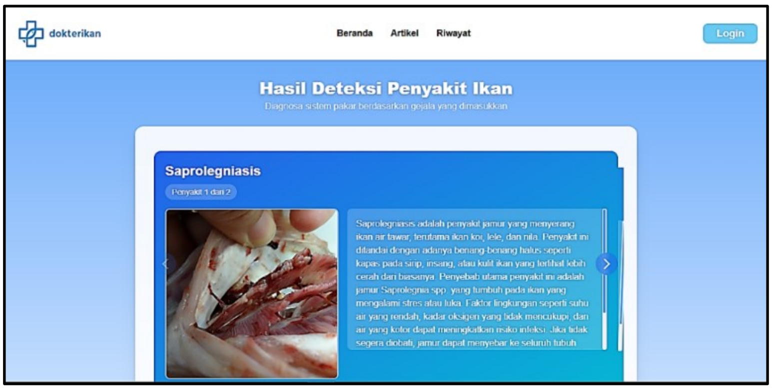

(a) Initial Page




(b) Result

**Figure 3.** Dokter Ikan Application Fish Detection Page.


(a) Input Symptoms




(b) Detection Results

**Figure 4.** Fish Doctor Web Application Fish Disease Detection Page


**Figure 5.** Fish Doctor Application Consultation Page

## 3. Results and Discussion

The Fish Doctor application was thoroughly tested through a series of test scenarios to evaluate its functionality, particularly in detecting fish species through image uploads and diagnosing fish diseases based on user-input symptoms. The following scenarios describe key outcomes of these tests, including successful and unsuccessful cases in both species' identification and disease diagnosis.

### 3.1. Scenario 1 - Successful fish species detection from image upload

In this scenario, the user uploads a fish photo using the species detection feature in the application. The image is sent to a cloud-based AI model through an internet connection. After processing, the system successfully identifies the species and displays general information, including the species name, scientific name, alternative names, habitat type, physical characteristics, feeding habits, and suitable environmental conditions. This helps users quickly recognize the fish species and access relevant care guidelines. Figure 6 shows the detection interface and information display.

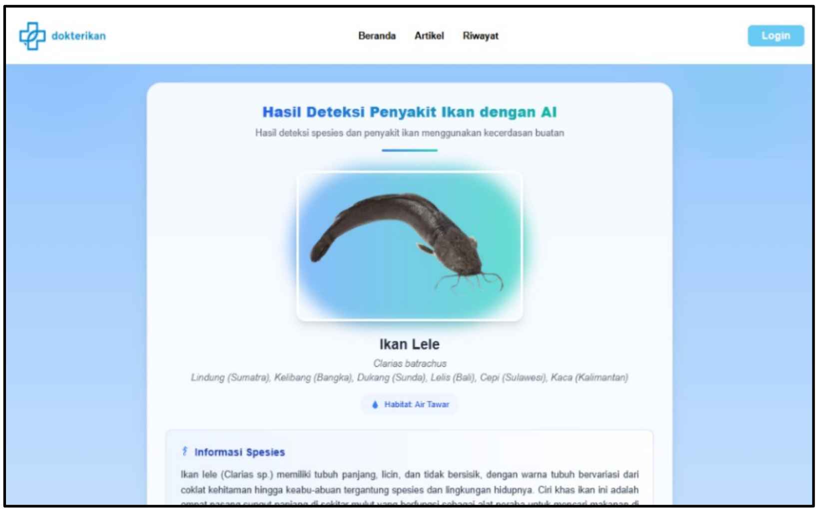



**Figure 6.** Fish Species Detection Result Page

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### 3.2. Scenario 2 - Failure in fish species detection

In this scenario, the user uploads a photo using the species detection feature, but the system fails to identify the fish. This may occur due to unclear images, poor lighting, or the species not being recognized by the model. The application then notifies the user that the detection was unsuccessful and suggests uploading a clearer photo or trying a different angle. This ensures users are still guided toward a solution even when the detection process cannot deliver a result. Figure 7 shows the interface and notification message in this situation.

