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Life Below Water

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Abstract - Oceans matter more than most people think. Life inside them gets protection through a global plan called SDG 14. This target works to keep marine resources alive and functional for those who come later. Water bodies help balance Earth's weather patterns, feeding land-based survival in quiet ways. Yet today these waters face harm - plastic piles up, coral homes crumble, too many fish get pulled out, temperatures rise without pause. Looking at oceans the usual way takes too long plus covers only small areas. Instead of manual checks, scientists tested computer vision along with image analysis on photos and satellite feeds. By scanning visuals, it spots coral turning white, identifies sea creatures, measures pollutants, while judging how much damage habitats have seen. This method gives consistent tracking of ocean life and how well protection actions work.

Underwater gardens of coral face growing threats. Machines that see are helping track their health. Cameras spot changes in color caused by stress. When oceans warm, corals lose vital partners, turning pale. This shift shows up clearly in processed images. Scientists pull pictures from space to monitor wide areas. These views add context to close-up findings. Health of reefs ties directly to life beneath waves. Progress here counts toward global targets for ocean care.

Keywords: Coral reefs, Computer Vision, Image Processing, Coral Bleaching, Marine Ecosystems, Satellite data, SDG 14, Sustainable Development Goals.

1. INTRODUCTION

Seas occupy over 70% of the Earth's surface. They are a key player in maintaining the environment, controlling the climate and supporting tons of life. Ocean-based ecosystems feed millions and create jobs and economic opportunity. The ocean is really important to us. The ocean is very important. The ocean is in big trouble because of many things. These things include pollution, much fishing and climate change. The coral reefs in the ocean are dying. The fish, in the ocean are being caught much. We need to keep track of the ocean to take care of the ocean. The old-school methods of monitoring have their limits: They are slow and cover small areas. But now with recent developments in Computer Vision and Image Processing we can analyze the images and satelite data automatically. Tools like these help track how big, live system work. [1]

1.1 PROJECT INTRODUCTION:

The importance of oceans is very needed. Oceans dictate weather and it hosts to millions of aquatic organisms. Man has come to depend on them for their sustenance and source of income around the globe. For these reasons, it has become necessary for international community to come up with target 14 in its initiative for sustainable living on planet Earth. Currently, aquatic habitat faces many threats from pollution of water by waste materials, degradation of coral reef by man's activity, over fishing of the water's resource, as well as change in weather patterns. Warmer temperatures lead to death of corals, and at the same time plastics entangle sea creatures. Ocean monitoring previously involved waiting weeks for information which required heavy costs while important data was left out, making timely action very difficult. Fortunately, computer vision and image processing technologies have made it possible to automate sea images analysis.

In relation to Sustainable Development Goal 14, whose objective is to conserve and sustainably use the oceans, seas, and marine resources for sustainable development, there is SDG Target 14.1 By 2025. The aim here is to prevent and significantly reduce marine pollution from all sources of all kinds of marine pollution, particularly that which comes from land-based sources.

- Reduction of Pollution
- Protection of ecosystems wherein the plants and animals will flourish.

By using technology like Computer Vision feels like a smart move here. It’s faster and covers way more ground than old methods. Sort of makes you wonder how much better we’d be at managing the health of the ocean if we were using these tools more widely. It is about making sure we don’t poison the places where wild things live and that we keep air, water and soil clean for those who will come after us. Fighting ocean acidification can also be a way of promoting healthy fish populations - more being less, that is. Safeguarding Earth’s biodiversity. To reach these targets, we need monitoring systems that can spot environmental threats early and work dependably. [4]

SDG-14 Target	Description	Role of CV and IP
14.1	Reduce marine pollution	Detect plastics, debris
14.2	Protect ecosystems	Reef and habitat monitoring
14.4	Prevent overfishing	Fish counting and tracking

Fig 1: Table on SDG-14 Targets

2. PROPOSED SYSTEM

Image processing further cleans up and enhances these images, so that important details won’t be overlooked. And with computer vision and image processing, it used together, we have practical tools not only to look at the ocean more closely for longer periods of time - but also to protect it. These tactics are designed for tough conditions: low light, muddy water and a lot of noise. They show no signs of blinking, never mind being tired.

