# Monitoring Aquaculture Fisheries Using Sentinel-2 Images by Identifying Plastic Fishery Rings

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## ABSTRACT

Plastics in the marine environment constitute a significant problem globally. It is estimated that almost 8 million tonnes of plastic enter the oceanic ecosystem every year. A high concentration of plastics is found within the Mediterranean Sea, which is approximately 22,000 tonnes. Indeed, the South-East Mediterranean, where Cyprus is located, faces a significant problem with plastic debris. Aquaculture fisheries can contribute to marine debris, especially as a result of storm damage or accidents, as their plastic rings float in the ocean and end up in the coastline. Remote sensing techniques can be used to monitor fisheries and plastic debris in marine settings. More recently, research has focused on the ability to detect plastic litter in the water using remote sensing techniques. This paper examines how temporal series Sentinel-2 satellite images can be used to detect the plastic rings from aquaculture fisheries in the Vassiliko area in the south coast of Cyprus. This detection methodology can be used to manage and monitor fisheries using Sentinel-2 images.

**Keywords:** remote sensing, plastics, fisheries, satellite images, Sentinel-2, spectral indices, spectroscopy

## 1. INTRODUCTION

The United Nations Environment Program (UNEP) and the European Commission define marine litter as “any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment” [1, 2]. The average proportion of plastics varies between 60 to 80% of total marine debris and can reach as much as 90 to 95% of the total amount of marine litter [3]. It is estimated that almost 8 million tonnes of plastic enter the oceanic ecosystem every year [4]. Other estimations reveal that the ocean may already contain more than 150 million tonnes of plastic [5]; around 250,000 tonnes of these contaminants is fragmented into 5 trillion plastic pieces, which may be floating on the oceans’ surface [6]. It has also been calculated that every year, between 4.8 and 12.7 million tonnes of plastic find their way into the ocean from coastal populations worldwide [7], while the Ellen Macarthur Foundation [8] estimates that approximately 25 million tonnes of plastic end up in the ocean. According to [9], plastic debris has now become one of the most serious problems affecting the marine environment, not only for coastal areas of developing countries that lack appropriate waste management infrastructures, but also for the world’s oceans as a whole because slowly degrading large plastic items generate microplastic (particles smaller than 1 to 5 mm) particles which spread over long distances by wind-driven ocean surface layer circulation [10, 11]. Nowadays, the global loading of plastics debris is taking shocking proportions, and is estimated to range from 93,000 to 236,000 metric tons yearly [12].

Although marine litter is a worldwide problem, it has not been adequately addressed in the Mediterranean area [13]. A high concentration of plastics are found within the Mediterranean Sea, with the highest amounts of municipal solid waste generated annually per person of 208–760 kg/year [14-19]. Also, the Mediterranean Sea ranks fourth in the list of oceans with the highest concentration of floating marine litter in the World, with 22,000 tonnes [19-20]. This is due to interaction of a number of factors, including that the Mediterranean is essentially a closed basin with limited exchange of water with the other oceanic bodies, combined with inadequate environmentally sound urban waste management systems, considerable marine vessel transportation in coastal waters, negligible tidal flow and heavily populated coastal areas [4, 20-21]. According to [22], sites along the shores of the Mediterranean show the greatest densities of marine debris in the world. In particular, the Levantine sub-basin, in which Cyprus is situated, has very little interaction with the rest of the Mediterranean [12]. Plastics that enters the sub-basin from surrounding countries (Cyprus, Egypt, Israel, Lebanon, Syria and Turkey) are also washed up on the beaches of these countries [22-23].

