Environmental Systems and Societies: Extended Essay

Variation of dissolved oxygen levels as an indication of maritime pollution according to five different locations in the shoreline of Yalıkavak, Bodrum, Turkey

Word Count: 3998

TABLE OF CONTENTS

IDENTIFYING THE CONTEXT

- Maritime Ecosystems and Their Degradation ... 3
- Effects of Maritime Pollution ... 3-4
- Indicators of Maritime Pollution ... 4
- The Situation in Turkey ... 5
- Personal Connection ... 5
- Research Question ... 5
- Connection Between the Research Question and the Main Issue ... 6
- Hypothesis ... 6

PLANNING

- Material List ... 6
- Table of Variables ... 7
- Procedure ... 7
- Justification ... 8
- Structure of the Aegean Sea Peninsula ... 8-9
- Anticipated Values to Dissolved Oxygen Measurements ... 9
- Risk Assessment and Ethical Considerations ... 9

RESULTS, ANALYSIS AND CONCLUSION

- Raw Data Table ... 10
- Processed Data Tables ... 11
- Statistical Testing ... 11
- Sample Calculations ... 12-13-14
- Processed Graphs of the Experiment ... 14-15
- Discussion ... 15-16
- Strengths ... 16
- Weaknesses ... 16
- Further Study ... 17
- Conclusion ... 17-18

BIBLIOGRAPHY ... 18-19

IDENTIFYING THE CONTEXT

1) Maritime Ecosystems and Their Degradation

Maritime ecosystems are open systems just like any other ecosystem. Energy can enter the system in the form of sunlight, for example, and leave in the form of heat. Matter can enter the system in many ways. Rain falls upon it and leaves by evaporation or streamflow, or animals migrate into the system and leave in the form of decay products.[1] Maritime ecosystems sustain great biodiversity within them and are an undisputable part of human life. With globalization and a drastically increasing human population, pollution has reached peak levels, which is alarming for every individual. According to United Nations, marine pollution is defined as direct or indirect introduction by humans of substances or energy into the marine environment (including estuaries), resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing, impairment of the quality of seawater and reduction of amenities.[2] In other words, it results in toxic water that cannot be used for essential purposes. Eighty percent of pollution to the marine environment comes from the land. One of the biggest sources is called nonpoint source pollution, which occurs as a result of runoff. Nonpoint source pollution includes many small sources, like septic tanks, cars, trucks, and boats, plus larger sources, such as farms, ranches, and forest areas. Millions of motor vehicle engines drop small amounts of oil each day onto roads and parking lots. Much of this, too, makes its way to the sea.[3] Therefore, it would be correct to deduce that as non-point sources of pollution cannot be identified easily, monitoring, and combatting it is a challenging task. To discuss further, correcting the harmful effects of nonpoint source pollution is costly. Each year, millions of dollars are spent to restore and protect areas damaged or endangered by nonpoint source pollutants.[3] That being said, even if it poses a smaller threat than non-point source pollution, point source pollution also continues to harm maritime ecosystems. In order to protect and promote the sustainability of our planet, national authorities and big third-party companies should make more effort by coming up with united responses and conservation plans against sea pollution.

2) Effects of Maritime Pollution

Just like its causes, high sea pollution levels have numerous effects on nature, including human health. Marine pollution forms as a combination of chemicals and trash, most of which comes from land sources and is washed or blown into the ocean. This pollution results in damage to the environment, to the health of all organisms, and to economic structures worldwide.[4] The effects can be outlined under different disciplines.

Chemical contamination, or nutrient pollution, is concerning for health, environmental and economic reasons. This type of pollution occurs when human activities, notably the use of fertilizer on farms, lead to the runoff of chemicals into waterways that ultimately flow into the ocean. The increased concentration of chemicals, such as nitrogen and phosphorus, in the coastal ocean, promotes the growth of algal blooms, which can be toxic to wildlife and harmful to humans. The negative effects on health and the environment caused by algal blooms hurt local fishing and tourism industries.[4] The pollution we cause humans link back to us by harming the practices we rely on for food sources and economic profit.

Marine trash encompasses all manufactured products—most of them plastic—that end up in the ocean. Littering, storm winds, and poor waste management all contribute to the accumulation of this debris, 80 percent of which comes from sources on land. Common types of marine debris include various plastic items like shopping bags and beverage bottles, along with cigarette butts, bottle caps, food wrappers, and fishing gear. Plastic waste is particularly problematic as a pollutant because it is so long-lasting.[4]

This trash poses dangers to both humans and animals. Fish become tangled and injured in the debris, and some animals mistake items like plastic bags for food. Small organisms feed on tiny bits of broken-down plastic, called microplastic, and absorb the chemicals from the plastic into their tissues. In this way, microplastic pollution migrates up the food chain, eventually becoming part of the food that we eat.[4] Biomagnification refers to this condition, where the chemical concentration in an organism exceeds the concentration of its food when the major exposure route occurs from the organism's diet. The term food web biomagnification is used to describe trophic enrichment of contaminants within food webs and refers to the progressive increase in chemical concentrations with increasing animal trophic status.[5] The average person who consumes seafood is also in danger as we eat the product that has integrated microplastics into its body and a result of digestion integrates it into our own body. The same principle can be applied to different trophic chains.

