DELIVERABLE D1.2-D: REQUIREMENTS BASELINE

MAPPING AQUACULTURE STRUCTURES AND USE OF MARINE RESOURCES IN PALAWAN, PHILIPPINES

BY

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Preface (common to the four Use cases)

The **Earth Observations for Sustainable Aquaculture (EO4SA)** project is funded by the European Space Agency (ESA) as part of its EO for Sustainable Blue Economy project under the ESA PEOPLE program. The project is implemented by the Nansen Environmental and Remote Sensing Center (project contractor and manager) in Bergen, Norway and Plymouth Marine Laboratory, UK.

The main objective of EO4SA is to consolidate the requirements and demonstrate the information opportunities needed by the aquaculture industry and public agencies using EO and other data sources. For selected Early Adopters (EA), the project implements four Use Cases, at several locations in Norway, Spain and the Philippines, related to:

1. Predicting risks of salmon lice infestation in Norway.
2. Forecasting toxic algal blooms (HABs) impacting shellfish farming in Norway.
3. Optimising the location of sustainable shellfish farming and tourism in Galicia, Spain.
4. Mapping aquaculture structures and use of marine resources in Palawan, Philippines.

Through these four use cases, EO4SA will contribute to enhancing the future operations of aquaculture management authorities, stakeholders and industry, by taking up new information based on satellite Earth observations data.

This report is the project deliverable **D1.2: Requirement Baseline. It** includes a detailed analysis of relevant policy aspects to each use case. Further, a characterization of the target user groups and their information needs are assessed with focus on how EO data can be beneficial. Direct meetings and a questionnaire survey are used to obtain the needed information from the Early Adopters. A further analysis identifies the technical requirements for the innovative EO-based solution to be developed and validated in each of the Use Cases.

This Deliverable is organised in four report documents addressing each of the Use Cases separately, denoted D.1.2.A-D. The first report also includes a common introduction to all Use Cases (Sections 1-2). From Section 3, the reports are specific to each Use Case, first describing each Use Case as proposed (3). Section 4 addresses the State-of-the-art activities and Section 5 the relevant regulatory (policy) and operational framework for each Use case. Based on direct meetings and a questionnaire survey (attached in Appendix 1), Section 6 summarises the Early adopters (further described in D1.1) and their specific requirements related to each of the use cases. In Section 7, the project Team presents the baseline and innovative algorithms to be used, and in Section 8, the available datasets to be used. The potential limitations of the approaches proposed are given in Section 9 and concluding statements in Section 10 for each Use Case.

In separate Deliverable D1.2-documents (A-D), the four EO4SA Use Cases are addressed in:

- Deliverable D1.2-A: Baseline Requirements – Introduction and Use Case 1: Predicting risks of salmon lice infestation in Norway.
- Deliverable D1.2-B: Baseline Requirements – Use Case 2: Forecasting toxic algal blooms (HABs) impacting shellfish farming in Norway.

- Deliverable D1.2-C: Baseline Requirements – Use Case 3: Optimising the location of sustainable shellfish farming and tourism in Galicia, Spain.
- Deliverable D1.2-D: Baseline Requirements – Use Case 4: Mapping aquaculture structures and use of marine resources in Palawan, Philippines

2 The EO4SA Use Cases (common to the four Use cases)

On this background, the EO4SA project will implement four use cases that will contribute to enhancing the future operations of aquaculture management authorities, stakeholders and industry, by taking up new information based on satellite Earth observations data. In brief these are entitled:

- Predicting risks of salmon lice infestation in Norway.
- Forecasting toxic algal blooms (HABs) impacting shellfish farming in Norway.
- Optimising the location of sustainable shellfish farming and tourism in Galicia, Spain.
- Mapping aquaculture structures and use of marine resources in Palawan, Philippines.

For each of these use cases, the EO4SA team has established contacts with Early adopters (EA). These EAs will contribute with their input to the development and assessment of each of the proposed Use cases (Table 1). The EAs will contribute to ensure relevance for further use and possible up-scaling of each Use case.

*Table 1. The description of the Use Cases and their pilot geographical locations and early adopters. (the Use Case addressed in this report is in **bold**).*

Use Case	***Pilot site locations***	***Early adopters (sector)***
i. Predicting risks of salmon lice infestation in Norway	Norwegian coastal and offshore waters	• Norwegian Directorate of Fisheries (governmental agency) • Lerøy Aurora AS (private company) • Grieg Seafood ASA (private company) • Sparebank 1 Sør Norge ASA (financial institution)
ii. Forecasting toxic algal blooms (HABs) impacting shellfish farming in Norway	Helgeland Fosen Namsen fjord Lyngen fjord	• Norgeskjell AS (private company) • Lyngsskjellan ENK (private company) • Norwegian Directorate of Fisheries (governmental agency) • Norwegian Institute of Marine Research (research institute) • Sparebank 1 Sør Norge ASA (financial institution)
iii. Optimising multi-use of marine areas for shellfish farming and tourism in Galicia, Spain.	Galician rias of NW Spain	• FEMEX (Federación de Mejilloneros) and Angulas Aguinaga (Cambados: depuración y transformación de mejillón) (industry) • INTECMAR: Technological Institute for the Monitoring of the Marine Environment in Galicia (monitoring) • CETMAR, Centro Tecnologico del Mar, Galicia, Spain (science) • CSIC-IIM: Institute of Marine Research (science)

		• National Park "Illas atlánticas de Galicia" (national park)
iv. Mapping aquaculture structures and use of marine resources in Palawan, Philippines.	**Puerto Princesa Bay, Palawan, Philippines**	• **Bureau of Fisheries and Aquatic Resources (BFAR)-Province and MIMAROPA Region: responsible for the development, improvement, management, and conservation of the Philippines' fishery and aquatic resources** • **Palawan Aqua-Agri Venture Agriculture Cooperative: 22 registered fish cage operators**

In preparing this Requirements document (D1.2.A-D), the Early Adopters have been approached directly through individual consultation meetings, phone calls, participation in thematic fora, and written documentation presenting the objectives and the initial plans for each EO4SA Use Case. These direct contacts were used to get the EA´s feedback on each Use Case. Further, a Google questionnaire online was distributed to be filled out by each Early adopter (the questionnaire is in Appendix 1). The questionnaire was adapted for all four Use case studies.

In the following, this report addresses the baseline requirements to meet the information needs as put forward by the Early adopters for all four Use Cases and focusing on the FOURTH use case: ***Deliverable D1.2-D Baseline Requirements – Mapping aquaculture structures and use of marine resources in Palawan, Philippines.***

3 Use Case 4: Mapping aquaculture structures and use of marine resources in Palawan, Philippines

Monitoring of aquaculture infrastructure is an important component for efficient management and control of marine resources as well as the reduction of environmental impacts (Meaden et al., 2013). This includes mapping the locations of aquaculture sites and the spatial distribution of fish cages, floating houses, and longline buoys, among others depending on the aquaculture type. While these assessments are commonly documented in regions like Europe, other regions — such as East Asia — face challenges in monitoring aquaculture infrastructure. Consequently, the information on aquaculture development and its environment is limited, and sustainability in these areas could be potentially at risk.

In Palawan, Philippines, coastal aquaculture is gaining momentum towards increasing fish production, a pressure that presents a challenge to the sustainability of these areas. Puerto Princesa City, Palawan, is known as the "Eco-Tourism Center of the Philippines" with many beach resorts and seafood restaurants. It has been recognised as the cleanest and greenest city in the Philippines and supporting sustainable use of ocean resources is one of the key priorities for the local government. There are three major bays in this area. Honday Bay is known as a tourist site in Palawan, particularly for island hopping activities. It is also known as one of the main fishing grounds in Puerto Princessa City. Puerto Princesa Bay is an aquaculture site where oysters, green mussels, seaweed, and fish cage culture are established. Uluga Bay is also a fishing area, and the majority of the locals rely on the bay for their livelihood. Sustainable development of blue economy in Puerto Princessa City is a challenging task due to variability of activities. It requires from the local government implementing accurate planning and efficient regulation of marine resources usage. All three Bays are included in EO4SA Use Case Study 4 and are shown in the map in Figures 1 and 2.