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Open-water and shoreline surveys that are designed to assess the distributions of plastic debris in oceans and lakes are time-consuming and costly; in addition, they provide only limited aerial coverage and temporal resolution [24]. Remote sensing techniques can be used to monitor plastic debris in marine settings [22, 24-28]. Research has found that large plastic debris can be identified using unmanned aerial vehicles (UAVs) [31-32]. Several studies have been conducted to examine marine litter in the Mediterranean [22, 33-35]. According to [9], the most likely causes of plastic loss from fisheries are due to extreme weather, poor waste management and installation wear and failure. Extreme weather, mostly in the case of large storms and extreme temperatures, are a major cause of lost debris from aquaculture operations, as they can cause moorings to fail, resulting in cages (e.g. collars and nets) being damaged or destroyed. Fisheries are also vulnerable to damage from marine vessels, especially if they are near a busy navigational route [9]. This study takes place in the Vassiliko area in the south coast of Cyprus, which is a very busy maritime route, as well as having a port for industrial use.

In 2019, the Cyprus University of Technology performed an experiment in Limassol Cyprus to identify floating plastics in the sea by placing a plastic target in the water in the Old Port area [36]. Through the study, the Plastic Index (PI) was developed, which was able to clearly identify plastics in the water using Satellite 2 images. In terms of the findings and the index developed, the author is attempting to use the same technique in order to identify the fishery rings in an effort to monitor the fisheries over time. The PI index will be used since plastic is widely used in aquaculture system components as it is light, reasonably strong and cheap, unaffected by sea water corrosion and can be formed to different shapes, including solid blocks, fibres and films [9]. This paper will examine if the methodology used to identify plastics using the Plastic Index can effectively determine the location of aquaculture fisheries in the south coast of Cyprus. Temporal Sentinel-2 satellite images will be processed using the Plastic Index to identify the aquaculture fisheries over time, in order to monitor any changes, damages and growth.

## 2. AQUACULTURE

High-density polyethylene (HDPE) floating cages are widely used in modern industrial marine aquaculture in many parts of the world owing to the versatility of the materials used, the simplicity in the various farming operations and the relatively contained investment capital required [37]. The main structural elements of these cages are the HDPE pipes, which can be assembled in various ways in order to produce collars of different sizes and shapes. The HDPE pipes, held together by a series of brackets with stanchions disposed throughout the entire circumference, form the floating collar ring, which is the main structure on which the fish net pen is secured. The floater is a flexible structure which is piercing the water surface. The floating collar of a circular fish farm is made of a HDPE type plastic. The floating collar of a circular fish farm typically consists of two concentric HDPE pipes, of which the distance between the centre of pipes are 85cm to 110cm. Typical dimensions are a ring diameter of 51 m and circumference of 160 m. [37].

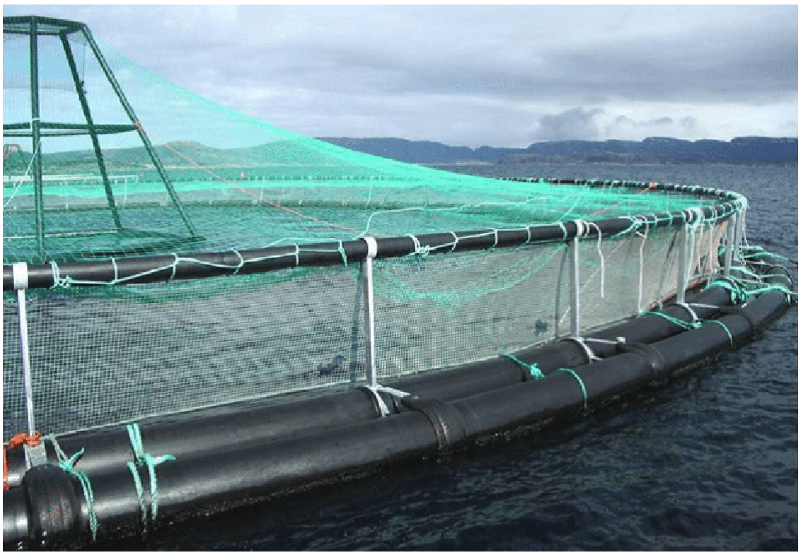

Fig. 1 Floating fish farm with circular plastic collar consisting of two concentric rings.
The photo is taken from [Faltinsen (2011)]. (Photo: SINTEF Fisheries and Aquaculture)