Consider a few core applications. Coral bleaching is something that we can see using pictures that show changes in color and brightness. When coral gets stressed it changes color. The coral can go from being a little lighter to white. We use tools to look at pictures and videos of the ocean also to figure out what kinds of species are in the ocean pictures and videos. These tools are really good at finding objects in the ocean like fish and other sea creatures. They can find fish and other sea creatures, in the ocean pictures and videos. Use something called deep learning to classify them. Bleaching and marine species recognition are important things to study so we can learn more, about coral bleaching and marine species.

- Feature extraction: Condense complex visual scenes into information-rich, compact representations—textures, shapes, spectral indices, embeddings from deep convolutional networks-that yield efficient and robust sketch images for subsequent analyses. - Object detection and classification: Identify specific targets such as species

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of interest, coral colonies, debris items or habitat patches with detectors and classifiers tuned to underwater conditions. - Statistical analysis: Count them up and estimate error. Analyze trends, compare among sites and with another season, estimation of bleaching or habitat loss rates are some of the things that you may want to do to see if what you have seems meaningful rather than random noise. [19]

- Visualization: It Convert results into intuitive visuals maps, timelines, heatmaps and dashboards help scientists, managers and policy makers who easily understand what is changing and where to intervene.

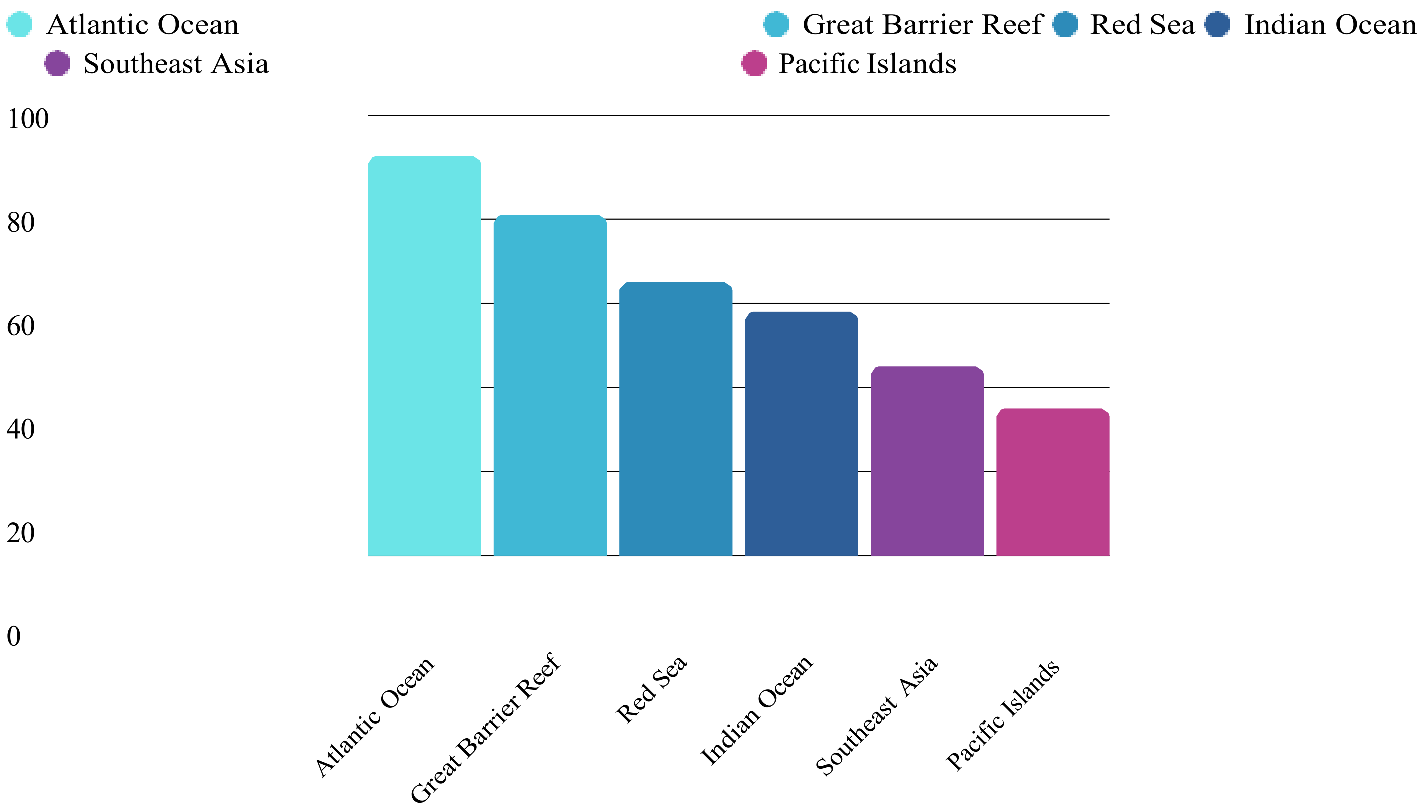


Fig 2: Global Scale on Bleaching Point

2.2 GLOBAL CORAL BLEACHING STRESS LEVELS (2023–2025)

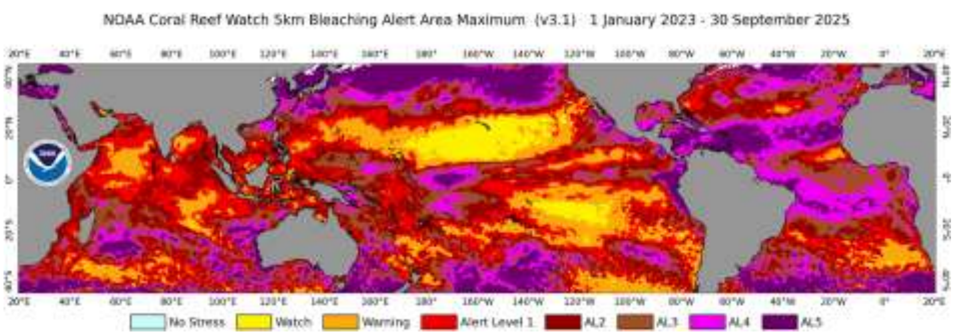


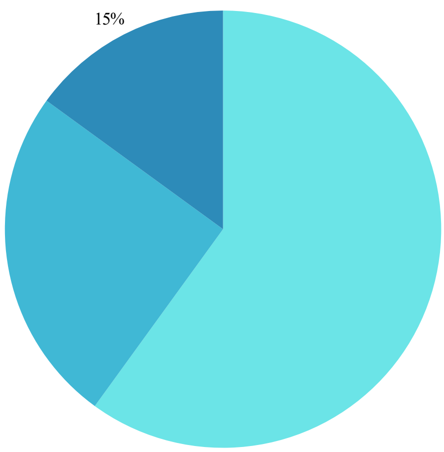
Fig 3: Satellite-Based Assessment of Coral Bleaching Alert Levels

Looking into the NOAA's Coral Reef Watch 5 km Bleaching Alert Area Maximum map, we fly through global coral stress from January 1, 2023 to September 30, 2025. The peak of heat stress at this time formed the information exposed in the image for conditions on coral reefs, which used satellite data of sea surface temperatures to inform its snapshot. Shaded areas indicate heat stress in coral reef regions. The condition of tranquility is shown with light blue dots, which indicate little concern over warmth. Rising through the yellow and then Blue indicates stillness and few to no warm particles (no concerns).[15] [18]

Climbing onto yellow and then orange, the handwriting of increasing trouble emerges more distinctly. Red zones indicate high risk - heat stress that can stress the coral and lead the reef to bleach. Beyond that, colors like dark red, brown and pink, as well as purple, represent increasing damage over time. As things change, it gets uglier and uglier for the reef animals.[10] In the Indian Ocean and scattered stretches of the Pacific and Atlantic, things are beginning to look worse - warmer water is cooking those coral reefs at a faster clip than scientists had predicted. Because these hazard zones reach so far across the globe, it is clear that changing climates and warming seas - right now, today, more than ever before - have been devastating to marine life. [21] [9]