Oceans have suffered a lot at the hands of humans and population growth has increasingly compounded the problem by pushing oceans to their limits and altering ecosystems beyond their natural state. Increase in human population contributed to coral bleaching, sea dumping, overfishing and warming temperatures and therefore risked the seawater quality by increasing the pollution.[6]

3) Indicators of Maritime Pollution

To be able to assess the seawater quality, its indicators are vital as it breaks down into a multitude of measurable factors. Scientists use many different instruments to determine the quality of water, including Secchi disks (measure water clarity), probes, nets, gauges, and meters.[7] Presence of nitrates, sediments, fertilizers, petroleum and radioactive substances all indicate a possible pollution.[8] There are also general observation factors, namely noting down some features like colour, odour, and floating matter.[7]

Among all indicators, dissolved oxygen (DO) is a most important one. Survival of fish and other aquatic organisms ultimately depends on it. DO can be expressed as a concentration per unit volume with the help of a probe, making it a more scientific and measurable indicator.[9] It is also comparable locally enabling to show extent of pollution.

4) The Situation in Turkey

Living in a peninsular country, we rely on the sea for things varying from tourism activities and income to food and welfare. Despite of the importance of our seas, how we treat them forms a great contradiction. As the sea is not a property of an individual, but the general public, we don't engage enough for its conservation as individuals and leave it up to other parties or get discouraged due to other people's carelessness. Furthermore, we don't hesitate to pollute it ourselves, justifying it by others also doing it which is an undeniable disgrace. That being said, our approach to seas and rest of our environment can be explained by the concept: "Tragedy of Commons". A situation in which individuals with access to a public resource (called a common) act in their own interest and, in doing so, ultimately deplete the resource.[10] Unfortunately this mentality is as global as it is local.

5) Personal Connection

My interest in this topic was aroused when I went on a trip to one of Turkey's best tourist attractions Bodrum. In particular, Yalıkavak, which hosts a luxurious facility and generates a great deal of GDP. The city is renowned for its unspoiled natural beauty. On the contrary, things went downhill rather quickly when went sightseeing to a local public beach. The water in the area was polluted by a mixed compound of oil spills, and land runoff, which was even distinguishable to the bare human eye. As I roamed the shoreline, it remained to be seen that the overall pollution was local but very dense. Later in my research, I found out that the beach was in fact deemed as "blue-flagged" by government inspection, which meant that it was perfectly fine to swim in the area. It raised the question of the source of this pollution and whether it had any correlation with "the high season" of the nearby dockyard or yachting activities. I was fairly convinced that operating natures of different areas would directly affect their waste output, which would change dissolved oxygen values.

I also vividly remembered the Mucilage/Sea lettuce crisis we experienced. It was greatly influencing as we couldn't use sea products and sea commutation was called off, we were economically devastated as tourism also took a drastic decrease.[11] I still wondered how our sea protection laws improved since then.

In light of all this, I constructed my research question as the following.

Research Question

How do different locations (a café, a dockyard, a private beach club, a public beach, a marine) in the shoreline affect the dissolved oxygen concentrations in milligrams per litre (mg/L) measured by a digital dissolved oxygen probe as an indication of seawater pollution in Yalıkavak, Bodrum, Turkey?

Connection Between the Research Question and the Main Issue

The main issue of the assessment is sea pollution. There are many previously listed ways to measure, monitor and evaluate water quality. The dissolved oxygen method does not require any expensive machinery or complex procedures. Therefore, there can't be any error due to my inexperience and the experiment will not be costly. DO measurements are simple with the digital probe, and it also has very low uncertainty. Dissolved oxygen as an independent variable varies spatially and makes a dependent variable of different places appropriate. It enables me to investigate a variation in seawater quality in an area where any other interfering factors would be very similar if not the same. Dissolved oxygen can greatly vary in the place of the experiment even if it's the prerequisite of life in the region. As it is a vital parameter of water quality in aquatic systems, it manifests itself as a key test of water pollution.[12] Therefore, this specific question will clearly address the main issue and form a worthwhile conclusion.

Hypothesis

The lowest concentration of dissolved oxygen will be measured near the shoreline of the dockyard due to substantially intense and frequent human activity in the area.