Aquaculture in Cyprus is currently carried out exclusively on the southern coasts of the country and the culture method utilized is open sea cages with circular plastic collars [38]. There are currently nine private offshore cage farms in operation. All marine fish farms are situated in the southern coast of the island [38]. One of them is located in Limassol, seven in the Moni – Vasilikos - Zygi area (east of Limassol) and one in Liopetri (east of Larnaca). Three private marine fish hatcheries are also in operation: one located in Akrotiri (west of Limassol), one in Paphos and one in Liopetri. The ongrowing units in marine fish production operate on an intensive basis, using offshore cages. They are located at a distance of 1-3 kilometres from the shore at water depths ranging from 20-75 meters. The main reasons for adopting this culture method are the strong competition for using coastal land and sea areas and more importantly, the fact that this system is considered to have the minimum impact on the environment and provide the best possible conditions for the fish in terms of animal welfare [38].

Fig. 2 Fisheries (Photo: www.levantinafish.com/)

## 3. METHODOLOGY

This study sought to determine if fisheries in the water off the coast of Limassol Cyprus can be identified through Sentinel 2 satellite images. This also secures that, in cases of damage from accidents or weather, the stakeholders can immediately monitor the status and track and debris that may result from such an incident. Time series Sentinel 2 satellite images of the south coast of Cyprus were processed using the PI index in order to monitor changes in the fisheries over time. The study area is off the coast of the village of Vassiliko, in the Larnaca District in the south coast of Cyprus. Figure 3 shows the fishery that is being monitored in this study, which is circled in red.

Fig 3. Study area circled in red – Vassiliko, Cyprus

### 3.1 Satellite images

The Sentinel-2 satellite is able to generate multispectral data with 13 bands in the visible, near infrared and short-wave infrared part of the spectrum with a spatial resolution of 10m, 20m and 60m. The satellite overpass occurs every five days and provides a systematic coverage of the entire Mediterranean Sea. The Sentinel-2 satellite was employed because (a) it provides free and open data, (b) it provides a systematic overview at the same location since the overpass occurs every five days, which provides the ability to revisit a specific location, and (c), the pixel size of the Sentinel-2 satellite has better spatial resolution from other satellite with freely available data, especially in the visible and NIR bands. Research by [36] study clearly shows that the 10m spatial resolution bands (B04 and B08) can identify a plastic litter target below the Sentinel-2 pixel size, since the PI can discriminate and identify plastic targets of 3m×10m.

Although the fishing collars used in the floating fish farms off the coast of Limassol have a diameter of 50m, the plastic pipe of the perimeter of the fishery is only 110 cm. Despite the small area of the plastic ring, Sentinel 2 images are able to define the geometry of the circular area of the fisheries by using the Plastic Index. In this way, the fisheries can be monitored over time using Sentinel 2 images in order to monitor and identify any movement, damage or growth by fishery owners and stakeholders.

### 3.2 Methodology

The Plastic Index was developed in order to identify plastic bodies in the water from spectral signatures. Spectral signatures show high reflectance in plastics and no reflectance for water in the near-infrared (NIR) domain [39-41]. Research by [36] indicated that plastics have high reflectance in the blue and NIR bands and the water has high reflectance in the blue and low reflectance in the NIR bands. In this study, detection of the plastic rings from fisheries was only examined between 400−900nm. Within this range, the reflectance of plastics is low in the red band, but increases in the infrared bands, where water absorbs all solar radiation and has almost no reflectance [32]. Therefore, fisheries can be identified using B04, B06, B07 and B08 of Sentinel-2 satellite images. The 20m spatial resolution in bands B06 and B07 makes it difficult to detect smaller targets, while B04 and B08 have a 10m spatial resolution, which can detect the objects due to higher spatial resolution.