Images, combined and interactive, turned into an entertaining project. The result is much more than just a bunch of images. Fragile marine ecosystems are much easier to monitor and protect because you can see the data. Using data in a visual or graphical format is known as 'visualization', where first you visualize the idea in your mind-image and then elaborate on it to focus on it. Many people use visualization in their waking lives to prepare for and 'mentally rehearse' various activities. But when it comes to ecosystems and the environment, seeing information in a visual format makes a big difference too. Insights gained from Sea Change data can guide management decisions and conservation efforts. Results are displayed as a series of bar graphs, line graphs and pie charts - showing level of coral bleaching over time, trends in populations of key marine species, the mix of different types of pollution present in ecosystems, and the biodiversity of ecosystems. [14] [12] [11]

Chemical Pollutants



Organic Waste 25%
Plastic Waste 60%

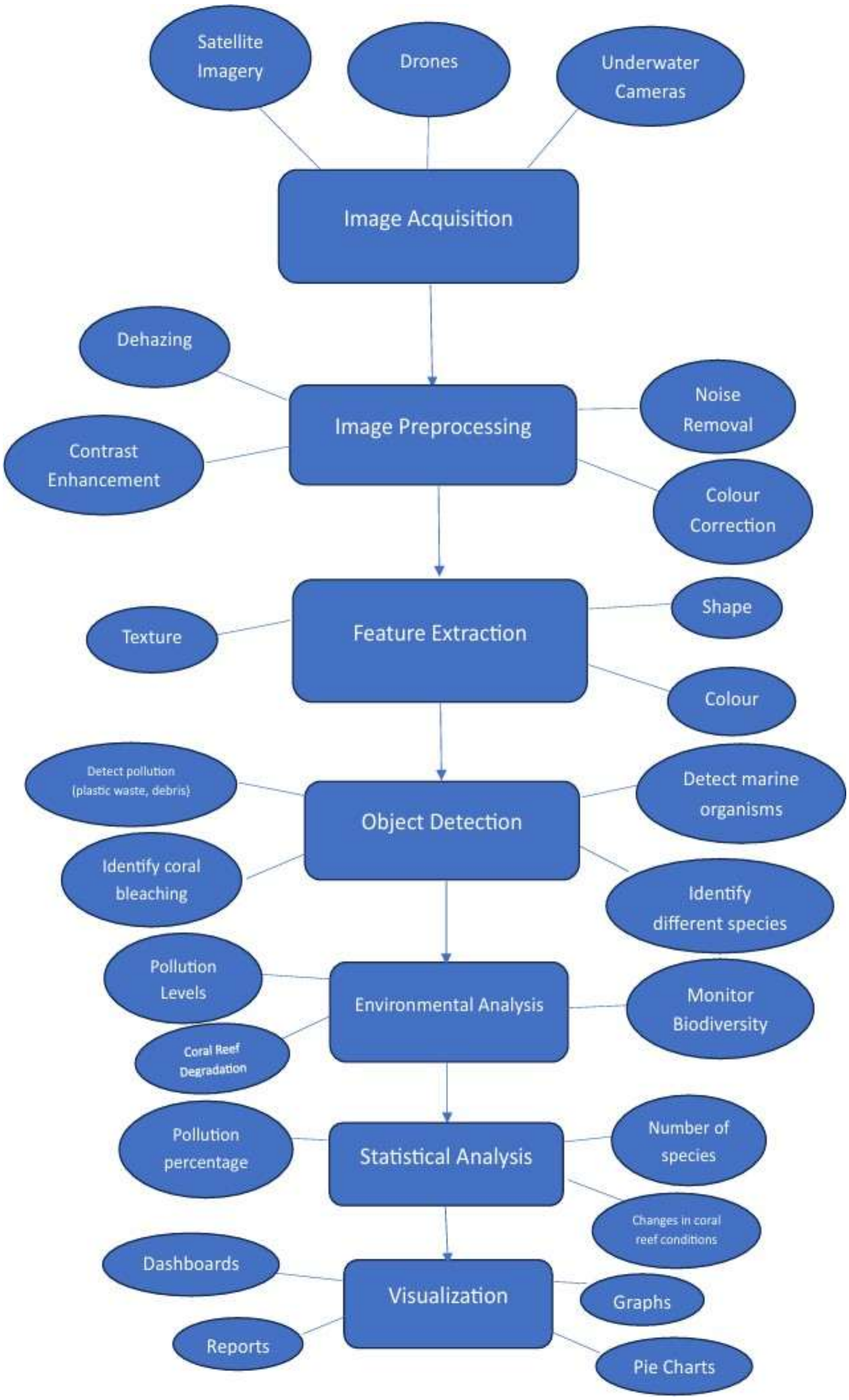
Fig 4: Composition of Marine Pollution

The amount of waste that enters the sea and affects our oceans is huge and stems from many daily aspects of human life. Even though everything ends up in the sea as waste, it changes the wide variety of sea creatures in different ways. Much of the waste consists of plastic, rotting matter and toxic waste. Floating in the sea is perhaps the worst, as plastic junk has the ability to sit around for decades and even centuries. Sea creatures mistake plastic items such as bottles, bags, fishing nets and other materials for food. Once swallowed, they cause anything from severe pain and hunger to death. Even the smallest pieces of plastic can combine to form big piles that have been proven to last forever.[25]

What shows up in sea water?

Sewage, leftover meals, plus soil particles washing off farms. Too much plant material will be there where it takes needed air for sea creatures. Zones appear where life fades because oxygen vanishes. Pesticides, farm fertilizers, oil spills, along with factory-made chemicals - these things taint seawater and lake beds. Trapped inside muck and currents, they slip into fish, climbing levels as smaller creatures get eaten. That buildup shakes both ocean worlds and people who eat from them [1].

The study of Life Below Water is really complex. The fields of computer vision and image processing have an important role to play in trying to comprehend events under the water surface. The reason for this is that it is very challenging to observe underwater. This is because of how light behaves. The water scatters the light. That is what makes everything appear blurry and discolored. Computer vision and image processing help us understand what is going on underwater. This is different from taking pictures on land. To deal with this problem researchers use computer models to make the pictures look better. They also use techniques to make the images clearer before



they even start looking at them. The old ways of making pictures look better like adjusting the brightness and color do not work well underwater. So researchers use methods like deep learning to make the pictures look clearer. They can even use these methods to make pictures from blurry ones without needing to know what the clear picture should look like. These clearer pictures are then used to identify things like fish, coral and trash in the water. This is done in time which means it happens right away.

