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SPACE SOLUTIONS

Delivery Report

Plastic litter detection and Water Quality Monitoring in Monte Carlo, Monaco

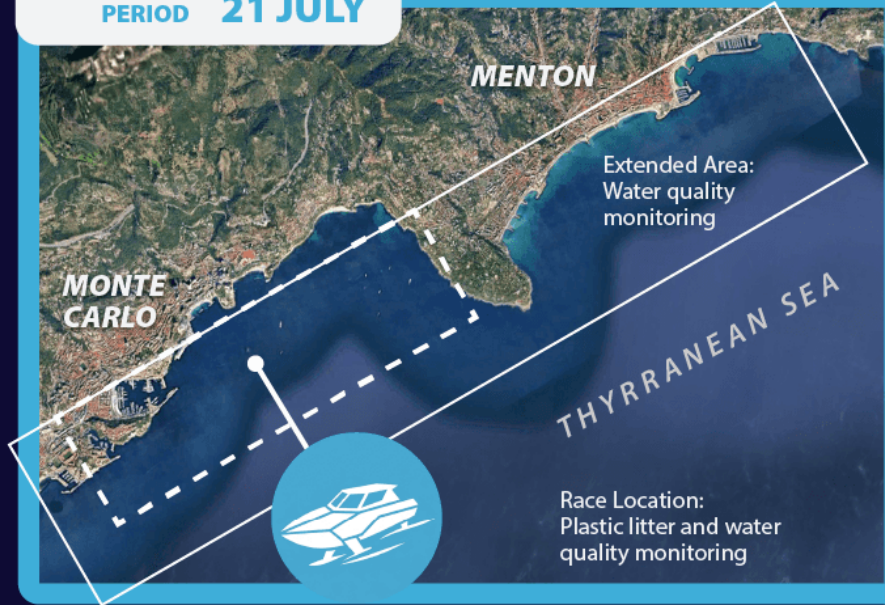
Date: July 24, 2026 | **Client:** ESA/ Angola Westbrook Racing

Authors: Stefan Mühlbauer, Nick Rotter

MONITORING OVERVIEW

JEDDA LAKE COMO DUBROVNIK MONACO LUANDA LAGOS MIAMI BAHAMAS

6 WEEKS
MONITORING
PERIOD
15 JUNE
21 JULY



FLOATING PLASTIC LITTER

TURBIDITY

CHLOROPHYLL

SECCHI DEPTH

HARMFUL ALGAE BLOOM

MONITORING RESULTS

ANALYSED
SCENES

26



TURBIDITY TREND
before and after the race



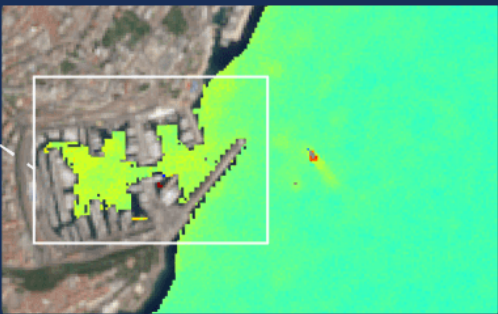
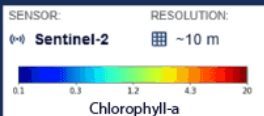
No clear difference can be observed between turbidity levels in the week of racing. Colour difference due to minimal variations.

0 FLOATING
PLASTIC
LITTER

No floating plastic litter patches larger than 10 sqm were found in the monitoring period.

SPECIFIC OBSERVATION

Higher phytoplankton concentrations in the harbour compared to areas in the open water on the 19th June 2026.