PLANNING

Material List

25 x 500mL medium sterile cups (±25mL)

1 x 500mL big wide-ended beaker (±5mL)

1 x 15cm long ebonite stick (±0.5cm)

1 x digital dissolved oxygen probe (±0.005mg/L)

Table of Variables

Type of Variable	Name of Variable	Measurement of Variable	Additional Explanations
Dependent Variable	Different locations along a shoreline (near a café, a dockyard, a private beach club, a public beach, a marine)	-	The water sampling and evaluation will be made from five different areas. The different areas will make discussing the variation possible and extend the purpose and comprehension of the research.
Independent Variable	Dissolved oxygen concentration (±0.005mg/L)	mg/L (with a dissolved oxygen probe)	Sea pollution measurements break down to a multiple of variables. Dissolved oxygen will be measured to reach census. All obtained values will be measurable, comparable and scientifically based. Usage of digital apparatus will increase ease of operation and data confidence. Furthermore, being able to show a changing trend with respect to locations will allow interpretations.
Constant Variable	Tools, equipment, specific date, time and amount of sampling and measurement.	Digital DO probe, medium sterile cups, 22 July 2022 noon, 500±25mL	All samplings and measurements will be made with same tools specifically in daytime during July. Therefore, seasonal and daily variations won't disrupt the fair comparison. The tourism season will yield more tangible changes as human activities are more intense and frequent.

Procedure

1) Take one medium sterile cup and take six steps (averaging 5 meters) from the land into the sea.
2) Fill the cup to its highest measurement (500±25mL) with water from the depths of the sea.
3) Go to the shore and transfer the water to the big wide ended beaker by pouring it.
4) Mix the water sample in the beaker with an ebonite stick, dispose of the sterile cup after transfer.
5) Test the water sample for concentration of dissolved water by injecting the dissolved oxygen prop in it until the displayed value becomes constant and write down the reading in milligrams per litre.
6) Repeat the four more times to a total trial of five. Wait five minutes between each repetition.
7) After concluding the fifth measurement, move to another location and repeat the process from the beginning four more times, that is, until all locations are covered.

Justification

The experiment requires making first hand measurements for seawater quality and then evaluates how they change in different places and relate to safe values. Furthermore, each measurement corresponds to a single measurable and comparable independent variable. Five different places will show different usages and operating natures, ensuring a variation in the measured value of the independent variable. Namely, it is highly probable that the oxygen levels will not be very low near a café, but it can be lower near dockyard facilities. Measurements will be carried out five times for each location and their arithmetic mean will be used for a precise conclusion. Although not ultimate, this strong abiotic indicator of seawater quality will form a direct statement on living conditions and pollution in the ecosystem by how much oxygen supply is available in the area.

All samples are automatically samples of a bigger ecosystem, the Aegean Sea. They have to comply with the general range and limits there. In other words, concentrations of dissolved oxygen should follow a similarity in minimum and maximum values of the Aegean. Still, they can't be identical or sometimes be far apart then anticipated as ecosystems are dynamic and conditions change spatially.[13] At this point, I believe Yalıkavak to have the most extreme values on the Turkish shores of the Aegean Sea approaching to that of a polluted system. This is still an assumption based on common sense that is strengthened by my personal experiences, but still lacks objective research. This claim can be justified by presence of many dockyards operating, an enormous marine facility, luxurious hotels, entertainment venues, more importantly a drastically high population during summer. They all form the general factor of increased frequency and intensity in human activities. The activities and density of the society are dominant over the pollution levels alongside their values and education. However, the societal structure of Aegean becomes very diverse and complex during the time of experiment due to the peak of tourism and trade activities. Regardless, the strong correlation between tourism activities and pollution can be pursued as Bodrum alone has attracted many guests and hopes to attract 1.5 million foreign tourists in 2022, exceeding the pre-pandemic figures.[14]

All round, the entire procedure will be scientifically to comment on the aerial pollution as it derives its power from focused and relevant data.

Structure of the Aegean Sea Peninsula

The cradle of two great ancient civilizations of Crete and Greece, the source of Western culture, the Aegean Sea is also naturally important. It possesses several unique characteristics that make it of considerable scientific interest.[15]

Salinity: The Aegean Sea, like the Mediterranean Sea in general, is the most impoverished large body of water known to science. The nutrient content, as indicated by the amount of phosphates and nitrates in the water, is on the whole poor.[15] The salinity is between 39.1%-39.2% according to Water Database.[16] This is considered very salty, due to great evaporation rate and low freshwater runoff in the area.[17] Salinity is not directly connected to the experiment, however, the extraordinary salinity influences the dissolved oxygen in the sea. As salinity increases, dissolved oxygen exponentially decreases.[18] This justifies the generally lower values of dissolved oxygen throughout the experiment when compared with an average sea.

Dissolved Oxygen: The concentration of dissolved oxygen in ocean water is typically between 7-8 milligrams per Litre (mg/L). If concentrations fall below 4 mg/L, organisms will begin to react with mobile forms either avoiding or migrating out of the area.[18] As previously discussed, the high salinity of Aegean influences dissolved oxygen drastically, meaning that lower values spatially can be expected, especially further from the shores.

