Report Card 2. Low Salinity and Oxygen Readings Recorded with an Multiparameter Sonde at an Oyster Farming site – the reasons

In this report, the STREAM project examined data obtained from a multi-parameter Exo2 STREAM sonde located in Dungarvan. This data showed notably low salinity levels and exceedingly reduced oxygen concentrations. Consequently, these findings prompted an investigation by STREAM.

The farmed oyster sector in the Republic of Ireland expanded in 2021 year on year by 8% in volume to 10,624 tones and in overall value to €47.55 million (an increase of 6.1% from 2019). Combined employment in the oyster sector was estimated to be 1,024 individuals, most of those working on *C. gigas* oyster farms of which just under half of this total is full-time employment (BIM 2023). The production of oysters is widespread along the Irish coast with concentrations of cultivation in the South-east and North-west regions. The main sales for Irish grown oysters is France, but product is increasingly being dispatched to other markets (BIM 2019). In 2018, the tonnage of oysters grown in Dungarvan was 1,834 and this comprised 18.12% of the total Irish national production for that year (BIM 2019).

In the area that the STREAM project operates aquaculture production along the South East, South and Southwest of Ireland amounts to 19,445 tonnes of fish and shellfish, with a value of €54.6 million, employing 748 people at 136 production units (BIM 2023). STREAM is working with shellfish farmers along the south and east coasts of Ireland to better understand the growing conditions in particular bays and track water quality conditions in an effort to improve management techniques that increase the quality and growth of their oysters and mussels. In particular STREAM has sensors placed in Bannow Bay, Dungarvan and Castletownbere. These three bays are all significant contributors to the overall shellfish production of the country and STREAM is providing a monitoring system for safeguarding the marine environment, an online portal connecting a diverse user community, it is developing toolkits for coastal communities to enhance resilience and providing improved ICT and sensor development expertise.

Dungarvan Harbour is situated in the south-western region of County Waterford. It forms a sizeable C-shaped harbour stretching eastward, encompassing Ballynacourty Point to the north and Helvick Head to the south. The bay's topography is substantially influenced by the orientation of the Cunnigar Spit, which runs from north to south, offering protective cover to the inner harbour. This location comprises three distinct estuaries. To the north, the River Colligan, originating from the Comeragh Mountains, flows southward and meets Dungarvan Bay at Dungarvan Town. The western entrance to the harbour welcomes the River Brickey, while the Glendine River enters from the northeast. Given the relatively modest size of these three rivers, the influx of freshwater is somewhat limited compared to the expanse of the site, leading to a predominantly marine-influenced environment. The intertidal zones primarily consist of sand flats, notably the expansive 'Whitehouse Bank,' a stable sandbank located on the eastern side of the Cunnigar Spit. On the sheltered western side of the Cunnigar Spit, which forms the inner harbour, mudflats take precedence, occasionally bordered by salt marsh habitats (Adapted from McCorry & Ryle, 2009).

The delicate balance of marine ecosystems relies heavily on the interplay of various physicochemical parameters, with salinity and oxygen content being among the most critical. The association between low salinity and oxygen readings in seawater has far-reaching implications for ecological health and coastal communities' well-being. This phenomenon can occur due to natural processes and anthropogenic influences, highlighting the necessity for comprehensive monitoring and management strategies.

Sensor Technologies for Remote Environmental Aquatic Monitoring (STREAM)

STREAM uses commercial sensors and is also developing innovative device technologies to monitor the marine environment, measure changes, and broadcast live data. As part of the project researchers have deployed sensors in Castletownbere, Bannow Bay and Dungarvan and in County Waterford to help better understand growing conditions and track water quality, in an effort to improve management techniques, and increase the quality and growth of oysters and mussels. These three bays in particular are significant contributors to the country's overall shellfish production.

The STREAM projects sensors are capable of measuring important indicators of water quality at these shellfish growing areas such as, temperature, salinity, nutrient levels, and pollutant concentrations in the marine environment. This information is critical for aquaculture operators, scientists and policymakers to gain a better understanding of changes and potential threats. This collected information can then be assessed to help implement effective management and conservation strategies where practical.

The website marinestream.eu provides an online portal for connecting the user community as a central hub for sharing information, related to the effects of changes on water quality. The portal facilitates collaboration among those that make their living from the sea, scientists and the general public, serving as a platform for knowledge exchange. The communities living along the coast, as well as the fishers and aquaculture businesses in the area, are at a higher risk of being affected by climate change because they are situated near the ocean.

STREAM is also in the process of developing custom toolkits to help coastal communities, fishers, and aquaculture businesses adapt to climate change. These will focus on creating a better understanding of the implications of water quality changes for groups at higher risk due to their proximity to the ocean.

Salinity, oxygen and temperature.

Oceans have a salinity or total dissolved solids content of approximately 3.5%, 35 parts per thousand (ppt), 35‰, or 35 practical salinity units (psu). Our oceans are salty because of millions of years of land weathering and outgassing from the earth's centre. It has been estimated that 50% to 80% of the oxygen we breathe in the atmosphere can come from phytoplankton and bacteria that photosynthesise in the sea. That is the process where these organisms absorb sunlight, carbon dioxide, and water and use these to create energy in the form of sugar and release oxygen. But, the amount of oxygen these organisms produce varies with the time of day, season, and location. It is also important to realise that when there is insufficient light, their respiration (converting sugar to energy for their metabolic processes) uses oxygen in the water. Also, when these organisms die, the bacteria that consume them will use up the dissolved oxygen in the water. Some of the oxygen in seawater may also be introduced through physical mixing of water by wind and waves.

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We also know that all things being equal, in pure aerated seawater samples, the relationships between salinity, oxygen and temperature are as follows;

Low temperature - High Oxygen	Low Salinity - High Oxygen
High temperature - Low Oxygen	High Salinity - Low Oxygen

Dissolved oxygen in water is typically measured using a Winkler iodine method in a laboratory, Clark electrode method and optical method.