Chlorophyll-a

BATHING WATER SAFETY INDEX AT RACE SITE

CRITICAL	•	•	•	•	•	•
POOR	•	•	•	•	•	•
FAIR	•	•	•	•	•	•
GOOD	●	●	●	●	●	●
WEEK	1	2	3	4	5	6
	RACE WEEK					

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1 Location

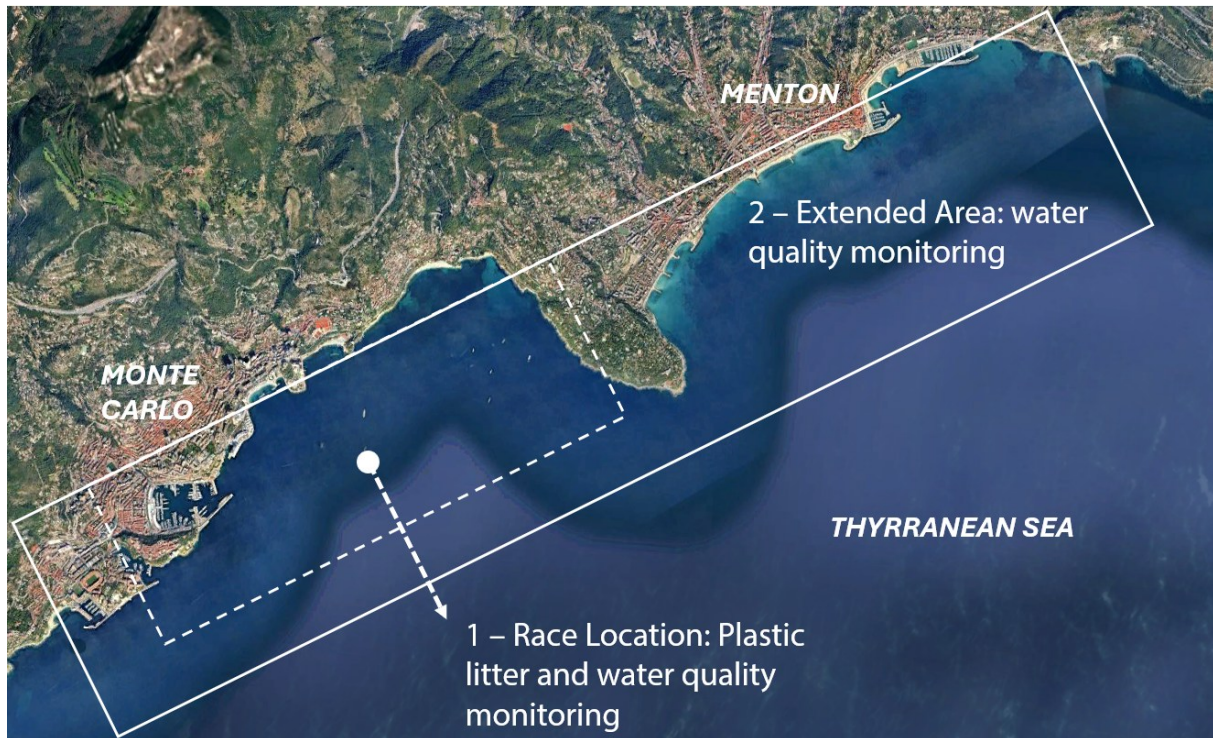


Figure 1: Coastline of Côte d'Azur between Monte Carlo (Monaco) and Menton (France). The box with the dashed line indicates the race location, while the box with the continuous line shows the extended area of water quality monitoring

The race location is located at Côte d'Azur in **Monte Carlo, Monaco**, in the East of Port Hercule and in front of Pointe Focinane.

2 Monitoring sites: The box with the dashed line in Figure 1 indicates the primary race area in front of Pointe Focinane in the Bay of Roquebrune (1 – Race location), while the box with the continuous line indicates the extended monitoring area covering the shoreline from Cap d'Ail until the Italian boarder at Ponte Ludovico (2 - Extended Area). Very high-resolution (VHR) monitoring of plastic litter and water quality was conducted in the Race Location, while water quality monitoring using high-resolution Sentinel-2 and Landsat-8/9 data was conducted in the Extended Area to obtain the big picture.

Coordinates of the race location: 43°44'22.0"N 7°26'05.9"E

2 Data and time frame

Monitoring time frame: 15th June – 21st July 2026

Planet Super Doves: The Planet data have a spatial resolution of 3m (VHR) and a daily repetition rate. The data was used for plastic litter and water quality monitoring in the Race Location in Monaco.

Sentinel-2: Sentinel-2 data have a spatial resolution of 10 m and a revisit frequency of 3 to 5 days and are distributed through the European Copernicus Service. This data was used for water quality monitoring across the Extended Area.

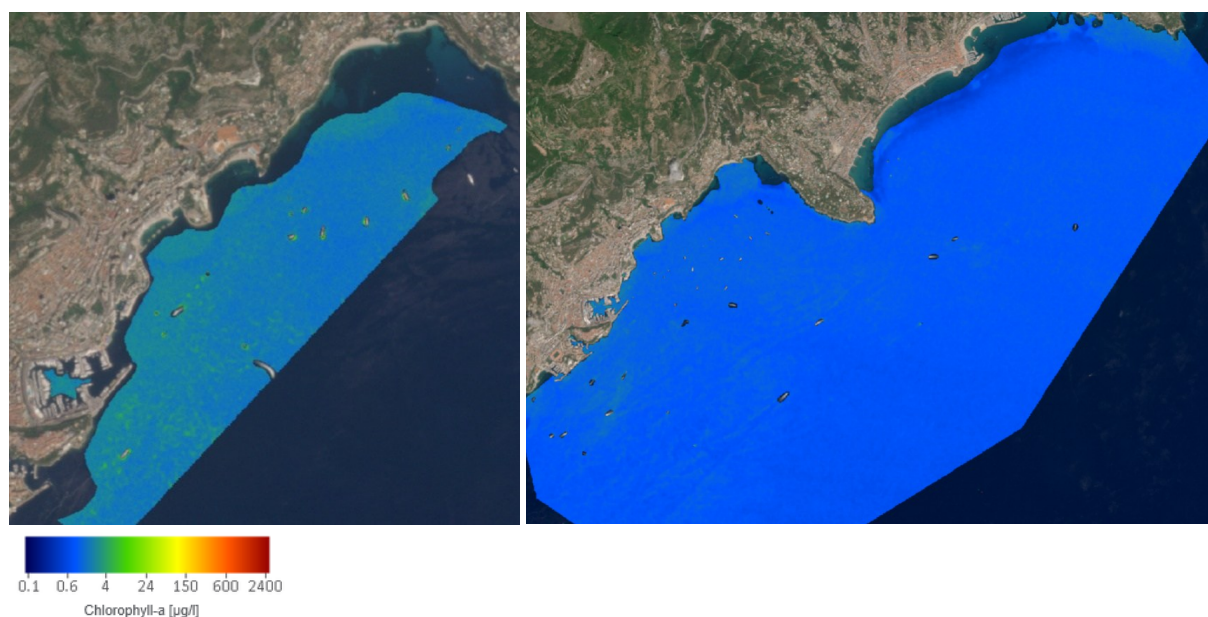


Figure 2: Left - Planet scene from 26th June 2026, 10:22 (UCP) at the Race Location used for for plastic litter and water quality monitoring showing the Chlorophyll product laid on top of the satellite imagery. Right - Sentinel-2 scene from 9th July 2026, 10:28 (UCP) in the Extended Area showing the Chlorophyll product on top of the satellite imagery.

Table 1 shows the collected satellite scenes at the Monaco monitoring sites.

