Port of Cork
Navigation Maintenance Dredging
2023-2030

Non-Statutory
Environmental Report

July 2022

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Project Nr
529

Client : Port of Cork

Project : Port of Cork Navigation Maintenance Dredging 2023-2030

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DATE	**SIGNATURE**	**SIGNATURE**
01/07/2022	[redacted]	[redacted]

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1. Introduction

1.1. Purpose of Document

This Non-Statutory Environmental Report (NSER) was requested by the Department of Housing, Local Government & Heritage after consultation with the Port of Cork. An Environmental Impact Assessment Report (EIAR) is not required for routine maintenance dredging applications as such activities are not listed in Annex I or Annex II of the EIA Directive.

The purpose of this NSER is to provide an outline of the ongoing maintenance dredging activities and summarise/outline each relevant area of potential environmental impact from the reports compiled. This process will facilitate the required licencing assessment to be carried out by the regulator.

1.2. Need for Project

The Port of Cork is the key seaport in the south of Ireland. Due to its favourable location on the south coast of Ireland and its modern deepwater facilities, the Port of Cork is ideally positioned for European trading. The marine facilities within Cork Harbour are spread throughout the estuary, stretching from berths within the city itself down to the crude oil facility at Whitegate. Between these sites, the facilities include Tivoli Container Terminal, Marino Point, Haulbowline Industries, Ringaskiddy Deep Water Port, Pfizer Jetty, Cobh Cruise Terminal and many other minor recreational and access locations that require ongoing maintenance. All of the harbours marine facilities are outlined in Section 2.1.

The Port of Cork is designated a Tier 1 Port of National Significance by the Irish National Ports Policy as it is responsible for at least 15% to 20% of overall tonnage through Irish ports, and has clear potential to lead the development of future port capacity in the medium and long term, when and as required. The criteria used by the European Commission are broadly similar to those used in identifying the Ports of National Significance (Tier 1). The continued commercial development of Tier 1 ports is a key objective of the National Ports Policy.

The Port of Cork Company is one of only two ports, the other being Dublin Port, capable of handling traffic across all five principal traffic modes (LoLo, RoRo, Break Bulk, Dry Bulk and Liquid Bulk). It handles approx. 19% of all seaborne trade in the State. It is second only to Dublin in its importance in the LoLo sector, handling around 21% of all LoLo traffic in the State (IMDO, 2012a).

The Port of Cork continues to be a critical part of the supply chain infrastructure to industries and the public in the south of Ireland and has been at the forefront of ensuring the continued delivery of food, crude oil, animal feed and other essential commodities during the COVID-19 crisis.

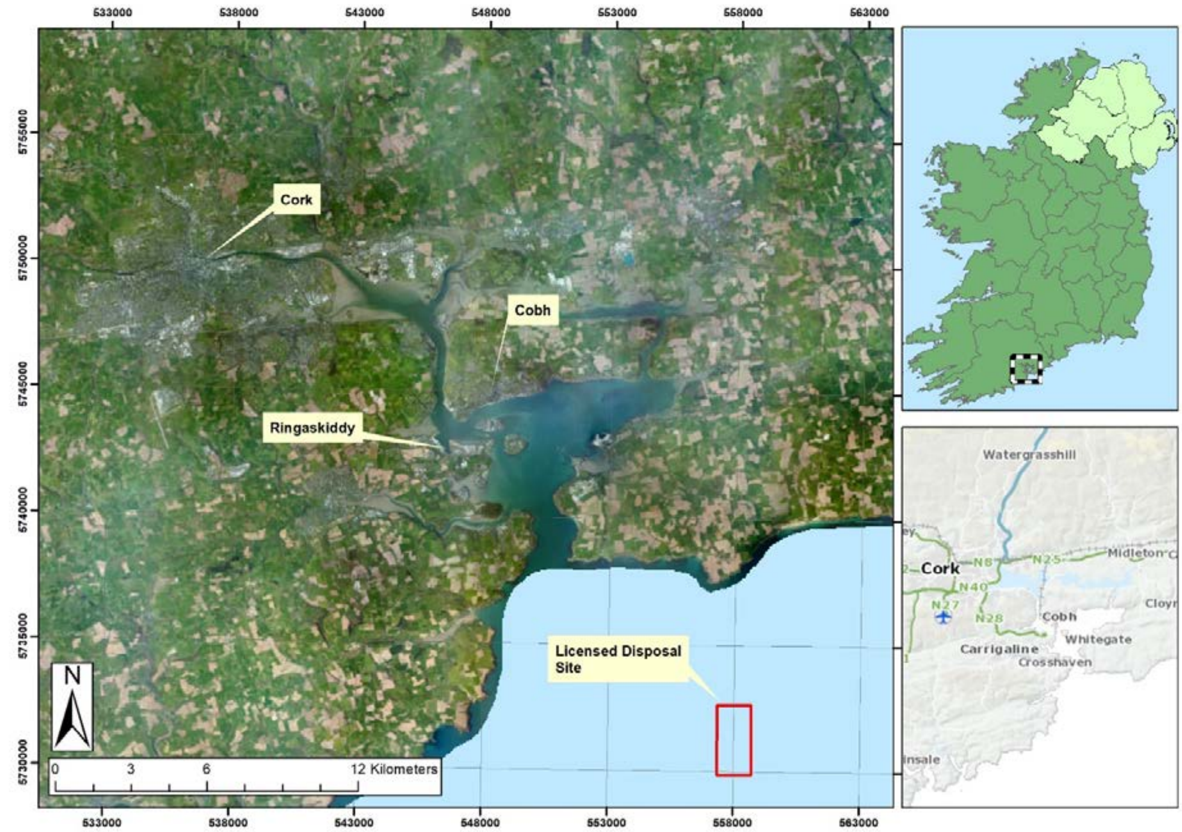

Figure 1 Overview of Cork Estuary

Between each marine facility, the navigational channel (fairway) is present to ensure vessels can safely transit to and from their destination berth, with sufficient clearance to the bed. The channel, shown in purple in Figure 2 below, stretches from Roches Point up to the Eamon de Valera and Michael Collins Bridges within Cork City, a distance of approximately 26 kilometres. With the exception of the newly constructed deep water container berth at Ringaskiddy, the remaining facilities, including the navigational channel have been in place for many decades and have undertaken regular maintenance over this period of time. Although Cork Harbour is naturally deep, it still has sediment input from storm events and fluvial sources (River Lee) and ongoing maintenance of all berths/marine facilities and the navigational channel to remove this material is regularly needed to ensure they remain fit for purpose and safe to use.

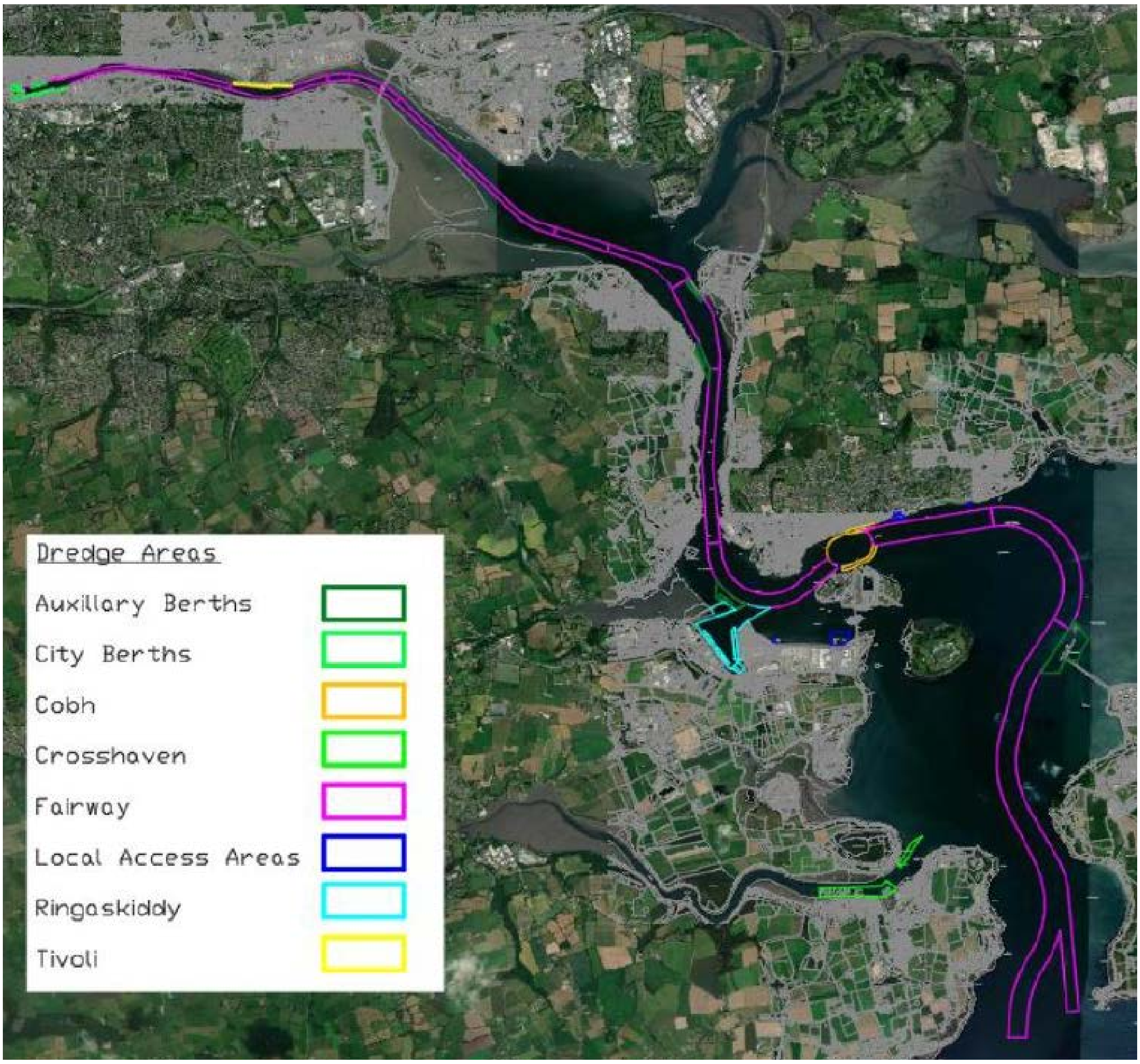

Figure 2 Marine Facilities and Navigation Channel within Cork Harbour

2. Project Description

2.1. Areas

As discussed in Section 1, the Port comprises facilities over a significant area. Whilst many of these areas are directly related to trade vessels (berths) and their access to the Port (navigational channel), many are included to assist smaller harbour users in ensuring their facilities can be maintained. These include such areas as local slipways for recreational craft, the local marina at Crosshaven, the jetty at the National Maritime College Ireland (NMCI), Kennedy Quay (for the Spike Island Ferry) and other minor piers. Should the responsible parties for each of these areas seek a permit/licence individually, it is unlikely they would have the resources required. Whilst areas such as these are not the responsibility of the Port of Cork, the Port recognises their importance to minor businesses and the general public and is happy to collaborate with them to ensure the licencing of the maintenance activities of the harbour as a whole is streamlined.

The areas proposed to be included in the forthcoming applications may be broken down as presented in Table 1. There are two general categories; primary/trigger areas and secondary areas. The primary areas are those that experience the greatest degree of sedimentation and therefore, over time, trigger the requirement for a maintenance dredging campaign to be undertaken.

Table 1 Breakdown of the Fairway and marine facilities maintained in Cork Harbour

Area Designation	Included Facilities
Primary/Trigger Maintenance Areas	
Fairway	Fairway - City
	Fairway - Tivoli
	Fairway - Blackrock
	Fairway - Passage West
	Fairway - Passage West to Ringaskiddy Bend
	Fairway - Ringaskiddy Bend
	Fairway - Ringaskiddy Bend to Spit Bend
	Fairway - Spit Bend
	Fairway - Whitegate
	Fairway (Whitegate to Outer Marker) - East Channel
	Fairway (Whitegate to Outer Marker) - West Channel
Cork City Berths	North Custom House Quay
	Albert Quay
	South Jetties
	Horgans Wharf
	South Deepwater Quay
Ringaskiddy Basin and Berths	Deep Water Berth
	Cork Container Terminal
	Ringaskiddy Basin
	RoRo Berth 1 and 2
Secondary Maintenance Areas	
Tivoli Berths	Tivoli Container Terminal
	RoRo Terminal
	National Oil Berth
Cobh Facilities	Cobh Deepwater Berth
	Cobh Turning Circle
Auxilary Berths	IFI Jetty
	Haulbowline Industries and approaches
	Whitegate and approaches
	Pfizer Jetty and approaches
Local Access Dredging Areas	Paddy's Point Slipway
	Ringaskiddy Slipway
	NMCI Jetty
	Cobh Boat Camber
	JFK Pier
Crosshaven and approaches	Crosshaven Marina and approaches

For all of the areas listed, only maintenance operations to maintain historical/current levels would be undertaken over the proposed license/permit duration.

2.2. Sediment Characteristics

As part of the application process, the Port collected and analysed sediment samples to determine potential contamination and the physical nature of the sediment to be dredged. In 2021, and after consultation with the Marine Institute, the Port commissioned Socotec to analyse 25 discrete sediment samples collected from throughout Cork Harbour. The physical composition of the material is relatively consistent throughout the harbour, being predominately sandy silt (13% sand and 87% silt). The sediment to be dredged is essentially clean sediment, comprising sand, silt and gravel and was found to meet all action-level threshold requirements to be disposed of at sea. This is consistent with all historical testing undertaken. The sediment test results are provided in Appendix A.

2.3. Dredging Methodologies

The dredging methodology utilised will vary depending on the following characteristics:

- Seabed/water depth;
- Access/manoeuvring within the area;
- Sediment type;
- Volume of sediment; and
- Time-frame for the works.

The primary dredging method will be by Trailing Suction Hopper Dredger, supported by a bed leveller. Allowances are also made for the utilisation of Mechanical Dredging, Water Injection Dredging and Plough Dredging. In some areas, multiple strategies may be required to be engaged.

Appendix B outlines the varying methodologies proposed for each area and Appendix C provides a concise description of each methodology.

2.4. Duration and Frequency

The Port of Cork is seeking an 8-year duration Dumping at Sea Permit and Foreshore License to run inclusively from 2023 to 2030.

Any maintenance operations will be dictated by the extent of sedimentation that has occurred in each area of the harbour. These rates can fluctuate significantly, based on inclement weather resulting in storm conditions and high rainfall. Historically, the Port has undertaken its primary dredging operations every three years (e.g. 2005, 2008, 2011, 2014, 2017, 2020) as a license was acquired for this frequency. However, on occasion, this frequency was either too short or too long, depending on the sedimentation rate. Therefore, rather than a prescriptive limit for each year, the Port seeks a license that results in a greater degree of flexibility on when operations can occur. The volume to be dredged in any specific year is requested to not be fixed as it has been previously. Instead, it is proposed to set a maximum annual disposal limit, based on the historically permitted tonnage for a primary campaign, that shall not be exceeded. Furthermore, primary campaigns will not occur in sequential years. This will replicate the historical practice/frequency but give the port flexibility in when it undertakes its primary campaigns (e.g. every 2 or 3 or 4 years). Secondary dredge campaigns for a lesser volume may occur in the intervening years. These campaigns may lengthen the time between primary campaigns. This will allow the Port to potentially extend periods between the primary campaigns, and not have to dredge at a set frequency due to license restrictions. Based on the above, the annual disposal rate will be maintained at historical levels, ensuring that no additional environmental impacts are created.

