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Policy Brief
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PROGRAM ON DATA SCIENCE FOR PUBLIC POLICY

Artificial Intelligence and Marine Litter Monitoring and Tracking

Investing in AI Technologies in the Philippines

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Introduction

Marine litter or Anthropogenic marine debris (AMD) pertains to "any persistent, manufactured, or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP 2017). It is harmful to marine life because sea creatures may ingest, or be entangled with it (i.e. plastics). Moreover, marine litter affects tourism and recreation in sites where it is found (Newman et al. 2015; Hamre et al. 2009). Perhaps its gravest consequence is that it threatens food security and human health in the Philippines. One-third of fish caught for human consumption has been found to contain plastic in their guts (Lusher, McHugh, and Thompson 2013). The presence of plastic in coastal ecosystems such as seagrass beds, mangroves, and coral reefs increases the likelihood that they will die (Walther and Bergmann 2022). Many of these ecosystems have abundant resources from which Filipinos obtain their food.

The amount of marine litter in the Philippines continues to increase due to the widespread use of single-use plastics (e.g., plastic bottles, sachets, plastic bags, etc.) and ineffective waste management systems. Several laws seek to address this issue: Republic Act (RA) No. 9003 or the Ecological Solid Waste Management Act of 2000, RA No. 9003 or the Climate Change Act of 2009, and other waste management and coastal/marine and biodiversity management-related policies (both local and national). However, the country has remained one of the world's top contributors of AMD. The statistics

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are staggering. One modeling study even ranked the Philippines as the top three contributors of plastic litter, discharging an estimated 0.28-0.75 million metric tons of plastic debris into the world's ocean (Jambeck et al. 2015).

Baselining, and monitoring the amount and extent of marine litter pollution, are crucial activities in addressing the problem. Both would lead to the identification of the main sources of marine litter, hotspots, and the development of targeted programs. However, tools (and approaches) for proper data gathering are either too expensive or require highly specialized skills to operate. For example, AMD monitoring must ideally be conducted on a regular basis every year because its quantity and distribution are affected by environmental factors (e.g., wind direction) and patterns of human activities.

Common approaches to establish data on AMD include beach surveys, volunteer scuba divers, and the use of submersibles. The first two usually take time and money, and require tremendous manpower. Additionally, a person's capacity to withstand the underwater environment (for both shallow and deep waters) and their observational skills can be limiting factors. Submersibles are expensive and may require specialized skills to operate.

AI-based technologies that can identify, quantify and characterize benthic[2] AMD in shallow coastal ecosystems have the potential to overcome the limitations of these aforementioned tools and approaches. Various AI technologies have been designed and deployed to tackle the problem of AMD in other countries such as those in the Mediterranean. The Philippines can adopt and invest in these technologies, and capacitate people to use them.

Along with technological advances, there should be enabling policies and guidelines that enforce the use of such technologies. In May 2021, the Department of Environment and Natural Resources (DENR), as mandated in the DENR Memorandum Circular No. 2021-10, published the National Plan of Action for the Prevention, Reduction and Management of Marine Litter (NPOA-ML). Strategy 1 of the Action Plan specifically provides for the establishment of science and evidence-based baseline information on marine litter. However, its implementation has largely been impeded by logistics and funding challenges.

This policy brief proposes to facilitate the implementation of Strategies 1 and 5 of the NPOA-ML by promoting the use of AI-based technologies to quantify. characterize, monitor, and track AMD in various marine ecosystems (beach, coastal, subtidal,[3] and benthic). These can address the limitations of a manual approach to monitoring and tracking litter in marine ecosystems.

Plastic: The Most Pervasive Marine Litter in the Philippines

Plastic items are used to create a wide range of products because they are lightweight, solid, durable, and inexpensive (Rosas, Martins, and Janeiro 2021). However, they decompose slowly or, in certain cases, not at all (Galgani, Hanke, and Maes 2015). Marine litter has four main classifications: glass, paper, plastic, and metal (Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory—GEF 2012).