Table 1: Collected scenes for the monitoring sites in Monaco

Sensor	Date, Time (UCP)	Sensor	Date, Time (UCP)
Planet Super Doves	16.06.2026, 10:57	Sentinel-2	17.06.2026, 10:38
	19.06.2026, 10:24		19.06.2026, 10:28
	20.06.2026, 11:00		21.06.2026, 10:29
	23.06.2026, 10:20		27.06.2026, 10:38
	25.06.2026, 10:23		29.06.2026, 10:28
	26.06.2026, 10:22		01.07.2026, 10:29
	27.06.2026, 10:58		02.07.2026, 10:38
	28.06.2026, 11:08		04.07.2026, 10:28
	29.06.2026, 10:21		07.07.2026, 10:38
	04.07.2026, 10:21		09.07.2026, 10:28
	05.07.2026, 10:24		11.07.2026, 10:29
	06.07.2026, 10:22		14.07.2026, 10:28
	07.07.2026, 10:23		19.07.2026, 10:28

3 Plastic litter detection

Plastic litter detection was conducted within the Race Location (Figure 1 – number 1) and is based on Planet data. Across all analysed time steps, no plastic litter detections were identified - indicated by the blue circles that are at the 0-level on the x-axis (Figure 3).

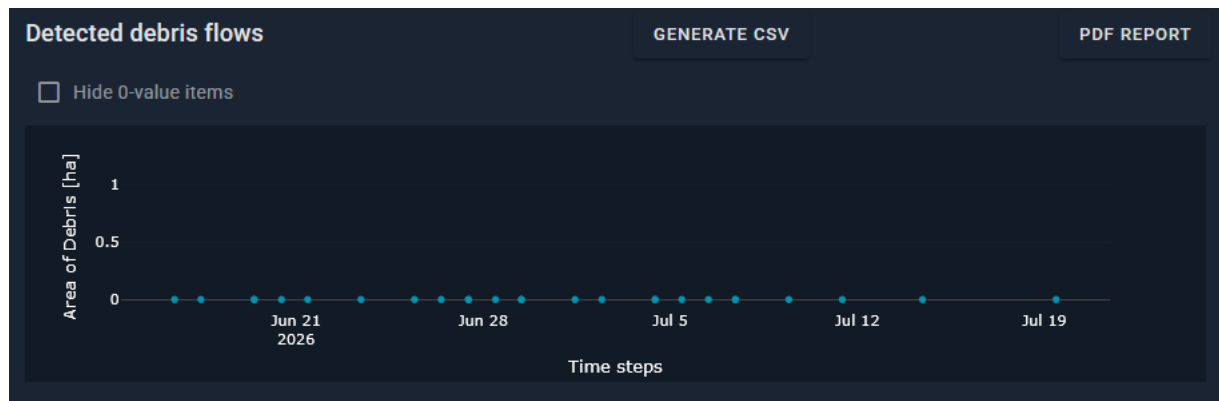


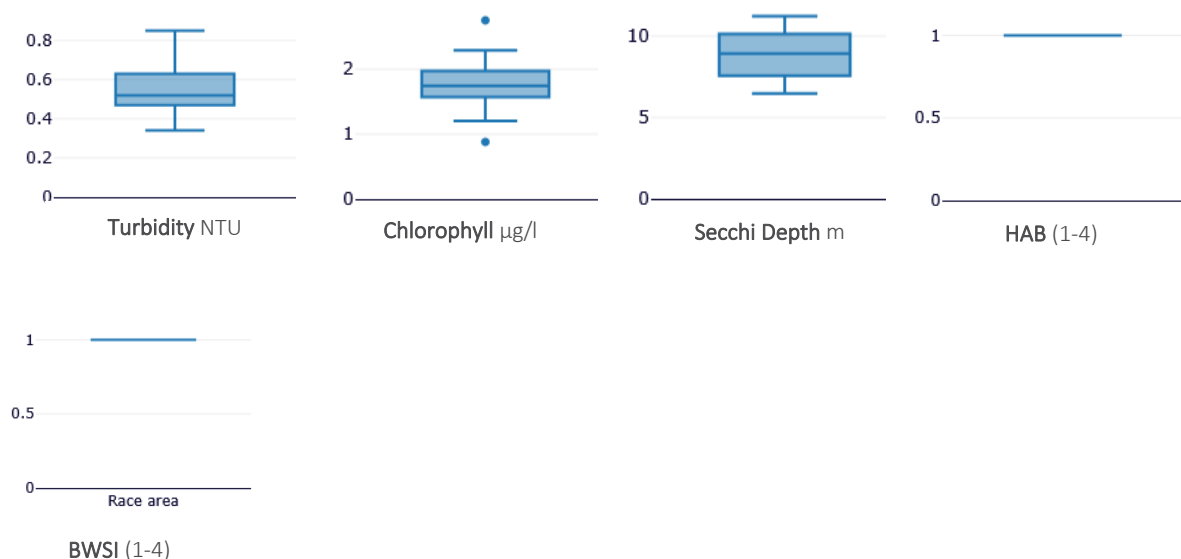
Figure 3: Plastic litter statistic across the monitoring time series

4 Water quality monitoring

Water quality monitoring was conducted in both AOIs of Figure 1. While Planet satellite data are available only for the Race Location, Sentinel-2 data cover the entire Monaco shoreline until the Italian border. For all time steps, the parameters chlorophyll (algae), turbidity, depth of visibility (Secchi Depth), Bathing Water Safety Index (BWSI) and the Harmful Algal Bloom (HAB) indicator were derived.

RESULTS

Boxplot diagrams for the Race Location (Figure 1 – number 1) indicate a slightly higher fluctuation for Secchi Depth, while the one of turbidity and chlorophyll is lower. For turbidity 50% of the measured values settle around 0.5 NTU corresponding to a very low turbidity level and very clear water conditions. This is also reflected by the Secchi Depth with 50% of the values around 9m. Both, the HAB and Bathing Water Safety Index (BWSI) are constantly at the best level (1). The phytoplankton concentration (chlorophyll) shows a median of 1,75µg/l, while an individual scene reached 2,75µg/l.