The introduction of excess nutrients into seawater, and when the water temperature rises, oxygen concentration can decrease. These reduced oxygen levels can hurt marine life, disrupting natural processes and changing the ecosystem. Physical processes such as water column mixing can affect the extent and frequency of oxygen depletion. Locations where permanent or seasonal stratification can occur, are most at risk for oxygen depletion, as the stratification level of the water column determines vertical mixing.

Dissolved oxygen (DO) in seawater is typically reported in milligrams per litre (mg/L) or as a per cent of air saturation. But, some studies report DO in parts per million (ppm) or micromoles (umol). One mg/L is equal to 1 ppm. The relationship between mg/L and % air saturation varies with the water's temperature, pressure and salinity. Fondriest Environmental, Inc. provide a useful table of for the conversion of dissolved oxygen % to mg/L taking into account salinity and temperature (see Appendix 2).

Climate Change

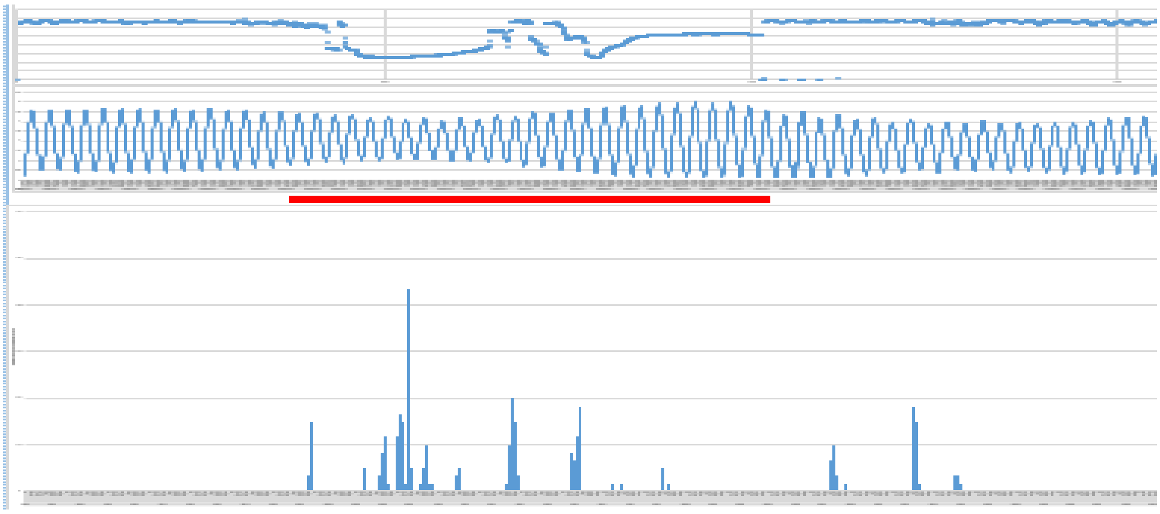
Climate change is one of the most alarming problems facing our planet right now. The effects of climate change are already being felt worldwide, as is clear from the daily headlines, and unfortunately, they are only predicted to get worse. According to Met Éireann, over the last 120 years, Ireland's surface air temperatures have increased by over 0.9 C, with "a rise in temperature being observed in all seasons." The nation's annual precipitation was six per cent higher from 1989 to 2012 compared to the 30 years between 1961 and 1990. Higher ocean temperatures and sea levels are also being observed in our coastal areas. Met Éireann (2023) project that "down-scaled simulations show significant projected decreases in mean annual, spring and summer precipitation amounts by mid-century. The projected decreases are largest for summer, with reductions ranging from 0% to 13% and from 3% to 20% for the medium-to-low and high emission scenarios, respectively. The frequencies of heavy precipitation events show notable increases of approximately 20% during the winter and autumn months. The number of extended dry periods is projected to increase substantially by mid-century during autumn and summer. The projected increases in dry periods are largest for summer, with values ranging from 12% to 40% for both emission scenarios." See https://www.met.ie/climate/climate-change.

An IPCC Report warns that coastal areas will face more frequent and severe flooding and erosion due to the ongoing rise in sea levels. It is predicted that extreme sea level events, which used to happen once every 100 years, may occur annually by the end of the century.

Issue investigated by the STREAM project.

Data from a multi-parameter STREAM sonde in Dungarvan showed low salinity and also very low oxygen levels and as a result these findings were investigated by the STREAM PM. The figure below shows the low salinity readings and tidal height on the uppermost chart, these underlined in red and the corresponding amount of rainfall recorded at the STREAM weather station at Faha.

Figure 1. Period of low salinity, tidal height and precipitation.



STREAM Actions

STREAM weather station rainfall data from Faha was analysed, and daily precipitation averages were plotted against the STREAM SONDE physiochemical data in Dungarvan.

As can be seen, elevated rainfall levels were recorded roughly between 4/6/22 and 17/6/22 (lowest chart). This rainfall may explain the lower salinity readings, exacerbated by the burial of the sensor in the sand that retained freshwater.

Also, on inspection of the STREAM sonde in Dungarvan, it was apparent that a lot of detritus (mainly macro algal fragments) had become deposited around the instrument's base and were decomposing, causing an anoxic layer in the sediment and probably reducing the available oxygen to the sensor.

Natural Factors that can influence salinity and oxygen levels

1. Freshwater Inputs: Low salinity levels in seawater can result from the influx of freshwater from rivers and rainfall. This dilution effect can reduce salinity but may lead to stratification (layering) within the water column in calm weather conditions. A halocline is a vertical zone in the ocean where the salt concentration changes rapidly with depth may be observed where fresh, less dense sweet waters sit on top of denser saline waters. Also, in estuaries where tidal motion is very weak or absent, seawater may intrude in a wedge along the sea bed due to the higher seawater density than fresh water.

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2. Tidal and Oceanographic Dynamics: Tides and currents can bring low-salinity water from estuaries or other areas into coastal regions. These processes are essential for nutrient exchange but may disrupt the balance of salinity and oxygen.