Detailed information about these aquaculture sites and local activities is presented in Appendix 1.

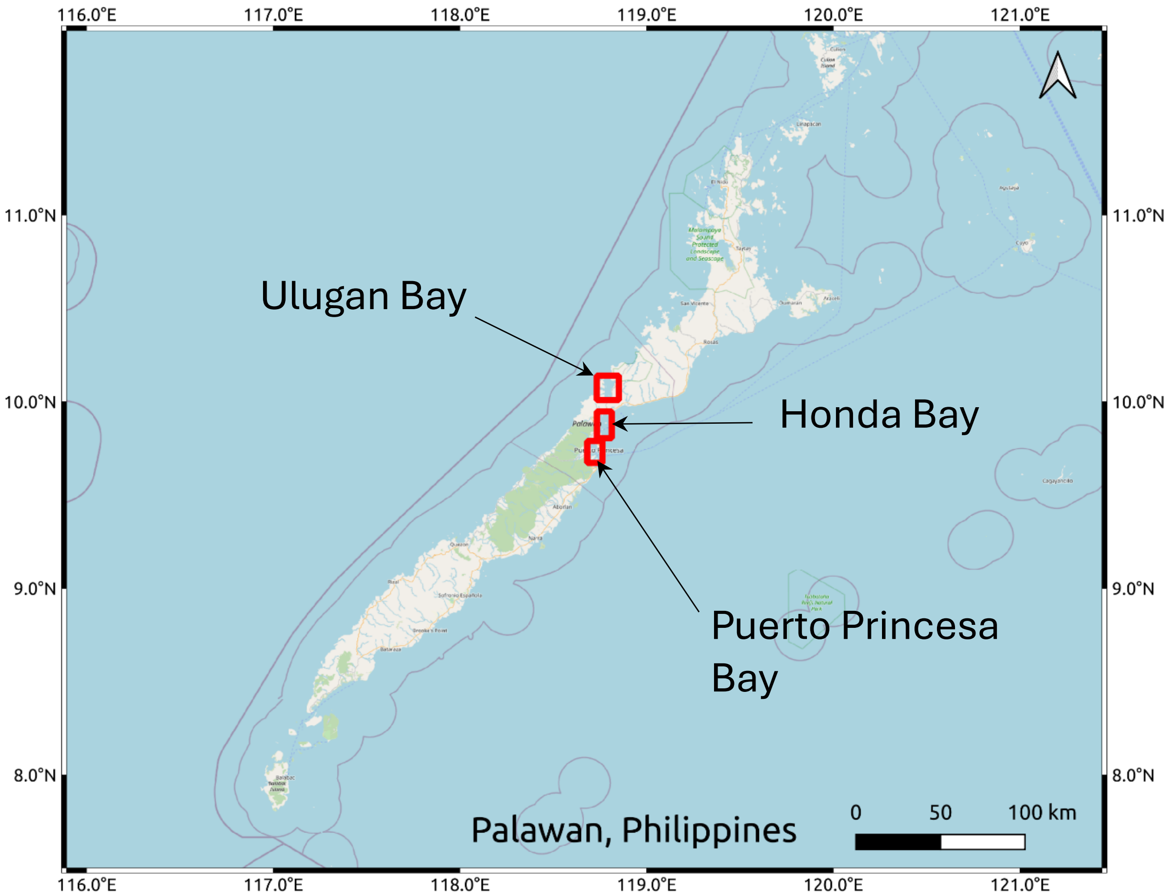

Figure 1. A map of Palawan, Philippines, showing the Use Case 4 study areas outlined in red.

Figure 2. A closer look at the Use Case areas: Ulugan Bay, Honda Bay and Puerto Princesa Bay.

4 State-of-the-art activities for the Use case

The projects and initiatives of local government in Puerto Princesa City region have been focused on achieving several objectives: the development of sustainable aquaculture, protection of marine resources, support of local fishermen and coastal communities.

The Bantay Puerto Program (Puerto Princesa Watch), was developed for Puerto Princesa to confront the challenges of increasing pressure on land and marine environment caused by quickly increasing population (Bantay Puerto Princesa Program, 2025). One of the main components of this program is Bantay Dagat or Baywatch. Its primary role is the protection and conservation of the city's marine ecology and protection against illegal fishing and related activities in its four strategic bays: Puerto Princesa Bay, Honda Bay, Turtle Bay, and Ulugan Bay.

In 2012 the fishery division of the province government developed a program for the enhancement of aquaculture sector, including the seaweed production, to promote generation of more income for local fisherman (Palawan Fishery, 2012). Training of fish farmers from the selected areas has been conducted to improve their knowledge and skills in aquaculture and project development. To complement the extension of aquaculture sector, new marine protected areas (MPA) were established and the support of existing MPAs was continued.

The local government in Palawan implemented several programs through the Bureau of Fisheries and Aquatic Resources (BFAR) to support sustainable aquaculture development. A total of 34 fisheries associations in Palawan received support from the government in 2024 from the National Mariculture Program worth PHP 2.760 million. This includes the Palawan Aqua-Agri Venture Agriculture Cooperative, Puerto Princesa City (Ace, 2024). The cooperative received new units of High-Density Polyethylene (HDPE) fish cages, two of which are circular fish cages and the other two are modular fish cages. The HDPE cages provided better durability, longer lifespan and reduced environmental impact. The cages were 10 m in diameter and featured a double collar stanchion design.

In 2024 the Department DA-BFAR proposed the National Aquaculture Development and Management Plan (ADMP) that outlines the framework for the development of aquaculture sector in the Philippines, facing several challenges: environmental impact, resource management and climate resilience (The Philippines, 2024). With the ADMP in place, it is expected that in the next 5 years the aquaculture sector will continue to grow. Implementation of this plan will require more accurate spatial planning and efficient management of aquatic resources.

5 Current relevant regulatory (policy) and operational framework

The national policies on fisheries and aquaculture development in the Philippines are implemented in various laws, including the Fisheries Code of 1998, the Agriculture and Fisheries Modernization Act of 1997 and the Local Government Code of 1991.

A summary of fisheries administrative orders is presented in Appendix 2.

Government Regulations and Policies: The Philippine government, through the Department of Agriculture's Bureau of Fisheries and Aquatic Resources (BFAR), has put in place regulations aimed at managing and developing the aquaculture sector. In Palawan, these policies are crucial given the province's ecological sensitivity, with its coral reefs, mangroves, and marine protected areas (MPAs).

The National Aquaculture Development Program (NADP): This program provided a framework for the sustainable development of aquaculture in the country, promoting environmentally-friendly practices and ensuring that aquaculture activities do not jeopardize the health of marine ecosystems. BFAR has also outlined guidelines for the establishment of aquaculture farms to prevent overexploitation of marine resources.

Marine Protected Areas (MPAs): Palawan has numerous MPAs to preserve its diverse marine life. Aquaculture operations in these areas are strictly regulated to avoid harmful practices such as overfishing, habitat destruction, or water pollution. The local government in Puerto Princesa City cooperates with BFAR to ensure compliance with environmental laws and support sustainable aquaculture practices.

Local Ordinances: Palawan's local government units (LGUs) have implemented their own policies regarding aquaculture, focusing on managing coastal resources. For example, some LGUs have instituted zoning laws that designate specific areas for aquaculture development, ensuring that these activities do not conflict with tourism, conservation efforts, or other industries.

Aquaculture Licensing and Monitoring: In Palawan, all aquaculture operators must obtain permits from BFAR or the respective LGUs. These permits require operators to comply with environmental impact assessments, biosecurity measures, and adherence to water quality standards. Regular monitoring is conducted to prevent illegal fishing, the spread of diseases, and other threats to aquatic ecosystems.

Sustainable Aquaculture Practices: As part of aquaculture policy, Palawan is increasingly focused on sustainability. The province has been integrating environmentally-friendly practices such as the promotion of integrated multi-trophic aquaculture (IMTA), which involves the cultivation of multiple species (e.g., fish, shellfish, and seaweed) together to minimize waste and enhance ecosystem health. Additionally, it is encouraged to develop eco-friendly fish farming techniques, using organic feeds and improved waste management.