Anticipated Values to Dissolved Oxygen Measurements

Pollution Indicator	Anticipated Range	Average Value	Percentage Uncertainty	Method
Dissolved Oxygen (mg/L)	4.4-8.5	7.1	<±0.0001% (negligible)	Winkler's Titration Method

Table 1: This table shows typical values of dissolved oxygen concentration in the Turkish shores of the Aegean Sea based on a profiling study made in the summer of 2017.[19]

Risk Assessment and Ethical Considerations

As the procedure was simple and eco-friendly, there were little to no risks involved. All the samples were taken from safe places clear from rocks dangerous surfaces that could cause injuries. The samples only included water and all the disposable items were thrown into recycling bins and disposed of correctly after usage.

RESULTS, ANALYSIS AND CONCLUSION

Raw Data Table

Locations	Trials	Dissolved Oxygen Concentration (±0.005mg/L)	Volume of Sampled Seawater (±25mL)
Shoreline of the Cafe	1	7.580	500
	2	7.590	
	3	7.580	
	4	7.590	
	5	7.590	
Shoreline of the Dockyard	1	7.330	500
	2	7.350	
	3	7.350	
	4	7.340	
	5	7.340	
Shoreline of the Private Beach Club	1	7.920	500
	2	7.920	
	3	7.920	
	4	7.930	
	5	7.920	
Shoreline of the Public Beach	1	6.880	500
	2	6.900	
	3	6.900	
	4	6.900	
	5	6.950	
Shoreline of the Marine	1	7.760	500
	2	7.720	
	3	7.720	
	4	7.580	
	5	7.720	

Table 2: The raw data table of the experiment shows the dissolved oxygen concentration measured in all of the five different places in each trial. A variable kept controlled throughout the experiment is also given alongside.

Processed Data Tables

Locations	Mean Dissolved Oxygen Concentration (±0.005mg/L)	Standard Deviation of Dissolved Oxygen Concentrations	Variance of Dissolved Oxygen Concentrations
Shoreline of the Cafe	7.586	0.00490	0.0000240
Shoreline of the Dockyard	7.342	0.00748	0.0000560
Shoreline of the Private Beach Club	7.922	0.00400	0.0000160
Shoreline of the Public Beach	6.906	0.02332	0.000544
Shoreline of the Marine	7.700	0.06197	0.00384

Table 3: This table shows the processed values of the independent (desired) variable dissolved oxygen concentration encompassing all the five different places of sampling. For statistical purposes, standard deviation and variance were used which are the most common features to illustrate data spread and distribution.

Statistical Testing

Hypotheses	Explanation
Null hypothesis ***(H_0)*** True if p-value ≥ 0.005	Samplings in five different places has no significant difference in dissolved oxygen concentrations measured.
Alternative hypothesis ***(H_1)*** True if p-value < 0.005	Samplings in five different places has a significant difference in dissolved oxygen concentrations measured.

Table 4: This table shows the hypothetical outcomes for the one-way ANOVA test.

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F-critical**
Between Groups	3.0145	4	0.7536	672.8714286	<0.0001	2.8861
Within Groups	0.0224	20	0.0011			
Total	3.0369	24	0	0	0	0

Table 5: This table features the important calculated values of the ANOVA results. Using the decision rule, F, 672.87143 is greater than the critical value of 2.8661. It is also seen that the p-value smaller than 0.005 as it should be. Both outcomes obey the alternative hypothesis. These results indicate a statistically significant rate between the five different places and the dissolved oxygen concentrations they have, showing a clear link between the dependent and independent variables.

Sample Calculations

Arithmetic Mean: The arithmetic mean is the sum of all observations in the data set divided by the total number of observations; therefore, it produces an average for a dataset. If we were to calculate the arithmetic mean of the dissolved oxygen concentration recorded in the shoreline of the marine, the procedure would be what follows:

$$\overline{X}(Arithmetic\ Mean) = \frac{sum\ of\ values}{number\ of\ values} = \frac{7.76 + 7.72 + 7.72 + 7.58 + 7.72}{5} = 7.7\ mg/L$$

Standard Deviation: Standard deviation is a measure of the amount of variation or dispersion of a set of values. A low standard deviation indicates that the values tend to be close to the mean (which is more favorable as it shows the experiment is appropriately designed) of the set, while a high standard deviation indicates that the values are spread out over a wider range. If we wanted to calculate the standard deviation of the trials of the dissolved oxygen concentrations recorded in different trials in shoreline of the café, the procedure would be what follows:

$$\sigma\ (Standard\ Deviation) = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

$$= \sqrt{\frac{(7.58 - 7.586)^2 + (7.59 - 7.586)^2 + (7.58 - 7.586)^2 + (7.59 - 7.586)^2 + (7.59 - 7.586)^2}{5-1}}$$

$$= \sqrt{\frac{0.000119999999999999}{5}} = \sqrt{2.3999999999999 \times 10^{-5}} = 0.0048989794855663$$

$$\approx 0.00490$$

Variance: Variance is a statistical measurement of the spread between numbers in a data set. More specifically, variance measures how far each number in the set is from the mean, thus from every other number in the set. The variance is the square of the standard deviation but also has a distinct formula. To exemplify we know that the standard deviation of the measured dissolved oxygen levels in the shoreline of the cafe is about 0.00490, therefore its variance can be calculated from standard deviation as its square or just removing the root from the standard deviation formula.