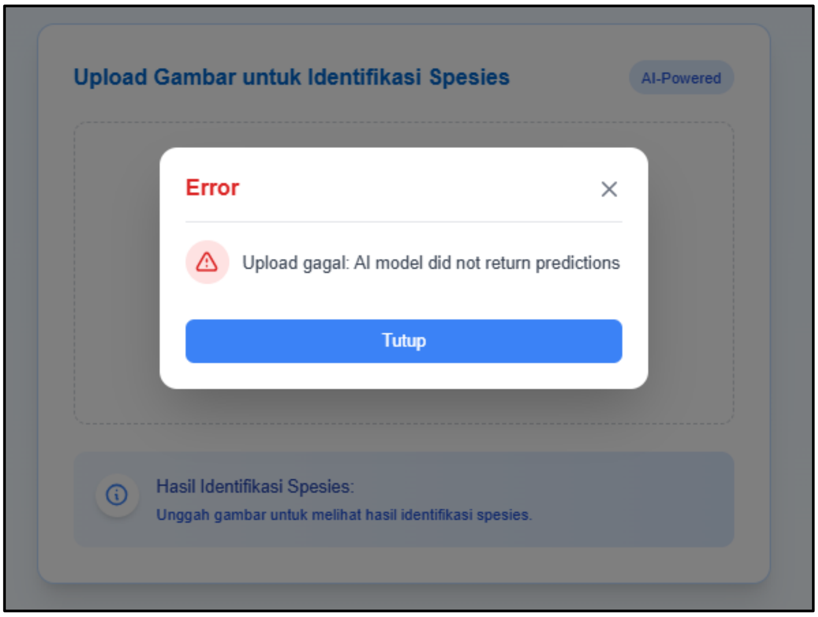


**Figure 7.** Failed Detection Result Page

To evaluate the performance of the fish species detection system, tests were conducted using ten images for each of the five fish species. This evaluation aims to measure the model's confidence in the detection results as well as the average processing time required per image. The recorded processing time includes the entire duration from image upload to the display of the detection result. The measured parameters include average confidence (percentage) and average detection time (in seconds). Using datasets of five fish species with ten images per class, the species detection feature achieved average confidence scores above 80% with detection times below 2 seconds Table 2.

**Table 2.** Fish Species Detection Results

| Class Detected | Average Confidence (%) | Average Time (s) |
|---|---|---|
| Gurame Fish | 85 | 2.1 |
| Catfish | 81 | 1.82 |
| Nile Tilapia | 84 | 1.9 |
| Tuna Fish | 83 | 1.85 |
| Pomfret | 86 | 1.94 |

### 3.3. Scenario 3 - Successful diagnosis based on selected symptoms

In this scenario, the user selects a set of symptoms observed in their fish through the application's interface that was designed to be interactive and straightforward, allowing users to tap or click on multiple symptoms relevant to their current fish condition. Once selected, the system performs rule-based reasoning using a forward chaining algorithm. This logic engine matches the selected symptoms against a structured knowledge base, which contains rules derived from expert knowledge in fish pathology. Each symptom carries a certain weight, contributing to the system's decision-making process. If a rule is strongly matched, the system infers the most probable disease and provides detailed information regarding its name, cause, symptoms, and suggested treatment. This rapid and accurate response aids fish farmers in taking immediate and appropriate action to prevent further spread or death. Figure 8, illustrates the diagnosis screen and disease detail interface presented to the user.

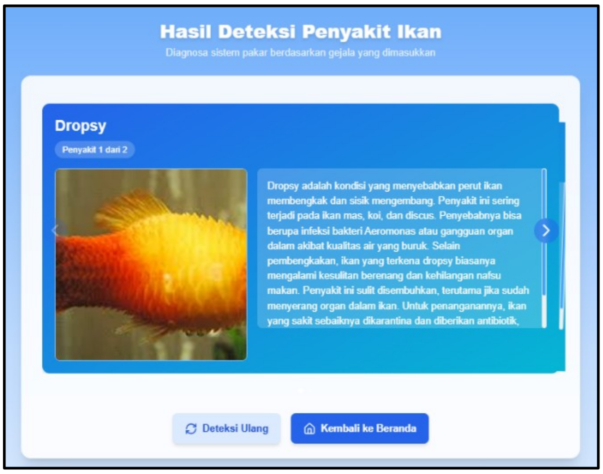


**Figure 8.** Fish Disease Diagnosis Result and Detail Interface

### 3.4. Scenario 4 – Failure to diagnose

In certain cases, the system may not be able to determine a reliable diagnosis based on the symptoms provided. This can occur when the user selects symptoms that are too general, conflicting, or incomplete, resulting in no strong rule match within the expert system's knowledge base. Rather than producing a misleading or low-confidence result, the application is designed to recognize this uncertainty and respond accordingly.