3. Global Climate Patterns: Climatic phenomena like El Niño and La Niña can also influence precipitation patterns, affecting freshwater inputs and altering salinity levels. For Ireland, Met Éireann (2023) reports a projected decrease in mean annual, spring and summer precipitation amounts by mid-century. The projected decreases are most significant for summer, with reductions ranging from 0% to 13% and 3% to 20% for the medium-to-low and high-emission scenarios, respectively. However, the frequencies of heavy precipitation events show notable increases of approximately 20% during the winter and autumn months. The number of extended dry periods is projected to increase substantially by mid-century during the autumn and summer. The projected increases in dry periods are most significant for summer, with values ranging from 12% to 40% for both emission scenarios. See https://www.met.ie/climate/climate-change

Impact on Dissolved Oxygen Content

Low salinity can influence oxygen content in several ways:

1. Stratification: Where low-salinity water tends to be less dense than higher-salinity water. This can lead to stratification, where less dense, freshwater-rich layers overlay denser, saltier layers. Such stratification can hinder vertical mixing and limit oxygen replenishment from the atmosphere.
2. Reduced Oxygen Solubility: Higher salinities can decreases the solubility of oxygen in seawater. This means that low-salinity water can hold less dissolved oxygen at the same temperature.
3. Microbial Decomposition: Organic matter carried by riverine freshwater can stimulate microbial decomposition. This process consumes oxygen, potentially leading to localized oxygen depletion zones.

Anthropogenic Factors

1. Urbanisation and Runoff: Urban development often leads to increased impervious surfaces and therefore higher rainfall runoff. This runoff water carries pollutants, organic matter, and freshwater into coastal waters, impacting salinity and oxygen levels.

2. Agricultural Practises: Runoff from agriculture, significantly when fertilisers are spread, can introduce excess nutrients into coastal waters, triggering algal blooms. These blooms can lead to oxygen depletion at night or when the population collapses and decomposes.

3. Climate Change: Rising global temperatures can intensify the water cycle, altering precipitation patterns and potentially leading to increased freshwater inputs and lower salinity levels in coastal areas.

Some Potential Implications

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1. Ecological Impact: Low oxygen levels, or hypoxia, can lead to fish kills, disruption of food webs, and habitat degradation. Sensitive species may be driven away, while opportunistic, less oxygen-demanding species could thrive.

2. Economic Consequences: Coastal communities dependent on fishing, aquaculture, and tourism can suffer economic losses due to compromised fisheries and reduced water quality.

3. Concerns: Reduced oxygen levels can contribute to releasing harmful compounds like hydrogen sulphide, which pose a further risks to aquatic life.

Management Strategies

1. Comprehensive Monitoring: Monitoring salinity, oxygen levels, and nutrient concentrations regularly is crucial for identifying trends and potential hypoxic events.
2. The use of an integrated weather radar, also known as Doppler weather radar, is used to detect precipitation in the atmosphere. It works by emitting pulses of electromagnetic energy and analysing the reflections from raindrops or snowflakes. This data can help meteorologists determine the intensity, motion, and type of precipitation, such as rain, snow, or hail. By identifying areas with dangerous weather conditions, radar can be an invaluable tool for protecting people and property.
3. Planning: Coastal development should consider natural hydrological dynamics and incorporate measures to reduce pollutant runoff.
4. Restoration Efforts: Protecting and restoring natural buffers like wetlands and hedgerows can help regulate freshwater inputs and promote healthy ecosystems.

5. Awareness raising: Engaging communities in understanding the link between human activities and the environment fosters responsible practices.

Conclusion

In conclusion, the association between low salinity and oxygen readings in seawater underscores the complex interactions that shape marine ecosystems. Addressing this association requires a holistic approach that considers both natural processes and human activities to ensure the resilience and sustainability of coastal environments.

According to the Hoegh-Guldberg et al. 2014 “regional risks and vulnerabilities to ocean warming and acidification can be compounded by non-climate related stressors such as pollution, nutrient runoff from land, and over-exploitation of marine resources, as well as natural climate variability (high confidence).”

The 2019 special report by the Intergovernmental Panel on Climate Change (IPCC) offers comprehensive insights into the repercussions of climate change on oxygen levels, stratification, and primary production. These factors are significant for inshore fishing and aquaculture activities along the Irish coast. A prominent concern is the emergence of oceanic "Dead zones," regions with insufficient oxygen for fish survival. This phenomenon is exacerbated by the reduced oxygen solubility in warmer waters, resulting in a depletion of oceanic oxygen levels as global temperatures rise.

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The 2019 IPCC special report reports on an emerging consensus indicating an overall oxygen decline in the open ocean, with a likely loss of 0.5–3.3% between 1970 and 2010, spanning from the ocean's surface to a depth of 1000 metres (medium confidence level). The global reduction in oxygen is not solely attributed to warming; it is reinforced by concurrent processes involving oceanic physics and biogeochemistry, with these combined factors primarily responsible for the observed decline in oxygen levels (high confidence level). Oxygen minimum zones (OMZs) are expanding, notably in tropical oceans, with a very likely range of 3–8%. Despite this, significant decadal variability complicates the determination of human activity's contribution to oxygen declines in tropical regions (high confidence level).

2019 IPCC projections indicate a further decline in oxygen content. On a global scale, the oceanic oxygen content is highly likely to decrease by 3.2–3.7% by 2081–2100 compared to the period from 2006 to 2015 under the RCP8.5 scenario or by 1.6–2.0% under the RCP2.6 scenario. The volume of OMZs in the oceans is projected to expand by a very likely range of 7.0–5.6% by 2100, according to the RCP8.5 scenario, relative to the period from 1850 to 1900. The discernible climate signal of oxygen loss is anticipated to emerge from historic climate patterns by 2050, with a very likely range of 59–80% of the oceanic area affected between 2031 and 2050. This trend is expected to intensify, encompassing a likely range of 79–91% by 2081–2100 under the RCP8.5 scenario. Conversely, the emergence of oxygen loss is projected to be smaller in the area for the RCP2.6 scenario in the 21st century. By 2090, the affected area is anticipated to diminish.

In response to escalating ocean temperatures and heightened stratification, disruptions in open ocean nutrient cycles are evident. These changes significantly impact primary producers, and there is a high degree of confidence in recognising the regionally variable repercussions. However, a lack of confidence exists in assessing historical trends in open ocean productivity, including satellite-derived data, due to newly recognized region-specific drivers of microbial growth and a dearth of supporting in situ time series datasets.