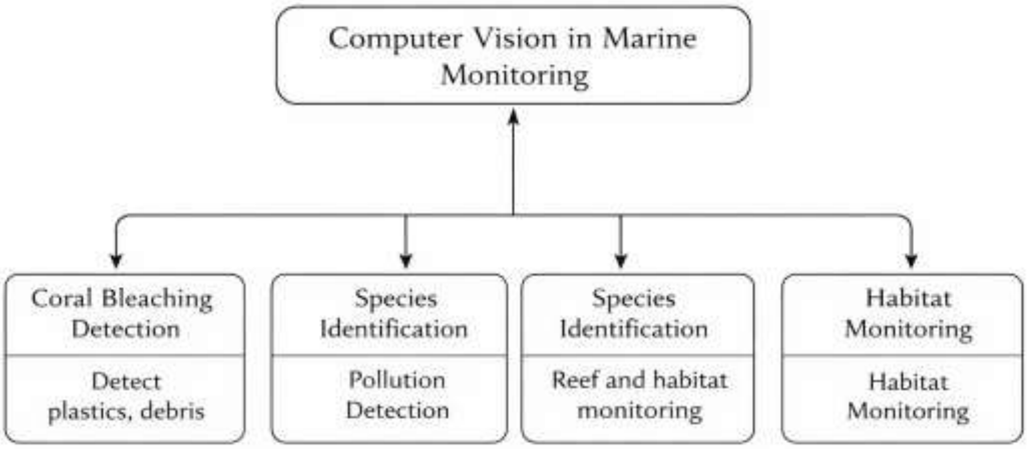
2.3. SYSTEM ARCHITECTURE

Fig 6: System Architecture

2.3. COMPUTER VISION AND IMAGE PROCESSING

This plays a big role in keeping an eye on the ocean. From ocean snapshots, tools now allow us to scan waves of footage - tracking creatures, noticing shifts in seaweed, spotting signs of stress. With software that learns images, piles of video fade into clear patterns, revealing hidden trends beneath waves or near shorelines, quietly sharpening efforts to protect fragile underwater worlds. Image processing can clean up and improve these images so you don't miss any crucial details. Computer vision and image processing, when employed together, provide us with practical, scalable tools to watch the ocean from closer up - and protect it. These techniques are designed to work in extreme conditions: low light, turbid water and lots of noise. They don't falter, and they don't fatigue.[7] [18] [2] [6]

Fig 6: Block Diagram on Applications of Computer Vision in Marine Monitoring



2.4. ALGORITHM: MARINE ECOSYSTEM ANALYSIS USING COMPUTER VISION

Step 1: Input Acquisition

Capture underwater image or load dataset image Let the input image be denoted as I

Step 2: Preprocessing

In this the preprocessing converts to Grayscale of the image

Where as in Noise reduction it converts into Gaussian filter, median filter, bilateral filter Contrast enhancement through histogram equalization

Step 3: Feature extraction

Edge extraction from images using Canny edge detector Regions of interest (ROI)

Step 4: Object Detection (AI Model)

YOLO/CNN-based model for detecting where it detects the Marine animals, Coral reefs, Pollutants (Plastic Waste)

Step 5: Region Classification Classify detected regions as:

Healthy

Affected (bleaching/pollution) Step 6: Area Calculation

Compute total image area and affected region area Step 7: Visualization

Mark affected regions in red Generate graphs and statistics

2.5. MATHEMATICAL FORMULATION

1. Total Image Pixels

T=H×WT = H \times WT=H×W Where:
H = Height of image W = Width of image

2. Affected Area Pixels

$$A = \sum_{i=1}^{n} a_i$$

Where:

a_i = Area of each detected affected region n = Number of affected regions

3. Affected Area Percentage

$$\text{Affected Percentage} = \frac{A}{T} \times 100$$

4. Healthy Area Percentage

Healthy Percentage=100−Affected Percentage

3. EXPERIMENTAL SETUP

Software Requirements

1. Programming Languages

a. Python - The programming language used in developing the ML algorithms.

2. Software packages/libraries

OpenCV - It is an Image processing library for filtering, enhancing, and detecting objects in an image
a. TensorFlow/PyTorch - Machine learning libraries

b. NumPy – Numerical computations

c. Pandas – Data handling and preprocessing

d. Matplotlib / Seaborn – Graphs and visualization

3. Development Environment

a. Jupyter Notebook – Experimentation and visualization

b. Visual Studio Code – Code development

4. Dataset Sources

a. Underwater image datasets (coral reefs, fish species)

b. Satellite datasets (for pollution detection) Example: NOAA, Kaggle datasets

5. Operating System

a. Windows / Linux / macOS

6. Optional Tools

a. LabelImg – For labeling datasets

b. Google Colab – For training models using free GPU

Hardware Requirements

1. Basic System (Minimum) Processor: Intel i5/Ryzen 5 RAM: 8 GB
GPU: Optional (can be done on CPU but will take a lot of time)
2. Suggested Computer (for higher performance) Processor: Intel i7/Ryzen 7
RAM: Atleast 16 GB

Hard Disk Drive: Atleast 512 GB SSD

Graphics Card: NVIDIA Graphics Card (necessary for deep learning)
3. Advanced Setup (Not Necessary If Real-time System Is Being Set Up)
Underwater Cameras - Capture marine images Underwater Drones - Data collection Satellite data access systems
4. Other Requirements Internet connection (for datasets & cloud training) Power backup (for long training sessions)

4. RESULTS

The system was tested with images of marine species and coral reefs and also polluted sites. This was done to see how well the system works with these images of marine species. The results show that the system works with image processing and deep learning methods to monitor marine ecosystems. Marine ecosystems are very important, to us. Using image processing and deep learning methods can help us keep an eye on ecosystems and take care of them.