The five time series plots below present the temporal evolution of the 5 parameters over the full monitoring period. Each plot shows two different spatial aggregations representing the two monitoring AOIs Race Location and Extended Area (Figure 1). For each aggregation, the median pixel value of all pixels within the corresponding AOI was calculated. In general, the overlap between data points from the Race Location and the Extended Area indicate similar conditions across the expanded monitoring location. A description of the plots is included with the caption of each figure.

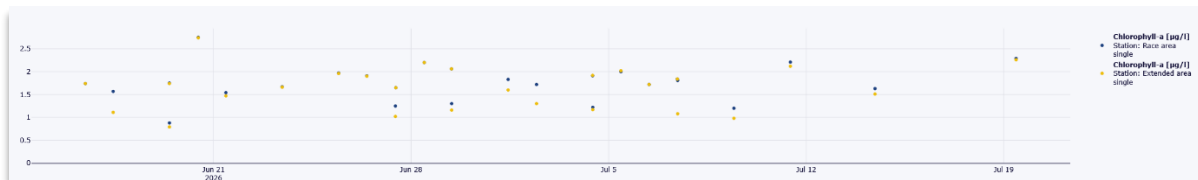


Figure 4: Time series plot for Chlorophyll aggregating the measurements for the Race Location and the Extended Area. The phytoplankton concentrations level around 1.5µg/l. The Extended Area often shows a slightly lower value than the Race Location.



Figure 5: Time series plot for Turbidity aggregating the measurements for the Race Location and the Extended Area. The pattern is similar as for chlorophyll with average values levelling at 0.5 NTU across most time steps and median values being slightly higher for the Race Location than the Extended Area.



Figure 6: Time series plot for depth of visibility (Secchi-Depth) aggregating the measurements for the Race Location and the Extended Area. While the average visibility is 9m, individual scenes show very clear water with visibility down to 11m.

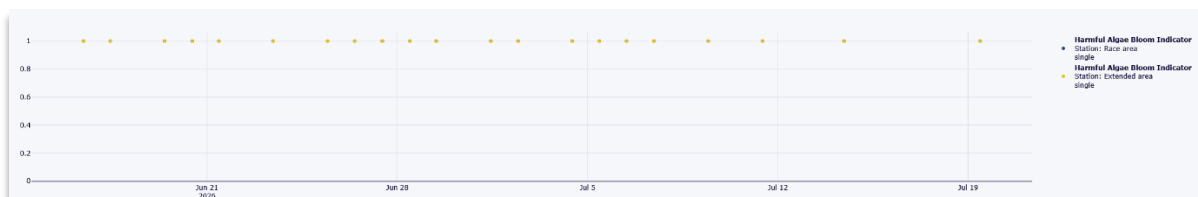


Figure 7: Time series plot for Harmful Algae Bloom Indicator aggregating the measurements for the Race Location and the Extended Area. The average HAB value for the monitoring regions is constantly at the best level.

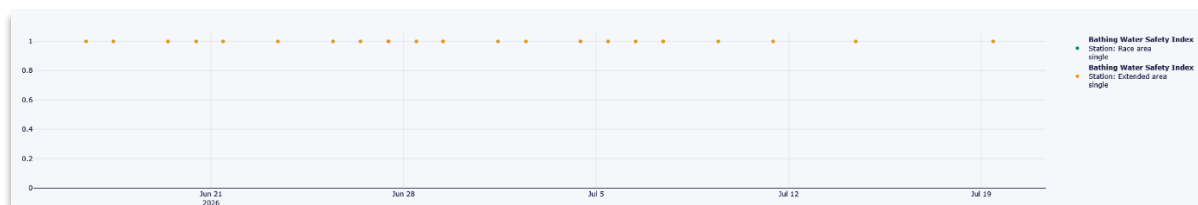


Figure 8: Time series plot for Bathing Water Safety Index aggregating the measurements for the Race Location and the Extended Area. The average BWSI value for the monitoring regions constantly shows excellent conditions.

MAPS - Single scene examples

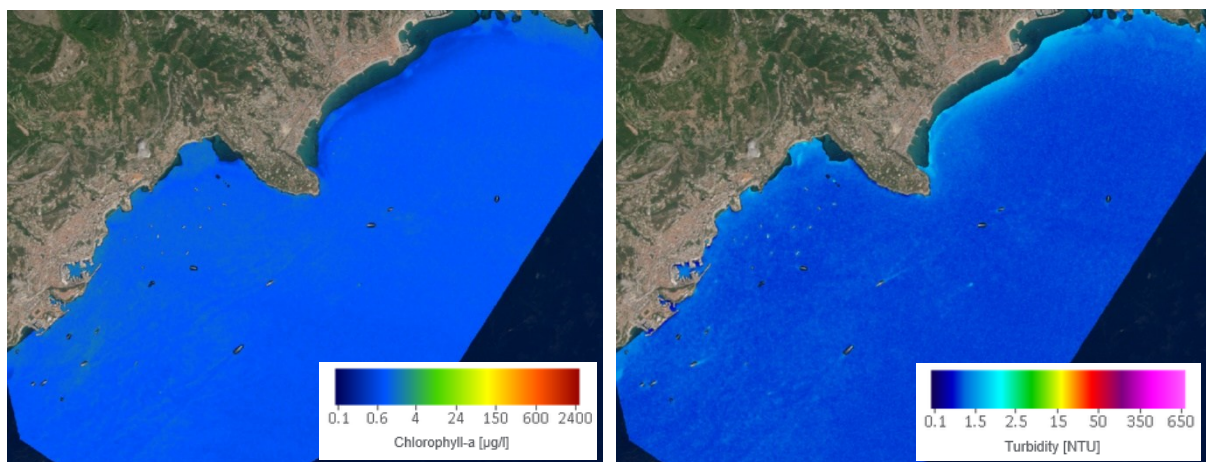


Figure 9: Chlorophyll (left) and turbidity (right) measurements from 9th July 2026. On that day, very low phytoplankton concentrations and turbidity values were registered in the port of Monaco until the Italian border.