Appendix B outlines the primary and secondary year characteristics.

2.5. Volumes/Tonnages

The previous permit/license acquired for maintenance dredging limited the annual offshore disposal at 387,200 dry tonnes. The licence being sought will not exceed this value for any primary dredging year. The only exception to this would be if an exceptional weather event occurs and exceptional sedimentation is incurred. To mitigate against such an exceptional event the Port has included a contingency tonnage that could be availed of for exceptional events, after approval by the regulator. This is a similar arrangement in place at other ports in Ireland.

Appendix B outlines the proposed dredging dry tonnages. It should be noted that the volumes and tonnages proposed are conservative. It is likely that a significant portion of the proposed licensed sediment tonnages will not be disposed at sea. Nevertheless, the Port must plan for the worst-case scenario when undertaking licensing applications.

2.6. Offshore Disposal Site

The historical licensed dredge disposal site is located approximately 4.5 km south of Power Head and the mouth of Cork Harbour (Figure 3). From 1978 to 1996, the current license area formed the eastern half of the full dumpsite, which was reduced to its current size in 1996, and has been in operation within those boundaries since. The dumpsite has received considerable amounts of dredge spoil since 1996. Table 2 list the amounts of spoil disposed at the site from 1978 to 2020, highlighting the active nature of the dumpsite on a continuous basis since it was established.

Figure 3 Location of Cork Harbour dredge spoil disposal area

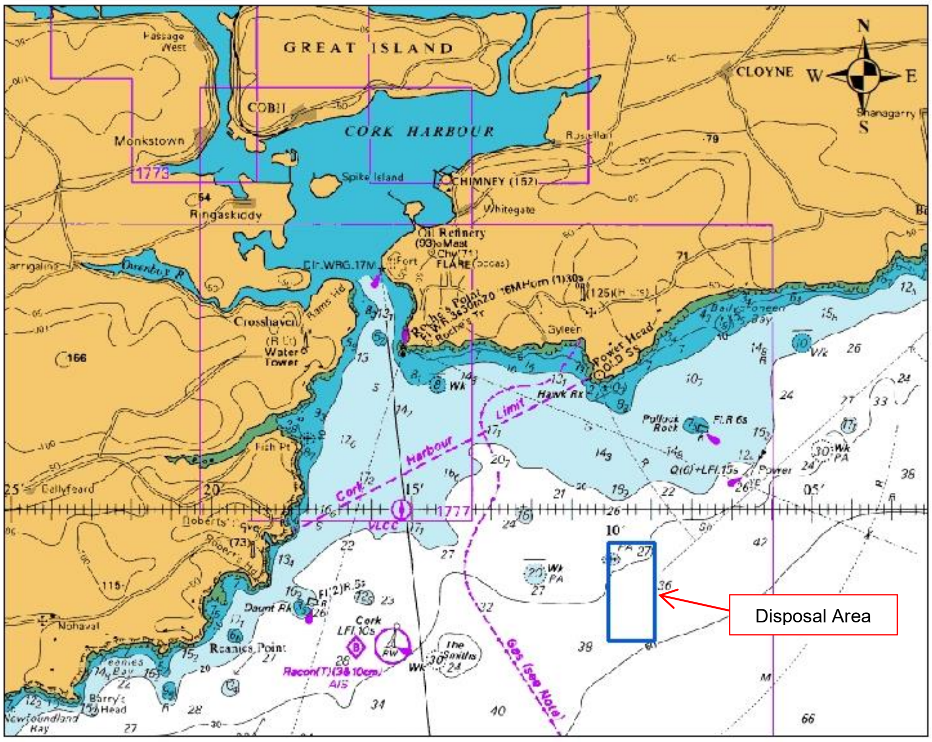

Table 2 Total quantities dumped at the Cork Harbour disposal area
Note: *Capital dredging from Ringaskiddy development

Year	Volume Disposed
1978 – 1999	6,730,000m^3
2000	149,854m^3
2003	373,942m^3
2005	133,979m^3
2008	253,848m^3
2011	272,075m^3
2014	214,976m^3
2017	267,267m^3
2018*	175,515m^3
2019*	85,872m^3
2020	398,460m^3

2.7. Assessment of Alternatives

Maintenance dredging is a necessary ongoing activity required to counter the natural sedimentation of the trade and recreational areas of the estuary. In line with the requirements for Dumping at Sea Permit application, an assessment of alternatives was undertaken. This is included in Appendix D for reference. There is no alternative to undertaking maintenance dredging activities other than a 'Do Nothing' approach. However, to the importance of the Port of Cork outlined in Section 1.2 this is not an acceptable option. Whilst navigational safety is paramount in determining the levels dredged to, whenever possible dredge volumes are minimised to reduce the substantial cost of dredging.

2.8. Project Consultation

In 2021, in advance of making a formal application, the Port of Cork developed and disseminated a consultation document outlining the proposed maintenance scope of works, the assessments being undertaken and the likely mitigation measures to be implemented. Consultation was sought with the statutory bodies.

3. Soils, Geology and Hydrogeology

Cork Harbour is a large natural harbour located on the southern coast of Ireland and exerts a considerable influence on the City of Cork. The topography of the landscape is gently undulating, with a mixed coastline consisting of built infrastructure, shallow cliffs, intertidal mudflats, reed beds, shingle and rocky foreshores.

As described in Section 2.2, the physical composition of the material is relatively consistent throughout the harbour, being predominately sandy silt (13% sand and 87% silt).

Geological surveys undertaken at the disposal site (INFOMAR, 2020) indicate that the site is dominated by rock with pockets of fine material. This is confirmed in drop-down video surveys undertaken in 2004 and 2020 (Aquatic Services Unit (ASU), 2020), which show that large parts of the disposal site contain exposed bedrock and cobble, interspersed with areas of sands and muddy sands. The area to the west of the disposal area is dominated by bedrock and gravels, with finer sediments present to the east of the disposal site.

Previous geophysical surveys of the disposal site indicate the resilience of the site, in terms of the dispersive nature of the site and the robust nature of the benthos present at the site (ASU, 2021).

As all dredge areas have been dredged in their current form for many years, and the disposal site has been receiving dredged material for over 40 years, there are no changes to the existing morphology or hydrogeology resulting from the continued dredging and disposal operation.

4. Coastal Processes

A modelling programme was undertaken to evaluate both the dredging and disposal phases of the proposed primary maintenance dredging operations within Cork Harbour, which included tide and sediment dispersion modelling (RPS, 2021).

An assessment of the primary maintenance dredging operations, which included the dredging and disposal, found that the average total suspended sediment concentration throughout Cork Harbour did not generally exceed 3mg/l during the 16 days of dredging. This was true for most of the harbour except at Ringaskiddy Ferry Port whereby the constrained nature of the tidal currents restricts initial mixing and results in a higher average total SSC of up to 10mg/l.

The maximum total suspended sediment concentration observed during the dredging simulations did not generally exceed 500mg/l outside of Ringaskiddy Ferry Port. These maximum concentrations were almost always related to times when the dredger was active and therefore represented the sediment source before any mixing or dispersion had occurred.

Sediment deposition within the harbour as a result of the dredging operations was minimal, with only a few localised areas of the harbour accreting 3-5mm of sediment.

An assessment of the disposal phase found that the average total suspended sediment concentration beyond the immediate vicinity of the licensed disposal site did not generally exceed 4.2mg/l. This sediment plume quickly dispersed to less than 0.5mg/l approximately 2km from the disposal site boundary.

Almost all the sediment disposed during the primary dredging operation was found to remain within the confines of the licensed disposal site. Beyond the immediate vicinity of the licensed disposal site, change in bed levels did not generally exceed 4mm.

Multibeam and side-scan sonar surveys have taken place across the disposal site in 1999, 2008 and 2013, which highlight the mosaic nature of the seabed substrate across the area, with areas of exposed bedrock interspersed with surface sediments across the site. Results of the 1999 survey, compared to the 2008 and 2013 surveys, indicate very little change in the nature of the seabed and its mosaic of hard substrates interspersed with expanses of sediment, highlighting the dispersive nature of the site, despite the high levels of spoil disposal at the site over these years. These factors indicate that the disposal site is exposed to strong currents which assist with the dispersal of fine sediments from the area during and following dredge spoil disposal operations (ASU, 2020).

As all dredge areas have been dredged in their current form for many years, and the disposal site has been receiving dredged material for over 40 years, there are no changes to the existing coastal processes resulting from the continued dredging and disposal operation. The results of the sediment dispersion modelling have been used to inform other assessments within this NSER.

5. Water Quality and Flood Assessment

In 2020, a review and analysis of water monitoring data around the Port of Cork before, during and after a dredging campaign was carried out by LCF Marine (2021). Overall, the use of a TSHD with no overflow yielded an imperceptible turbidity footprint within the natural variability of turbidity and total suspended solids in Cork Harbour.

As all dredge areas have been dredged in their current form for many years, and the disposal site has been receiving dredged material for over 40 years, and the material to be dredged is regularly tested every three years (see Section 2.2) there is no change to water quality or flood risk resulting from the continued dredging and disposal operation.

6. Biodiversity, Flora and Fauna

In 2020, the ASU undertook benthic and fisheries surveys of the dredge areas and benthic surveys of the offshore disposal site, and carried out assessments of the potential impacts of the proposed dredging and disposal programme 2022-2029 on the benthic and fisheries communities within Cork Harbour, following the approach of their previous assessments in 2011 and 2012 (ASU, 2020 & 2021). This section draws on the findings of the ASU reports.

6.1. Benthic Ecology

6.1.1. Dredge Areas

Receiving Environment

The estuary comprises a narrow channel from the City Quays as far as Blackrock Castle and after that widens out into the mud and sandy mud expanses of Lough Mahon. The intertidal area of Lough Mahon comprises mud and sandy mud flats, both north and south of the shipping channel, with narrow rocky belts in the mid to upper intertidal. There are also extensive mussel beds in places e.g. by Carrigrenan Point on Little Island. Between Marino Point and Fota there are extensive intertidal flats, forming part of the extensive Cork Harbour Special Protection Area (SPA) (Site Code:004030).

Intertidal particle size analysis during the 2020 survey (ASU, 2020) highlighted the relatively homogenous distribution of sediment types across the shore, with sediments dominated by poorly sorted muds, with all sites containing >80% mud. In subtidal areas, particle size results were similar to results obtained previously, with Areas 2 & 3 (Tivoli Area & Ringmahon) dominated by muds and sandy muds, with mixed sediment dominating the downstream part of Area 4 (Lough Mahon).

Intertidal faunal results indicated the presence of fauna typical of sandy mud intertidal systems, dominated by polychaete worms and bivalve molluscs. Subtidal faunal results indicated the presence of fauna typical of muddy subtidal estuarine systems in Areas 2 & 3, and coarser estuarine systems in Area 4.

The 2020 survey identified the presence of two distinct faunal communities in the main shipping channel which was largely similar to those identified in 2011 and 2012. Although some changes were noted in the community in Area 3, these related to the reduced faunal abundances present in the area, but the dominant taxa present in the area remained the same as previously identified.

Results from the 2020 survey (ASU, 2021) mirror the findings from the previous 2011-2012 surveys: although differences were identified in terms of biomass and relative faunal abundances, the benthic community within the dredge areas has remained stable across the survey years. All species identified in 2020 were identified in previous surveys and the communities identified are similar to those identified previously. The distinct differences in faunal structure between Area 4 and the remaining areas is consistent across the years, indicating the stable nature of the benthic community within the shipping channel. The 2011-2012 surveys identified the same community across the survey areas before and after maintenance dredging, with recovery evident in the shipping channel immediately after maintenance dredging was completed in 2012.

Impact assessment

Direct removal of habitat within the dredge footprint

The direct removal of sediment from the areas to be dredged will have a localised effect on the number of species, individuals and biomass in these areas. Within the areas to be dredged, much of the benthos is characterised by the presence of sandy muds and muddy sands (these dominate Areas 1-3), and the downstream portion of Area 4 is characterised by coarser mixed sediment. Sub-tidal estuarine communities which inhabit sandy mud habitats are typically dominated by fast growing, opportunistic species (such as *Nephtys* and *Streblospio*). As a result, the faunal communities in these areas (1-3) are expected to recover rapidly (within 12-18 months) once dredging is completed (from Newell *et al.,* 1998). The seaward end of Area 4 consists of mixed sediments, with more established fauna present. Direct removal of this habitat will result in a longer recovery period (2-4 years) following completion of dredging (from Newell *et al.,* 1998).

The benthos in the areas to be dredged in Cork Harbour are subject to regular maintenance dredging and as a result, the benthic communities present are well adapted to rapid recovery after dredging events. A baseline survey was undertaken in 2011, prior to maintenance dredging taking place in the 2011/2012 season. Results indicated that the benthos in all areas subjected to maintenance dredging were in the process of recovery within 6 months following cessation of dredging. This timescale is consistent with previous studies on the recovery of sub-tidal dredged sediments in estuarine conditions (Bonsdorff, 1980; Clarke *et al.,* 1990 in Newell *et al.*, 1998).

As all dredge areas have been dredged in their current form for many years, and the disposal site has been receiving dredged material for over 40 years, there is no new habitat loss resulting from the continued dredging and disposal operation.

<u>Increased turbidity and sedimentation</u>

The system in Cork Harbour is a turbid system and subject to regular increases in turbidity following heavy rainfall and strong tides. The benthic communities present in this system are adapted to increases in turbidity and as a result, impacts associated with increased turbidity are expected to be negligible. Previous surveys in 2011-2012 indicated no impact from maintenance dredging on the intertidal communities, and modelling undertaken by RPS in 2020 (see Section 4) indicated that only small areas of the intertidal would be subjected to between 1 – 2.5mm of sediment deposition, but most of the intertidal and subtidal area within Lough Mahon and the North Channel would have accumulated deposits of sediment of only 0mm - 1mm as a result of the dredging campaign. These levels of sedimentation are considered small.

No significant impacts are expected on the intertidal communities from the maintenance dredging of the shipping channel. As dredging has been ongoing in its current form for many years, impacts on subtidal communities within the dredge areas are expected to be minimal.

6.1.2. Disposal site

Receiving environment

The 2020 survey (ASU, 2021) comprised sub-tidal benthic grabs to assess the benthic infauna community and to measure grainsize, and a drop-down video survey to characterise the subtidal habitats present. The disposal site was last surveyed in 2004.

The granulometric assessment indicates the presence of sands across large parts of the survey area where soft sediment is present. Results from the video survey indicate the presence of mixed sediment (gravel, cobbles & boulders) as well as large areas of exposed bedrock. Direct comparisons with the 2004 survey are difficult as the sampling locations were not exactly the same; nevertheless, general observations can be made on the distribution of sediment across the survey area. In 2004, more muddy sediment was observed across the central part of the disposal site. Results from the 2020 survey show differences in the sedimentary composition within the site, with more muddy sediment present along the southern and northern parts of the site and lower mud levels in the central area. Apparent changes in the gravel composition of the sediment can be explained by the targeting of soft sediment areas within the disposal site.

Analysis of the infaunal data highlights the presence of one large faunal grouping which is located across the full extent of the survey area. Three faunal communities were identified from the survey area, with a single sample being classified as an outlier. The 2004 survey identified a single soft sediment community, on top of which is a mosaic of small-scale spatial patchiness, resulting in localised differences in taxa and faunal abundances. The results from the 2020 survey mirror these findings, with a single community dominating the survey area with localised small-scale patchiness present across parts of the site.