Climate models predict a probable decline in net primary productivity (NPP) by 4–11% for the RCP8.5 scenario by 2081–2100, relative to the period from 2006 to 2015. This decline is a consequence of combined influences such as warming, stratification, light availability, nutrient availability, and predation. It is expected to display geographical variations between low and high latitudes (low confidence level). In the tropical ocean, NPP is likely to decline by 7–16% under the RCP8.5 scenario, supported by medium confidence, and improved insights from historical variability in this region. At a global scale, the sinking flux of organic matter from the upper ocean into the ocean's depths is highly likely to decrease by 9–16% under the RCP8.5 scenario due to increased stratification and diminished nutrient supply, especially in tropical regions (medium confidence level). This decline will impact the supply of organic carbon to deep-sea ecosystems with high confidence. Consequently, a projected reduction of 5–6% in the biomass of benthic biota is expected to affect over 97% of the abyssal seafloor by 2100 (medium confidence level).

Selected references

The STREAM project is part funded through the ERDF Ireland Wales Programme

Aquafact (2021). Sanitary Survey Report and Sampling Plan for Dungarvan. Produced by Aquafact International Services Limited in conjunction with The Sea Fisheries Protection Authority August 2021. 154 pages.

BIM (2022). Annual Aquaculture –report 2022 (66 pages). https://bim.ie/publications/aquaculture/

Hoegh-Guldberg, O., R. Cai, E.S. Poloczanska, P.G. Brewer, S. Sundby, K. Hilmi, V.J. Fabry, and S. Jung, (2014): The Ocean. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1655-1731.**https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap30_FINAL.pdf**

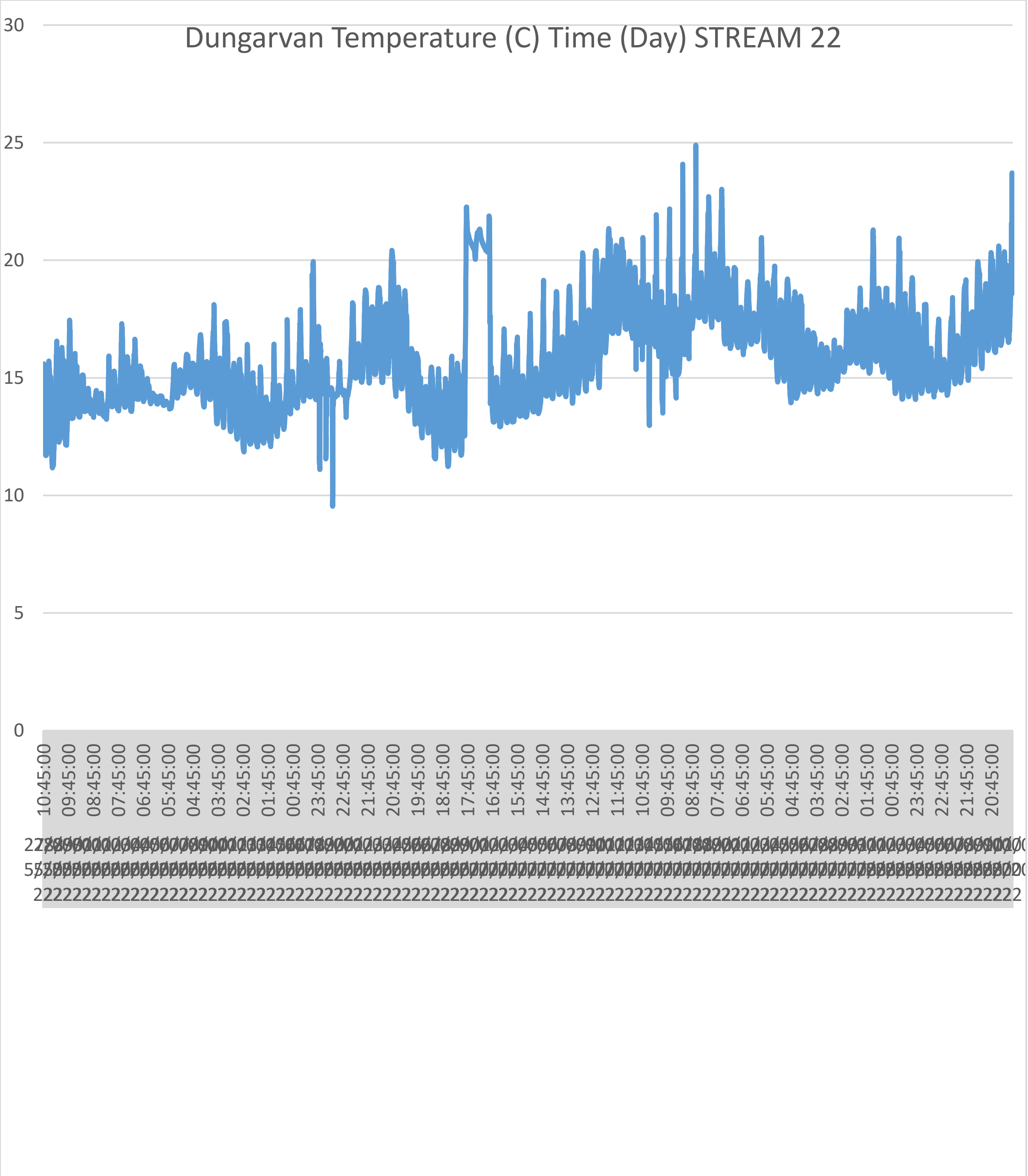
IPCC (2019). Special Report on the Ocean and Cryosphere in a Changing Climate. (D. R.-D. [H.-O. Pörtner, Ed.) 755. Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/3/2019/12/SROCC_FullReport_FINAL.pdf

McCorry and Ryle (2009). Saltmarsh Monitoring Project 2007-2008 Contract reference D/C/227 Mark McCorry & Tim Ryle, A Report for Research Branch, National Parks and Wildlife Service Final Report (2009).