$$\sigma^2(Variance) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$$

$$= \frac{(7.58 - 7.586)^2 + (7.59 - 7.586)^2 + (7.58 - 7.586)^2 + (7.59 - 7.586)^2 + (7.59 - 7.586)^2}{5-1}$$

$$= \frac{0.000119999999999999}{5} = 2.3999999999999 \times 10^{-5} \approx 0.0000240$$

One Way Analysis of Variance (ANOVA) Test: ANOVA is an analysis tool used in statistics that at the simplest level compare the means of multiple groups of data. Ultimately, they measure the degree to which levels and groups of an independent variable differ from each other. As there is only one independent variable, a one-way analysis is appropriate within the assessment. This analysis has multiple layers as seen below.

1: Defining the Null and Alternative Hypothesis

$(H_0) Null\ Hypothesis;$

$\mu_{cafe} = \mu_{dockyard} = \mu_{beach\ club} = \mu_{public\ beach} = \mu_{marine}\ (all\ groups\ are\ equal)$

$(H_1) Alternative\ Hypothesis;$

$\mu_{cafe} \neq \mu_{dockyard} \neq \mu_{beach\ club} \neq \mu_{public\ beach} \neq \mu_{marine}\ (all\ groups\ are\ not\ equal)$

2: Stating the Alpha

$\alpha = 0.05\ (standardized)$

3: Calculation of Degrees of Freedom (df)

$df_{Between} = total\ different\ levels\ of\ dependent\ variable(a) - 1 = 4$

$$df_{Within} = total\ number\ of\ values\ for\ all\ levels\ of\ depedent\ variable(N) - a \\ = 25 - 5 = 20$$

$df_{Total} = N - 1 = 25 - 1 = 24$

4: Stating Decision Rule

$Critical\ Value: Two\ different\ degrees\ of\ freedom\ are\ looked\ up\ from\ critical\ value\ matrix$

$If\ F\ is\ greater\ than\ 2.8661, reject\ the\ null\ hypothesis$

5: Calculating Test Statistic

$(Sum\ of\ Squares)\ SS_{Between}:$

$$\frac{\sum(\sum a_i)^2}{n(number\ of\ values\ for\ one\ level)} - \frac{T^2(square\ of\ sum\ of all\ values)}{N(number\ of\ all\ values\ of\ dependent\ variable)}$$

$$= \frac{37.93^2 + 36.71^2 + 39.61^2 + 34.53^2 + 38.5^2}{5} - \frac{187.28^2}{25} = 3.014464 \approx 3.01$$

$SS_{Within}:$

$$\sum Y^2(square\ of\ every\ individual\ value) - \frac{\sum(\sum a_i)^2}{n}$$

$$= 1405.9888 - \frac{37.93^2 + 36.71^2 + 39.61^2 + 34.53^2 + 38.5^2}{5} = 0.0224$$

$SS_{Total}:$

$$\sum Y^2 - \frac{T^2}{N} = 1405.9888 - \frac{187.28^2}{25} = 3.036864 \approx 3.04$$