In this study, four Sentinel-2 satellite images, dated October 6 2017, October 16 2018, October 16 2019 and October 25 2020, were processed using the Plastic Index. The satellite images were then compared in order to identify changes over time. To detect plastic targets by introducing purpose-built relationships, [36] developed the Plastic Index (PI) as expressed by Equation (1) to examine the use of the specific wavelength identified from the spectral signatures.

$$PI = B08 / (B08 + B04) \tag{1}$$

The PI equation was applied to the southern coast of Cyprus, to identify fisheries in the Vassiliko area, which is featured in Figure 3.

## 4. RESULTS

Four Sentinel-2 satellite images from the MSIL1C sensor, dated October 6 2017, October 16 2018, October 16 2019 and October 25 2020, were processed using the PI index, as featured in Figure 4.

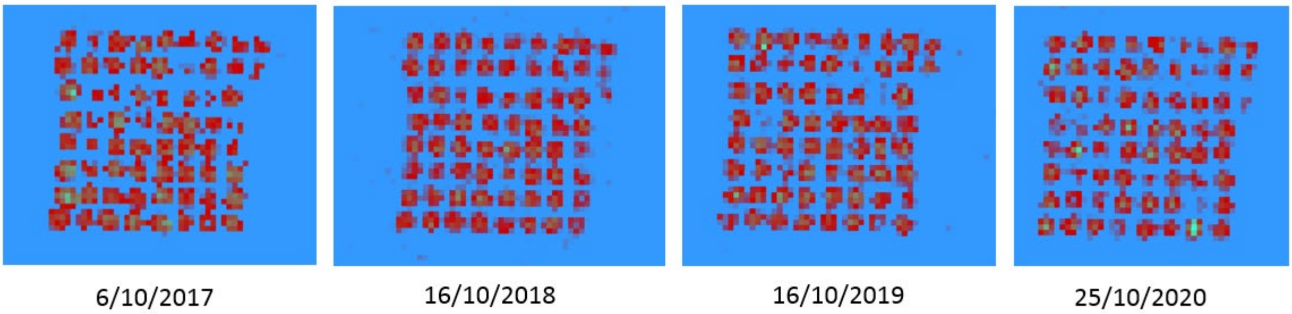


Fig.4 Sentinel-2 satellite images, October 6 2017, October 16 2018, October 16 2019 and October 25 2020, processed using the Plastic Index

As shown in Figure 4, the fishery rings were able to be identified from Sentinel-2 MSIL1C sensor using the Plastic Index without performing atmospheric correction due to the water spectral absorption. It was found that atmospheric correction, the values of water and plastic bodies are absorbed by the atmospheric correction algorithm; therefore, atmospheric correction was not applied [36]. Even though the size of the plastic ring is only 110 cm in diameter, it can be easily detected from the Sentinel-2 satellite sensor. The results indicate that there were no changes to the fisheries in the area of interest during the four-year period between 2017 to 2020.

## 5. CONCLUSIONS

The study found that Sentinel-2 satellite images can effectively identify fisheries rings in the southern coast of Cyprus using the Plastic Index. In this way, the fisheries can be monitored over time by fishery owners and stakeholders using Sentinel 2 images in order to monitor, manage and identify any damage or growth of the fisheries. The study of time-series Sentinel -2 images in this paper showed that the fishery rings had not changed over time. The methodology using the Plastic Index to process Sentinel-2 images can be an effective tool to manage aquaculture fisheries. It can also be used by government agencies to monitor compliance with licenses and permits given to fisheries. One of the limitations of using this methodology is the satellite pixel size of the Sentinel-2 images [30]. Future research can replicate this study by using high resolution satellite sensors (e.g., Planet Imagery, WorldView, GeoEye) to identify and monitor the fisheries and can investigate the use of Sentinel-1 Synthetic Aperture Radar (SAR) images for the identification of fisheries in the seas.

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