Results from the drop-down video survey highlight the diverse habitat structure of the seabed in the area. The seabed contains areas of bedrock, colonised by typical epifauna of the 'Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock' (CR.MCR.EcCr.FaAlCr) community. This area extends to areas beyond the disposal site where bedrock is present, primarily to the west. Between these areas of bedrock, mixed sediments dominate the seabed, with gravelly sands and muddy sands common in the area. Sandy muds, with occasional cobble and boulder are also present. Low lying areas of cobble and boulder, which frequently occur adjacent to the soft sediment areas, are classified as 'Echinoderms and crustose communities' (CR.MCR.EcCr). From the video assessment, this habitat dominates the hard benthos within the disposal site.

In summary, although there was an increase in the number of families during the 2020 survey, broadscale similarities exist between the communities identified in the 2004 and 2020 surveys. The dominant families present in 2004 consisted of the polychaetes *Capitellidae*, *Lumbrineridae* and *Scalibregmatidae*. No *Capitellidae* were identified in the 2020 survey, but *Lumbrineridae* and *Scalibregmatidae* were the most abundant families present. In addition, broad similarities were noted between the hard benthos communities identified in 2004 and in 2020. The dominant fauna present in both surveys on the hard substrates (rock and boulders) were bryozoans, hydrozoa and sponges as well as the common sea urchin *E. esculentu*s and the common starfish *A. rubens*, which were present across all hard benthos sites.

Impact assessment

The ecological impacts associated with dredge spoil disposal are considered site specific (Ware *et al.*, 2010), with factors such as hydrodynamic regime of the receiving environment, dispersive nature of the site, habitat type of the receiving environment and the nature and volume of sediment to be disposed all playing a role. Impacts on benthic communities from disposal operations alter the macrobenthic community structure and do not necessarily result in areas of seabed devoid of life (Ware *et al.*, 2010). Large areas of the current disposal site consist of hard and mixed seabed, dominated by epilithic fauna such as sponges, bryozoans, cup-corals, hydrozoans and cnidaria. This fauna is susceptible to smothering due to its sessile nature. The deposition of large volumes of soft sediment on top of hard benthos would result in the covering of the benthos in a layer of soft sediment which could potentially impact the epilithic fauna present. A review of this habitat type (Stamp & Tyler, 2016) classified it as having a high resistance to light smothering and medium resistance to heavy smothering. Due to the nature of the fauna present, resilience is considered high in both instances, meaning recovery is expected within 2 years (Stamp & Tyler, 2016).

At soft sediment sites, recovery is expected to follow a typical pattern. If the sediment to be disposed is similar in nature to the receiving environment, then the impacts will be lessened, with recovery proceeding more rapidly than if the sediment was different to the receiving environment. This feature of recovery has been noted in several studies (Smith & Rule, 2001; Ware *et al*., 2010; Bolam *et al.,* 2006). After spoil deposition, macroinvertebrate species diversity, abundance and biomass will be reduced. If the sediment deposited on the site is similar in nature to the native sediment, and the layer of deposition is thin (<15cm) then vertical migration through the sediment of existing fauna may occur (Wilbur *et al.,* 2007; Fredette & French, 2004, Maurer *et al.,* 1981 (a), Maurer *et al.,* 1981 (b), Maurer *et al.,* 1982). This will be complimented by lateral migration of mobile fauna from adjacent areas and through larval settlement from plankton.

Where the dredge spoil contains different sediment than the native sediment, recovery occurs in a number of stages depending on a range of factors. In highly dynamic areas, such as those identified in the Cork disposal site, the silt fraction initially settles with the sand fraction. Vertical migration through predominantly mud sediments would be reduced and recolonisation of these sediments would be through lateral migration of mobile species and larval settlement from the plankton. Initial colonisation will be by small, fast-growing, opportunistic species, especially small polychaete and oligochaete worms. Due to the dynamic nature of the site, the finer material will disperse away from the site in under a year leaving coarser, mixed sediment behind which will gradually revert, through the process of recolonisation, to a community more closely resembling that which occurred before disposal, i.e. typical of the dominant substrate and the prevailing hydrodynamic regime.

A video and grab survey of the disposal site was undertaken in 2004 for a previous licence application (RPS-KMM, 2004), 12 months after the disposal of approx. 380,000 m^3 of dredge spoil. Results from the survey identified that the infaunal benthic community at the disposal site belonged to a single distinct community, on which is a mosaic of small-scale patchy habitats across the survey area. In addition, although there was evidence of disposal at the site in terms of minor silt build up on some areas of hard benthos at the time, analysis of the infauna indicated little evidence of organic enrichment or prolonged disturbance.

An earlier benthic survey of the disposal area undertaken in 1993 (Neiland, reported in RPS-KMM 2004) concluded that '*The faunal composition of the sites sampled at the dredge spoil dumpsite compared favourably with sites outside the dumpsite. There was no indication of any build-up of depositional material. In conclusion, it can be said that the present dumping operations at the site are not having a deleterious effect on the benthos.*'

A dispersal model undertaken by RPS simulated the disposal of 385,000m3 of sediment over a 15-day period (RPS, 2015). The results of the model show the proposed sea disposal of this volume of dredge material would result in the deposition of material mainly within the dumpsite, and that the highest levels deposited immediately outside the dumpsite would be 5cm with no measurable levels of deposition beyond 4km from the disposal area. A more recent modelling exercise undertaken by RPS for the current disposal application (see Section 4) corroborated those results and refined them, indicating that at the end of each disposal season, deposition would mainly occur within the boundaries of the disposal site with deposition thicknesses falling to below 10mm farther than 1-2km beyond the site with the main dispersal axis in a SE and to a lesser extent NW direction.

In view of the dispersive nature of the site and the findings of previous studies which recorded similar habitats despite regular spoil disposal, it is considered that the impacts associated with the deposition of dredge spoil, following a similar pattern to previous disposal events, will be temporary and negative in nature, principally affecting the direct footprint of the disposal site, and that substantial recovery can be expected to occur within 12 to 24 months of the cessation of disposal, depending on the quantities being disposed in any given year.

6.2. Fisheries

6.2.1. Dredge areas

Receiving environment

The 2020 fisheries survey of the dredge areas (ASU, 2021) indicates that Cork Harbour is an important nursery area for juvenile flatfish including dab, sole and plaice and for young gadoids, in particular whiting. Other species also frequently encountered in trawls and which maybe even more estuarine dependent include black goby, sand goby, and Nilsson's pipefish. Also frequently recorded, although generally present in smaller numbers, included species such as dragonet and pogge.

The two most abundant mobile invertebrate species taken in the survey area were green crab and the brown shrimp (*Crangon crangon*). Other important species included prawn, mainly *Palaemon serratus*, and the peacock fan worm (*Sabella pavonina*). Green crab and *Crangon* are key food web structuring species in estuaries and shallow inshore environment (Selleslagh and Amara, 2008) where they are extremely important predators of juvenile fish. Both species have a broad salinity tolerance range which allows them to penetrate the Lower Lee estuary at least to the City Quays, in the case of green crab. *Crangon* may spawn more than once in a season with spawning at Irish latitudes perhaps extending from early spring into early summer (see Campos & Van der Veer, 2008).

Impact assessment

<u>Entrainment</u>

TSHDs with their powerful pumps will suck up fish and mobile invertebrates living on or close to the sediment surface (entrainment). Although any species and any size of fish can be entrained, the highest numbers tend to be those living closest to the bottom e.g. juvenile flatfish (which in the case of Lough Mahon and the Lee Estuary would be flounder, plaice, dab and sole), sand and common gobies, black goby, dragonet and pogge. Gadoids such as whiting, cod and poor cod while still susceptible, are likely to be less so because while they do frequently feed on the bottom they are not as closely associated with it.

Pelagic species such as sprat and mackerel, and to a lesser extent mullet and bass, are also less at risk of entrainment as they generally occur farther up in the water column. However, if the pumps are still operating as the drag head is raised from the bottom, e.g. in preparation for dredging a new line, then all fish in proximity to the drag head, even in the water column, would be susceptible to entrainment. In general, these impacts are likely to be relatively minor to moderate because: (i) all the species involved are widespread and common within the study area; (ii) the vast majority of the subtidal and extensive intertidal area of Lough Mahon will remain untouched by the dredging and all these species of fish and invertebrate will be abundant in those areas also; and (iii) the majority of the species involved have short life cycles, with high reproductive rates, with many also having very wide diet ranges.

Salmon would be most susceptible to entrainment in the narrow channel areas between the City Quays and Tivoli Docks. Smolts from the River Lee tributaries below the Inniscarra Dam (i.e. the Bride, Shournagh and Martin), as well as smolts reared in the ESB Hatchery at Carrigadrohid would be migrating from the end of March to early May, with the hatchery smolts migrating earlier in this window. A tracking study (Moore *et al*., 1998) has shown that once smoltified and ready to go to sea, smolts tend to move seaward quickly, swimming actively and moving with the tide, mainly at night and during ebb tide within the main flow, and close to the surface. In the lower estuary, they tend to migrate both day and night. During flood tides they move to the sides of the channel and closer to the bed of the estuary in order to avoid being pushed upstream. However, smolts continue to actively swim and can move at speeds up to 1.5km per hour seaward on ebb tides and about 0.5km per hour during flood tides. These observations suggest that during dredging, even in the narrowest parts of the channel in the stretch from the City Quays to Blackrock Castle, smolts would only ever be in potential contact with the dredger for short periods during the strongest period of the flood tide toward the edges of the channel, probably mainly at night. Even during such periods, given that the dredger is only dredging actively for approximately 30 minutes in every 2.5 hours, and the channel is 105 m to 290 m wide compared to the active suction field of the dredger (~4-5m), there would be very limited overlap between the paths of the dredger and the movement of the smolts at any one time. Moreover, the extended period over which smolts, migrate (6-8 weeks at least) compared to the time the dredger would be active in the narrow upper part of the estuary (1-2 weeks) further reduces the overlap between the migrating population and dredging. At a population level, dredger-associate mortality of smolts is likely to be a very small fraction of overall natural smolt mortality caused by avian and other predators and other natural causes.

Adult salmon return to the Lee catchment throughout the summer and early autumn months, probably from May/June to September/October i.e. over an extended period, so the risk of entrainment, though still possible in the narrow sections of the channel, is very unlikely to be an issue at the population level because of the limited time overlap between dredging in narrow City Quays to Blackrock Castle and the extended migration period of the adults. Moreover, the combination of the localised area of active dredging i.e. around the dredger drag head, versus the width of the channel, further considerably reduces the potential encounters between the dredger and migrating fish. The likelihood of any significant numbers of salmon smolts or adults being entrained by the dredging operation is not considered to be significant at the population level for the River Lee catchment.

Increased suspended sediment concentration

RPS (2020) have modelled the evolution of suspended solids into the water column caused by the dredger and how that plume dissipates over a tidal cycle. This has shown that concentrations can reach a maximum of approximately 425mg/l milligrams per litre when dredging is being undertaken in the narrow City Quays to Blackrock section of the estuary and around 350mg/l for dredging in the Lough Mahon area. In each case, the highest concentrations are within a few hundred metres of the dredger dropping off rapidly due to tidal mixing and dilution, eventually dropping below 4 mg/l above background at distances of 1-2 km. Each loading event is associated with its own plume envelope, which is tidally drawn toward the lower harbour expanding and diluting as it travels, with the highest residual concentrations focused along the line of the shipping channel dropping rapidly as the plume spreads laterally toward the shallow subtidal and intertidal sand and mudflats. The levels of suspended sediments are not high enough to cause mortalities in fish, especially as fish are mobile and likely to avoid the areas of highest concentrations, thereby reducing their time of exposure. Those likely to be exposed to the highest concentration, i.e. bottom-dwelling species such as flat fish and gobies, are likely to be among the most tolerant to high levels of suspended sediments, as their habitats on fine silts and muds are naturally turbid.

Migrating species such as salmon are known to pass through estuaries where the turbidity maximum can be even higher than the solids levels predicted by the RPS model, so the dredging is not expected to delay either inward or outward migration of this species.

Overall, the spatially limited nature of the increased levels of suspended solids associated with dredging are unlikely to have any significant adverse impacts on the fish population within the Lower Lee or Lough Mahon areas.

Disturbance/displacement

The presence of a dredging vessel may disturb or displace fish from the dredge areas; however, all areas are already subject to periodic maintenance dredging, and are part of the busy shipping channel and operational harbour with frequent vessel movements, so the presence of one additional dredging vessel is unlikely to disturb or displace fish so effects are considered to be negligible.

6.2.2. Disposal site

Receiving environment

The 2020 drop-down video survey of the disposal site (ASU, 2020) noted the presence of several fish species including lesser spotted dogfish, grey gurnard, dragonet and several species of wrasse. Pollack, a common gadoid species in the Celtic Sea over hard ground, is also likely to be present within the site. Smaller bottom dwelling species such as gobies, or flat fish such as lemon sole, may also be present over mixed sediments on the bottom but would not be noticeable in a video.

Pelagic species in the area are likely to included sprat, herring and mackerel. Details of commercial fishing in the area of the disposal site is not known but in the wider Celtic Sea area pollack, cod, haddock and whiting are taken by gill nets (pollack) and bottom otter trawls (cod, whiting and haddock), and while in theory all these species could be caught in the disposal site, most of the heavier fishing activity for these species tends to be in deeper water than the disposal site (pollack and haddock), i.e. farther off shore or toward the south west of the Celtic Sea area off Wexford (cod and whiting) – Anon. (2019). Hake is also an important white fish in the Celtic Sea, but landings are from deeper and more offshore waters than the disposal site. All white fish landings other than hake are low in recent years, especially cod, which is below sustainable levels (Anon., 2019).

Historically, herring is the most intensively fished pelagic species in inshore waters off Cork Harbour. A detailed survey of spawning grounds around the Irish coast (O'Sullivan *et al.,* 2013) identified 7 spawning beds and 4 spawning grounds in the Daunt spawning area, which is located south and west of Cork Harbour. The 7 identified beds, which in total only make up a very small proportion of the Daunt spawning area, are distributed between the southwestern entrance to Cork Harbour and west as far as the Old Head of Kinsale. The nearest spawning bed to the disposal site is named Daunt 5 in the report and is the smallest of the beds in Daunt spawning area. It is located just over 5km west of the western edge of the disposal site. The Daunt spawning area is estimated at 307km^2 and does not include the disposal site which is east of its eastern boundary. The location of the spawning beds was based mainly on interviews with very experienced fishermen, often several, covering the same area, so that locations could be cross-checked.

Impact assessment

De-Groot (1996) indicated that anthropogenic activities could have a serious adverse impact on herring spawning areas if fine material from dredging (in that instance marine aggregate extraction) were deposited on the spawn, which the fish lay directly on the bottom. Similarly, dredge spoil deposited onto a spawning bed, either during spawning or before larvae had hatched and dispersed from the bed, would also be detrimental.

To assess the near and farther field deposition rates due to dredge spoil disposal at the site, RPS undertook a dispersal modelling study of the site which simulated the disposal of 385,000m^3 of spoil continuously over a 15 day period at the rate of 1 load every 205 minutes (see RPS 2015, Chapter 12, Coastal Processes). The modelling exercise found that beyond 4km from the centre of the site, the quantity of fines deposited would not be measurable. These results have been corroborated by a more recent modelling exercise (RPS, 2020 – see Section 4) which noted that deposition levels dropped below 10mm beyond 1-2km from the disposal site with the longest axis of dispersal in a mainly SW direction. These analyses suggest that the nearest spawning bed, Daunt 5, at just over 5km east of the disposal site, would experience negligible if any deposition, so if herring did spawn at the site during a disposal event, the likelihood is that it would lead to little or no reduction in hatching success of the deposited spawn.