Among these types, plastic is the most pervasive item in the ocean, forming at times up to 95 percent of the litter that amasses on coastlines, the ocean surface, and the ocean floor (Galgani, Hanke, and Maes 2015). On beaches, plastics also constitute at least 80 percent of litter (Rosas, Martins, and Janeiro 2021), which in another study includes plastic bags, plastic bottles, and fishing gear (Topçu et al. 2013; Thiel et al. 2013). Likewise, 90 percent of litter on the seabed are plastics (Ramirez-Llodra et al. 2013).

In 2017, Ocean Conservancy reported that plastics comprised most items recovered during the annual International Coastal Clean-up (ICC). These included cigarette butts with plastic filters, plastic bags, plastic containers, and others. In the Philippines in 2023, during the International Coastal Clean-up Philippines (ICCPH), most of the items recovered on beaches,

[2] Benthic pertains to the seafloor or seabed.

[3] The subtidal zone is the zone close to shore, but is constantly submerged.

underwater, and on the water, were made of plastic, as expected (Table 1).

Unlike beach clean-ups, underwater clean-ups had fewer volunteers. Thus, the quantity of litter on the seabed may be underestimated, but may be quite similar to that in beaches in terms of type and proportion.

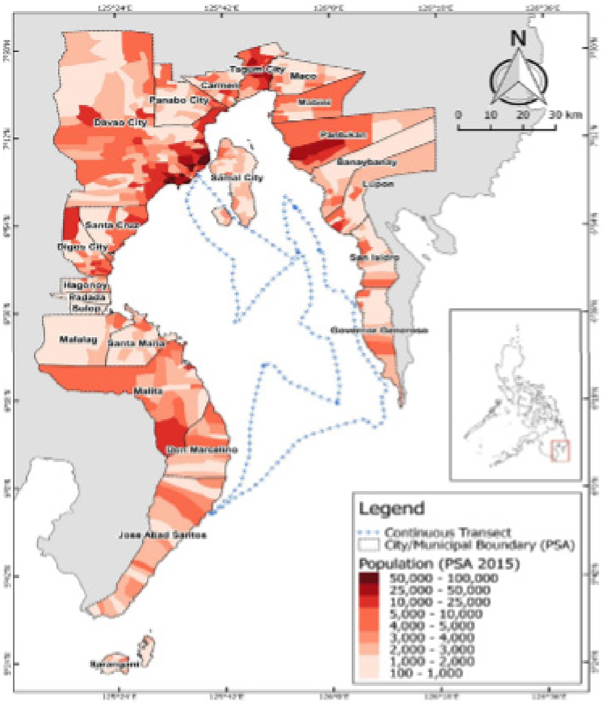
	TYPE	NUMBER OF ITEMS RECOVERED
1	Plastic grocery bags	340,200
2	Food wrappers	264,196
3	Plastic beverage bottles	243,669
4	Other plastic bags	211,759
5	Cups, plates (plastic)	140,553
6	Plastic sachet packaging	130,733
7	Plastic bottle cap	108,953
8	Plastic straws	87,683
9	Cigarette butts	78,926
10	Beverage pouches	76,613

■ Table 1. Top 10 items recovered during the 2023 International Coastal Clean-up Philippines (ICCPH 2023)

Wildlife and Marine Litter: Case of the Davao Gulf

Davao Gulf covers an area of about 7,300 km^2 enclosed by the different Davao provinces (Alcala, Ingles, and Bucol 2009). The gulf area consists of six cities and 24 municipalities. As a Marine Key Biodiversity Area (MKBA), Davao Gulf offers refuge to unique fauna and exemplifies the significance of Philippine waters within the Coral Triangle.[4] Moreover, Davao Gulf supports million-peso fisheries and provides livelihood for Filipinos.

However, because of marine litter, it is also considered a hotspot for cetacean[5] stranding (Aragones et al. 2010) and marine plastics ingestion by animals (Abreo, Blatchley, and Superio 2019). In the Philippines, the first cases of plastic ingestion by a whale shark (*Rhincodon typus*) and by Derinayagala's beaked whale (*Mesoplodon hotaula*) were recorded within Davao Gulf (Abreo, Blatchley, and Superio 2019; Abreo et al. 2016). In 2018, another case (a marine turtle) was reported in the Municipality of San Isidro (Garay et al. 2019).