Local aquaculture initiatives also aim to increase the production of high-value species, like mangrove-friendly shrimp farming, which can coexist with the protection of coastal ecosystems. In the MIMAROPA Region, which includes Palawan, BFAR plays a pivotal role in implementing national policies and supporting local aquaculture initiatives. BFAR is tasked with the development, improvement, management, and conservation of the country's fisheries and aquatic resources. Key regulatory instruments and programs of BFAR related to aquaculture activities include:

- Fisheries Administrative Order No. 197-1 (2010): This order governs the lease of public lands for fishpond and mangrove-friendly aquaculture. It outlines the procedures for application, requirements for Fishpond Lease Agreements (FLAs), and stipulates the conditions for commercial-scale production.
- National Mariculture Program (NMP): BFAR's NMP aims to promote sustainable mariculture practices. In Palawan, this program has provided support to fisherfolk associations through the distribution of high-density polyethylene (HDPE) fish cages, facilitating the development of aquaculture ventures.
- Strategic Agriculture and Fisheries Development Zones (SAFDZs): BFAR collaborates with other agencies to identify and establish SAFDZs, which are areas designated for the development of agriculture and fisheries. These zones aim to enhance productivity and ensure sustainable resource use.

Overall, aquaculture policy is focusing on stronger enforcement of regulations, enhancing community awareness and participation in sustainable practices, and ensuring that the sector remains aligned with broader environmental conservation goals.

6 Early adopters and their specific requirements

Palawan has 23 municipalities that are all coastal, thus, fishing is primarily the source of livelihood for the locals. The continued exploitation of the aquatic resources of Palawan is a major threat to biodiversity, especially since the people rely on marine resources for food and livelihood. As capture fisheries face challenging environmental changes, aquaculture offers resource-efficient food production strategies that are easy to adopt and create economic opportunities. The alternative source of fisheries production is fishcage culture of milkfish, groupers, and other marine species.

Aquaculture is a potential industry in Palawan, but several challenges persist in Palawan's aquaculture sector. Issues such as illegal fishing, destructive farming practices, and climate change-related disruptions to marine life pose risks to the long-term viability of aquaculture in the region. Moreover, balancing the needs of the aquaculture industry with the preservation of Palawan's natural environment and its growing tourism sector is a challenging task.

The early adopters identified for this case study (EO4SA) are the Bureau of Fisheries and Aquatic Resources (BFAR) -Province and MIMAROPA Region, Philippines; and Palawan Aqua-Agri Venture Agriculture Cooperative (PAAVACO), Puerto Princesa City. Both agencies provided the project team with a letter of intent signifying their interest to participate as the early adopters of the project. Initially, a face-to-face meeting was done with the Regional director of BFAR-MIMAROPA to enlighten him on the goal of the project. A separate meeting was also held with the Board of Directors (BOD) of PAAVACO for the same purpose. The Chairman and members of BOD were present during the meeting. An online survey was conducted to obtain information about the adopters' requirements for Palawan aquaculture structures mapping.

A summary of the survey questionnaire is presented in Table 2 and Figures 8-12 in Appendix 3.

Table 2: Requirements of early adopters evaluated through the EO4SA questionnaire survey. The responses are colour coded - Blue for not relevant, red for useful, and orange for essential.

		BFAR, Province and MIMAROPA Region	**PAAVACO, Puerto Princesa City**
What environmental and other variables do you monitor or monitor through other sources? Blue for not relevant, red for useful, and orange for essential.	Physical (e.g., temperature)		
	Chemical (e.g., DOC)		
	Biological (e.g., Chl-a)		
	Salmon lice		
	Medication or treatments		

What satellite-based products or parameters would be relevant for you? Blue for not relevant, red for useful, and orange for essential.	Physical (e.g., temperature)		
	Chemical (e.g., DOC)		
	Biological (e.g., Chl-a)		

Why do you measure the environmental variables selected in the previous question? Blue for not relevant, red for useful, and orange for essential.	To select new areas to put my cage/aquaculture site		
	To fulfil obligations with environmental policies		
	To fulfil obligations with food/health Standards policies		

What satellite products would you be interested in? Blue for not relevant, red for useful, and orange for essential.	SST		
	SSS		
	DOC		
	POC		
	pH		
	Turbidity		
	Chl-a		
	HAB species		
	Algae toxins		
	Salmon lice density		
	Location of cages		

Initial specification of aquaculture cage detection product. Blue for minimum, red for preferred, and orange for ideal.	Spatial resolution 5x20m		
	Temporal frequency 12 days		
	Spatial extent: Palawan coastal area		
	Temporal coverage: 2024-2026		

How would your preference to receive information from EO4SA? Blue for not answered, red for preferred, and orange for ideal.	Web portal		
	Access data offline		

A total of 27 respondents from BFAR and PAAVACO took part in the survey. Generally, results indicated that fish cage operators are keenly aware of how closely linked their productivity is to the health of the surrounding marine environment. As several literatures suggests, maintaining good water conditions is critical not only for fish welfare but also for the sustainability of the farming activity over time. In Palawan, where marine ecosystems are increasingly pressured by both natural and human-induced changes, ongoing environmental monitoring becomes especially important.

The respondents showed concern for a wide range of water quality factors, grouped into physical, chemical, and biological categories. Physical aspects like water temperature, salinity, currents, and turbidity were often mentioned, as these directly affect how fish feed, their stress levels, and oxygen availability. Chemical parameters such as pH and dissolved oxygen, along with organic carbon content, were seen as essential indicators of water health. Biological markers, including chlorophyll-a levels, signs of harmful algal blooms, and toxin presence, were also considered crucial because they can signal potential problems like fish kills. Most agreed that keeping track of these factors is necessary not just to improve production but also to meet environmental regulations and ensure the long-term viability of their local ecosystems, which is consistent with environmental policies set by the Philippine Department of Environment and Natural Resources.

Many of the surveyed PAAVACO members expressed interest in using newer technologies to better monitor their farms and the environment. Real-time water quality sensors that can measure multiple parameters simultaneously were rated very important, especially if these devices could work offline due to the unreliable internet connection in some coastal areas of Palawan. Some fish farmers also suggested combining these monitoring tools with automated feeding systems and sensors to check the physical condition of their cages—ideas that could help reduce labour costs and better manage environmental challenges like temperature swings and algae growth. There was also a noticeable interest in using Geographic Information Systems (GIS) and mobile apps for better planning, such as choosing the best cage locations and tracking seasonal changes. This enthusiasm for technology reflects a growing awareness among local operators that innovation is key to sustaining their livelihoods amid environmental and logistical challenges.

Beyond technology, respondents also pointed out several practical difficulties they face daily, like limited access to service boats, unreliable electricity, and challenges in equipment maintenance—problems common to many small-scale aquaculture communities in the region. Several mentioned the potential benefits of solar-powered devices and backup energy sources to keep their monitoring and feeding systems running smoothly. Pollution from nearby coastal developments, increased boat traffic, and sediment runoff were additional concerns, which aligns with research showing how human activities affect water quality around Palawan's shores. Despite these issues, the group showed a strong commitment to sustainable practices, cooperation in sharing data, and continuing education programs. Taken together, the feedback from PAAVACO members highlights a clear need for integrated approaches that blend scientific monitoring, technological tools, and community involvement to support responsible aquaculture development in Palawan.

6.1 Bureau of Fisheries and Aquatic Resources (BFAR) -Province and MIMAROPA Region, Philippines

Early Adopter: BFAR is responsible for the development, improvement, management, and conservation of the Philippines' fishery and aquatic resources.

Use case 4: Mapping aquaculture structures and use of marine resources in Palawan, Philippines.

The Bureau of Fisheries and Aquatic Resources (BFAR) in Palawan plays a critical role in regulating and promoting sustainable aquaculture. As an end user of aquaculture mapping services, BFAR relies on geospatial technologies and mapping tools to monitor fish farms, assess environmental impact, enforce regulations, and support local aquaculture communities.

Application of Earth Observation technology is believed to be beneficial for BFAR as they play pivotal role in implementing Philippine policies on the development, improvement, management, and conservation of the country's fisheries and aquatic resources. Likewise, providing support to local aquaculture initiatives. BFAR collaborates with other agencies to identify and establish Strategic Agriculture and Fisheries Development Zones (SAFDZs), which are areas designated for the development of agriculture and fisheries. These zones aim to enhance productivity and ensure sustainable resource use.