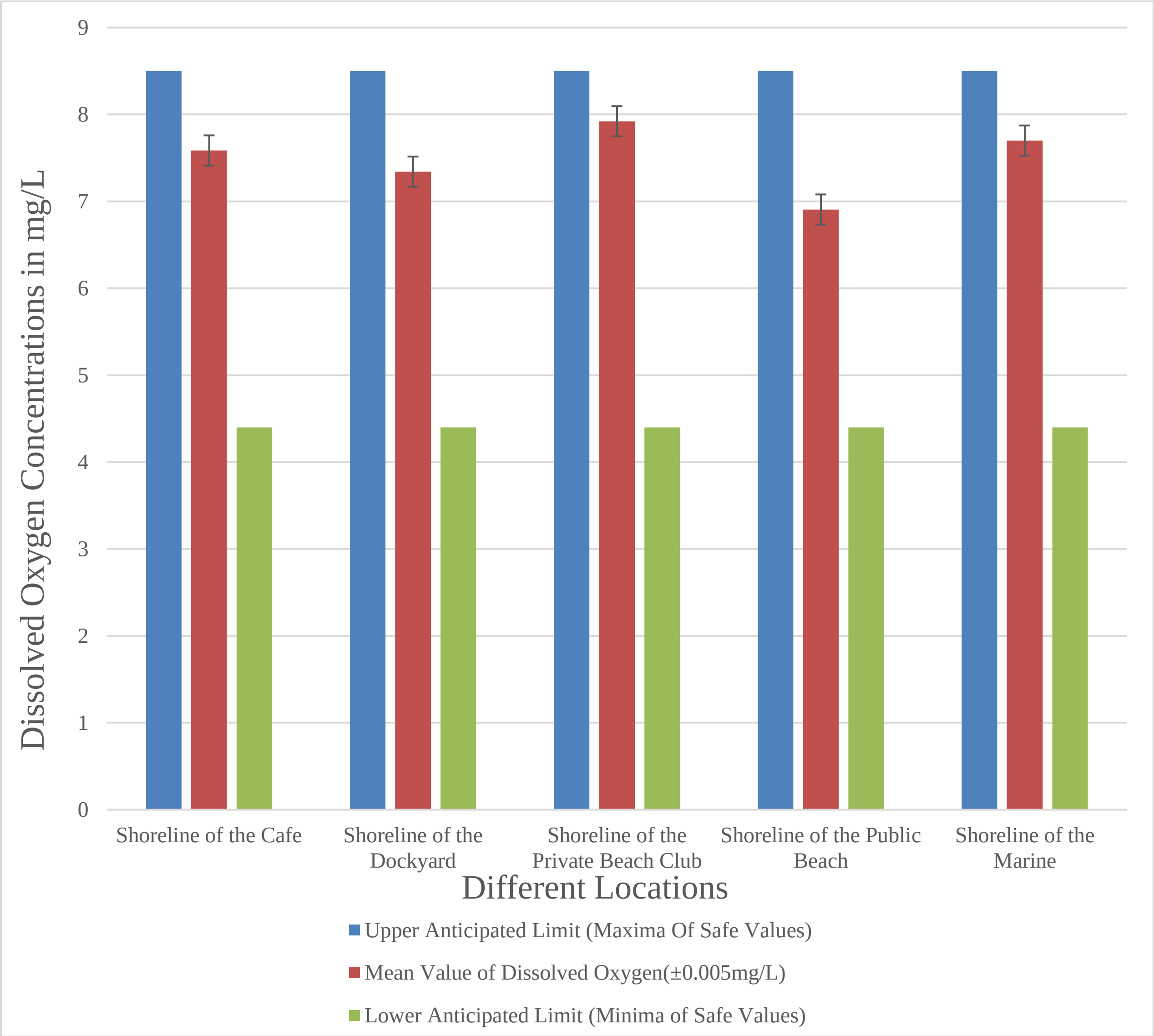
$$MS = \frac{SS}{df}$$

$$\therefore MS_{Between} = \frac{3.014464}{4} = 0.753616 \approx 0.754 \quad and \quad MS_{Within} = \frac{0.0224}{20} = 0.00112$$

$$F = \frac{MS_{Between}}{MS_{Within}} = \frac{0.753616}{0.00112} = 672.8714286 \approx 673$$

Processed Graphs of the Experiment

Graph 1: This line graph illustrates the relationship between different areas and their dissolved oxygen concentration in mg/L which is the research question of the assessment. As the profiling studies and decided safe limits have very low uncertainties especially compared with my measurements, they will be neglected. Upper and lower limits which were discussed previously and given in Table 1 are entertained, showing all values are healthy even in Aegean standards. Seeing a trend among different places with the help of a dotted trend line is possible in this line graph.



Graph 2: This chart graph also shows the fluctuation of dissolved oxygen concentrations. Differently, it is more focused on highlighting individual values for locations and their relationship with anticipated values.

Discussion

All of the values were measured successfully. Firstly, the shoreline of the café had 7.586mg/L dissolved oxygen which was normal but might be slightly affected from the human waste. The shoreline of the dockyard had 7.342mg/L dissolved oxygen which showed a slight reduction of oxygen, showing that there might be intermediate pollution. The private beach club had 7.922mg/L dissolved oxygen, which was very favourable, as it had the best quality seawater among all. The public beach had an alarming value of 6.906mg/L dissolved oxygen, making it the most unsuitable for biological life. The shoreline of the marine had 7.7 mg/L dissolved oxygen, which was also favourable considering the density of ships and human population in the area. All values are influenced by the saline nature of the Aegean Sea. Despite the prior learning and considerations, the hypothesis was rejected.

Standard deviation was very low within each place of sampling, showing that the data was reliable. It can also be supported with literature work.

Strengths

Strength	Why is it a strength?
Usage of a digital dissolved oxygen probe	All the measured values had low uncertainties and errors were neglectable. Readings were also concise in three significant figures.
Significance of each different place of sampling	The assessment's main objective was recording a discernible difference in dissolved oxygen concentration in a bigger ecosystem, which was possible because each chosen place had appropriate operating nature and significance.
Five different samplings used for measurements	Taking different samplings in single area minimized random errors and showed the comprehensive mean value of a greater extent of the intended area.