https://www.npws.ie/sites/default/files/publications/pdf/McCorry_%26_Ryle_2009_Saltmarsh_survey_V1.pdf

Appendix 1:

Dungarvan Temperature °C



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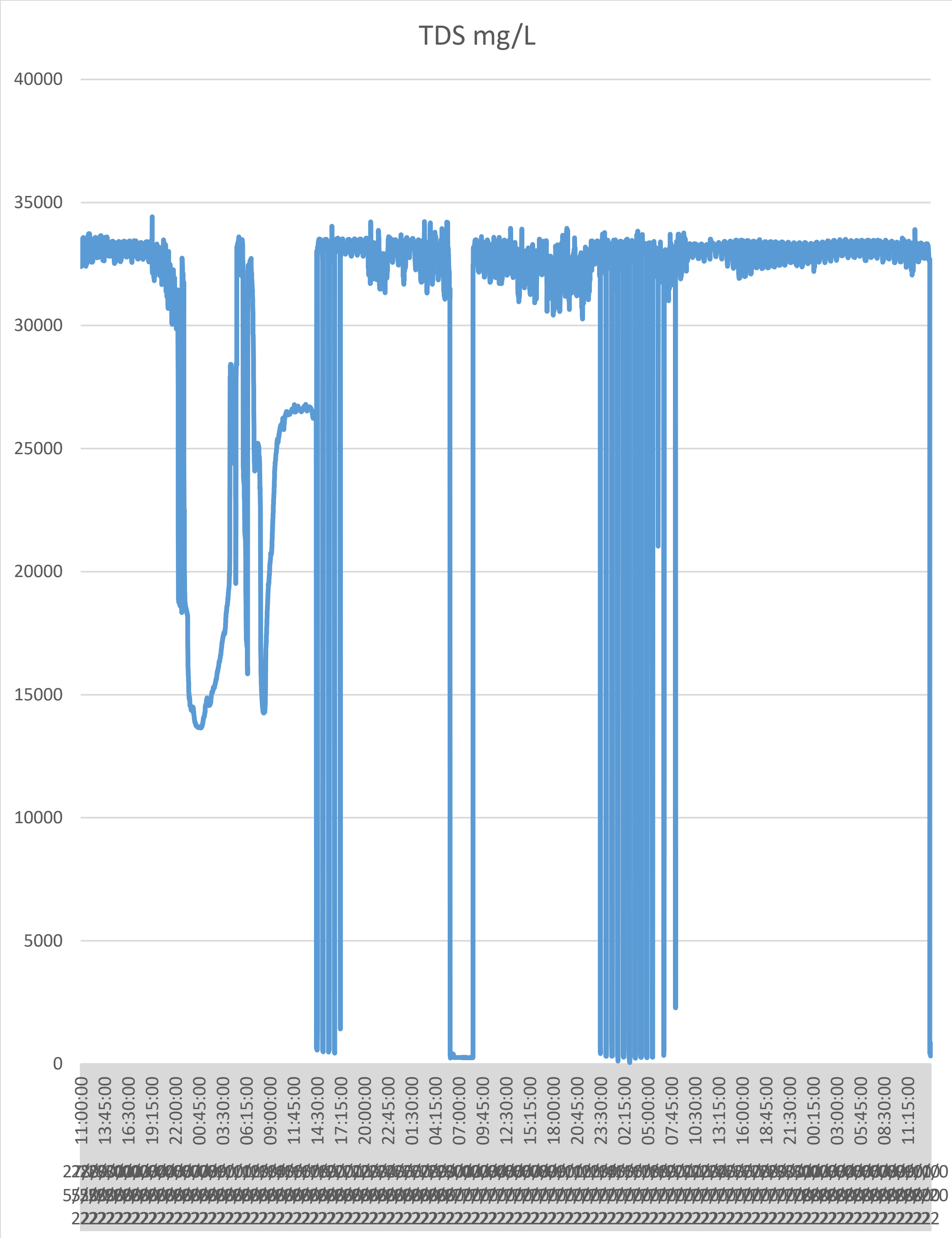
Dungarvan TDS mg/L