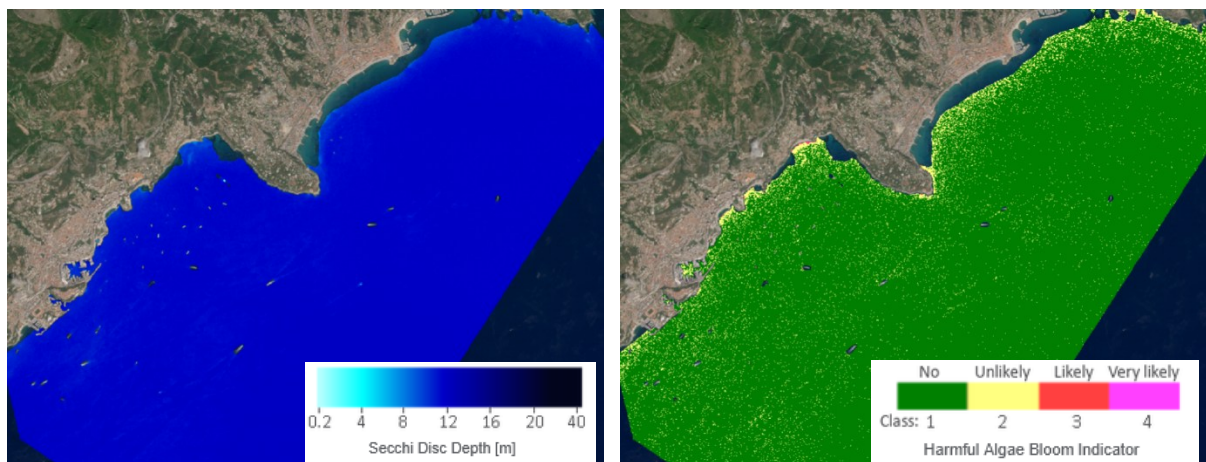


Figure 10: Secchi-depth (left) and HAB (right) from 9th July 2026. The low phytoplankton concentrations and turbidity values result in a high depth of visibility of 11m on average.

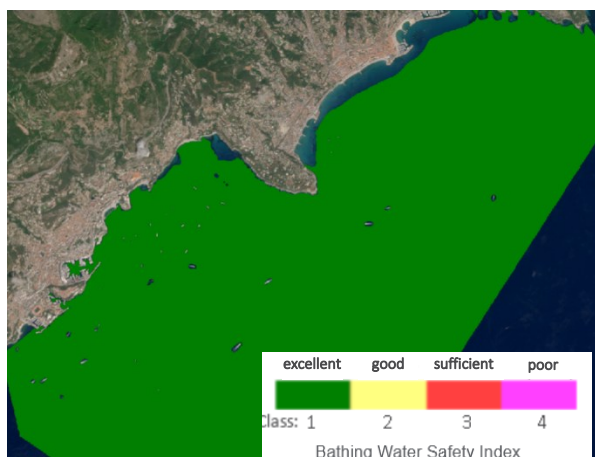


Figure 11: BWSI from 9th July 2026 shows consistently excellent conditions for the monitored area.