Table 4: This table exemplifies the strengths of the experiment and comments on their significance.

Weaknesses

Weakness	How did it influence the assessment?	Possible improvement
Inevitable contact between the water sample and air	As the water contacted atmospheric air, some of the oxygen within the sample escaped, causing a systematic error.	Closed containers might be used while sampling and measurements could be made in a laboratory. Better yet, a diving gear and dissolved oxygen sensor might be used to make a more instantaneous testing of the environment.
Testing a single abiotic condition	A single variable was used to form a census on a bigger concept, seawater pollution. Consequently, my investigation lost comprehensiveness.	Other variables such as salinity, pH, turbidity, and temperature could be included into the assessment for stronger data and therefore a conclusion.
Lack of testing for any biotic indices	Biotic indices are prominent to monitor the effects of pollution. Therefore, there was no indication of the different extents of pollution and how it affected local biological life.	Presence or population density of indicator species such as aquatic earthworms, crayfish or freshwater shrimp could be monitored.

Table 5: This table exemplifies the weaknesses of the experiment and comments on their effects alongside some proposals to improve them.

Further Study

There are specific reasons for the dissolved oxygen fluctuation with respect to different places, and I was able to uncover some of them.

The shore of the dockyard had the second lowest dissolved oxygen concentration. The prominent reason for that is probably the increase in algae growth due to excessive phosphorus released into the sea by the ships. Heavy metals or petroleum leaking from the ships will strengthen this effect. As the dockyard was operating during the time of sampling, I talked with the dockmaster. The data of released/accepted ships indicated that the dockyard was especially busy this time of year. He added that the operation was eco-friendly, and they were under effective strict supervision, which showed with the safe values. However, the sound pollution was extreme, which isn't in the scope of the assessment but still harmful for animals nearby.

The beach club charges extensive fees for environmental servicing. Usage of biodegradable cups and straws are mandatory which might be a reason of their difference of water quality especially when compared with café and public beach.

The free-of-charge public beach was crowded. As everyone brought their own food, beverages and etc. there was high litter which wasn't systematically disposed of like the café or the beach club. Suspended waste on the sea was frequently observed, which contribute to pollution by dissolving. This increases the mortality rate of sea animals and decrease biodiversity. This can even pose a serious local threat if this problem persists.

I personally anticipated lower values in the marina. Multi-story yachts are common sight, and it is impossible to see a vacant place among the 620 berths and 140 dry docks available.[19] The monstrous yachts rely on multiple combustion engines to function, producing devastative amounts of waste. After researching the advanced technology of the marine and high funding dedicated to environmental service,[20] I grasped why there was no drastic difference.

Conclusion

After the experimentation made regarding seawater pollution, the research question could be answered with reference to processed data even though the initial hypothesis was rejected. On the contrary, the shoreline of the public beach had the least amount of dissolved oxygen making it the actual supported hypothesis. The effect of human activity's intensity and frequency on the pollution was still prominent, but the well-implementation or the complete absence of precautions and conservation practices was decisive as reflected by the outcome of the experiment. Although there is room for improvement, the data won't change considerably thus the conclusion is firm. The methodology and procedure of the equipment was strong and straightforward, and the data confidence overall was very high. Similar research papers were published by institutions of Republic of Turkey and United Nations, outlining similar findings. Their professional equipment and personnel meant that their findings were a reference and guidance in my work.[21,22]

As literature work suggests, this issue is global and there are many risks involved if we do no not take inclusive, decisive and timely action. Therefore, there are many groups that this assessment would appeal to. Marine biologists, environmental scientists and environmental engineers might find this data useful and refer to it in their work. NGOs might find this useful to emphasize on conservation and raise awareness. As an individual, I am glad that I uncovered something worthwhile that I was personally curios of and produced a scholarly work out of it.

BIBLIOGRAPHY

1: "Open System." Environmental Encyclopedia, Encyclopedia.com Website, Retrieved 23/11/2022, Last Updated 15/11/2022, https://www.encyclopedia.com/environment/encyclopedias-almanacs-transcripts-and-maps/open-system

2: Marine Pollution UN Data, Environmental Glossary, Retrieved 17/11/2022, http://data.un.org/Glossary.aspx?q=marine+pollution

3: “Facts: Pollution” National Oceanic and Atmospheric Administration, National Ocean Service Website, Retrieved 17/11/2022, Last Updated 26/02/2021, https://oceanservice.noaa.gov/podcast/july17/nop08-historical-maps-charts.html

4: “Resource Library: Marine Pollution” National Geographic Society, National Geographic Education, Retrieved 23/11/2022, Last Updated 20/05/2022, https://education.nationalgeographic.org/resource/marine-pollution