The 2013 spawning bed survey (O'Sullivan *et al.*, 2013) also included data on the dispersal of early and late stage herring larvae which were modelled as dispersing over a very wide geographical area along the Cork coast, covering hundreds of square kilometres. It would therefore be inevitable that the water column over the disposal site would contain herring larvae in its zooplankton in the weeks and months after spawning, i.e. October - November in particular. In such a scenario, were disposal actively taking place at the time, the possibility of some of the larvae present being killed within the footprint of the disposal site could not be ruled out because of the very high concentrations of suspended solids that they would be exposed to at this vulnerable life stage. It is important to note, however, that the effect would be temporally and spatially limited i.e. confined to the main dredge plume within the disposal site and close to the dredger during a dumping event. This assumption is supported by the findings of the dispersion modelling exercise undertaken for the current application (RPS, 2020), which found that the average total suspended sediment concentration beyond the immediate vicinity of the licensed disposal site did not generally exceed 4.2mg/l and this sediment plume quickly dispersed to less than 0.5mg/l approximately 2km from the disposal site boundary.

Overall, given that the disposal site is over 5km from the nearest and smallest of the 7 identified spawning beds within the Daunt spawning area, and that the dispersed larvae would cover hundreds of square kilometres, it is considered extremely unlikely that disposal of dredge spoil at the licensed disposal site would have any measurable negative impact on herring recruitment in that spawning area or on commercial catches in the Celtic Sea region.

As described in Section 6.1.2, a drop in both benthic diversity and biomass are anticipated as a result of disposal within and immediately adjoining the disposal site, which will require up to two years for recovery. It is likely therefore that fish foraging at the disposal site would also experience a reduction in the density and biomass of prey items during this period. While this would not exclude fish from the site, the carrying capacity of the affected area in terms of fish biomass could be expected to be lower than in adjoining areas of similar habitat type. The extensive seabed survey work undertaken in the wider region including the disposal site, which is reported in O'Sullivan *et al.* (2013), clearly shows that the disposal site substrate mix is typical of hundreds of square kilometres off the Cork Coast, such that a temporary reduction of fish food at the disposal site is likely to have a negligible adverse on fish biomass in the wider area.

Mitigation measures

To minimise the risk of dredging and disposal affecting herring spawning, dredging will not be carried out during February or November.

6.3. Ornithology

A Screening for Appropriate Assessment has been produced for the maintenance dredging and disposal activities (RPS, 2021). This section outlines supporting information to inform any further assessment required (e.g. Stage 2).

6.3.1. Receiving environment

Cork Harbour and its surroundings is an important area for birds, reflected by the designation of a Special Protection Area (SPA), Ramsar site, Important Bird Area and Nature Reserves. The Cork Harbour SPA is designated for 24 species of regularly occurring migratory waterbirds, including one breeding species of tern, and wetland habitat as a resource for the waterbirds that utilise it.

6.3.2. Impact assessment

Aerial noise and visual disturbance

Birds can be vulnerable to aerial noise and visual triggers of disturbance. The maintenance dredging will involve activities emitting aerial noise and associated with the movement of vessels. These activities will, however, not occur in isolation but as a series of vessel movements in the operational berths and navigational areas of the Cork Harbour shipping lanes. Cork Harbour is an existing busy shipping area and there is no possibility that an additional ship will trigger behavioural changes or disturbance to birds. The loading activities will simply be viewed as another ship in a place that ships regularly visit or transit.

As with overwintering birds, breeding species can be vulnerable to aerial noise and visual triggers of disturbance. Cork Harbour SPA has one breeding special conservation interest, common tern, which has been known to breed at a number of sub-colonies across Cork Harbour, and not always within the boundary of the SPA. As dredging could occur within any month throughout the year (excluding November and February), there is potential for dredging to occur within the period terns are breeding within Cork Harbour. No direct impacts are predicted on the breeding sites of the terns as where these sites lie within the zone of the dredging activities (for example, Ringaskiddy Deepwater Berth), they are already subject to high levels of disturbance associated with the movement of commercial ships and other vessels. As such it is considered that there is no potential for disturbance to breeding birds from aerial noise or visual disturbance associated with the dredging and disposal works.

It should be noted that the maintenance dredging and disposal operations have been ongoing in their current form for many years with no known impacts on birds.

Water quality and habitat deterioration

Suspended sediments from dredging and/or disposal activities has the potential to result in adverse effects on the wetland habitats that support various bird species. The 2020 sediment plume dispersion study (see Section 6.1.2) assesses the impact of the maintenance dredging and disposal on the sediment transport regime. Dispersion simulations show that there will be no plumes carrying sufficient concentrations of suspended sediments so as to cause significant deposition on mudflat, sandflat, saltmarsh or wetland habitats in and around Cork Harbour.

Given that: the dredge plume will disperse quickly after dredging activity; the dredge plume will be largely limited to areas within the immediate zone of operations; the breeding tern population has large foraging area which is unlikely to be significantly affected by the low levels of modelled sediment increase in a relatively localised area; it is not at all likely that the proposed maintenance dredging works will result in a significant decrease in the range, timing or intensity of use of this area by any bird species, provided that the mitigation measures set out below are complied with.

<u>Loss of prey species</u>

As described in Section 6.1 and 6.2, no significant effects are predicted on benthic species or fish as a result of the maintenance dredging or disposal. As such, there are no anticipated effects on the prey species of birds.

Mitigation measures

The following mitigation measures will apply to the dredging and disposal activities:

- No over-spilling (overflowing) from the dredger will be permitted while the TSHD dredging activity is being carried out.
- A documented Accident Prevention Procedure will be in place prior to commencement
- A documented Emergency Response Procedure will be in place prior to commencement
- A full record of loading and dumping tracks and record of the material being dumped will be maintained for each trip.
- Offshore dumping will be carried out through the vessel's hull.
- The disposal site will be divided into subsections with each used sequentially to ensure uniform spread of the dredged sediments.

6.4. Marine mammals

A Marine Mammal Risk Assessment (MMRA) has been produced for the maintenance dredging and disposal activities (Irish Whale and Dolphin Group, undated), and the findings are summarised in this section.

6.4.1. Receiving environment

Marine mammals sighted during previous maintenance dredging campaigns

Sightings of marine mammals have been recorded during previous dredging campaigns in Cork Harbour. Russell and Levesque (2014) recorded a total of 25 marine mammal sightings during dredging and dumping operations over 30 days between 13 September and 13 October 2014. Grey seal was the most commonly recorded species with 15 records (60%) followed by common dolphin (20%), harbour porpoise (12%) and two sightings (8%) of fin whales. The only marine mammal observed during dredging was grey seal with all other sightings on transit at the mouth of the harbour or at the disposal site.

O'Dwyer (2017) recorded a total of 32 marine mammal sightings during dredging and dumping operations over 36 days from 25 September to 30 October 2017. Grey seal was the most commonly recorded species with 15 records (47%) followed by harbour porpoise with 14 records (44%). There were two records (6%) of common dolphins and one record (3%) of a minke whale. The animals were well distributed with sightings occurring at both disposal and dredge sites as well as while transiting between these. The only marine mammal observed during dredging was grey seal.

Shine (2020) recorded a total of 54 sightings of marine mammals between 19 August and 5 October 2020. Most sightings were of common dolphins outside Cork Harbour or off Roches Point but unidentified cetaceans were recorded off Passage West and Ringaskiddy. Most sightings (72%) were observed during pre-watches. Marine mammal activity was, at times, high around the disposal site, however delays were rarely enacted as to animals were not within the 500m mitigation radius at the commencement of disposal operations.

Cetaceans

Harbour porpoise *(Phocoena phocoena)*

Harbour porpoise are the most widespread and abundant cetacean in inshore Irish waters, with highest abundances in the Irish Sea (Berrow *et al*. 2010). Harbour porpoise were one the most frequently recorded cetacean species during maintenance dredging operations over the September-October period (see above). Harbour porpoise are widespread and have been sighted within Cork Harbour and at the disposal site. Harbour porpoise are typically encountered as individuals or in small groups of 2-3 animals throughout the year, but with a peak in group size during the autumn off the Cork coast. They normally will avoid medium and large vessels.

Common dolphin *(Dephinus delphis)*

Common dolphins occur frequently and at high densities off the Cork coast (Wall *et al.* 2013). They are frequently encountered in the dredge areas for most of the year including in the inner harbour near the city, though these individuals frequently strand. Abundance typically falls to a minimum during April and May, and peaks in the vicinity of Cork Harbour during autumn and winter, coinciding with the presence of pelagic schooling fish in the area (Wall *et al.* 2013). Common dolphins are regularly recorded at the disposal site. They are gregarious and commonly occur in group sizes of tens of animals. During the autumn and winter, group sizes numbering many tens or even hundreds of animals are not uncommon off the Cork coast. They readily approach vessels and may bow ride for extended periods.

Bottlenose dolphin *(Tursiops truncatus)*

Bottlenose dolphins occur off the Cork coast but at relatively lower frequency than along the west coast (Berrow *et al*., 2010). Animals encountered inshore are likely to derive from a coastal population which range around the entire Irish coastline and to adjacent UK and mainland Europe coasts (O'Brien *et al.,* 2009; Robinson *et al., 2012).* Sightings of bottlenose dolphins are infrequent for most of the year but data from land-based effort watches indicate a peak in late autumn / early winter which may coincide with the presence of pelagic schooling fish in the area. Bottlenose dolphins are typically encountered in group sizes of 5 to 30 animals. Inshore animals will readily approach vessels but are less likely to engage in extended periods of bow riding than common dolphins.

Risso's dolphin *(Grampus griseus)*

Risso's dolphins are sighted occasionally at the entrance to Cork Harbour and adjacent waters. They are not abundant in Irish waters and tend to be patchily distributed (Wall *et al.,* 2013).

Killer whale *(Orca orcinus)*

Killer whales are occasionally sighted in waters adjacent to Cork Harbour. Most killer whales sighted in Ireland are the 'West Coast' community. Killer whales are typically encountered as individuals or in a small loose group of 2-10 animals.

Minke whale *(Balaenoptera acutorostrata)*

Minke whales occur frequently off the Cork coast and at the entrance to Cork Harbour, including at the disposal site. They occur from late spring to early winter but are largely absent during winter and early spring (Berrow *et al.* 2010). Minke whale abundance in the vicinity of Cork Harbour peaks in late summer and autumn, and coincides with the presence of pelagic schooling fish in the area (Wall *et al.,* 2013). Minke whales were recorded off Roches Point during transit to the disposal site during dredging operations in 2014 and 2017. Minke whales are typically encountered as individuals; in the late summer and autumn, loose feeding aggregations of two to five animals may be encountered. They do not typically approach large vessels but can be quite inquisitive and may approach slow moving or static vessels.

Fin whale *(Balaenoptera physalus)*

Fin whales regularly occur off the Cork coast (Whooley *et al.* 2011) and have been recorded at the entrance to Corrk Harbour and near the disposal site. They occur from June to January but are largely absent from February to May (Berrow *et al.* 2010). Fin whale abundance in the vicinity of Cork Harbour coincides with the presence of pelagic schooling fish (Wall *et al.,* 2013). Fin whales were observed during dredging operations in 2014. Fin whales are typically encountered as individuals or in small groups of 2-3 animals but during autumn and early winter loose feeding aggregations of up to 10 - 12 animals may be encountered. They do not typically approach large vessels.

Humpback whale *(Megaptera novaengliae)*

Humpback whales occur regularly but in smaller numbers than fin whales off the Cork coast. They are recorded from June to January but are largely absent from February to May. Humpback whales occur in the vicinity of Cork Harbour peak in autumn and early winter, which coincides with the presence of pelagic schooling fish in the area (Wall *et al.*, 2013). Humpback whales are typically encountered as individuals or in pairs off the Cork coast. They do not readily approach large vessels but can be quite inquisitive and may approach slow moving or static vessels.

Pinnipeds

Grey and harbour seals are distributed around the entire Irish coast with grey seals being more abundant along the western seaboard (Cronin *et al.* 2004; O'Cadhla *et al.* 2007; O'Cadhla & Strong 2007).

Grey Seal *(Halichoerus grypus)*

There are no recorded grey seal breeding sites in Cork Harbour (O'Cadhla *et al.* 2007; Morris and Duck 2019); however, grey seals have been observed hauled out in Cork Harbour. Grey seals range long distances while foraging (Cronin *et al.* 2016) and may be encountered regularly within the harbour and at the disposal site. They were the most frequently recorded marine mammal during dredging operations in 2014 and 2017 with between 57% and 70% of all sightings being of grey seals, usually single individuals. Grey seals encountered during dredging are likely the same individuals associating with dredging, which could provide foraging opportunities.

Harbour or Common Seal *(Phoca vitulina)*

There were no harbour seal haul-out sites or breeding sites recorded within Cork Harbour during National Parks and Wildlife Service (NPWS) surveys (Cronin *et al.* 2004; Morris and

Duck 2019). A small number of harbour seals (six) were recorded hauled out at Kinsale harbour (Cronin *et al.* 2004). Harbour seals are less frequently recorded within Cork Harbour and at the disposal site than grey seals but have been recorded at both locations. Harbour seals pup in June-July and the moulting period occurs after breeding, starting in June and ending in November, with a peak in mid-September (Cronin *et al.,* 2014).

6.4.2. Impact assessment

Underwater noise

Received levels of dredging noise by marine mammals can exceed ambient levels at considerable distances depending on the type of dredger used (Richardson *et al.* 1995). TSHDs produce broadband sound between 20-1000 Hz and the highest levels occur during loading. Evans (2000) suggested dredging activities produce sounds varying from 172-185 db re 1 ųPa at 1 m over the broadband range 45 Hz to 7 kHz. Audiograms for bottlenose dolphins show peak sensitivity between 50-60 kHz and no sensitivity below 2 kHz and above around 130 Khz (Richardson *et al.* 1995). Because of rapid attenuation of low frequencies in shallow water, dredger noise normally is undetectable underwater at ranges beyond 20-25km (Richardson *et al.* 1995). The effects of low frequency (4-8 kHz) noise level and duration in causing threshold shifts in bottlenose dolphins were predicted by Mooney *et al.* (2009), who found that if the Sound Exposure Level was kept constant, significant shifts were induced by longer duration exposures but not for shorter exposures.

NPWS (2014) found that increased sound pressure levels above ambient due to dredging could be detected up to 10km from shore. These levels may cause masking or behavioural effects but are not thought to cause injury to a marine mammal.

McKeown (2016) carried out underwater noise measurements during the 2016 maintenance dredging campaign in Dublin Port, and found that show some lower frequency tonal components between 200 Hz and 2 kHz were attributed to the pump. The dredging operation has a higher frequency signal in comparison to the disposal operation. Sound levels for the dredging operations at ranges of 213 and 268 m were below the disturbance threshold for harbour porpoise of 140 dB re 1 µPa SPLRMS and 140 dB re 1μPa^2 s SEL. Noise levels were below the National Oceanic and Atmospheric Administration (NOAA) general behavioural threshold for marine mammals of 160 dB re 1 µPa SPLRMS (McKeown, 2016).

Given the busy nature of Cork Harbour and shipping lane and the level ambient noise already experienced at this location (Sutton *et al.* 2014) the presence of an additional vessel and associated noise is extremely unlikely to be significant.

The disposal site has been routinely used for disposal of dredged material for many years. Increased noise is restricted to <100m from disposal operations (McKeown, 2016), thus increased sound pressure associated with disposal will be above ambient noise levels off Roches Point within a very small area (radius <100m).