The following key applications of aquaculture mapping service have been identified for BFAR in MIMAROPA region.

Identifying suitable aquaculture zones based on multiple factors: water depth and quality (temperature, salinity, dissolved oxygen); proximity to critical habitats (mangroves, coral reefs, seagrass beds); risk assessments for flooding, typhoons, and harmful algal blooms (HABs).

Example: aquaculture mapping service can help to determine areas for sustainable milkfish cage farming in Honda Bay while ensuring minimal environmental impact.

Monitoring aquaculture expansion and environmental compliance. Satellite imaging of aquaculture structures will help to detect illegal fish cages or pond expansions in protected areas, monitor mangrove deforestation due to shrimp farming, track changes in coastline and water quality linked to aquaculture activities.

Example: using mapping service to monitor fish pen density and prevent overcrowding in marine aquaculture zones.

Disease and Pollution Risk Assessment. Using aquaculture maps to identify high-risk zones for fish disease outbreaks, overlap of aquaculture structures with the areas with water pollution, proximity to the locations of harmful algal blooms (HABs) and red tide events.

Example: aquaculture maps helping to predict the risk of red tide impact in Puerto Princesa Bay.

Disaster Preparedness and Climate Change Adaptation. Aquaculture mapping will help to assess aquaculture vulnerability to climate change effects, including typhoon-prone areas where storm surges can damage fish cages.

Example: BFAR uses aquaculture maps and historical storm tracking maps to guide climate-resilient aquaculture planning.

6.2 Palawan Aqua-Agri Venture Agriculture Cooperative (PAAVACO), Puerto Princesa City, Philippines

Early Adopter: Cooperative of 22 registered fishcage operators, each operator was given the right to operate about 400 sq.m. Historically, (PAAVACO), established in 2018, is a testament to the collective efforts of local fisherfolk in Puerto Princesa City. Originally known as the Puerto Princesa Fish Cage Operators, the cooperative was formalized with the assistance of the Cooperative Development Authority (CDA). Starting with 19 members and an initial capital of ₱30,000, PAAVACO has grown to 44 members with total assets amounting to PhP1.5 million. Currently, 44 members include the fishcage operators and milkfish traders.

PAAVACO's operations focus on the cultivation of milkfish fingerlings in fish cages and ponds. Such fingerlings were then sold to fishcage operator-members for grow-out culture at relatively lower than the prevailing price in the market. Fishcage milkfish products were then sold to traders who are now members of PAAVACO.

The cooperative has diversified its products to include value-added items such as boneless fish and smoked fish, enhancing its market presence and income streams. Support from BFAR has been instrumental, with the agency providing essential resources including freezers, smoked fish equipment, fish cages, and fry for nursery rearing in ponds.

Use case 4: Mapping aquaculture structures and use of marine resources in Palawan, Philippines.

The Palawan Aqua-Agri Venture Agriculture Cooperative (PAAVACO) is a key player in Palawan's sustainable aquaculture and agribusiness sector. As an end user of aquaculture mapping services, PAAVACO leverages geospatial technology to enhance farm productivity, optimize site selection, mitigate environmental risks, and comply with regulatory standards.

We identified the following key applications of the aquaculture mapping product by PAVAACO in Puerto Princesa City.

Site Selection and Farm Planning: water depth and quality at the location of aquaculture cages, proximity to farm infrastructure (roads, ports, feed supply chains), assessment of damage of aquaculture structures caused by storms.

Example: using aquaculture maps to help PAAVACO to optimise fish cage location.

Environmental Monitoring and Compliance: prevent fish mortality due to Harmful algal blooms (HABs), ensuring compliance with BFAR regulations and preventing illegal farm expansion in mangrove areas.

Example: using aquaculture maps by PAAVACO to avoid aquaculture zoning violations and maintain BFAR's Environmental Compliance Certificate (ECC).

Disaster Preparedness and Climate Resilience: Identifying typhoon-prone areas where floating cages need reinforcement, planning for climate-resilient aquaculture infrastructure, estimating integrity of fish cages after typhoon events.

Example: estimating damages and losses during peak typhoon season.

6.3 Summary of the Early Adopters Requirements

The requirements for aquaculture maps product are shaped by the applications for BFAR and PAAVACO end users outlined above. These requirements can be summarised as follows:

Spatial resolution. Aquaculture maps should provide sufficient accuracy of object location. Low accuracy may prevent discrimination of small objects, such as fish cages, pens and traps. On the other hand, the accuracy of object localisation is limited by sensor spatial resolution, and it is important to make sure that the objects of small size can be mapped using remote sensing data. This requirement is particularly relevant to the applications such as assessment of aquaculture objects damaged by storms and disease risk assessment by monitoring the distance between aquaculture cages.

To find the resolution requirement baseline, we reviewed aquaculture gears used in Puerto Princesa City, Palawan, and estimated their dimensions. The potential locations of aquaculture objects were identified using an aquaculture map developed by PML in 2019 in project GCRF Blue Communities, a 4-year research capacity-building programme for marine planning in East and South-East (E/SE) Asia. An example of the map covering Honda Bay is shown in Figure 3. The map was compared with the Google Earth very-high-resolution satellite image to estimate the dimensions of aquaculture objects outlined in Figure 3 in red. Examples of the aquaculture objects, identified in the Google Earth image, are illustrated in Figure 4. The size of these objects varied from 12 to 40 meters, and the required spatial resolution was estimated as 6 meters (50% of the minimum object size).

We compared this requirement with the results of a survey conducted among early adopters in the Philippines. Figure 11 in Appendix 3 shows the number of survey participants who responded to the question of whether a spatial resolution of 5 to 20 meters per pixel would be sufficient for the aquaculture map product. Ninety percent of respondents indicated that this resolution would be ideal for their tasks.

Figure 3. A Google Map of Honda Bay, Palawan. The locations of aquaculture objects are shown in red.


Google Earth
Image © 2025 Airbus
20 m
N


Google Earth
Image © 2025 Airbus
30 m
N

Figure 4. Examples of aquaculture gears used by local community in Puerto Princesa, Palawan identified in Google Earth images. The size of gears varies from 12 to 40 meters.

Update rate. The rate at which we need to update the aquaculture maps can be different depending on the application scenario. For most of the applications outlined above frequent updates are not required. For the tasks of site selection and planning, monitoring aquaculture expansion, disaster and pollution risk assessment the update rate once in 4-6 months is acceptable. However, for the estimation of structural damages of aquaculture infrastructure after typhoons and other severe weather events, it is important to reduce the delay of map update to minimum. The map of aquaculture objects has to be updated in 7-10 days after the typhoon event.

In the survey conducted among early adopters, approximately 80% of participants indicated that a 12-day update rate would be ideal for their tasks, while 4% stated that this update rate would be the minimum acceptable (see Figure 11, Appendix 3).

The material of aquaculture cages. In Puerto Princesa, Palawan, different designs and materials are used to build aquaculture cages. The most popular are traditional cages and pens made of bamboo, Norwegian type cages made of PVC or steel pipes, or rope framed cages. It is important to ensure that fish cages and other aquaculture objects made of bamboo, plastic or metal will be reliably detected and mapped.

7 Algorithms available – Baseline and innovative

Aquaculture infrastructure can be assessed by satellite remote sensing methods that are less expensive and more efficient. Monitoring by remote sensing can be automated and applied regularly to map larger areas while minimizing additional costs (Alexandridis et al., 2008; Gernez et al., 2021; Travaglia et al., 2004). We will use both multi-spectral optical and microwave synthetic aperture radar (SAR) sensors for such tasks (Ottinger et al., 2017; Travaglia et al., 2004). In particular, SAR shows the advantage of providing information even through cloud-covered scenes day and night. The satellite mapping of aquaculture cages and other equipment can therefore support the control of density and proliferation of aquaculture activities and ensure sustainable exploitation of marine resources while minimizing the environmental impact.