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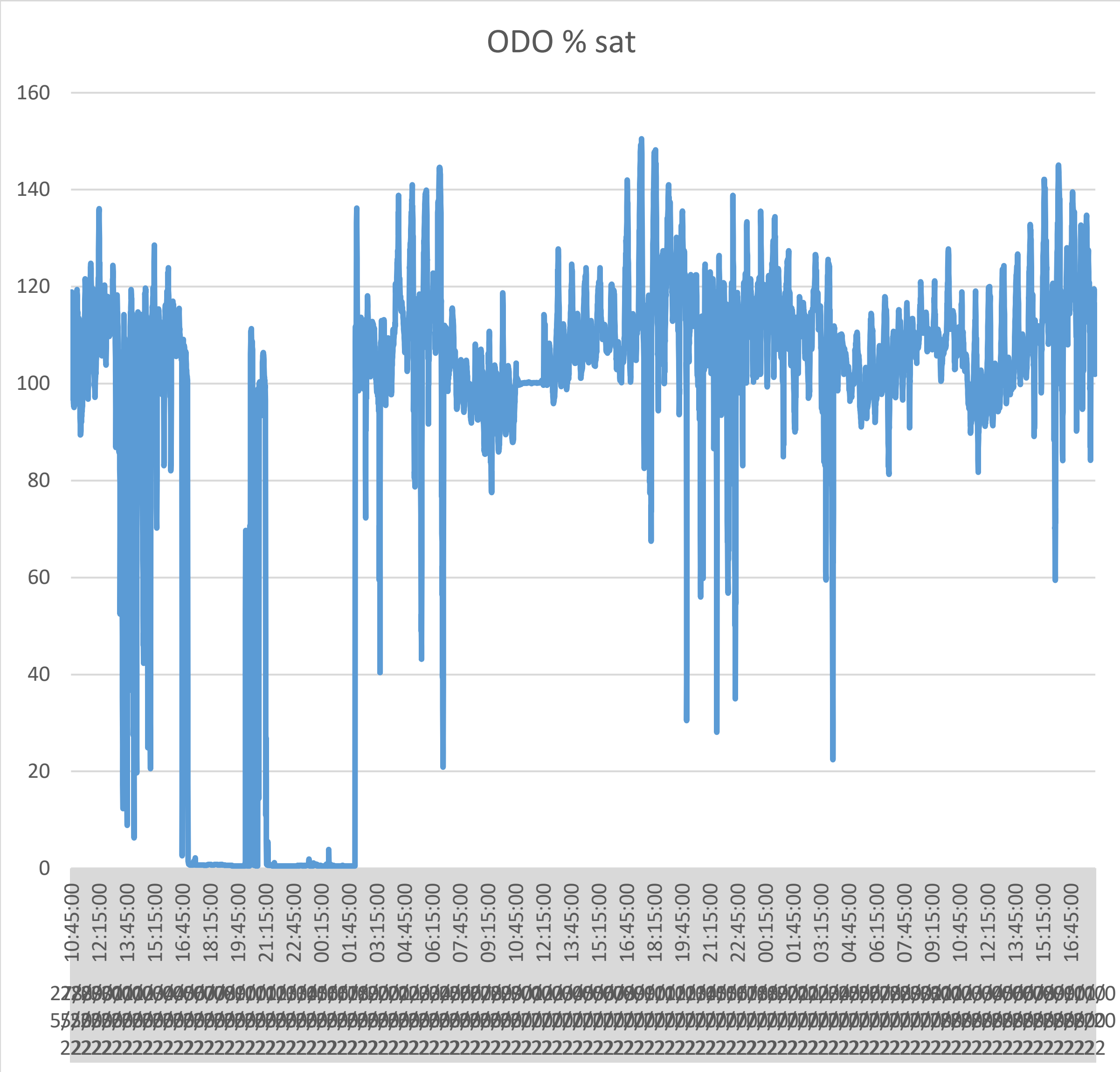
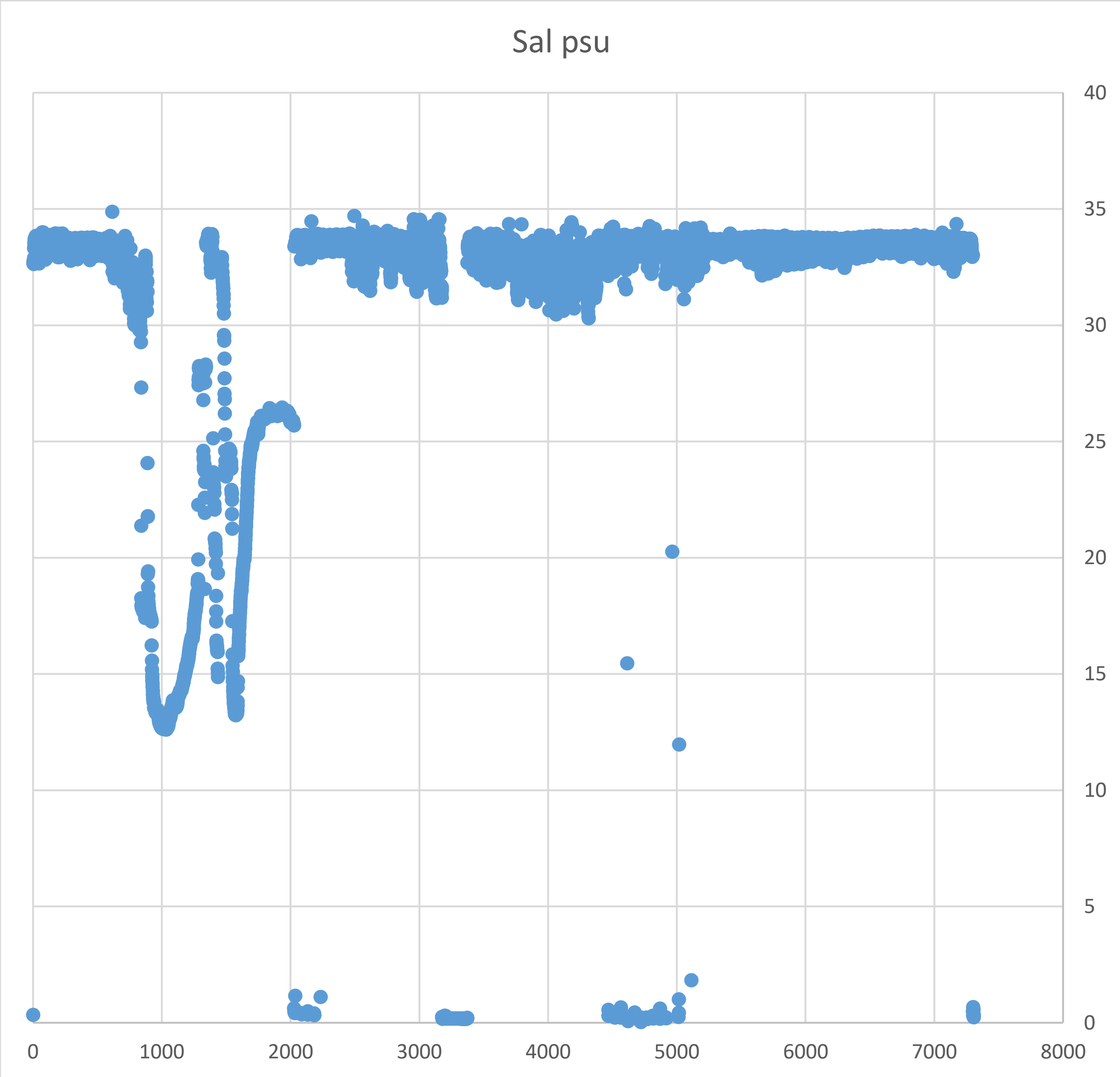
Dungarvan Dissolved Oxygen % Saturation.