Marine mammals are tolerant of shipping noise, being repeatedly exposed to many vessels, small and large. Pinnipeds also exhibit high tolerance and often haul out on man-made structures where there is considerable human activity. In areas with repeated exposure, mammals may become habituated with a decline in avoidance responses and thus become less sensitive to noise and disturbance (Richardson *et al.* 1995). Thus, dredging seems to have less effect on marine mammals than moving sound sources although avoidance behaviour of whales exposed to high levels of activity have been documented. Reactions, when measured, have only occurred when received sound levels are well above ambient levels.

The MMRA concludes that it is extremely unlikely any noise generated during dredging and disposal activities will be capable of causing permanent or temporary hearing injury to a marine mammal. Localised disturbance to marine mammals in the immediate area may occur during operations, but current evidence from recent dredging operations suggests no disturbance occurs and indeed dredging may provide increased foraging opportunities for grey seals.

Physical disturbance and collision risk

The risk of injury or mortality is considered extremely low as marine mammals are exposed to considerable vessel traffic on a daily basis and would be aware of their presence. The dredge vessel is slow moving so any animals in the area would have sufficient time to avoid any collisions and thus injury or mortality. During disposal, the chance of releasing dredged material on top of a marine mammal is extremely unlikely.

Indirect impacts on preferred prey

As described in Section 6.2, no significant adverse effects on fish species are expected from dredging and disposal operations.

6.4.3. Mitigation measures

The following mitigation measures will be implemented to minimise potential impacts on marine mammals and to allow animals to move away from the area of dredging operations:

- A dedicated, qualified and experienced Marine Mammal Observer (MMO) will conduct a 30 minute watch for marine mammals within 200m prior to start up. If a seal or cetacean (or otter) is sighted within 200m of the TSHD, start-up must be delayed until the animal(s) is observed to move outside the mitigation zone or the 30 minutes has passed without the animal being sighted within the mitigation zone.
- Dredging activities shall only commence in daylight hours where effective visual monitoring, as performed and determined by the MMO, has been achieved. Where effective visual monitoring, as determined by the MMO, is not possible the sound-producing activities shall be postponed until effective visual monitoring is possible.
- Once normal dredging operations commence, there is no requirement to halt or discontinue the activity at night-time, nor if weather or visibility conditions deteriorate nor if marine mammals occur within a 500m radial distance of the sound source, i.e., within the mitigation zone.

7. Aquaculture

7.1. Receiving environment

Ireland's Marine Atlas [accessed 22 June 2022] shows that there is one aquaculture site for blue mussel within Cork Harbour, as shown in the figure in Appendix J. Within this site, there are two licensed areas for mussels: T05-522A and T05/522B (gov.ie - Aquaculture/Foreshore Licence Applications - Cork (www.gov.ie)).

7.2. Impact assessment

The system in Cork Harbour is a turbid system and subject to regular increases in turbidity following heavy rainfall and strong tides. Aquaculture communities present in this system are adapted to increases in turbidity and as a result, impacts associated with short-term increased turbidity during maintenance dredging operations are expected to be negligible.

As described in Section 4, an assessment of the primary maintenance dredging operations found that the average total suspended sediment concentration throughout Cork Harbour did not generally exceed 3mg/l during the 16 days of dredging.

As all dredge areas have been dredged in their current form for many decades, there are no changes to the existing sediment regime that will adversely affect aquaculture sites.

8. Air Quality and Climate

As per Section 1, the Port of Cork provides important national trade infrastructure. Trade vessels are regularly entering and leaving the harbour. Fuel emissions are limited to the temporary undertaking of the dredging works and are not expected to impact local air quality or climate. However, the Port shall record the fuel used during the dredging works and monitor the carbon emissions using published conversion factors where available.

There is a relatively low potential for odour generation and nuisance to occur during the proposed dredging. Some potential exists where decayed organic material has the potential to release sulphurous compounds (such as hydrogen sulphide H_2S). However, no significant non-temporary effects from odour are expected.
The impact of the dredging on the local air quality and climate as a direct result of the interaction with the seabed by the dredger is considered insignificant to nil.

9. Noise and Vibration

There will be some localised underwater noise impacts from the dredging vessel, which are discussed under Section 6.4 for Marine Mammals. The distances from the dredging areas and the disposal location to the mainland areas are great enough that any airborne noise levels associated with the dredging and disposal at sea process are not expected to reach potential receptors on land. There may be some noticeable noise levels immediately adjacent to the dredger on flat calm days or when there is little to no background noise from the sea or environment. However, any impact will be minor and temporary given the inherent nature of the activities and so no special requirements for specific noise mitigation measures, other than those mentioned in Section 6.4, are considered necessary.

10. Cultural Heritage

No Underwater Archaeological Impact Assessment (UAIA) and/or full-time archaeological monitoring has been undertaken previously as the majority of sites have been maintained regularly for several decades by dredging. However, pre-application consultation was undertaken with the Underwater Archaeology Unit of the Department of Culture, Heritage and the Gaeltacht and based on this consultation, the following risk mitigation conditions will apply:

- No dumping should take place to the northwest external perimeter of the dumpsite where a wreck is recorded as being located. All dumping should keep away from the previously identified anomaly that lies just outside the edge of the dumpsite at plot 280 (188723.5 54463.1). A 250m radius exclusion zone has been implemented.

- Should any material be recovered (e.g. potential cultural material like timbers, artefacts, etc.) during the course of dredging work, there is a statutory obligation to report same to the National Monuments Service under the National Monuments (Amendment) Act 1930-2004.

- Where a wreck is discovered or other material recovered from the marine environment, there is also a statutory obligation to report same to the Receiver of Wreck under the Merchant Shipping (Salvage and Wreck) Act 1993.

- Dredging should be suspended in the area where the cultural material has been recovered until the Department have had the opportunity to assess it, so as to avoid any further potential impact to a site or other archaeological feature or object.

No other underwater cultural heritage concerns were raised during the Port's consultation with the Department of Culture, Heritage and the Gaeltacht.

11. Landscape and Visual

The proposed works are maintenance dredging activities, which are marine-based and temporary. From a visual perspective, marine vessels frequent the Port of Cork regularly and therefore, the presence of dredging vessels will not have a significant landscape or visual impact. Furthermore, maintenance dredging activities are temporary and dredging vessels or supporting vessels will inherently relocate frequently.

No significant landscape or visual impacts are expected and therefore no specific mitigation measures are proposed.

12. Population and Human Health

The dredging activities are not expected to have any negative impact on either the local population or human health. Therefore no mitigation measures or conditions are considered necessary. Conversely, by maintaining the Port for its users, dredging and maintaining recreational and educational areas will provide an ongoing positive benefit for its users.

13. Waste

Dredged material is classified as a waste material and thus requires to be managed appropriately. The Port of Cork have applied to the Environmental Protection Agency for a Dumping at Sea permit to run concurrently to the proposed foreshore licence being applied for. The application is currently under review.

Any man made debris recovered during the dredging works will be segregated, stored and disposed of responsibly ashore.

All waste produced by the dredger and its crew (e.g. wastewater, domestic waste) will be landed ashore and managed responsibly.

14. Supporting Documentation

Several environmental assessments were undertaken to support this application and they are referenced throughout this document. However, they should be reviewed in turn to ensure all pertinent information has been considered. The reports include:

- Assessment of Benthic and Fisheries Impacts of Maintenance Dredging in Lough Mahon and the Lower River Lee;
- Survey of Benthic Habitats at the Port of Cork Licensed Dumpsite off Power Head including notes on Fisheries and an Impact Hypothesis;
- Port of Cork maintenance dredging sediment plume dispersion assessment;
- Integrated Report on Environmental Aspects of Water Injection Dredging;
- A review and analysis of the water quality monitoring data around the Port of Cork before during and after the dredging campaign in 2020.

These documents are included in the appendices. An appropriate assessment screening , Natura Impact Statement and Marine Mammal Risk Assessment have also been undertaken and are provided as sperate individual reports.

15. References

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Appendix A – 2021 Sediment Test Results

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	**MAR01090**
Issue Version	3
Customer	Aquatic Services Unit, Environmental Research Institute, Lee Road, Cork, Ireland
Customer Reference	Cork Harbour Marine Sediment Analysis
Date Sampled	03-04/08/2021
Date Received	09-Aug-21
Date Reported	15-Nov-21
Condition of samples	Cold Satisfactory

This is a revised report containing updated results for Arsenic following re-extraction and analysis and replaces all previously issued versions.

[redacted]

Authorised by: [redacted]

Position: Laboratory Manager

Any additional opinions or interpretations found in this report, are outside the scope of UKAS accreditation.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Method No	SOCOTEC Doncaster*
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Visual Description**
CQ1	MAR01090.001	Sediment	Grey Silt
CQ2	MAR01090.002	Sediment	Grey Silt
CQ3	MAR01090.003	Sediment	Grey Silt
T4	MAR01090.004	Sediment	Grey Silt
BB5	MAR01090.005	Sediment	Grey Silt
LM6	MAR01090.006	Sediment	Grey Silt
LM7	MAR01090.007	Sediment	Grey Silt
H1	MAR01090.008	Sediment	Grey Silt
R1	MAR01090.009	Sediment	Grey Silt
R2	MAR01090.010	Sediment	Grey Silt
R3	MAR01090.011	Sediment	Grey Silt
R4	MAR01090.012	Sediment	Grey Silt
R5	MAR01090.013	Sediment	Grey Silt
2_A	MAR01090.014	Sediment	Grey Silt
3_A	MAR01090.015	Sediment	Grey Silt
4_A	MAR01090.016	Sediment	Grey Silt
5_A	MAR01090.017	Sediment	Grey Silt
6_A	MAR01090.018	Sediment	Grey Silt
7_A	MAR01090.019	Sediment	Grey Silt
8_A	MAR01090.020	Sediment	Grey Silt
9_A	MAR01090.021	Sediment	Grey Silt
10_A	MAR01090.022	Sediment	Grey Silt
11_A	MAR01090.023	Sediment	Grey Silt
12_A	MAR01090.024	Sediment	Grey Silt

* See Report Notes

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	%	%	Mg/m3	% M/M	% M/M
		Method No	ASC/SOP/303	ASC/SOP/303	SOCOTEC Doncaster*	SOCOTEC Env Chem*	SOCOTEC Env Chem*
		Limit of Detection	0.2	0.2	N/A	0.02	0.04
		Accreditation	UKAS	UKAS	N	UKAS	No
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Total Moisture @ 120°C**	**Total Solids**	**Particle Density**	**TOC**	**Carbonate Equivalent (%CO3)**
CQ1	MAR01090.001	Sediment	77.8	22.2	2.58	6.40	1.44
CQ2	MAR01090.002	Sediment	76.1	23.9	2.45	6.27	0.96
CQ3	MAR01090.003	Sediment	68.0	32.0	2.61	4.40	1.68
T4	MAR01090.004	Sediment	68.3	31.7	2.64	2.83	5.04
BB5	MAR01090.005	Sediment	69.8	30.2	2.54	2.52	2.88
LM6	MAR01090.006	Sediment	55.7	44.3	2.63	1.50	6.24
LM7	MAR01090.007	Sediment	60.4	39.6	2.65	2.09	4.80
H1	MAR01090.008	Sediment	63.0	37.0	2.58	0.88	4.08
R1	MAR01090.009	Sediment	42.4	57.6	2.67	0.87	5.76
R2	MAR01090.010	Sediment	62.0	38.0	2.62	1.82	8.40
R3	MAR01090.011	Sediment	63.1	36.9	2.64	2.47	11.5
R4	MAR01090.012	Sediment	67.9	32.1	2.63	1.17	7.20
R5	MAR01090.013	Sediment	66.4	33.6	2.68	2.15	9.12
2_A	MAR01090.014	Sediment	54.0	46.0	2.61	1.72	6.24
3_A	MAR01090.015	Sediment	59.6	40.4	2.65	1.85	10.3
4_A	MAR01090.016	Sediment	50.9	49.1	2.66	1.33	6.00
5_A	MAR01090.017	Sediment	61.9	38.1	2.64	2.21	9.12
6_A	MAR01090.018	Sediment	44.7	55.3	2.61	1.48	8.88
7_A	MAR01090.019	Sediment	59.1	40.9	2.68	1.36	8.88
8_A	MAR01090.020	Sediment	65.2	34.8	2.66	1.53	8.88
9_A	MAR01090.021	Sediment	67.3	32.7	2.67	1.52	11.0
10_A	MAR01090.022	Sediment	52.9	47.1	2.67	1.44	5.76
11_A	MAR01090.023	Sediment	39.0	61.0	2.65	0.94	11.3
12_A	MAR01090.024	Sediment	68.2	31.8	2.65	2.05	8.64
		Reference Material (% Recovery)	NA	NA	NA	100	99
		QC Blank	NA	NA	NA	<0.02	NA

* See Report Notes

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)
		Method No	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*
		Limit of Detection	0.5	0.2	0.5	2	2	0.5	3
		Accreditation	UKAS	UKAS	No	UKAS	UKAS	No	No
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Arsenic as As***	**Cadmium as Cd***	**Chromium as Cr**	**Copper as Cu**	**Lead as Pb**	**Nickel as Ni**	**Zinc as Zn**
CQ1	MAR01090.001	Sediment	11.0	0.5	60.2	38.2	42.7	29.3	239
CQ2	MAR01090.002	Sediment	11.2	0.4	58.5	35.2	41.2	29.3	268
CQ3	MAR01090.003	Sediment	10.9	0.4	64.0	33.8	46.1	30.5	174
T4	MAR01090.004	Sediment	13.0	0.3	65.6	21.0	39.9	28.5	147
BB5	MAR01090.005	Sediment	13.9	0.3	63.9	18.4	32.8	27.1	143
LM6	MAR01090.006	Sediment	6.8	0.18**	52.4	13.9	23.6	24.1	107
LM7	MAR01090.007	Sediment	5.4	0.13**	61.9	17.4	31.9	26.3	136
H1	MAR01090.008	Sediment	11.8	0.3	39.5	10.4	19.2	18.2	87.5
R1	MAR01090.009	Sediment	6.4	0.4	48.3	12.9	22.8	33.3	185
R2	MAR01090.010	Sediment	9.8	0.2	59.1	13.2	29.4	26.3	131
R3	MAR01090.011	Sediment	7.1	0.19**	59.3	17.4	30.1	26.4	151
R4	MAR01090.012	Sediment	11.2	0.3	53.8	14.1	27.2	28.8	151
R5	MAR01090.013	Sediment	12.4	0.3	61.3	16.1	30.9	27.4	138
2_A	MAR01090.014	Sediment	7.2	0.3	53.1	12.2	28.3	24.1	107
3_A	MAR01090.015	Sediment	7.7	0.2	89.8	18.3	52.2	44.6	183
4_A	MAR01090.016	Sediment	7.1	0.19**	64.4	41.2	59.6	29.7	161
5_A	MAR01090.017	Sediment	11.0	0.2	45.7	10.5	28.3	21.4	104
6_A	MAR01090.018	Sediment	10.4	0.15**	51.9	10.0	30.2	22.8	96.1
7_A	MAR01090.019	Sediment	6.6	0.2	53.5	14.4	41.1	29.5	170
8_A	MAR01090.020	Sediment	7.4	0.4	54.5	11.5	25.7	28.7	139
9_A	MAR01090.021	Sediment	7.6	0.5	58.9	7.60	23.9	31.6	147
10_A	MAR01090.022	Sediment	10.7	0.3	29.8	7.30	40.9	16.1	90.8
11_A	MAR01090.023	Sediment	6.7	0.12**	32.9	8.40	32.7	17.8	90.0
12_A	MAR01090.024	Sediment	8.0	<0.2	64.3	13.6	35.3	28.6	128
CRM 1	MAR01090.025	Sediment	–	–	44.6	11.4	21.5	25.0	123
Certified Reference Material 2702 (Measured Value)			45.7	0.56	329	103	123	70.6	490
Certified Reference Material 2702 (Certified Value)			45.3	0.817~	352~	117.7	132.8	75.4~	485.3~
Certified Reference Material 2702 (% Recovery)			103	82	101~	117	103	101~	99~
QC Blank			<0.5	<0.2	<0.5	<2	<2	<0.5	<3

* See Report Notes

~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.