When this occurs, the system immediately notifies the user that a diagnosis could not be made with the current inputs. A prompt appears on the interface offering three options:

1. Re-enter or refine symptom selections, encouraging users to provide more accurate or additional information.
2. Initiate a consultation with a certified fish health expert, directly through the platform's integrated messaging system.
3. Return to Home Page, if the user prefers not to proceed with expert consultation or re-enter symptoms, they are provided with a clear and accessible option to return to the Home Page. This allows users to explore other features of the application, such as fish species detection or educational articles, without disrupting the experience. This option supports flexibility and reduces user frustration by ensuring that even when diagnosis

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fails, the interaction does not feel like a dead end. It also reinforces the app's user-centered and non-linear navigation design.

This scenario demonstrates the application's fail-safe mechanism, ensuring that users are not left without guidance even in ambiguous or complex cases. The inclusion of a human-in-the-loop element reflects the system's hybrid approach: combining automated AI and expert rule-based reasoning with real-world expertise when needed. Such a design not only preserves user trust but also encourages iterative learning, allowing farmers to better observe and report fish health symptoms over time. Figure 9 illustrates the user interface for diagnosis failure, along with the expert contact options available.

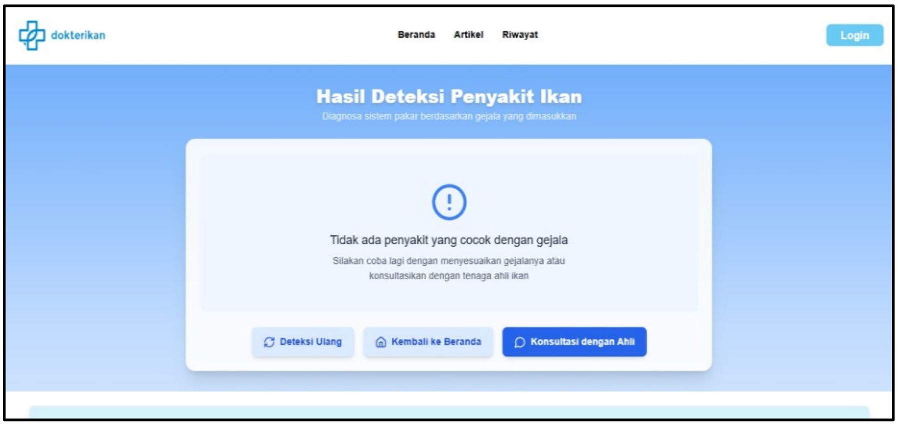


**Figure 9.** Failed Diagnosis Interface with Guidance for Next Steps

The evaluation was conducted to assess the diagnostic accuracy of the expert system in identifying fish diseases based on provided symptoms. Each test case consisted of a set of symptoms commonly associated with a specific disease. The system processed the input symptoms and automatically generated a diagnosis. The recorded process time includes the total duration from the moment the symptoms were submitted until the diagnostic result was displayed by the system, as presented in Table 3.

**Table 3.** Diagnosis Accuracy Based on Symptom Input and Processing Time

| Symptoms Provided | System Output | Expected Output | Process Time (s) |
|---|---|---|---|
| Body surface wounds, damaged scales, dark body color, damaged fish tail, excessive mucus production [23]. | Aeromonas | Aeromonas | 1.73 |
| Swollen and bulging eyes, fluffy scales, damaged gills, loss of appetite, abnormal swimming [24]. | Dropsy | Dropsy | 1.82 |
| Red spot fins, red sores, body rubbing behavior, decreased appetite, fin sores [25]. | Argulosis | Argulosis | 1.67 |
| Red sores, irritation, inflammation, and respiratory distress, and can trigger secondary infections due to tissue damage [26]. | Lerneasis | Lerneasis | 1.95 |
| Body surface wounds, damaged scales. | No Diagnosis | Insufficient symptoms | 1.27 |

For disease diagnosis, the rule-based expert system produced outputs consistent with expert expectations in most cases while maintaining response times under 2 seconds Table 3. This evaluation not only confirms the validity of the expert system's knowledge base but also supports the practical utility of the application in field conditions where rapid and accurate diagnosis is critical for preventing widespread fish mortality.