Dungarvan Salinity psu



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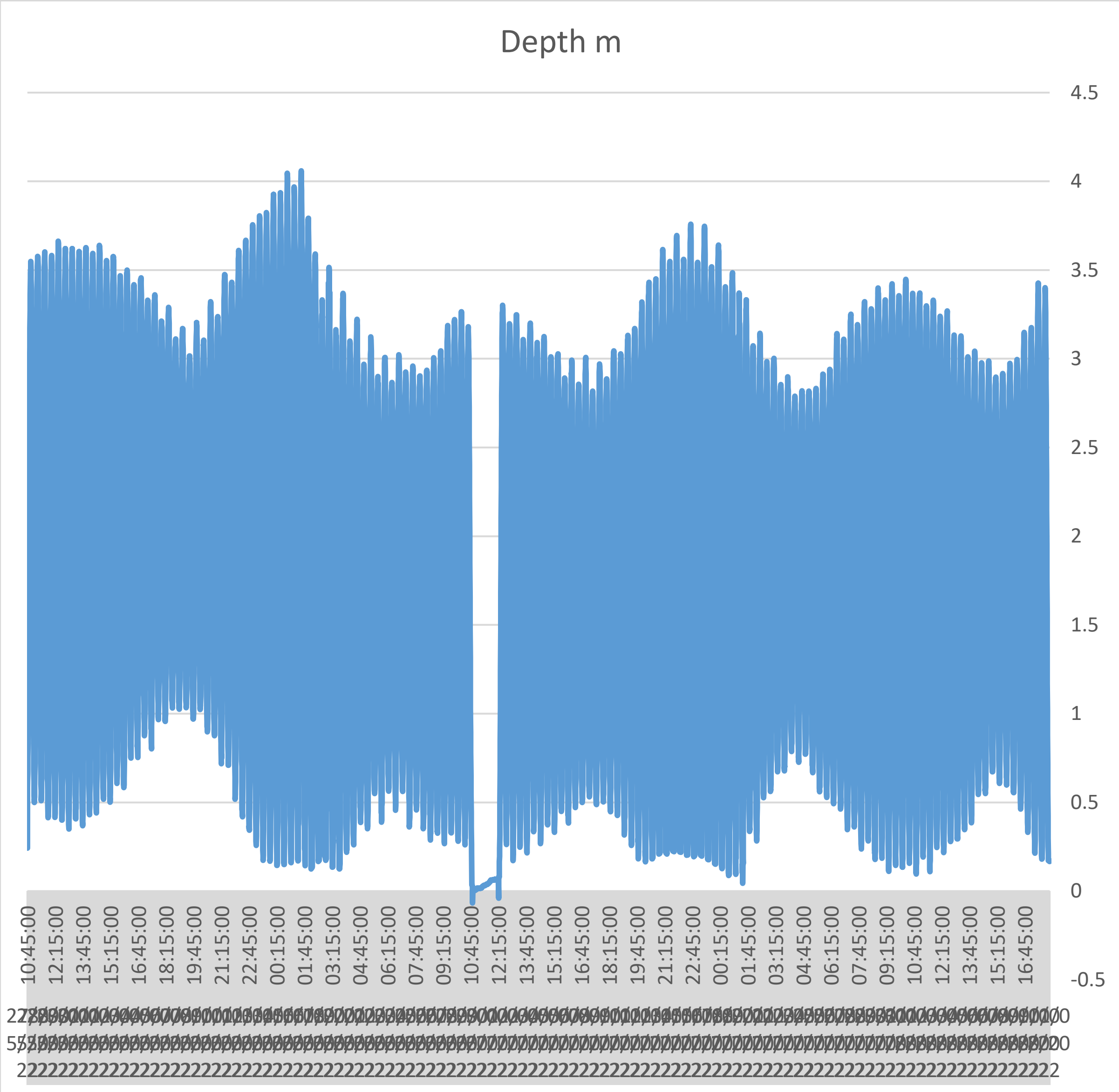
Dungarvan Depth (m)



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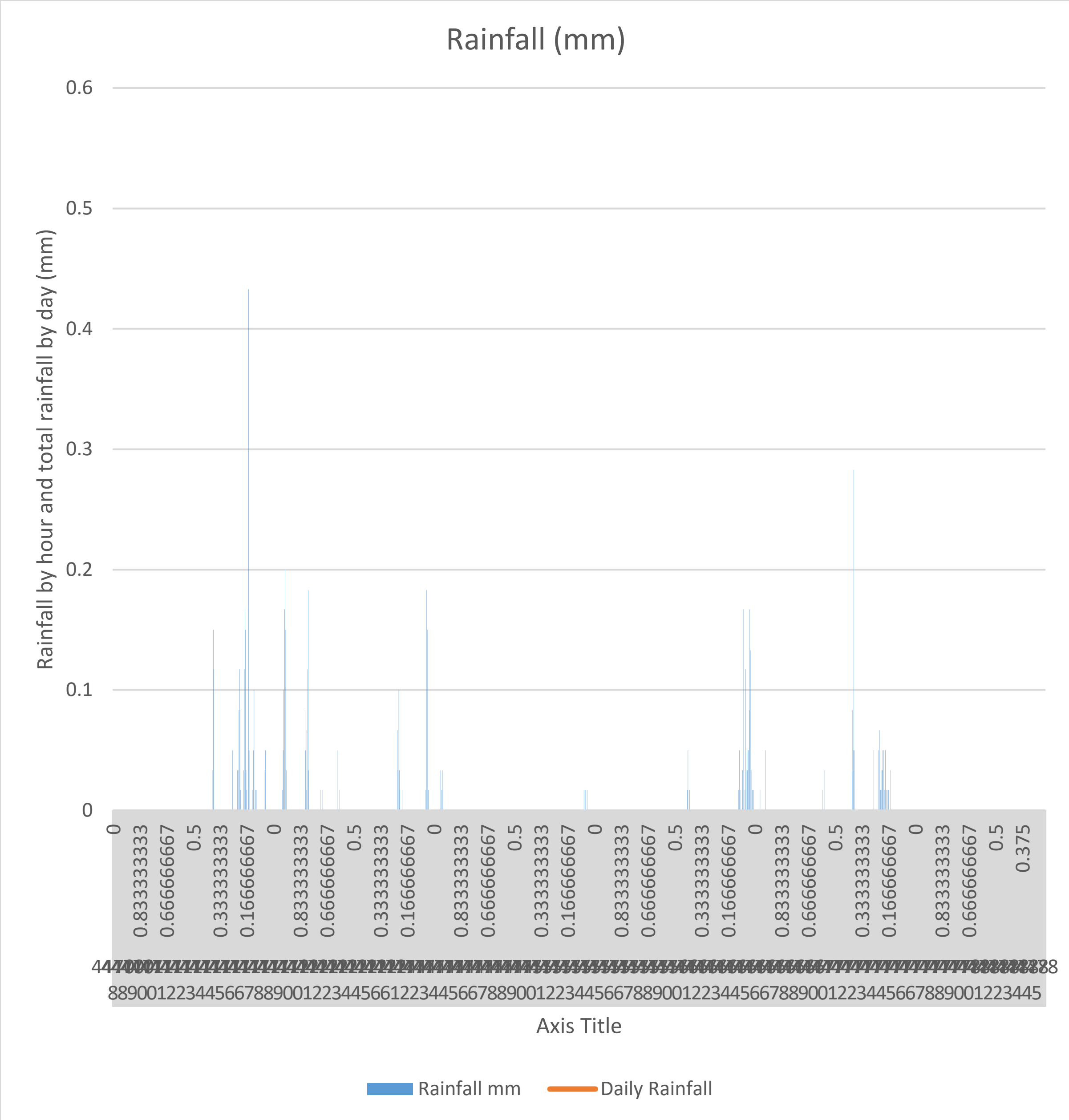
Dungarvan rainfall (mm)