**Data reported below the method LoD of 0.2mg/kg.
This is not UKAS Accredited and is for information purposes only.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)	mg/Kg (Dry Weight)
		Method No	SOCOTEC Env Chem*	SOCOTEC Env Chem*	SOCOTEC Env Chem*
		Limit of Detection	0.01	10	0.5
		Accreditation	No	UKAS	No
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Mercury as Hg**	**Aluminium as Al**	**Lithium as Li**
CQ1	MAR01090.001	Sediment	0.11	43600	41.5
CQ2	MAR01090.002	Sediment	0.09	44000	40.1
CQ3	MAR01090.003	Sediment	0.10	47000	46.2
T4	MAR01090.004	Sediment	0.09	45200	49.6
BB5	MAR01090.005	Sediment	0.07	45700	50.8
LM6	MAR01090.006	Sediment	0.06	37600	40.7
LM7	MAR01090.007	Sediment	0.07	42800	48.1
H1	MAR01090.008	Sediment	0.04	29500	34.0
R1	MAR01090.009	Sediment	0.03	32700	43.4
R2	MAR01090.010	Sediment	0.06	42600	48.4
R3	MAR01090.011	Sediment	0.04	42200	47.4
R4	MAR01090.012	Sediment	0.04	37300	45.5
R5	MAR01090.013	Sediment	0.06	44500	50.6
2_A	MAR01090.014	Sediment	0.08	38300	40.8
3_A	MAR01090.015	Sediment	0.05	84000	78.9
4_A	MAR01090.016	Sediment	0.06	40000	45.1
5_A	MAR01090.017	Sediment	0.23	33600	38.0
6_A	MAR01090.018	Sediment	0.09	38800	42.8
7_A	MAR01090.019	Sediment	0.05	37600	47.1
8_A	MAR01090.020	Sediment	0.05	38300	48.6
9_A	MAR01090.021	Sediment	0.06	43100	50.6
10_A	MAR01090.022	Sediment	0.05	23000	28.8
11_A	MAR01090.023	Sediment	0.05	24700	30.9
12_A	MAR01090.024	Sediment	0.07	48600	55.1
CRM 1	MAR01090.025	Sediment	0.05	30800	39.2
Certified Reference Material 2702 (Measured Value)			0.24	80229	76.0
Certified Reference Material 2702 (Certified Value)			0.04~	84000	78.2
Certified Reference Material 2702 (% Recovery)			100~	99	107
QC Blank			<0.01	<10	<0.5

* See Report Notes

~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.

**Data reported below the method LoD of 0.2mg/kg.
This is not UKAS Accredited and is for information purposes only.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	
		Method No	ASC/SOP/301	
		Limit of Detection	1	1
		Accreditation	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Dibutyltin (DBT)**	**Tributyltin (TBT)**
CQ1	MAR01090.001	Sediment	37.5	<5
CQ2	MAR01090.002	Sediment	<5	28.4
CQ3	MAR01090.003	Sediment	28.7	23.9
T4	MAR01090.004	Sediment	<5	<5
BB5	MAR01090.005	Sediment	<5	23.6
LM6	MAR01090.006	Sediment	<5	<5
LM7	MAR01090.007	Sediment	<5	13.6
H1	MAR01090.008	Sediment	<5	<5
R1	MAR01090.009	Sediment	<5	<5
R2	MAR01090.010	Sediment	73.0	<5
R3	MAR01090.011	Sediment	<5	<5
R4	MAR01090.012	Sediment	<5	<5
R5	MAR01090.013	Sediment	<5	<5
2_A	MAR01090.014	Sediment	<5	<5
3_A	MAR01090.015	Sediment	<5	<5
4_A	MAR01090.016	Sediment	<5	18.2
5_A	MAR01090.017	Sediment	<5	<5
6_A	MAR01090.018	Sediment	<5	<5
7_A	MAR01090.019	Sediment	<5	<5
8_A	MAR01090.020	Sediment	<5	<5
Certified Reference Material BCR-646 (Measured Value)			831	364
Certified Reference Material BCR-646 (Certified Value)			770	480
Certified Reference Material BCR-646 (% Recovery)			108	76
QC Blank			<1	<1

* See Report Notes

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	
		Method No	ASC/SOP/301	
		Limit of Detection	1	1
		Accreditation	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**Dibutyltin (DBT)**	**Tributyltin (TBT)**
9_A	MAR01090.021	Sediment	<5	<5
10_A	MAR01090.022	Sediment	<5	<5
11_A	MAR01090.023	Sediment	<5	<5
12_A	MAR01090.024	Sediment	<5	<5
CRM3	MAR01090.027	Sediment	220	246
Certified Reference Material BCR-646 (Measured Value)			541	277
Certified Reference Material BCR-646 (Certified Value)			770	480
Certified Reference Material BCR-646 (% Recovery)			70	58
QC Blank			<1	<1

* See Report Notes

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304
		Limit of Detection	1	1	1	1	1	1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**ACENAPTH**	**ACENAPHY**	**ANTHRACN**	**BAA**	**BAP**	**BBF**
CQ1	MAR01090.001	Sediment	10.3	8.98	23.0	64.7	82.2	83.2
CQ3	MAR01090.003	Sediment	20.3	16.1	53.3	157	175	182
T4	MAR01090.004	Sediment	4.35	6.08	33.9	65.2	68.2	83.7
H1	MAR01090.008	Sediment	4.11	3.92	36.4	53.3	55.8	64.0
R1	MAR01090.009	Sediment	1.25	1.01	3.58	9.64	13.3	22.0
R3	MAR01090.011	Sediment	16.9	4.55	16.2	21.0	24.5	42.8
R5	MAR01090.013	Sediment	3.60	3.21	9.05	23.9	30.5	46.3
2_A	MAR01090.014	Sediment	10.3	5.08	15.1	45.2	51.6	52.4
3_A	MAR01090.015	Sediment	1.66	2.11	4.93	17.0	22.6	29.1
4_A	MAR01090.016	Sediment	12.0	4.77	18.9	82.4	88.8	86.7
5_A	MAR01090.017	Sediment	28.5	13.7	44.0	92.6	104	119
6_A	MAR01090.018	Sediment	37.7	54.1	167	85.8	32.4	134
7_A	MAR01090.019	Sediment	2.42	<1	5.33	14.3	18.3	29.6
8_A	MAR01090.020	Sediment	3.02	5.40	19.3	52.6	52.1	66.1
Certified Reference Material QPH103MS (Measured Value)			1.74	2.32	3.88	14.6	18.9	68.6
Certified Reference Material QPH103MS (Certified Value)			2.28	2.02	4.32	22.1	26.2	98.4
Certified Reference Material QPH103MS (% Recovery)			76	115	90	66	72	70
QC Blank			<1	<1	<1	<1	<1	<1

For full analyte name see method summaries
~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.
As the method uses surrogate standards to correct for losses, the RM results are reported as percentage trueness, not recovery.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID MAR01090
Issue Version 3
Customer Reference Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304
		Limit of Detection	1	1	1	1	1	1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**BENZGHIP**	**BKF**	**CHRYSENE**	**DBENZAH**	**FLUORANT**	**FLUORENE**
CQ1	MAR01090.001	Sediment	79.8	53.7	84.2	17.1	154	15.4
CQ3	MAR01090.003	Sediment	150	97.4	172	29.8	340	26.0
T4	MAR01090.004	Sediment	71.3	50.4	97.1	14.9	143	10.7
H1	MAR01090.008	Sediment	58.8	42.1	118	12.2	115	10.2
R1	MAR01090.009	Sediment	16.2	10.9	13.7	2.74	24.0	3.18
R3	MAR01090.011	Sediment	33.7	21.6	31.4	6.74	57.3	29.8
R5	MAR01090.013	Sediment	38.5	30.2	33.6	8.60	52.2	9.46
2_A	MAR01090.014	Sediment	48.8	38.9	59.2	6.97	127	11.3
3_A	MAR01090.015	Sediment	27.7	17.1	24.0	5.65	36.3	4.41
4_A	MAR01090.016	Sediment	67.8	45.1	97.5	13.3	218	10.8
5_A	MAR01090.017	Sediment	89.2	64.5	118	20.9	263	35.4
6_A	MAR01090.018	Sediment	85.8	58.5	631	2.28	747	266
7_A	MAR01090.019	Sediment	24.8	13.8	18.6	3.89	35.1	5.40
8_A	MAR01090.020	Sediment	47.6	39.1	66.9	9.77	136	9.28
Certified Reference Material QPH103MS (Measured Value)			75.5	29.6	25.8	13.6	33.9	4.94
Certified Reference Material QPH103MS (Certified Value)			91.0	37.6	30.7	17.0	43.3	5.87
Certified Reference Material QPH103MS (% Recovery)			83	79	84	80	78	84
QC Blank			<1	<1	<1	<1	<1	<1

For full analyte name see method summaries
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As the method uses surrogate standards to correct for losses, the RM results are reported as percentage trueness, not recovery.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID MAR01090
Issue Version 3
Customer Reference Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/306
		Limit of Detection	1	1	1	1	100
		Accreditation	UKAS	UKAS	UKAS	UKAS	N
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**INDPYR**	**NAPTH**	**PHENANT**	**PYRENE**	**THC**
CQ1	MAR01090.001	Sediment	75.4	31.4	70.1	154	434000
CQ3	MAR01090.003	Sediment	136	29.1	117	357	743000
T4	MAR01090.004	Sediment	72.4	20.0	66.4	134	331000
H1	MAR01090.008	Sediment	68.9	16.8	50.5	110	218000
R1	MAR01090.009	Sediment	19.7	5.66	11.7	21.9	69900
R3	MAR01090.011	Sediment	42.2	29.4	89.1	58.8	474000
R5	MAR01090.013	Sediment	44.9	20.1	33.8	47.5	194000
2_A	MAR01090.014	Sediment	53.8	14.8	79.7	110	106000
3_A	MAR01090.015	Sediment	32.6	8.94	18.5	34.1	75000
4_A	MAR01090.016	Sediment	69.0	17.6	118	195	63400
5_A	MAR01090.017	Sediment	96.3	24.2	151	254	406000
6_A	MAR01090.018	Sediment	68.6	56.3	2840	1220	24500000
7_A	MAR01090.019	Sediment	27.1	10.9	21.4	31.8	109000
8_A	MAR01090.020	Sediment	55.7	16.7	69.8	114	150000
Certified Reference Material QPH103MS (Measured Value)			84.0	17.8	40.1	27.6	NA
Certified Reference Material QPH103MS (Certified Value)			115	20.1	45.4	34.0	NA
Certified Reference Material QPH103MS (% Recovery)			73	88	88	81	68~
QC Blank			<1	<1	<1	<1	<100

For full analyte name see method summaries
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Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304
		Limit of Detection	1	1	1	1	1	1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**ACENAPTH**	**ACENAPHY**	**ANTHRACN**	**BAA**	**BAP**	**BBF**
9_A	MAR01090.021	Sediment	2.42	8.9	10.2	28.8	35.1	43.9
10_A	MAR01090.022	Sediment	4.22	6.24	9.66	25.0	31.6	37.8
11_A	MAR01090.023	Sediment	6.41	6.08	34.3	146	75.9	106
12_A	MAR01090.024	Sediment	2.67	2.70	10.2	31.6	39.8	64.2
CRM2	MAR01090.026	Sediment	4.33	4.35	14.3	43.7	52.7	90.9
Certified Reference Material QPH103MS (Measured Value)			2.12	2.41	3.97	14.9	20.6	66.7
Certified Reference Material QPH103MS (Certified Value)			2.28	2.02	4.32	22.1	26.2	98.4
Certified Reference Material QPH103MS (% Recovery)			93	119	92	67	79	68
QC Blank			<1	<1	<1	<1	<1	<1

For full analyte name see method summaries
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Certificate of Analysis

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SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304
		Limit of Detection	1	1	1	1	1	1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**BENZGHIP**	**BKF**	**CHRYSENE**	**DBENZAH**	**FLUORANT**	**FLUORENE**
9_A	MAR01090.021	Sediment	33.2	30.7	38.0	6.76	59.0	7.96
10_A	MAR01090.022	Sediment	32.0	26.3	37.8	5.24	85.9	8.45
11_A	MAR01090.023	Sediment	41.7	65.3	169	8.55	260	11.6
12_A	MAR01090.024	Sediment	50.0	35.7	46.7	9.02	74.1	8.71
CRM2	MAR01090.026	Sediment	94.0	54.4	64.9	14.8	95.9	8.25
Certified Reference Material QPH103MS (Measured Value)			75.7	37.9	27.3	13.4	34.8	4.77
Certified Reference Material QPH103MS (Certified Value)			91.0	37.6	30.7	17.0	43.3	5.87
Certified Reference Material QPH103MS (% Recovery)			83	101	89	79	80	81
QC Blank			<1	<1	<1	<1	<1	<1

For full analyte name see method summaries
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Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/304	ASC/SOP/303/306
		Limit of Detection	1	1	1	1	100
		Accreditation	UKAS	UKAS	UKAS	UKAS	N
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**INDPYR**	**NAPTH**	**PHENANT**	**PYRENE**	**THC**
9_A	MAR01090.021	Sediment	36.5	13.5	31.9	60.7	140000
10_A	MAR01090.022	Sediment	32.6	13.0	68.1	77.7	98200
11_A	MAR01090.023	Sediment	42.1	59.0	70.2	345	58400
12_A	MAR01090.024	Sediment	54.8	19.5	41.9	69.4	199000
CRM2	MAR01090.026	Sediment	85.6	31.9	66.6	92.8	NA
Certified Reference Material QPH103MS (Measured Value)			82.7	17.4	41.8	29.3	NA
Certified Reference Material QPH103MS (Certified Value)			115	20.1	45.4	34.0	NA
Certified Reference Material QPH103MS (% Recovery)			72	86	92	86	93~
QC Blank			<1	<1	<1	<1	<1

For full analyte name see method summaries

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Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302
		Limit of Detection	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**PCB28**	**PCB52**	**PCB101**	**PCB118**	**PCB138**	**PCB153**	**PCB180**
CQ1	MAR01090.001	Sediment	0.48	0.44	0.51	0.43	0.61	0.66	0.38
LM7	MAR01090.007	Sediment	0.53	0.41	0.29	0.26	0.23	0.24	0.12
R1	MAR01090.009	Sediment	0.25	0.24	0.15	0.09	0.17	0.15	<0.08
R3	MAR01090.011	Sediment	0.39	0.29	0.24	0.26	0.30	0.24	<0.08
R5	MAR01090.013	Sediment	0.34	0.26	0.22	0.22	0.21	0.20	<0.08
2_A	MAR01090.014	Sediment	0.32	0.26	0.16	0.14	0.18	0.13	<0.08
3_A	MAR01090.015	Sediment	0.19	0.14	0.12	0.13	0.13	0.13	<0.08
4_A	MAR01090.016	Sediment	0.23	0.21	0.10	<0.08	0.13	<0.08	<0.08
5_A	MAR01090.017	Sediment	0.37	0.40	0.38	0.38	0.38	0.43	0.23
6_A	MAR01090.018	Sediment	0.21	0.18	0.27	0.17	0.70	0.56	0.44
7_A	MAR01090.019	Sediment	0.28	0.24	0.12	0.18	0.16	0.16	<0.08
Certified Reference Material QOR134 MS (Measured Value)			0.12	0.83	0.98	0.54	0.97	0.97	0.52
Certified Reference Material QOR134MS (Certified Value)			0.13	0.72	0.83	0.50	0.97	0.96	0.61
Certified Reference Material QOR134MS (% Recovery)			94	115	118	109	100	101	85
QC Blank			<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