### 3.5. System Performance and Failure Cases

The high accuracy and low latency demonstrate that the proposed system is suitable for near real-time use in aquaculture environments. However, failed detections occurred in cases of blurred images, poor lighting, or incomplete symptom inputs. These limitations are consistent with findings from previous studies on AI-based aquaculture tools, where input quality strongly influences system reliability [28], [29]. Addressing these issues requires dataset expansion, improved preprocessing techniques (e.g., noise reduction, image enhancement), and training on more diverse environmental conditions.

### 3.6. Comparative Study with Related Fish Health Applications

Nevertheless, Fish Doctor provides a more comprehensive solution by integrating both fish species detection and disease diagnosis, along with expert consultation. While prior systems have focused either on image-based detection [28] or symptom-based diagnosis [29], this integration enhances flexibility for end users. However, unlike purely mobile-native applications, Fish Doctor's current reliance on stable internet connectivity can limit usability in remote aquaculture sites in Table 4. This trade-off highlights the need to further strengthen the offline-first architecture.

**Table 4.** Comparative Analysis with Related Works

| Systems | Platform | Input Method | Output |
|---|---|---|---|
| End User Interface Design of Mobile-Based Fish Disease Detection [27] | Mobile app | Image upload | Disease |
| Sistem Pakar Diagnosis Penyakit Ikan Mas Menggunakan Metode Certainty Factor [28] | Web-based | Symptom input | Disease + solution |
| Fish Doctor | Web-based PWA | Image upload + symptom input | Fish species + disease + solution |

### 3.7. Implications, Limitations, and Future Work

The findings of this study support the applicability of YOLOv11 for aquaculture tasks, as its single-stage detection framework enables rapid classification with sufficient accuracy, consistent with prior literature on real-time object detection in agriculture [28]. Likewise, the forward chaining method proved effective for structuring expert knowledge into diagnostic rules, validating its relevance in aquaculture decision support systems [29]. These results demonstrate the feasibility of combining AI-based detection and expert system reasoning to

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enhance fish health management, contributing to Sustainable Development Goals (SDG 2 and SDG 12) by improving food security and reducing reliance on antibiotics.

However, several limitations remain. The current evaluation was restricted to five fish species and a small set of representative diseases, and the system still depends on internet connectivity for some functions. Large-scale usability testing with farmers has not yet been conducted, and real-world conditions such as poor image quality or unstable networks may affect system performance. Future research will therefore expand the dataset, integrate adaptive learning from user feedback, and conduct detailed usability testing to assess scalability and generalizability.

## 4. Conclusion

The development of the *Fish Doctor* application demonstrates potential as an accessible tool for supporting fish farmers in managing fish health. By integrating fish species detection powered by YOLOv11, rule-based disease diagnosis through expert system inference, and real-time expert consultation features, the system addresses key challenges in aquaculture particularly in remote or low-resource environments. Evaluation results indicate diagnostic accuracy above 80% and fast response times, with average processing durations under 2 seconds, suggesting suitability for early intervention to prevent mass fish mortality and reduce economic loss.

Beyond technical functionality, the application supports sustainable aquaculture by encouraging responsible disease management and reducing dependence on chemical treatments. This aligns with the goals of SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production) by improving food security and promoting environmentally conscious practices. However, limitations remain, including restricted species coverage, reliance on internet connectivity for full functionality, and the need for broader validation with more fish farmers across diverse regions. Future research will focus on expanding the dataset, improving offline capabilities, incorporating adaptive learning through user feedback, and conducting large-scale usability testing with more than 100 fish farmers across multiple provinces to strengthen generalizability and practical impact.

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