MAPS - Turbidity weekly

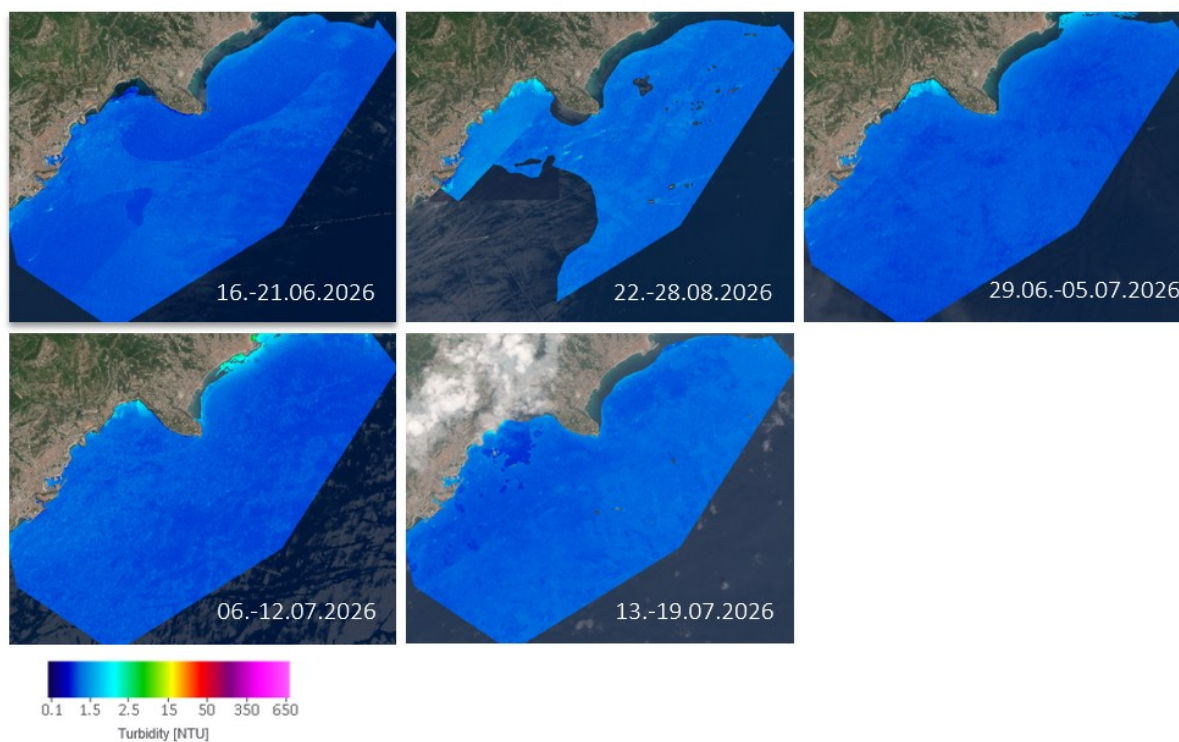


Figure 12: Weekly maps of turbidity

MAPS - Chlorophyll weekly

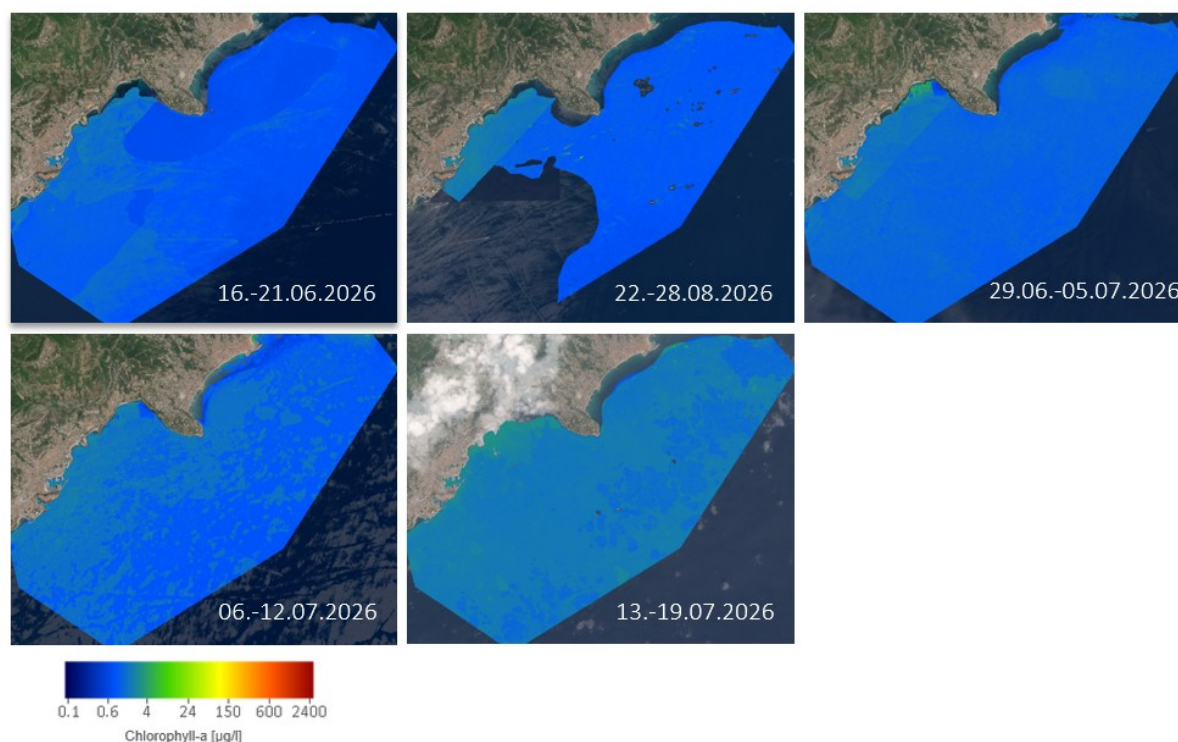


Figure 13: Weekly maps of chlorophyll

DISCUSSION

Chlorophyll

The chlorophyll content for most scenes was around $1,5\mu\text{g/l}$. For most scenes, the average (median) value for phytoplankton was slightly higher in the Race Area compared to the Extended Area, indicating higher phytoplankton concentrations close to the city centre and central port (Port Hercule, Figure 14). On 19th July 2026, higher algae concentrations were measured ($2,75\mu\text{g/l}$) compared to other dates. In general, the low algae concentrations result in a good visibility of the water.

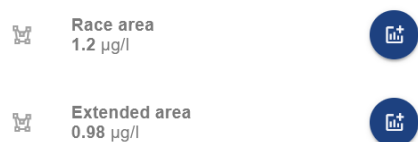


Figure 14: Median value for chlorophyll in the race area (Figure 1 – number 1) and the extended monitoring area (Figure 1 – number 2)

Turbidity

Turbidity measurements exhibit a pattern similar to that of chlorophyll. The turbidity value for most scenes lies below 1 NTU, on average ranging between 0.4 – 0.7 NTU and thus corresponds to very clear water conditions. The race location often exhibits slightly higher turbidity values than the extended

monitoring area, indicating more turbid water conditions in the city centre of Monaco and its Port Hercule. However, the very low turbidity values result in excellent visibility.

Visibility

The average visibility is around 9m for the extended monitoring area, while individual scenes show a visibility of 11m. In the port area or close to the city centre lower values between 8 and 9m are measured. In general, the visibility is excellent, even in the port area, indicating very transparent water conditions.

Harmful Algae Indicator (HAB)

Toxic algae is not expected anywhere in the extended monitoring area across any time step, except nearshore areas close to the shoreline, where the probability remains low.

Bathing Water Safety Index (BWSI)

The Bathing Water Safety Index considers total amount of algae in water, depth of visibility and HAB as input parameters. It classifies pixels into four classes: excellent – good – satisfactory – poor. The conditions in both the Race Location and the Extended Area are consistently excellent.