For full analyte name see method summaries

~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302
		Limit of Detection	0.08	0.08	0.08	0.08	0.08	0.08	0.08
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**PCB28**	**PCB52**	**PCB101**	**PCB118**	**PCB138**	**PCB153**	**PCB180**
8_A	MAR01090.020	Sediment	0.32	0.23	0.12	0.14	0.10	0.17	<0.08
9_A	MAR01090.021	Sediment	0.32	0.27	0.19	0.18	0.19	0.20	<0.08
10_A	MAR01090.022	Sediment	0.31	0.30	0.16	0.13	0.16	0.13	<0.08
11_A	MAR01090.023	Sediment	0.26	0.21	0.30	0.18	0.55	0.46	0.39
12_A	MAR01090.024	Sediment	0.31	0.26	0.23	0.22	0.21	0.28	0.16
CRM2	MAR01090.026	Sediment	0.36	0.58	0.45	0.49	0.51	0.54	0.21
Certified Reference Material QOR134 MS (Measured Value)			0.13	0.87	0.86	0.56	0.97	0.93	0.54
Certified Reference Material QOR134MS (Certified Value)			0.13	0.72	0.83	0.50	0.97	0.96	0.61
Certified Reference Material QOR134MS (% Recovery)			98	120	104	113	100	97	89
QC Blank			<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

For full analyte name see method summaries

~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302
		Limit of Detection	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS	N*	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**AHCH**	**BHCH**	**GHCH**	**DIELDRIN**	**HCB**	**DDE**	**DDT**	**DDD**
CQ1	MAR01090.001	Sediment	<0.1	<0.1	0.13	0.58	0.15	0.86	<0.1	0.74
LM7	MAR01090.007	Sediment	<0.1	<0.1	<0.1	<0.1	0.11	0.19	0.17	0.17
R1	MAR01090.009	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.05
R3	MAR01090.011	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.18	0.14	0.13
R5	MAR01090.013	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2_A	MAR01090.014	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	0.25	0.12
3_A	MAR01090.015	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	<0.1
4_A	MAR01090.016	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	0.10
5_A	MAR01090.017	Sediment	<0.1	<0.1	<0.1	0.27	<0.1	0.28	<0.1	0.26
6_A	MAR01090.018	Sediment	<0.1	<0.1	<0.1	0.34	<0.1	0.11	0.13	<0.1
7_A	MAR01090.019	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.14	<0.1	<0.1
Certified Reference Material QOR134 MS (Measured Value)			<0.1	<0.1	<0.1	<0.1	0.09	0.13	<0.1	0.05
Certified Reference Material QOR134MS (Certified Value)			0.03	NA	NA	0.08	0.10	0.13	0.08	0.13
Certified Reference Material QOR134MS (% Recovery)			100~	95~	104~	83~	95	82	118~	36
QC Blank			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

For full analyte name see method summaries

~ Indicates result is for an In-house Reference Material as no Certified Reference Materials are avaliable.

* See Report Notes

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

		Units	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)	µg/Kg (Dry Weight)
		Method No	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302	ASC/SOP/302
		Limit of Detection	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Accreditation	UKAS	UKAS	UKAS	UKAS	UKAS	UKAS	N*	UKAS
Client Reference:	**SOCOTEC Ref:**	**Matrix**	**AHCH**	**BHCH**	**GHCH**	**DIELDRIN**	**HCB**	**DDE**	**DDT**	**DDD**
8_A	MAR01090.020	Sediment	<0.1	<0.1	<0.1	<0.1	0.11	0.12	<0.1	<0.1
9_A	MAR01090.021	Sediment	<0.1	<0.1	<0.1	0.15	0.11	0.12	<0.1	<0.1
10_A	MAR01090.022	Sediment	<0.1	<0.1	<0.1	<0.1	0.15	0.12	0.44	0.21
11_A	MAR01090.023	Sediment	<0.1	<0.1	<0.1	<0.1	<0.1	0.09	0.30	0.58
12_A	MAR01090.024	Sediment	<0.1	<0.1	<0.1	0.09	<0.1	0.27	<0.1	0.13
CRM2	MAR01090.026	Sediment	<0.1	<0.1	0.06	0.02	<0.1	0.12	0.05	0.04
Certified Reference Material QOR134 MS (Measured Value)			0.02	<0.1	<0.1	<0.1	0.12	0.15	<0.1	0.11
Certified Reference Material QOR134MS (Certified Value)			0.03	NA	NA	0.08	0.10	0.13	0.08	0.13
Certified Reference Material QOR134MS (% Recovery)			84	80~	101~	88~	121	97	100~	89
QC Blank			<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

For full analyte name see method summaries

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SOCOTEC

Test Report ID	MAR01090
Issue Version	3
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REPORT NOTES

Method Code	Sample ID	The following information should be taken into consideration when using the data contained within this report
SOCOTEC Env Chem*	MAR01090.001-024, 025	Analysis was conducted by an internal SOCOTEC laboratory. UKAS accredited analysis by this laboratory is under UKAS number 1252.
SOCOTEC Env Chem*	MAR01090.001-024	Arsenic & Cadmium were re extracted and analysed using the microwave assisted HF/Boric digest.
SOCOTEC Doncaster*	MAR01090.001-024	Analysis was conducted by an internal SOCOTEC laboratory.
ASC/SOP/301	MAR01090.001-024	The matrix of this sample has been found to interfere with the result for this test. The sample has therefore been diluted, but in doing so, the detection limit for this test has been elevated.
ASC/SOP/302	MAR01090.001-024, 026	The Primary process control data associated with this Test has not wholly met the requirements of the Laboratory Quality Management System QMS with one or more target analytes falling outside acceptable limits. The remaining data gives the Laboratory confidence that the test has performed satisfactorily and that the validity of the data may not have been significantly affected.However in line with our QMS policy we have removed accreditation, where applicable, from the affected analytes (DDT) . These circumstances should be taken into consideration when utilising the data.
ASC/SOP/303/304	MAR01090.001-024, 026	Chrysene is known to coelute with Triphenylene and these peaks can not be resolved. It is believed Triphenylene is present in these samples therefore it is suggested that the Chrysene results should be taken as a Chrysene (inc. Triphenylene).This should be taken into consideration when utilising the data.

DEVIATING SAMPLE STATEMENT

Deviation Code	Deviation Definition	Sample ID	Deviation Details. The following information should be taken into consideration when using the data contained within this report
D1	Holding Time Exceeded	N/A	N/A
D2	Handling Time Exceeded	N/A	N/A
D3	Sample Contaminated through Damaged Packaging	N/A	N/A
D4	Sample Contaminated through Sampling	N/A	N/A
D5	Inappropriate Container/Packaging	N/A	N/A
D6	Damaged in Transit	N/A	N/A
D7	Insufficient Quantity of Sample	N/A	N/A
D8	Inappropriate Headspace	N/A	N/A
D9	Retained at Incorrect Temperature	N/A	N/A
D10	Lack of Date & Time of Sampling	N/A	N/A
D11	Insufficient Sample Details	N/A	N/A
D12	Sample integrity compromised or not suitable for analysis	N/A	N/A

Certificate of Analysis

Issuing Laboratory SOCOTEC, Marine Department, Specialist Chemistry, Etwall House, Bretby Business Park, Ashby Road, Bretby, Burton-upon-Trent DE15 0YZ

SOCOTEC

Test Report ID	MAR01090
Issue Version	3
Customer Reference	Cork Harbour Marine Sediment Analysis

Method	Sample and Fraction Size	Method Summary
Total Solids	Wet Sediment	Calculation (100%-Moisture Content).Moisture content determined by drying a portion of the sample at 120°C to constant weight.
Total Organic Carbon (TOC)	Air dried and seived to <2mm	Carbonate removal and sulphurous acid/combustion at 1600°C/NDIR.
Carbonate	Air dried and seived to <2mm	Quantitative digestion with Hydrochloric Acid back titration with 1M Sodium Hydroxide to pH 7
Metals	Air dried and seived to <2mm	HF/Boric extraction followed by ICP analysis.
Organotins	Wet Sediment	Solvent extraction and derivatisation followed by GC-MS analysis.
Polyaromatic Hydrocarbons (PAH)	Wet Sediment	Solvent extraction and clean up followed by GC-MS analysis.
Total Hydrocarbon Content (THC)	Wet Sediment	Solvent extraction and clean up followed by GC-FID analysis.
Polychlorinated Biphenyls (PCBs)	Air dried and seived to <2mm	Solvent extraction and clean up followed by GC-MS-MS analysis.
Organochlorine Pesticides (OCPs)	Air dried and seived to <2mm	Solvent extraction and clean up followed by GC-MS-MS analysis.

Analyte Definitions					
Analyte Abbreviation	Full Analyte name	Analyte Abbreviation	Full Analyte name	Analyte Abbreviation	Full Analyte name
ACENAPTH	Acenaphthene	C2N	C2-naphthalenes	THC	Total Hydrocarbon Content
ACENAPHY	Acenaphthylene	C3N	C3-naphthalenes	AHCH	alpha-Hexachlorcyclohexane
ANTHRACN	Anthracene	CHRYSENE	Chrysene	BHCH	beta-Hexachlorcyclohexane
BAA	Benzo[a]anthracene	DBENZAH	Dibenzo[ah]anthracene	GHCH	gamma-Hexachlorcyclohexane
BAP	Benzo[a]pyrene	FLUORANT	Fluoranthene	DIELDRIN	Dieldrin
BBF	Benzo[b]fluoranthene	FLUORENE	Fluorene	HCB	Hexachlorobenzene
BEP	Benzo[e]pyrene	INDPYR	Indeno[1,2,3-cd]pyrene	DDD	p,p'-Dichlorodiphenyldichloroethane
BENZGHIP	Benzo[ghi]perylene	NAPTH	Naphthalene	DDE	p,p'-Dichlorodiphenyldichloroethylene
BKF	Benzo[k]fluoranthene	PERYLENE	Perylene	DDT	p,p'-Dichlorodiphenyltrichloroethane
C1N	C1-naphthalenes	PHENANT	Phenanthrene		
C1PHEN	C1-phenanthrene	PYRENE	Pyrene		

Appendix B – Proposed Maintenance Dredging Dry Tonnages

Dredge Area Name	Method of Dredging	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Total	Contingency
		(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes)	(tonnes/year)
		Primary Year	**Secondary Year**	**Secondary Year**	**Primary Year**	**Secondary Year**	**Secondary Year**	**Primary Year**	**Secondary Year**		
Trigger Areas											
Approach Channel & Fairways	TSHD supported by WID/bed-leveller	195,000			195,000			195,000		**585,000**	75,000
	TSHD /Mechanical		97,500	97,500		97,500	97,500		97,500	**390,000**	50,000
	WID/Plough		15,000	15,000		15,000	15,000		15,000	**60,000**	10,000
Cork City Berths	TSHD supported by WID/bed-leveller	20,000			20,000			20,000		**60,000**	7,500
	TSHD /Mechanical		10,000	10,000		10,000	10,000		10,000	**40,000**	5,000
	WID/Plough		2,500	2,500		2,500	2,500		2,500	**10,000**	1,000
Ringaskiddy Basin and Berths	TSHD supported by WID/bed-leveller	140,000			140,000			140,000		**420,000**	50,000
	TSHD /Mechanical		70,000	70,000		70,000	70,000		70,000	**280,000**	25,000
	WID/Plough		32,500	32,500		32,500	32,500		32,500	**130,000**	20,000

Secondary Areas											
Tivoli Berths	TSHD supported by WID/bed-leveller	10,000			10,000			10,000		**30,000**	4,000
	TSHD /Mechanical		5,000	5,000		5,000	5,000		5,000	**20,000**	2,000
	WID/Plough		1,250	1,250		1,250	1,250		1,250	**5,000**	750
Cobh Turning Circle and Berth	TSHD supported by WID/bed-leveller	7,200			7,200			7,200		**21,600**	2,500
	TSHD /Mechanical		3,600	3,600		3,600	3,600		3,600	**14,400**	1,000
	WID/Plough		900	900		900	900		900	**3,600**	500
Auxillary Berths	TSHD supported by WID/bed-leveller	10,000			10,000			10,000		**30,000**	3,000
	TSHD /Mechanical		5,000	5,000		5,000	5,000		5,000	**20,000**	2,000
	WID/Plough		1,250	1,250		1,250	1,250		1,250	**5,000**	500
Other Areas											
Local Access Dredging Areas	WID/Plough	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	**105,000**	7,000
	Mechanical	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	**35,000**	2,500
Crosshaven	WID/Plough	21,000		21,000		21,000		21,000		**84,000**	4,000

Total Disposed at Sea (excl. contingency)	**387,200**	**196,100**	**196,100**	**387,200**	**196,100**	**196,100**	**387,200**	**196,100**	**2,142,100**	
Total Disposed at Sea (incl. max contingency)	**462,200**	**246,100**	**246,100**	**462,200**	**246,100**	**246,100**	**462,200**	**246,100**	**2,617,100**	
Total Disposed by WID/Plough (excl. contingency)	**15,000**	**89,400**	**89,400**	**15,000**	**68,400**	**89,400**	**15,000**	**89,400**	**471,000**	
Total Disposed by WID/Plough (incl. max. contingency)	**22,000**	**109,400**	**109,400**	**22,000**	**88,400**	**109,400**	**22,000**	**109,400**	**592,000**	

Appendix C – Description of Common Dredging Methodologies

Trailing Suction Hopper Dredger (TSHD)

Trailing suction hopper dredgers (TSHD) can fill their own holds by sucking material from the seabed using pipes that trail over the bed as the ship moves forward. TSHDs can operate independently of any other equipment and are able to transport the dredged material over long distances if necessary. Internationally they are the most commonly used dredger for maintenance dredging.

A TSHD operates as follows:
To start the dredging operations, the TSHD sails to the area to be dredged. Once in the vicinity of its dredging area, the TSHD lowers its draghead(s) to the bed and dredging can commence. The draghead loosens the bed material, if required, by ripping (with teeth) and/or high pressure water jets. The centrifugal dredge pump, installed inside the dredger, sucks up a mixture of water and sediment through the draghead and suction pipe and pumps the mixture into its hold, known as a hopper. The sediment settles in the hopper and the excess transport water can be discharged through an overflow system. When the draught of the vessel reaches the dredging loading mark or when circumstances do not allow for further loading, dredging is ceased and the draghead and suction pipe are hoisted back on deck. The dredger fills the hopper as efficiently as possible prior to sailing to the disposal site to deposit the material.