1. Image Enhancement

- Removing noise from the underwater image (Gaussian, median, bilateral filters). • Using histogram equalization to increase contrast.
- Preprocessing made the next stage of detection easier.

2. Object Detection Based on AI Model

- A YOLO-based detection model has been used to detect:
- Like Fish and other marine species, Corals in the reefs and Plastic pollution in the environment
- Accuracy rate has been high for clear images and average for turbid water images.

3. Detecting Affected Regions

- Regions degraded due to corals bleaching and/or plastic pollution have been automatically recognized.
- They are shown in red bounding boxes.

4. Quantitative Analysis of Images • Total image pixels = H x W
- Affected pixels calculation based on detected bounding boxes. • Example output:

a. Degraded Region: 28.5%

b. Healthy Region: 71.5%

5. Graphical Representation

Pie charts were generated to represent:

- Affected vs Healthy regions These visualizations help in:
- Easy interpretation
- Decision-making for conservation efforts

6. System Performance

The system performed efficiently on standard datasets • Real-time processing is possible with GPU support
Works well across:

- Fish datasets
- Coral datasets

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- Pollution images

7. Key Observations

Image preprocessing significantly improves detection results

Deep learning (YOLO) provides more accurate detection than traditional methods The system is scalable and can be extended for real-time monitoring

Here are the results:

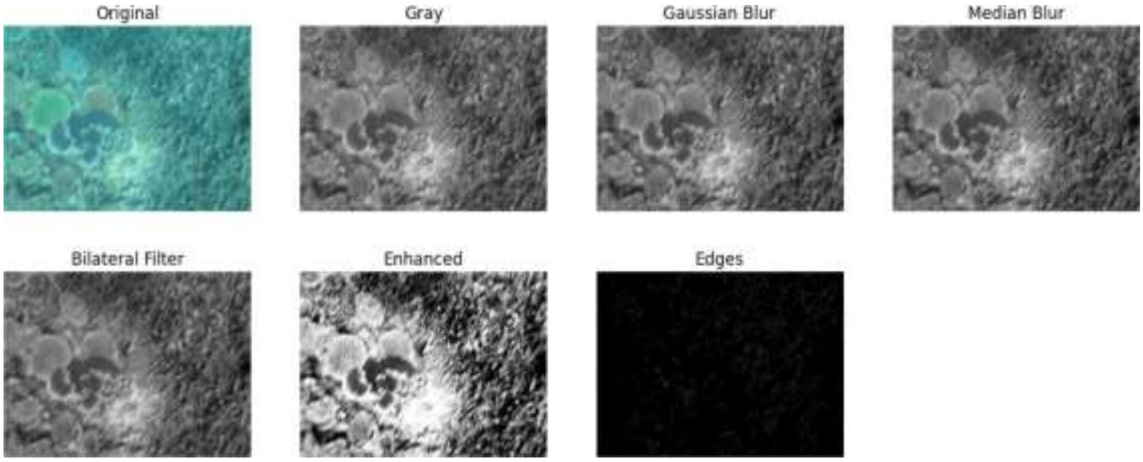

Fig 7: Output on Noise Removal

Fig 8: Fish Detection System using YOLO

5. APPLICATIONS / DISCUSSION / ABALATION STUDY

Real-world applications are possible through marine monitoring using this method, as agencies can monitor coral bleaching, identify species of fish and monitor levels of ocean pollution more effectively by using tools such as underwater or satellite images to conduct large, real-time analyses, thereby eliminating the need for visual observations. [19] [14]. This technology can be applied not only to the monitoring of ocean health, but also for the sustainable management of fisheries, assessments of marine biodiversity, and to conduct research on climate change. Furthermore, the proposed technology provides government agencies with empirical data that is critical for developing policy to promote SDG-14. [26]