RACE IMPLICATION - turbidity

To assess the potential impact of the race on water turbidity, five monitoring stations were established at which turbidity values were measured and evaluated (Figure 15). The results are presented in Figure 16. Across all stations, average turbidity values range between 0.4 NTU and 0.7 NTU and thus are very low. Given the scale of the values, the differences between the stations are negligible, as the small differences in turbidity (around 0.2 NTU) are within the accuracy of the measurement. The values on 14th July 2026 before the race are slightly higher than on 19th July after the race. This reveals the race has no impact on turbidity values due to the boat movements. **Consequently, no clear difference can be observed between turbidity levels before and after the race event.** This finding is consistent with the time series analysis and weekly maps of turbidity. Consequently, the race in Monaco including the training phase did not have had a measurable impact on turbidity, Secchi depth, or chlorophyll concentrations.

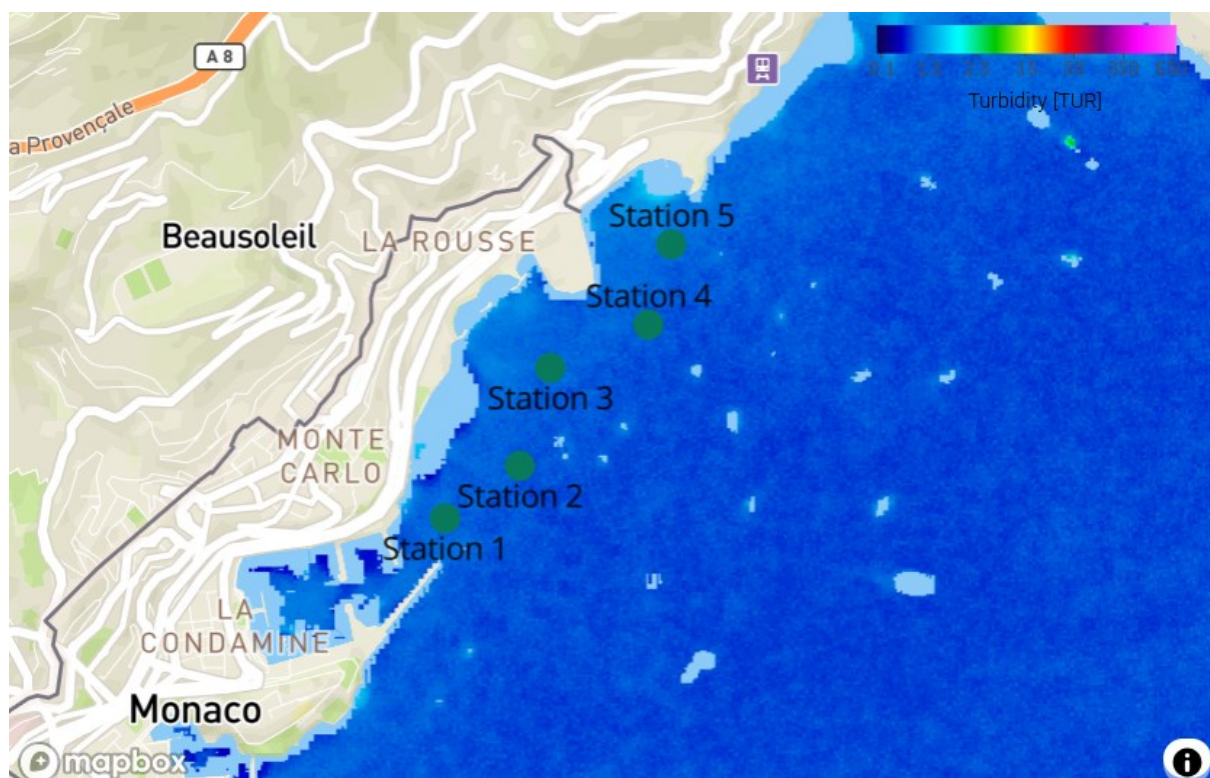
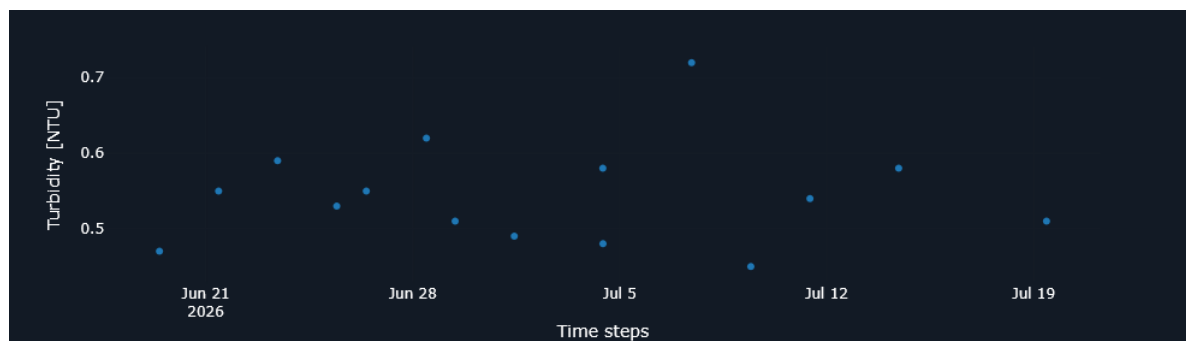