The capabilities of SAR and multispectral optical sensors to detect aquaculture objects from space were investigated by Alexandridis et al. (2008). In their experiment, long-line mussel farms were identified in SAR sensor images but not observed in optical images, even at higher spatial resolution. One of the main factors that adversely affected the detection of aquaculture structures in SAR sensor images was the speckle noise, formed by the coherent interaction of microwaves. To reduce speckle in SAR images Profeti et al. (2003) proposed a multivariate analysis technique. This technique was based on applying an averaging operator along the time dimension in the time series of co-registered SAR images. This allowed to improve the accuracy of mapping aquaculture objects without loss of spatial resolution. A similar approach was employed by Ottinger et al. (2017) for mapping aquaculture ponds in China and Vietnam using time series of Sentinel-1 SAR data. To improve detection accuracy of aquaculture pond features, embankments, levees and dikes, Ottinger et al. (2017) replaced the averaging operator with the median. This technique was applied for processing large volumes of SAR data and mapping coastal aquaculture over a large area. Sun et al. (2020) successfully adapted this methodology for the Google Earth Engine, while Prasad et al. (2019) applied it for mapping coastal aquaculture in India.

The methodology pioneered by Ottinger et al., (2017), was suitable for mapping inland aquaculture ponds of rectangular shape, but not for small inshore and offshore aquaculture objects located in the open sea, such as fixed net cages, longline rafts, floating houses and other types of aquaculture structures that can be found in Philippines' coastal waters (Aguilar-Manjarrez et al., 2004). These objects are traditionally made of bamboo sticks and can be characterized as having relatively low backscattering coefficients. They are relatively small and can occupy only several pixels in the medium resolution satellite SAR image, such as Sentinel-1 SAR. The detection of small objects at the open water background is a challenging task. It was approached by Ariel Russell et al. (2020), who used the dual-polarization signatures, estimated in Sentinel-1 SAR single look complex (SLC) VV+VH images. They applied the unsupervised Wishart classification to dual-polarization data to improve the accuracy of fish cage detection. However, the impact of wind and waves on the detector performance was not fully studied.

Ballester-Berman et al. (2018) applied dual-polarization SLC Sentinel-1 data for mapping fish cages in the Norwegian fjords and floating mussel farms in Galiza, Spain. Promising experimental results were obtained for the fish cages of round shape, but not for the mussel farm structures. It is worth noting that Ariel Russell et al. (2020) and Ballester-Berman et al. (2018) used separate SAR images and did not study time series.

Mapping of aquaculture infrastructure will be carried out automatically by adapting the methodology developed by PML (Kurekin, 2022). This methodology uses historical time series of Sentinel-1 SAR and Sentinel-2 MSI multispectral images. The images will be aggregated over extended period using median operator to discriminate moving and stationary objects. This operation will also help to reduce speckle noise in SAR images and fill the gaps in MSI optical images produced by clouds. An improvement in detecting small aquaculture objects of about 5 meters in diameter, will be achieved by utilizing the Sentinel-1 SAR Single Look Complex (SLC) product, which offers a spatial resolution four times higher than that of a Ground Range Detected (GRD) product.

The main stages of data processing are illustrated in the block diagram in Figure 5. At the first stage we will access Sentinel-1 SAR and Sentinel-2 MSI data archive through the Copernicus Data Space Ecosystem and the Alaska Satellite Facility (ASF) service. Then, the SAR and optical images will be pre-processed and aggregated in time domain. Following that the static objects will be detected in the composite images. At the third stage we will analyse microwave and spectral signatures of the detected static objects to discriminate aquaculture cages and other structures. Discrimination of the signatures will be carried out automatically using machine learning methods, such as linear discriminant analysis, support vector machines, deep learning neural networks. The algorithm will be trained using ground truth data provided by our end users in the Philippines and augmented with visual inspection results of WorldView-2,3,4 VHR images. At the final stage the detected aquaculture objects will be presented on a map, for example, in a Google Earth KML format.

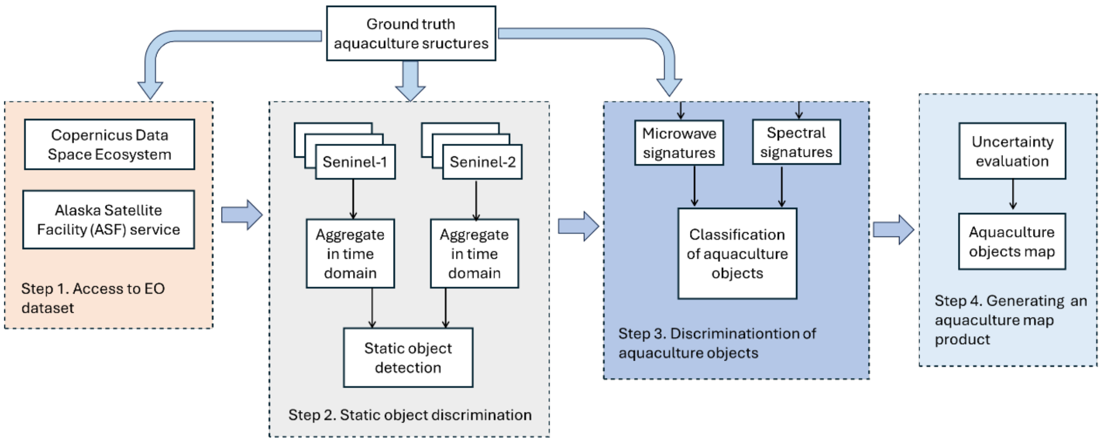

Figure 5. The processing chain for EO data.

8 Datasets available

8.1 Input Datasets

A summary of the available and to be used input data sets and their sources is given in Table 3.

Table 3: Brief descriptions of the planned EO variables and their data sources for developing EO-based products for aquaculture mapping.

Variables	Brief description	Public source
The radar backscattering coefficient at VV and VH polarisations	Sentinel-1A and Sentinel-1C SAR data, the Interferometric Wide Swath (IWS) mode, Single Look Complex (SLC) data format	Copernicus Data Space Ecosystem (CDSE) (https://dataspace.copernicus.eu/) Alaska Satellite Facility (ASF) Vertex (https://search.asf.alaska.edu/)
Bottom of Atmosphere (BOA) reflectance	Sentinel-2B and Sentinel-2C MSI Level-2A BOA product with less than 15 percent cloud cover.	Copernicus Data Space Ecosystem (CDSE) (https://dataspace.copernicus.eu/) Alaska Satellite Facility (ASF) Vertex (https://search.asf.alaska.edu/)

For mapping aquaculture sites, we'll use open access Sentinel-1 SAR and Sentinel-2 MSI satellite sensor data distributed by the European Space Agency (ESA). The Sentinel-1 and Sentinel-2 datasets for Palawan, Philippines, are available at the Copernicus Data Space Ecosystem (CDSE) portal and will be used starting from 2022. Currently only Sentinel-1A sensor data are available for Palawan region for the descending paths of the satellite every 12 days at around 21:50 Coordinated Universal Time (UTC). We are planning to use the Sentinel-1 C sensor data when they become available. This will at least double the amount of received information and improve the quality of aquaculture mapping.

Sentinel-1A SAR uses several operation modes depending on the geographical location. In the Palawan coastal zone it uses the Interferometric Wide Swath (IWS) mode with radar signal transmitted at vertical (V) polarization and received at both vertical and horizontal (H) polarizations. We use IWS mode data to map aquaculture structures, as the backscatter coefficient of aquaculture objects (mainly made of bamboo sticks), is higher at VV polarization, while the VH polarization mostly measures the multiple scattering effect.

In the IWS mode the Sentinel-1 sensor swath is 250km wide. It is divided into several parts by using the technique called "Terrain Observations with Progressive ScansSAR (TOPSAR)". In IWS mode the Sentinel-1 SAR data are available in two formats: Single Look Complex (SLC) data format at sensor maximum spatial resolution 3m in the range direction and 20m in the azimuth direction and Ground Range Detected High Resolution (GRDH) data format with range resolution reduced to 20m in range and 20m resolution in azimuth. In this study, we'll apply the SLC product as it has a better spatial resolution in range direction. However, this will require: to combine different sub-swath images stored separately; to translate slant range coordinates to the ground range; and to convert the data from complex to amplitude format.