■ Figure 1. Map of Davao Gulf and surrounding municipalities and cities. Created by authors.

Technologies and Necessity for Marine Litter Monitoring

Assessing the composition of marine litter is essential because it provides information about each litter item. Moreover, such data are used as a basis for actions and programs for its mitigation and control. Identifying the type of litter helps determine its source (Galgani, Hanke, and Maes 2015). For example, plastic sachets originate from coastal communities with limited disposable income. Discarded fishing gears and nets come from ships and small boats. Moreover, proper identification of litter can hint at their movement

[4] This area pertains to waters of the Western Pacific Ocean covering Indonesia, Malaysia, the Philippines, Papua New Guinea, Timor Leste and Solomon Islands.

[5] This is a group of aquatic mammals that includes whales and dolphins.

and at the factors that affect their accumulation and distribution. Understanding the sources and factors influencing the generation of marine litter may lead to better waste management practices.

Marine Litter Quantification, Identification, and Mapping

Several technologies have been used and developed for marine litter monitoring over the past years. Since litter can be found in different marine environments—like dry beaches, subtidal zones, benthic areas, and sea surfaces (floating litter)—approaches and equipment for surveying should also vary accordingly. For example, drones are typically used for aerial surveys of floating litter and litter found on beaches. Submersibles or underwater vehicles are employed to investigate which litter tends to settle on the seabed. Table 2 lists the different surveying technologies, and determines which approaches are using AI.

TECHNOLOGY/ EQUIPMENT	TARGET MARINE ENVIRONMENT	AI INTEGRATION	MODE OF AI DEPLOYMENT	PURPOSE	COST (PHP)	COUNTRIES
Trawl	Seabed and sea surface	None	N/A	Quantification,[6] litter collection	1500 –2000	Greece, Cyprus, and Romania
Drones equipped with camera and GPS	Beaches, coastal area, offshore (floating litter)	Object detection algorithm, image classification	Offline	Quantification, litter density, and composition	70,000 – 150,000	Maldives, Saudi Arabia, Canada, Malta, China, Japan
Towed camera system (equipped with various sensors)	Shallow coastal areas	Object detection, object segmentation	Online	Quantification, identification, and mapping	50,000 – 90,000	Philippines and Greece
Satellite	Beaches, sea surface	Image analysis	Offline	Quantification, mapping	Satellite is expensive*	Japan
Balloon	Beaches, sea surface	None	N/A	Quantification, mapping	Unreported	Japan
Fixed wing airplane	Beaches, sea surface	None	N/A	Quantification, mapping	450,000 – 900,000	Japan
Submersible	Underwater	Object detection	Offline	Quantification, identification, and mapping		Japan and Canada

■ Table 2. AMD survey technologies, with/without AI, and their function

6 Quantification refers to counting the pieces of litter.

DEVICE	PURPOSE	COST (IN PHP)
GPS	Geotagging[7]	1,600
Visible Cameras	Image /video capture	4,000
Near infrared camera; Short Wavelength Infrared cameras;	Image capture	20,000
Synthetic aperture radar imaging	Image capture (typically used in satellites)	40,000

■ Table 3: Accessories that can be added to the system for location and image capture.

Drones are by far the cheapest and most accessible technology for AMD monitoring. Off-the-shelf or commercial drones equipped with GPS and camera cost around PhP 70,000–PhP 150,000.

Another alternative is to use mini-drones which may cost around PhP 40,000. Drones capture images and videos of the survey area, which are then analyzed to detect litter. Since the images are geotagged, litter can also be consequently mapped and located. This approach is called offline AI deployment wherein the AI technology for AMD monitoring is not embedded in the drone, and where detection is not done in-situ and in real-time.