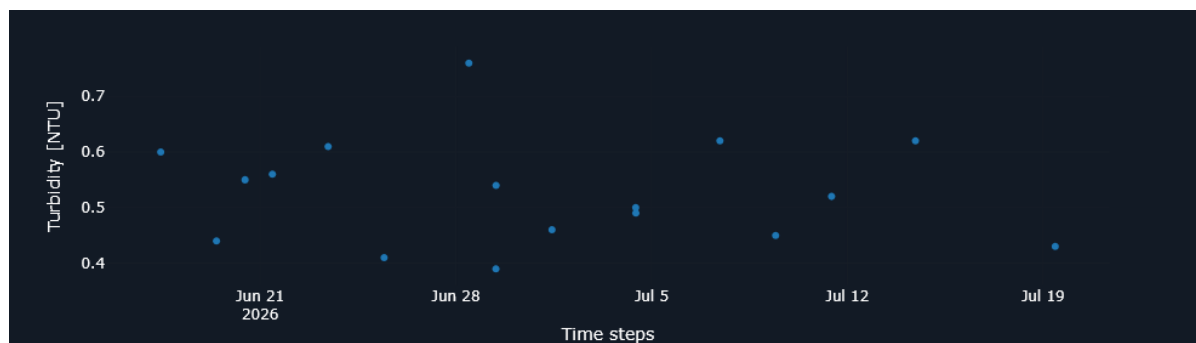
Figure 15: Map indicating the measurement stations for turbidity in the race area

Turbidity measurements for 5 stations

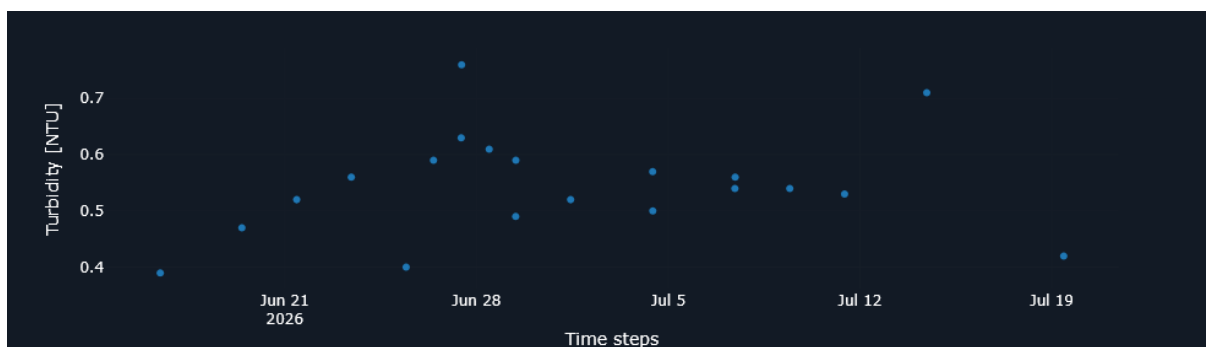
Station 1



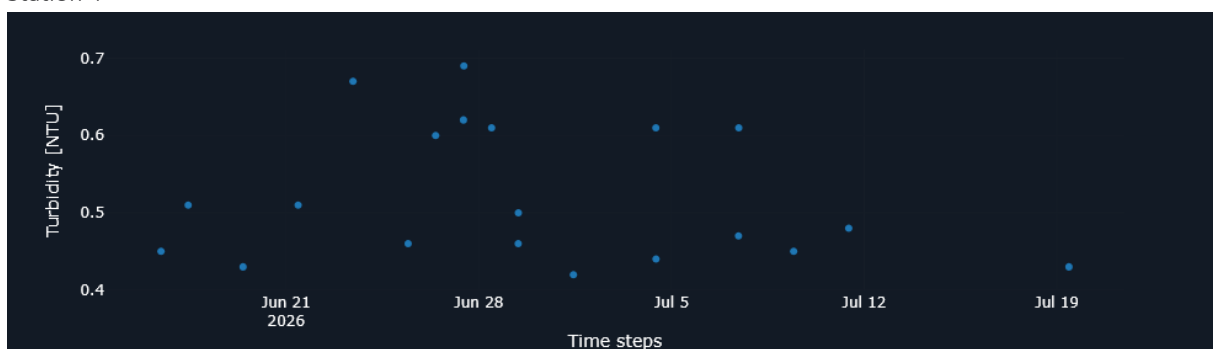
Station 2



Station 3



Station 4



Station 5

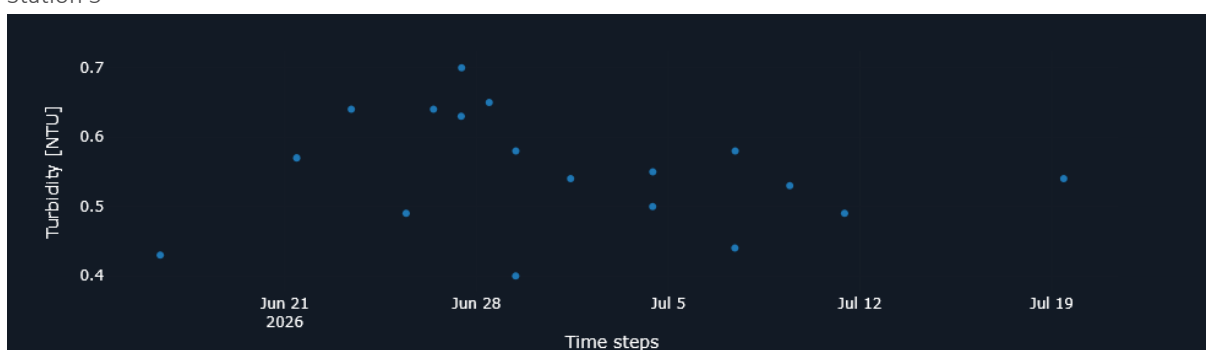


Figure 16: Turbidity measurements at 5 points in the actual race location. The order of panels follows following order from top to bottom: Station 1, Station 2, Station 3, Station 4, Station 5

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Acronyms

Acronym	Description
AOI	Area of Interest
BWSI	Bathing Water Safety Index
HAB	Harmful Algae Bloom

Contact

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