To generate an up-to-date land mask, we'll use time-series Sentinel-2 MSI images that will be downloaded from the CDSE portal and then composited to fill in the gaps due to cloud cover. The mask will be built using Level-2A Bottom of Atmosphere (BOA) reflectance products with less than 15 percent cloud cover. Currently, Sentinel-2B and Sentinel-2C sensor data are available at CDSE portal for the case study area. The dataset provides sufficient temporal resolution to produce a high-quality land/sea mask for the study area.

8.2 Validation Datasets

Validation of the developed product will be carried out using two datasets. An EO-based dataset will be created to validate historical aquaculture maps developed for the period starting in January 2022. As no ground truth information will be available for the historical data, validation will rely on very high-resolution (VHR) optical satellite images. Images of the case study area will be analysed manually to identify the parameters of fish cages and other aquaculture structures. The results of the visual identification will be stored in a table containing the date of observation, latitude and longitude, object type (fish cage, mussel farm raft, caretaker shed, jetty), dimensions, and shape. This table will be compared with the objects detected in Sentinel-1 and Sentinel-2 images to estimate accuracy, false alarm rate, and other performance measures.

To access the archive of historical VHR data, we applied to ESA's Third-Party Missions programme. The proposal we developed was submitted to ESA on 5 June 2025. In this proposal, we requested access to GeoEye, QuickBird, or WorldView MAP Ready (ortho) data collections, including panchromatic and pan-sharpened four-band imagery with a spatial resolution of 15 cm to 60 cm.

The second dataset will be used to validate the most recent aquaculture mapping products. It will consist of ground truth data collected by PML's sub-contractor in the Philippines: the College of Fisheries and Aquatic Sciences at Western Philippines University (WPU). The in-situ validation dataset will include the following information: latitude and longitude coordinates of aquaculture objects, object photographs, descriptions of type, size, and material. To collect this information, WPU will organise several trips to the case study areas.

8.3 Output Datasets

The output dataset will cover three bays located in Puerto Princesa City: Puerto Princesa Bay and Honda Bay on the eastern side, and Ulugan Bay on the northwestern side of Puerto Princesa. A historical time series of aquaculture maps will be generated at regular four-month intervals starting in 2022 and continuing through 2026 (see Table 4). The generated maps will show the location of detected aquaculture objects, along with their width, length, and orientation.

Table 4: Details of the output datasets produced for Use Case 4 in Palawan, Philippines.

Study areas	Geographical extension	Estimated parameters	Period	Update rate
Puerto Princesa Bay	118.68° - 118.76° E 9.67 - 9.79 N	latitude and longitude, width and length orientation	2022 - 2026	Every 4 months
Honda Bay	118.73° - 118.81° E 9.8° - 9.95° N			
Ulugan Bay	118.73° - 118.85° E 10.0° - 10.14° N			

Responses from adopters to the questionnaire in Section 6 identified offline access to the developed product as a key requirement, due to the unstable internet connection in the case study area. To simplify access for early adopters, we decided to distribute the product in Keyhole Markup Language (KML) format, which can be opened using Google Earth Pro desktop application or Geographic Information System (GIS) software. The size of the generated KML files does not exceed 1 MB, and the maps will be distributed via e-mail or FTP. For each bay in the Use Case area, we will provide an aquaculture map in KML format showing the location of detected objects, their dimensions, and orientation, as illustrated in the map in Figure 6. The positions of detected objects on the map are outlined in pink.

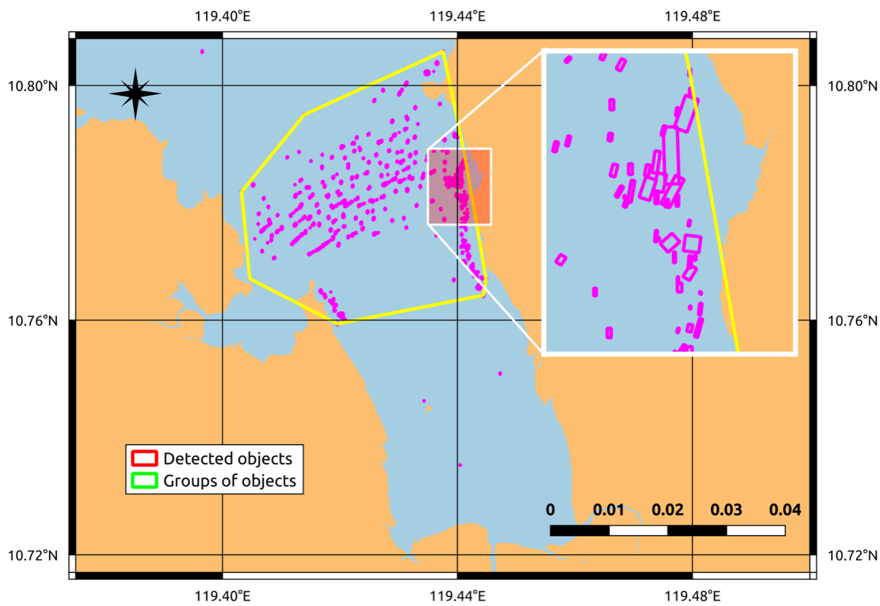

Figure 6. Example of an aquaculture map product in Palawan. The locations of fish cages are shown in pink.

9 Potential limitations of the approach

Detection and mapping of aquaculture structures in Palwan, Philippines using EO methods is a challenging task. The main factors that affect efficiency of EO methods are the material and dimension of aquaculture gears. The fish cages that are used for cultivation of bangus (milkfish) and other mariculture species are traditional bamboo cages, modern Norwegian type cages and rope-framed cages. The size of these cages varies from 6 to 20 meters which is comparable to the spatial resolution of Sentinel-1 SAR sensor in the IWS mode (see Table 5 and examples in Figure 7). As the net and frame of the gear are submerged in water and only top of the frame can be seen above the surface, the cages are difficult to observe and detect using Sentinel-2 multispectral images. However, the part of the cage frame located above the water, can be detected in Sentinel-1 SAR images, as demonstrated in (Kurekin et al., 2022). Nevertheless, reliable detection of such objects requires combining multiple Single Look Complex Sentinel-1 SAR images to reduce speckle and implementing more complex data processing chain using the Terrain Observation with Progressive Scans SAR (TOPSAR) processing stages.

The numerous small rocks, islands and sand banks in the case study area are the additional challenges in discrimination of aquaculture objects. To improve the accuracy of aquaculture detection we are planning to use time series of Sentinel-2 MSI data that will be automatically analysed to map small islands and sand banks in the area, taking into consideration tidal variations of the sea surface height to improve the accuracy.

Table 5: Aquaculture gears used in Palawan, Philippines. See examples in Figure 7.

Aquaculture gear	**Size**	**Material**	**Features**
Traditional cages	6 to 25 meters	bamboo	Frames made of bamboo sticks
Modern Norwegian type cages	10 to 20 meters	polyethylene composites	A circular frame made of polyvinyl chloride (PVC) or steel pipes
Rope-framed cages	10 to 20 meters	Plastic, rope	Using rope frame
Caretaker sheds	5 to 15 meters	bamboo	Floating or stationary structures

Figure 7. Aquaculture structures in Palawan: (a) floating and (b) fixed fish cages; (c) caretaker sheds used in seaweed production.

10 Conclusions

We analysed main factors that define the requirements to aquaculture mapping product. This includes the national polices in the Philippines aimed at development of sustainable aquaculture and support of coastal communities, and implementation of these policies by local government units. We reviewed the key applications of aquaculture mapping service for the end-users and the characteristics of aquaculture gears used in Puerto Princesa, Palawan. For the developed aquaculture maps we identified the baseline requirements for spatial resolution and update rate of aquaculture map, as well as for the material and size of detected objects.

We reviewed the remote sensing aquaculture mapping methods, and the innovative method presented in the proposal. We considered the limitations of proposed approach and estimated its potential in satisfying the outlined end-user requirements. Overall, we concluded that end-user requirements to aquaculture maps in the Philippines can be met by using time series of Sentinel-1 SAR and Sentinel-2 MSI sensor data.