Because of their capabilities and affordability, numerous studies have used drones for litter surveys. Protocols on their vary and may be difficult to compare and consolidate. In fact, an AI model developed for a specific drone study performs poorly when used in other research. Fortunately, researchers are currently developing standards and protocols on drone use for AMD monitoring and tracking, so that the collected data are comparable across different surveys (Gonçalves et al. 2022; Fakiris et al. 2022).

For underwater AMD monitoring, submersible and towed systems are the most appropriate. They too are equipped with cameras and GPS. Submersibles are typically used for deepwater surveys, while towed systems are suitable for both shallow and deepwater AMD monitoring. There are several challenges for underwater AMD monitoring, however. First is light attenuation or the inadequate source of light. Second, water in shallow coastal areas can become turbid, which obscures visibility. Third, old litter on the seafloor is sometimes degraded and partially buried. All these contribute to making detection difficult.

A recent technology developed by a team of reserchers headed by Kobayashi (2023) has managed to develop a camera-based system that can be towed. The technology comes from a project, "Cost-Effective Technology for Monitoring and Quantifying Benthic Area covered by Marine Litter in Shallow Coastal Areas," funded through the Department of Science and Technology-Philippine Council for Industry, Energy, and Emerging Technology Research and Development (DOST-PCIEERD).

The technology performs image preprocessing to improve the properties of an image, and then runs AI models for detection and segmentation.[8] The AI models are deployed in the device itself (AI-embedded technology). Thus, most of the AI functionalities happen in real time. The cost of this technology is approximately PhP 60,000. Furthermore, aside from detection, the device can also map litter distribution, again, using AI. With further processing, heat maps showing the extent of pollution and the composition of litters can be created.

Combining different technologies suited for different marine environments provides a holistic approach to AMD monitoring. The data collected and results of the analysis could offer an evidence-supported strategy that can be implemented by local government units. Results from AI models and other sources of data—such as the demographics of inhabitants living near coastal areas, the average plastic waste per individuals, and body of waters emptying to the sea or ocean, among others—can be integrated to create models that will predict the future distribution of litter if nothing is done, identify the main

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7 Geotagging generally refers to a process whereby data, such as images, encode the location where they were obtained.

8 Image segmentation is a computer vision technique that partitions a digital image into discrete groups of pixels—image segments—to inform object detection and related tasks

types of litter, and assess how litter will impact benthic regions and other life forms that depend on them.

Conclusion and Policy Recommendations

The availability of easy-to-use and relatively cheap technologies enhanced with AI capability for AMD monitoring would pave the way to help address the deteriorating problem of marine litter. This can be achieved through the regular collection of up-to-date data about its quantity, distribution, and composition. As echoed in the aphorism, "what we cannot measure, we cannot manage," accurate and up-to-date information about AMD pollution would stimulate solutions. Data would help estimate the extent of the problem, what targets we can pursue (in terms of reducing the amount of litter), and ways to mitigate the input of litter to the marine environment.

Although these technologies need capital outlay, the benefits far outweigh the costs, most especially of which is that marine litter harms our ecosystems, health, and economy. To reduce the burden of adopting these technologies, government and private investments should collaborate, concomitantly continuing the development of AI technology and the reduction of marine litter. Aside from procuring the technologies, an investment on capacity-building should also be made, particularly on equipping individuals with the necessary AI and engineering skills. In doing so, civil society will have the potential to innovate and address emerging challenges brought about by marine litter.

Existing or prospective policies would then include:

1. Add a section or provision in the NPOA-ML about using AI technologies for marine litter monitoring and tracking. This will lead to cost reduction in other respects, since AI technologies can replace manual monitoring, which relies on visual census that is often laborious and time-consuming.

2. Develop guidelines to standardize monitoring and tracking of marine litter across large, hard-to-reach areas, alongside flexible, frequent data collection to obtain up-to-date information on marine pollution. Both can support the promulgation of other policies, ordinances, and laws to control marine litter and protect the marine environment.

3. Enact local laws and/or ordinances that would guide the implementation of marine litter prevention and reduction, and allocate sufficient resources for the development of technologies for such purposes.

4. Amend RA No. 9003 to include provisions that would focus specifically on marine litter and develop training programs to capacitate individuals to produce AI-based technologies.

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