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Appendix 2. Conversion of dissolved oxygen % to mg/L taking into account salinity and temperature.

Fondriest Environmental, Inc. “Dissolved Oxygen.” Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. < https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ >.

O2 mg/L = (Measured % DO)*(DO value from chart at temperature and salinity)

Example if 70% Dissolved oxygen is measured in seawater that is 35 ppt and at a temperature of 15 C then multiply 0.70 * (Table figure) 8.135 = 5.69 mg/ L DO

TEMPERATURE (°C)	SALINITY (g/kg)								
	0	5	10	15	20	25	30	35	40
0	14.621	14.120	13.636	13.167	12.714	12.277	11.854	11.445	11.051
1	14.216	13.733	13.266	12.815	12.378	11.956	11.548	11.154	10.773
2	13.829	13.364	12.914	12.478	12.057	11.650	11.256	10.875	10.507
3	13.460	13.011	12.577	12.156	11.750	11.356	10.976	10.608	10.252
4	13.107	12.674	12.255	11.849	11.456	11.076	10.708	10.352	10.008
5	12.770	12.352	11.947	11.554	11.175	10.807	10.451	10.107	9.774
6	12.447	12.043	11.652	11.272	10.905	10.550	10.206	9.872	9.550
7	12.139	11.748	11.369	11.002	10.647	10.303	9.970	9.647	9.335
8	11.843	11.465	11.098	10.743	10.399	10.066	9.744	9.431	9.128
9	11.559	11.194	10.839	10.495	10.162	9.839	9.526	9.223	8.930
10	11.288	10.933	10.590	10.257	9.934	9.621	9.318	9.024	8.739
11	11.027	10.684	10.351	10.028	9.715	9.412	9.117	8.832	8.556
12	10.777	10.444	10.121	9.808	9.505	9.210	8.925	8.645	8.379
13	10.537	10.214	9.901	9.597	9.302	9.017	8.739	8.470	8.210
14	10.306	9.993	9.689	9.394	9.108	8.830	8.561	8.300	8.046
15	10.084	9.780	9.485	9.198	8.921	8.651	8.389	8.135	7.888
16	9.870	9.575	9.289	9.010	8.740	8.478	8.223	7.976	7.737
17	9.665	9.378	9.099	8.829	8.566	8.311	8.064	7.823	7.390
18	9.467	9.188	8.917	8.654	8.399	8.151	7.910	7.676	7.449
19	9.276	9.005	8.742	8.486	8.237	7.995	7.761	7.533	7.312
20	9.092	8.828	8.572	8.323	8.081	7.846	7.617	7.395	7.180
21	8.914	8.658	8.408	8.166	7.930	7.701	7.479	7.262	7.052
22	8.743	8.493	8.250	8.014	7.785	7.785	7.561	7.344	6.929
23	8.578	8.334	8.098	7.867	7.644	7.426	7.214	7.009	6.809
24	8.418	8.181	7.950	7.725	7.507	7.295	7.089	6.888	6.693
25	8.263	8.032	7.807	7.588	7.375	7.168	6.967	6.771	6.581
26	8.113	7.888	7.668	7.455	7.247	7.045	6.849	6.658	6.472
27	7.968	7.748	7.534	7.326	7.123	6.926	6.734	6.548	6.366
28	7.827	7.613	7.404	7.201	7.003	6.810	6.623	6.441	6.263
29	7.691	7.482	7.278	7.079	6.886	6.698	6.515	6.337	6.164
30	7.558	7.354	7.155	6.961	6.772	6.589	6.410	6.236	6.066
31	7.430	7.230	7.036	6.846	6.662	6.483	6.308	6.137	5.972
32	7.305	7.110	6.920	6.735	6.555	6.379	6.208	6.042	5.880
33	7.183	6.993	6.807	6.626	6.450	6.278	6.111	5.948	5.790
34	7.065	6.879	6.697	6.520	6.348	6.180	6.017	5.857	5.702
35	6.949	6.767	6.590	6.417	6.248	6.084	5.924	5.768	5.617
36	6.837	6.659	6.485	6.316	6.151	5.991	5.834	5.681	5.533
37	6.727	6.553	6.383	6.218	6.056	5.899	5.746	5.597	5.451
38	6.619	6.449	6.283	6.121	5.963	5.810	5.660	5.513	5.371
39	6.514	6.348	6.186	6.027	5.783	5.722	5.575	5.432	5.292
40	6.412	6.249	6.090	5.935	5.783	5.636	5.492	5.352	5.215

STREAM

Sensor Technologies for Remote Environmental Aquatic Monitoring

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Waterford City River Rescue - Monitoring sites

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Report

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