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Appendix 1. – Aquaculture Sites and Local Initiatives

Honda Bay, Puerto Princesa City

Location: Honda Bay is situated on the eastern shore of Palawan Island, near Puerto Princesa City.

Coordinates: Latitude 9.89038° N, Longitude 118.8088° E

Nearby Barangays:

Barangay	Primary Fisheries Activities	Ecological Features	Economic Transition / Notes	Key Reference
Sta. Lourdes	- Ecotourism-related fishing - Island-hopping services by local boat operators	- Mangroves - Coral reefs - Seagrass beds	- Shift from fishing to tourism - 80% of boatmen rely on island tours as primary income	Dela Peña et al. (2017); BIMP-EAGA Journal for Sustainable Tourism Development
Binduyan	- Community-based aquaculture - Fishpond and topshell (Trochus niloticus) enhancement	- Seagrass beds - Dugong feeding areas	- FRMP-supported stock enhancement project - Local hatchery and coastal livelihood programs	Puerto Princesa CLUP (2014); BFAR-FRMP
San Jose	Coastal fishing - Small-scale aquaculture (milkfish, tilapia) - Post-harvest processing	- Marine coastal area - Proximity to commercial zones	-Fisheries integrated with local markets - Processing centers for added value	Puerto Princesa City Government; CLUP Data
San Pedro	- Coastal resource management - Participatory marine protection programs	- Seagrass beds - Nearshore habitats	- Focus on sustainable fisheries - Involvement in BFAR and DENR initiatives	Puerto Princesa CLUP (2014); PCSD Environmental Programs

Puerto Princesa Bay

Location: Puerto Princesa Bay is located on the western side of Puerto Princesa City, facing the Sulu Sea.

Coordinates: Latitude 9° 44' N, Longitude 118° 43' E

Nearby Barangays:

Barangay	Primary Fisheries Activities	Ecological Features	Economic Transition / Notes	Key Reference
Sta. Lourdes	Oyster culture (e.g., *Crassostrea iredalei*) - Mariculture park development - Marine hatchery establishment	Mangroves - Coral reefs - Seagrass beds	Shift from traditional fishing to aquaculture - Establishment of marine hatcheries and mariculture parks	Republic Act No. 11734; Chinese investors' interest in aquaculture
San Manuel	Coastal resource management - Fisheries law enforcement - Mangrove reforestation	Mangrove forests - Coral reefs - Seagrass beds	Active participation in integrated coastal resource management programs - Collaboration with BFAR and DENR	FAO Country Papers
Tiniguiban	Sustainable fisheries programs - Mangrove conservation - Community-based fisheries management	Mangrove forests - Seagrass beds - Coral reefs	Emphasis on sustainable fisheries practices - Community involvement in resource management	State of Mangroves in Tiniguiban Cove

Aquaculture Activities:

- **Sta. Lucia**: The establishment of a central multi-species marine hatchery in Sta. Lucia is a significant development. This facility aims to support sustainable aquaculture practices and provide training for local fisherfolk.
- **San Manuel**: The barangay has been actively involved in coastal resource management, including mangrove reforestation and the implementation of fisheries law enforcement programs. These efforts contribute to the sustainable use of marine resources.
- **Tiniguiban**: A study conducted in 2003 assessed the state of mangroves in Tiniguiban Cove, highlighting the diversity of mangrove species present and the threats they face. This underscores the importance of conservation efforts in the area.

Ulugan Bay

Location: Ulugan Bay is located on the central-western coast of Palawan Island, approximately 47 kilometers from Puerto Princesa City.

Coordinates: Latitude 9.5° N, Longitude 118.7° E

Nearby Barangays:

Barangay	Primary Fisheries Activities	Ecological Features	Economic Transition / Notes	Key Reference
Bahile	Sustainable aquaculture practices - Mangrove conservation efforts - Community-based fisheries management	Mangrove forests - Coral reefs - Seagrass beds	Emphasis on sustainable resource use - Community involvement in conservation programs	Palawan Council for Sustainable Development (PCSD) Reports
Macarascas	Brackishwater aquaculture (e.g., milkfish, tilapia) - Coastal fisheries - Fish processing and marketing	Coastal and marine ecosystems - Mangrove areas	Active participation in fish marketing initiatives - Support from BFAR for aquaculture projects	Bureau of Fisheries and Aquatic Resources (BFAR) Region VI Reports
Buenavista	Mariculture (e.g., bangus fish cage culture) - Fish processing (e.g., fishball, fish sausage) - Fisheries law enforcement	Coastal waters - Marine biodiversity	Development of fish ports to boost local economy - Collaboration with BFAR for capacity-building	Puerto Princesa City Government News
Tagabinet	Community-based fisheries management - Mangrove reforestation - Sustainable fishing practices	Mangrove forests - Coral reefs - Seagrass beds	Focus on conservation and sustainable fisheries - Community-led initiatives	Palawan Council for Sustainable Development (PCSD) Reports
Cabayugan	Aquaculture (e.g., tilapia, bangus) - Coastal fisheries - Fish processing and marketing	Coastal and marine ecosystems - Mangrove areas	Engagement in sustainable aquaculture practices - Support from BFAR for capacity-building	Bureau of Fisheries and Aquatic Resources (BFAR) Region VI Reports

Aquaculture Activities:

- **Bahile**: This barangay is actively involved in sustainable aquaculture practices, focusing on species like tilapia and bangus. Community members participate in mangrove conservation efforts, enhancing local biodiversity and supporting sustainable fisheries.

- **Macarascas**: Known for its brackish water aquaculture operations, Macarascas produces species such as milkfish and tilapia. The barangay has a history of fish processing and marketing, with support from the Bureau of Fisheries and Aquatic Resources (BFAR) Region VI for various aquaculture projects.
- **Buenavista**: The barangay is engaged in mariculture activities, particularly bangus fish cage culture. Fish processing activities include the production of fishball and fish sausage. Buenavista is also developing fish ports to boost the local economy and has collaborated with BFAR for capacity-building initiatives.
- **Tagabinet**: Tagabinet focuses on community-based fisheries management, emphasizing sustainable fishing practices and mangrove reforestation. The barangay is involved in conservation efforts to protect marine ecosystems and support local fisheries.
- **Cabayugan**: Cabayugan engages in aquaculture, cultivating species like tilapia and bangus. The barangay is involved in fish processing and marketing, with support from BFAR Region VI for capacity-building programs aimed at enhancing sustainable aquaculture practices.

Appendix 2. – Philippian Fisheries Administrative Orders (FAOs)

1. **FAO No. 197-1 (Revised Rules on Lease of Public Lands for Fishpond and Mangrove-Friendly Aquaculture)**
    - **Purpose**: Governs the leasing of public lands for aquaculture, emphasizing mangrove-friendly practices.
    - **Key Requirements**:
        - Submission of a sketch plan and technical description.
        - Proof of financial capacity.
        - Adherence to Good Aquaculture Practices (GAqP).
        - Environmental Compliance Certificate (ECC) from DENR.
        - Notarized affidavits and legal documents.
        - Commitment to commercial-scale production within specified timelines.
    - **Reference**: FAO No. 197-1
2. **FAO No. 259 (Rules on Importation of Frozen Fish for Wet Markets)**
    - **Purpose**: Regulates the importation of frozen fish during closed fishing seasons or calamities to ensure food security.
    - **Key Provisions**:
        - Importation allowed only from countries with equivalent food safety systems.
        - Compliance with Philippine food safety standards.
        - Coordination with relevant agencies for monitoring and enforcement.
    - **Reference**: FAO No. 259
3. **FAO No. 270 (Operations of Philippine Flagged Fishing Vessels in Distant Waters)**
    - **Purpose**: Establishes regulations for Philippine-flagged vessels operating beyond national jurisdiction.
    - **Key Requirements**:
        - Compliance with international fisheries management organizations.
        - Vessel marking and specification standards.
        - Prohibition of Illegal, Unreported, and Unregulated (IUU) fishing activities.
    - **Reference**: FAO No. 270
4. **Administrative Order No. 16 (Identification of Fisheries Management Areas as SAFDZs)**
    - **Purpose**: Directs the identification of Fisheries Management Areas (FMAs) as Strategic Agriculture and Fisheries Development Zones (SAFDZs).
    - **Key Actions**:
        - Coordination among DA, DENR, DILG, and DOST.
        - Integration of FMAs into SAFDZs for sustainable development.
    - **Reference**: AO No. 16

Appendix 3. - Summary of the EAs replies to the questions in the survey

As summarized in Table 2 (main report), the following figures present the EA responses to the questions addressed in the EO4SA questionnaire survey (Appendix 1).