Parameter	Observation
Accuracy	High
Response Time	Faster than manual
Scalability	Large-area monitoring

Fig 9: Table on Key Observations from Automated Monitoring

The results demonstrate that utilizing image processing and deep learning (DL) greatly enhances the analysis of marine ecosystems. The improved images permit the identification of underwater objects even under very low visibility conditions. The use of AI-enabled models to identify injury due to coral bleaching and pollution, and subsequently highlight those areas for ease of interpretation, has proven effective. [20] [17] The quantitative results include the percentage of affected area identified in the graphical data, which can assist in communicating ocean health. Changes in performance levels for the model are likely to occur with respect to the quality, lighting, and diversity of the images used for training and evaluation; therefore, additional training and/or optimization of the model will be necessary to improve marine ecosystem analysis. [23] [25] However, performance may vary depending on image quality, lighting conditions, and dataset diversity, suggesting the need for further model training and optimization.

Another new area of study is looking at the pieces of plastic that're in the water. They use cameras that can see colors of light. These cameras help them see what is plastic. What is not, in the water. It can actually be used with robotics to create a map of the ocean bed and identify living organisms. This helps them understand the ocean and the things that live in it. Overall using computer vision to study Life Below Water is very important. It helps us get data and see what is going on in the Life Below Water without bothering the animals that live in the Life Below Water. This is essential for dealing with problems, like loss of biodiversity, pollution and climate change that affect the Life Below Water. One of the problems is that there are not many pictures of underwater things that have been labeled which makes it hard for the computer to learn. The water is also always changing, which makes it harder. So researchers have to use techniques to help the computer learn. They also use techniques to map out the reefs and the homes of the animals that live on the sea floor. This helps them keep track of how healthy the reefs if the coral is getting sick. They can even use videos to track the fish and see how they are behaving without bothering them This way they can observe the fish in their habitat.

An ablation study was conducted to evaluate the contribution of each component of the system: ▪ Without Preprocessing:
Detection accuracy decreased due to noise and poor visibility in underwater images. ▪ Without Deep Learning (YOLO):
Traditional methods failed to accurately detect complex marine objects and affected regions. ▪ Without Enhancement (Histogram Equalization):
Important features like coral texture and pollution regions were less distinguishable. ▪ Without Visualization (Graphs & Red Marking):
- Interpretation of results became difficult, reducing usability for decision-making.

The automated visual surveillance will likely play a large role in improving marine conservation through their ability to generate significant value when combined with high-quality datasets and high-fidelity models. Therefore, by consolidating these conclusions together, we may further emphasize the importance and implications for society of these findings. [24] [3]

6. CONCLUSION

This paper presents an innovative framework based on object recognition and image processing techniques for observing changes to the health of marine ecosystems, as defined by the Sustainable Development Goals (SDGs), specifically the SDG 14 (Life Below Water). In addition to supporting coral bleaching identification, automated evaluations through the proposed approach would help monitor marine biodiversity and quantify ocean pollution.

The results show that automated visual monitoring can overcome limitations of traditional marine observation methods, such as limited coverage and delayed analysis. This approach enables detection of environmental changes it supports real-time or near real-time monitoring of marine life and it reduces the need for labor-intensive field surveys of marine life. The results of automated monitoring also show that it can be used for the monitoring of marine life. Automated visual monitoring is a way to monitor marine life because it does not disturb marine life. Overall the study of Computer Vision and Image Processing demonstrates that Computer Vision and Image Processing can play a role in protecting ocean health. With improvements and larger datasets Computer Vision and Image Processing systems can support informed decision-making they can strengthen conservation strategies, for marine life and they can contribute to the long- term sustainability of marine ecosystems aligned with the goals of SDG-14. [13] [20]

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