5: K.G. Drouillard, “Biomagnification” Encyclopedia of Ecology (Second Edition), Elsevier, 2008, Pages353-358, Retrieved 23/11/2022, https://www.sciencedirect.com/science/article/pii/B9780444637680003772

6: A. Davis,“How does population growth impact ocean health?”, Population Education, Retrieved 12/03/2023, Published 02/10/22, https://populationeducation.org/how-does-population-growth-impact-ocean-health/

7: “Measuring Water Quality” Southwest Florida Water Management District, Water Matters Org Website, Retrieved 17/11/2022, https://www.swfwmd.state.fl.us/residents/education/kids/measuring-water-quality

8: Encyclopaedia Britannica, “Water pollution” Encyclopædia Britannica, Last updated 02/03/2023, Retrieved 12/03/2023, https://www.britannica.com/science/water-pollution

9: USF Water Institute, School of Geology, Dissolved oxygen, “Learn More: Dissolved Oxygen”, Sarasota County Water Atlas, Sarasota.WaterAtlas.org, Retrieved 12/03/2023, https://sarasota.wateratlas.usf.edu/library/learn-more/learnmore.aspx?toolsection=lm_dissolvedox#:~:text=It%20is%20essential%20for%20the,other%20aquatic%20organisms%20cannot%20survive

10: A. Spiliakos, “Tragedy of the Commons: What it is and 5 Examples”, Business Insights, Harvard Business School Online, Retrieved 13/03/2023, https://online.hbs.edu/blog/post/tragedy-of-the-commons-impact-on-sustainability-issues

11: K. Yetilmezsoy, “Tears of marmara: Sea mucilage”, Turkish Academy of Sciences Publications, Retrieved 13/03/2023, https://www.tuba.gov.tr/en/publications/non-periodical-publications/science-and-thought-series-1/ecology-of-the-marmara-sea-formation-andinteractions-of-marine-mucilage-and-recommendations-for-solutions/tears-of-marmara-sea-mucilage

12: N. H. Omer, "Water quality parameters", IntechOpen, Retrieved 13/03/2023, Published 16/10/2016, https://www.intechopen.com/chapters/69568

13: Fletcher, Robert & Fortin, Marie-Josee," Introduction to Spatial Ecology and Its Relevance for Conservation: Applications with R.", Retrieved 13/03/2023, Published 2018, https://www.researchgate.net/publication/331137497_Introduction_to_Spatial_Ecology_and_Its_Relevance_for_Conservation_Applications_with_R

14: O. Töre,"Turkey's Bodrum Eyes 1.5 million tourists in 2022", FTNnews, Retrieved March 13/03/2023, Published 15/05/2022, https://ftnnews.com/news-from-turkey/43982-turkey-s-bodrum-eyes-1-5-million-tourists-in-2022

15: Encyclopaedia Britannica, "Aegean Sea", Encyclopædia Britannica, Retrieved 13/03/2023, Last updated 07/02/2023, https://www.britannica.com/place/Aegean-Sea

16:"Aegean Sea", World Water Database, Retrieved 13/03/2023, https://www.waterdatabase.com/seas/aegean-sea/

17: M. F. Fava, "Why is the ocean salty: All the facts you have to know" Ocean Literacy Portal, Retrieved 13/03/2023, Published 09/06/2022, https://oceanliteracy.unesco.org/ocean-salty/

18: "What is the relationship between dissolved oxygen and salinity?", Atlas Scientific, Retrieved 13/03/2023, Published 08/11/2022, https://atlas-scientific.com/blog/dissolved-oxygen-and-salinity/#:~:text=Dissolved%20oxygen%20and%20salinity%20are,less%20dissolved%20oxygen%20than%20freshwater

19: "Marina", Yalıkavak Marina, Retrieved 14/03/2023, Last Updated 02/10/2022, https://yalikavakmarina.com.tr/marina/

20: "Marina: Environmental Services", Yalıkavak Marina, Retrieved 14/03/2023, Last Updated 02/10/2022, https://yalikavakmarina.com.tr/marina/

21: T. Katağan, A. Tokaç, Ş. Beşiktepe, B. Öztürk, "The Aegean Sea: Marine Biodiversity Fisheries, Conservation and Governance", No 41., Turkish Marine Research Foundation, Retrieved 11/03/2023, Published 2015, http://tudav.org/wp-content/uploads/2018/04/the_aegean_sea_2015.pdf

22: "Fact Sheets on Marine Pollution Indicators", United Nations, United Nations Environment Programme, Retrieved 22/11/2022, Published 11/05/2005, https://wedocs.unep.org/rest/bitstreams/7196/retrieve

23: PhD M. Loyd-Smith, J Immig, "Ocean Pollutants Guide: Toxic Threats to Human Health and Marine Life" National Toxics Network and International Pollutants Elimination Network, Retrieved 13/03/2023, Published October 2018, https://ipen.org/sites/default/files/documents/ipen-ocean-pollutants-v2_1-en-web.pdf