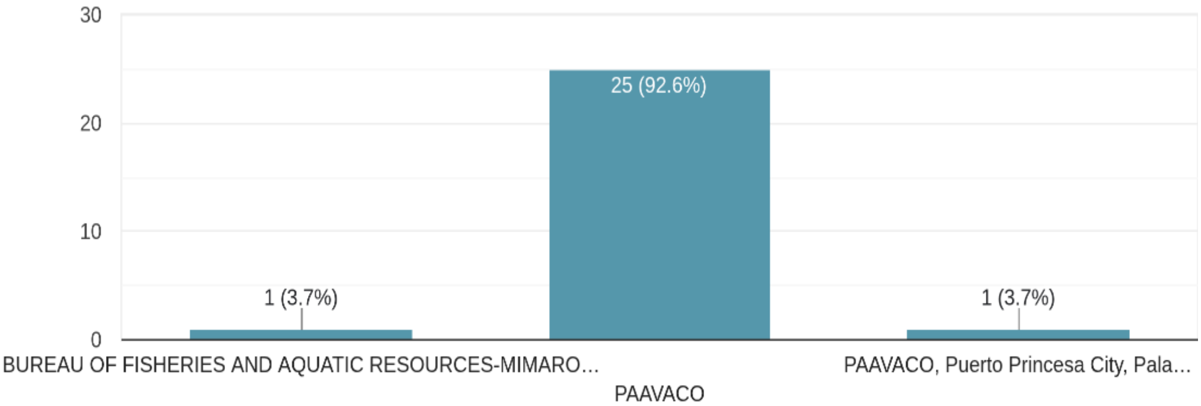

Figure 8. Answers to the question: in which organisation or company do you work?

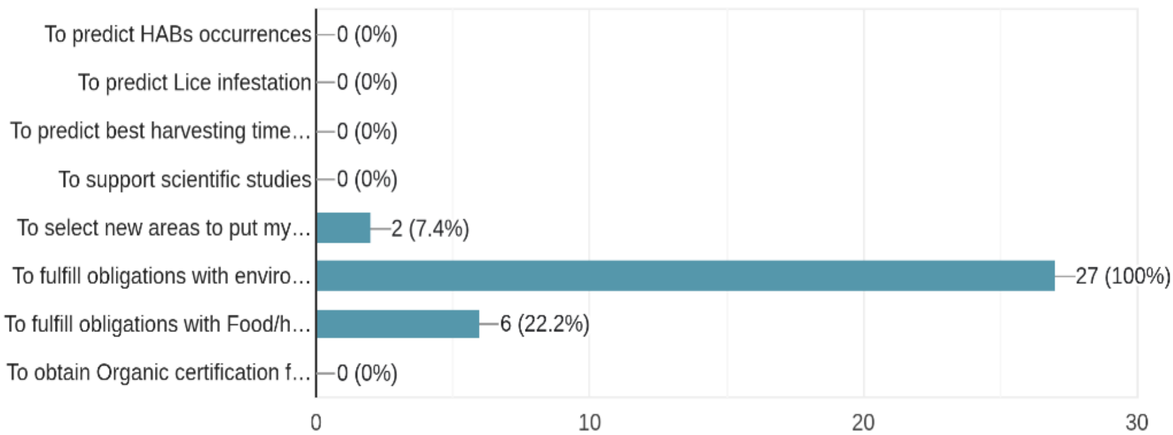

Figure 9. Responses to the question: why do you need to measure the environmental variables? The answers are grouped into the following categories: to predict HAB occurrences; to predict lice infestation; to predict best harvesting time for the size of the animal; to support scientific studies; to select new areas to put my cages/aquaculture site; to fulfil obligations with environmental policies; to fulfil obligations with Food/health Standards policies; to obtain Organic certification for my product.

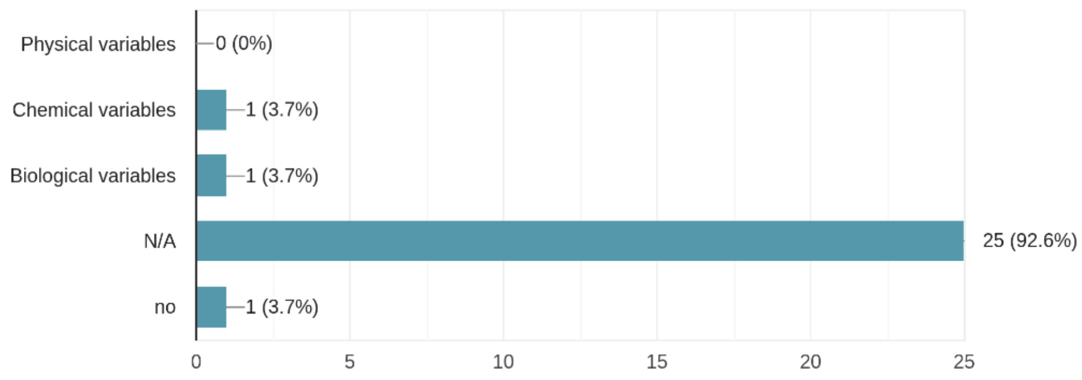

Figure 10: Number of responses to the question: do you use satellite remote sensing for any of environmental variables?

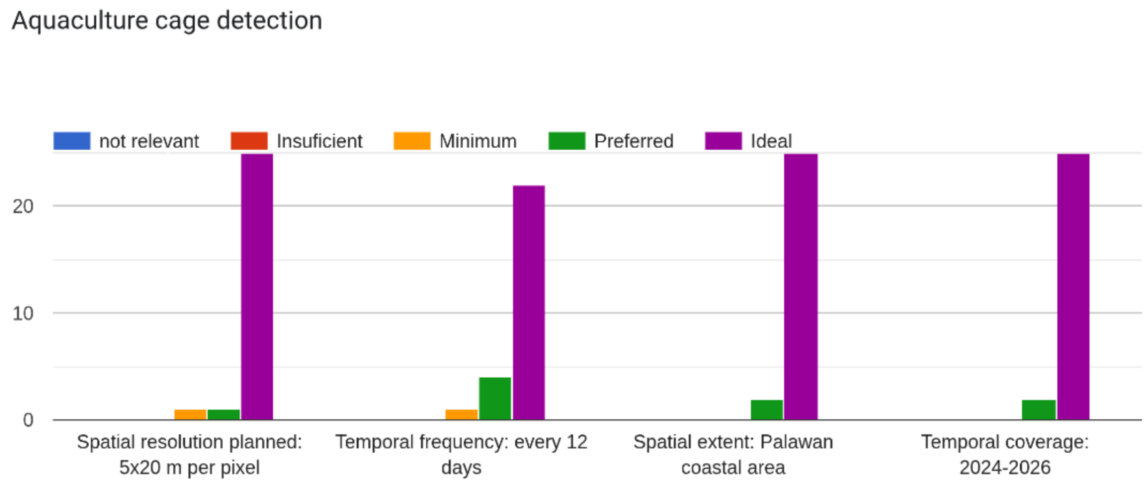

Figure 11: Number of responses to the question: what are the requirements to the aquaculture cage mapping product?

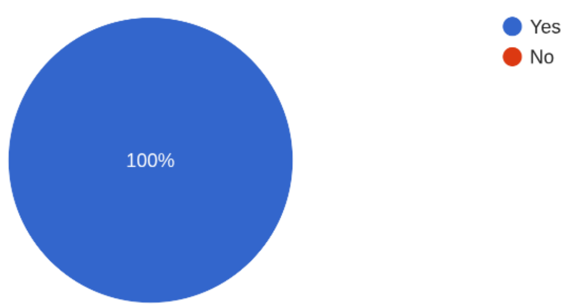

Figure 12. Number of responses to the question: is data access through a Web portal useful for you?

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