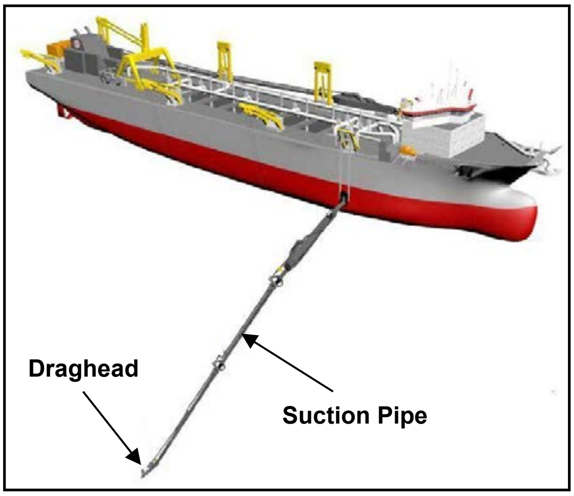


Figure 1. A large TSHD with its draghead and suction pipe in operation

Discharge from the TSHD can be undertaken in several ways. The primary method is release from the bottom of the dredger. Upon arriving at the disposal site the dredger slows to approximately one to two knots. The dredger then opens bottom doors or splits along its hull to allow the release of its contents over several minutes. The sediments contained within the hopper will then either settle in the immediate area or be dispersed. The dispersion characteristics will depend on the particle size distribution of the material being disposed of and environmental characteristics of the disposal site (retentive or dispersive). Other discharge methods include rainbowing (spraying) of material onto a designated location or pumping through a pipeline to an area which may be inaccessible to the dredger.

The size of TSHD is generally stated by their hopper capacity and can range from 400m³ up to 48,000m³. The larger dredgers are generally used for large land reclamation projects where material dredged has to be transported over long distances that are not suitable for pipeline transportation. For maintenance dredging small to medium sized dredgers are generally used as draught limitation of the site being dredged must be taken into account. TSHD are generally the most efficient form of bulk dredging over a large area. However, they do have restrictions in terms of accessibility due to their limited manoeuvrability relative to their size and can also find stiffer materials such as consolidated clays and rock difficult to remove.

Backhoe Dredger

Backhoe dredging involves excavation at subsurface level by the use of a pontoon mounted excavator. It operates by dislodging material from the seabed and raising it to the surface using its bucket and then deposited into a separate vehicle, whereby it can be transported via a suitable method to the required disposal site. Backhoe dredgers have the advantage of being able to remove the dredge material at practically the same solids content as the in-situ material. The pontoon is fixed in position with either spuds or anchors. Although these types of dredgers can have their own integral hopper, in general they fill an adjacent barge with the dredged material (see Figure 5).

Figure 2. Typical Backhoe and Barge Combination

When full the barge sails to a disposal site or placement area and deposits the dredged material through doors on the bottom of her hull. When the distance to the placement site is large more than one barge may be required to ensure that the dredger always has a barge to fill and is not waiting for returning barges as this can result in inefficient operation.

A backhoe dredger has the advantage of applying direct pressure on the seabed and hence can have significant breakout force. This allows the dredger to recover almost all forms of sediment, with the exception of unfragmented rock, where pre-treatment may be required. However, this form of dredger is restricted in the depths it can operate, with greater depths reducing the bucket size used and breakout forces that can be exerted. Thus, the size of a backhoe is generally based on a combination of its available power and bucket size capabilities (0.5m³ to 40m³). Similar to a CSD a Backhoe Dredger does not operate well in exposed waters, required relatively calm conditions to function.

Figure 3. Examples of large Backhoe Buckets

Alternatively a mechanical dredger can contain its own hopper, known generally as a grab hopper. This method required the dredger to fill its own integral hopper and then to stop dredging and then transport the material to the discharge location. Although the number of vessels required on site is reduced actual dredging time is lost during transport to the disposal site and also when departing or arriving at the dredge site as anchors need to be dropped/retrieved, which can be very time consuming unless spuds are used.

Water Injection Dredging

Although Water Injection Dredging (WID) is generally described as a method of dredging it does not ‘dredge’ in the conventional sense. To dredge is defined as; *to bring up or clear away*, but WID does not ‘*bring up*’ and only ‘*clears away*’ and that to a rather limited extent. With WID the sediment is mobilised using water jets. A pipe, with water nozzles arranged at small separations perpendicular to the sea bed is lowered close to the seabed (See Figure 7). A large flow of water at relatively low pressure is then pumped into the bottom sediment.

Figure 4. Water Jets from Water Injection Dredger (in raised position)

The water breaks the cohesion in the seabed sediments and fluidises the material into a dense near-bed suspension. This produces near seabed layer of higher density than that of the surrounding water. This high density layer of fluidised material can then move down gradient under gravity, perhaps aided by local currents, or be instilled with a directional flow produced by the advancing WID unit. The potential transport distance of the suspended material depends largely on its grain size, composition and density as well as the local hydrological and bathymetric conditions. However, as the material is only displaced the final settling location is difficult to ascertain.

The use of WID for dredging purposes is generally limited to the movement of fine grained loose or low density sediments down gradient to locally deeper areas, where they may settle and consolidate at a level too low to cause restriction, or they may be removed by conventional dredging plant and disposed off-site. Generally WID methods are not very effective in purely granular sediments, because these quickly fall out of suspension and hence do not readily form into a dense fluid.

Ploughing

Ploughing is a method of moving bottom sediments over short distances to level an irregular bed; to move sediment from a location where it causes a restriction or obstruction; or to move sediment from an area that is inaccessible to other larger dredging plant to a location where it can be accessed dredged and removed. Sediment movement is achieved by towing a bottomless rectangular box shaped steel implement behind a powered vessel, usually a small workboat or tug. See Figure 8.

Figure 5. Setup of Plough on Workboat A-frame

If used correctly, the plough is suspended at a controlled height from an A-frame mounted over the stern of the towing vessel. The height of the plough, or depth of submergence, is controlled by a deck mounted winch. The cutting blade at the leading edge of the plough slices the surface sediment which is then contained within the sides and rear of the plough box until reaching an area where the bed level is lower than the level of the plough, whereupon the contained sediment falls from the open bottom of the plough. The plough is then raised above the general seabed level and the towing vessel returns to the area from which sediment is to be moved and repeats the cycle. The greatest merits of ploughing are simplicity, ease of deployment, low cost and minimal environmental impact. One of the most common uses is as a support vessel to a TSHD. The plough can level an area previously dredged, allowing the TSHD to focus on bulk dredging (Figure 9).

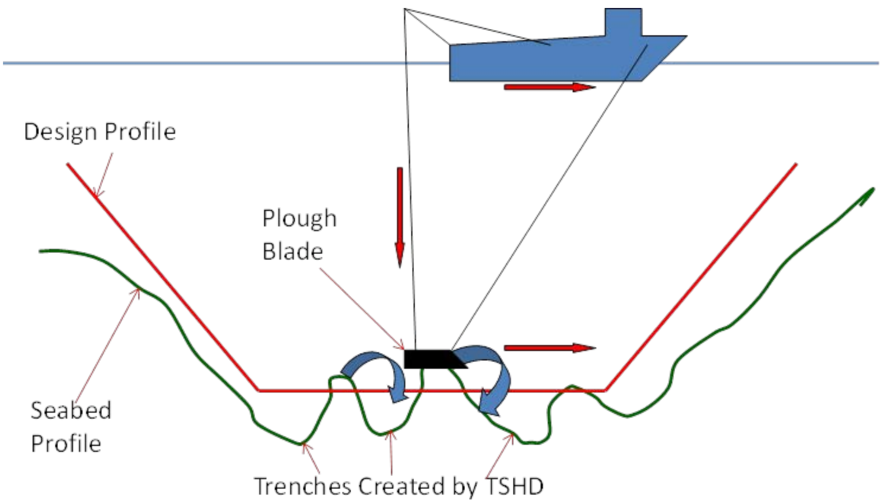


Figure 6. Plough levelling crests into dredged trails of TSHD

The production of a plough is proportional to the width and volume of the plough, the bollard pull of the towing vessel and the distance over which soil is to be moved. It is also dependant on the characteristics of the sea bed soils, but not to the same extent as is the WID. The increased versatility is because, whereas the WID relies on fluidising the soil, the action of a plough is mechanical. Subject to the bollard pull of the towing vessel, it is possible to move materials with significant internal strength including weak clay and sand, but in each case the production rate declines sharply with increasing strength or density of the soil.

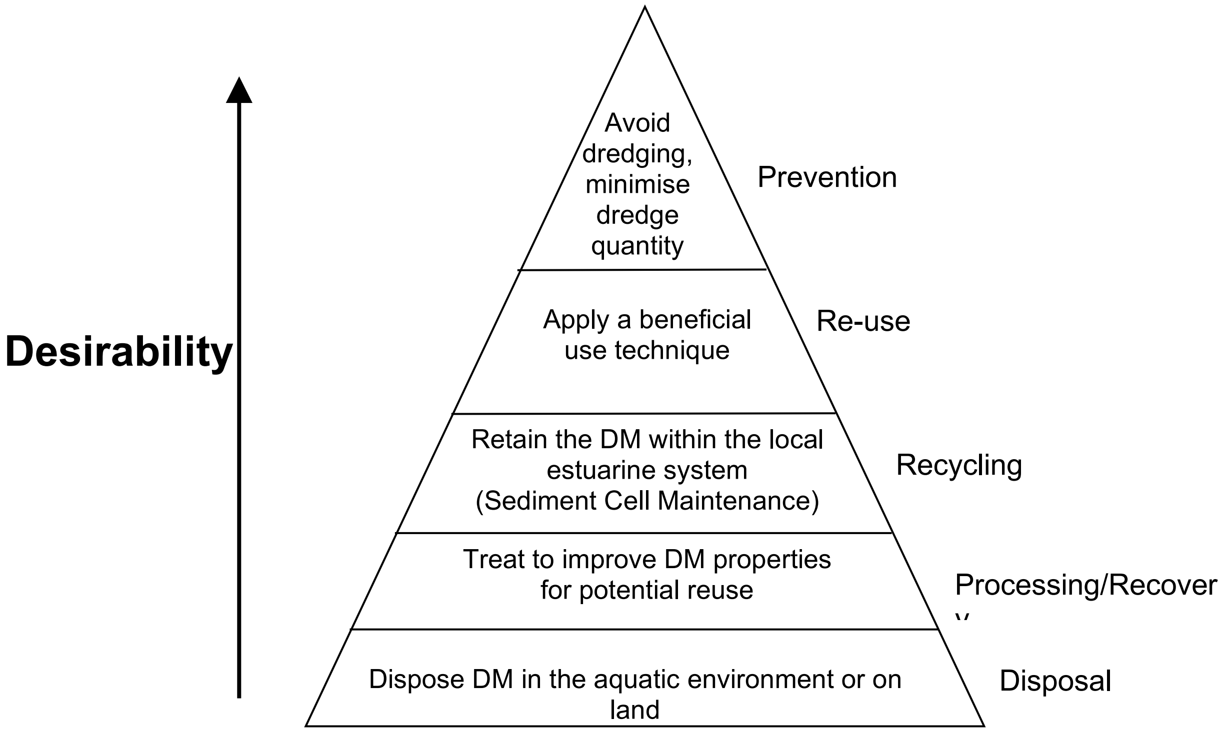
Appendix D – Dredge Material Management Alternatives

The OSPAR Convention recognises that dredging is essential to maintain navigation in ports and harbours as well as for the development of port facilities and that much of the material removed during these necessary activities requires disposal at sea. Within the OSPAR Convention framework dredged materials have been listed in Article 3.2 of Annex II as being permitted to be dumped at sea.

However, the OSPAR Convention requires consideration of beneficial use of dredged materials, over dumping at sea, where possible. The OSPAR Commission's Guidelines for the Management of Dredged Material (2009) states "*that where no beneficial or financially viable use for dredged material is available then disposal of material at sea is acceptable*".

When planning for both maintenance and capital dredging projects over the past decades the Port of Cork has assessed numerous potential dredge material management techniques other than disposal at sea. However, to date all have been rejected due to technical, logistical, environmental and economic issues.

However, prior to this license application a review of potential alternatives was undertaken for a variety of techniques based on the hierarchy for prioritising dredge material management. This hierarchy has been developed from the Waste Framework Directive (2008/98/EC), from which Ireland's Waste Management Acts are derived.



Hierarchy for Prioritising Dredge Material Management (Sheehan, 2010)

Prevention

Without major capital works to train the flow of the River Lee, increasing the local velocity above the appropriate settling velocity, prevention of maintenance dredging in the upper limits of the harbour is unfeasible. Indeed, such works have never been seriously considered due to the significant impact the works would have over a very large area of the harbour. Therefore, such an option has is deemed environmentally unfeasible. For the lower harbour, the navigational channel is in open water so river training measures could not be utilised.

Other measures such as implementing ‘passive nautical depth’ are also not applicable to the Port of Cork as the sediment consolidates to a density greater than 1.3t/m³ and the layers are relatively thin, negating the benefits of assessing navigable fluid mud.

The “Do Nothing” Scenario would allow siltation to occur with the navigational areas of the Port. The effect of siltation will seriously hamper the Port’s ability to make the most efficient use of their existing facilities. In turn, any reduction in the published water depths would seriously affect the various types of shipping trades that could access the Port. From a strategic perspective, such a scenario will severely constrain the Port’s potential to support crucial trade in not only the local area but to the province and nationwide.

Minimising the quantity of dredged material generated should therefore be a priority as prevention is impractical. However, consideration of the minimisation of dredging volumes is constantly being undertaken by the Port of Cork. Dredging is only undertaken when absolutely necessary to allow trade to safely navigate the approach channels and berths. Due to the high cost of dredging, excessive or unnecessary dredging is avoided.

To minimise the volume of dredging undertaken, the Port of Cork operate a limited access procedure in their navigation channels for some trade vessels. This restricts the size of trade vessels that can reach suitable berths at times other than high water. Further feasible methods to minimise the volumes dredged have not been identified.

Beneficial Use

A beneficial use for DM is one that uses the material in a productive manner rather than mere disposal; this recycling approach is not a new concept. Beneficial uses of DM can be categorised as follows:

- Engineering uses;
- Environmental enhancement;
- Agricultural and product uses.

A review of the available information pertaining to the above categories was undertaken to determine what the merits and limitations of each potential scheme was. The results of this review are included in the following tables.

Beneficial Use	Description	Advantages (+)/Disadvantages(-)
Land Improvement	Filling, raising and protecting a periodically submerged area and/or generally improve the quality of the land (e.g. public parks, replenishing agricultural soil, golf courses, sports fields, etc).	+ Provides a possibly cheaper and more environmentally conscious alternative to disposal + Facilitates creation of land for Port, industrial or agricultural use. + Potential profits to be made are substantial. — Not all DM may facilitate the basic requirements to sustain plant and animal life or support appreciable loads. — Consolidation and drainage is slow, thus the strength achieved may be low. — May only be suitable for capital dredging projects. If long term development is not acceptable sporadic maintenance dredging spoil cannot be used. — Requires extensive impact studies of the local environment and ecology. — Water bed depth must be adequately shallow. — Quality of the foundation material must be adequate for final design use — Potential land ownership issues must be resolved.
Land Reclamation	Raising a permanently submerged area to use for a specific motive	
Beach Nourishment	Replacement of the required quantities of sand and gravel material lost through the natural erosion of beaches and shorelines.	+ Provides a naturally occurring aquatic material to replace a shortfall in a similar material. + Process could potentially operate in tandem with maintenance DM collection. + Tourism may be dramatically improved upon completion. + Value of surrounding land may increase. — DM may be contaminated with material unsuitable for the beach environment — Material must be the same size or larger than insitu material — Material must be the same colour shade as the original material or slightly darker. — Quantity of material must be sufficient for both the visible portion of the beach and the submerged portion.
Offshore Berms	Creation of submerged berms to moderate the inshore wave climate, thus, reducing the loss of beach material	+ Using a wide range and collection of material from rock, sand and clay. + May be created by simple discharge of DM from hoppers. + Can protect areas of high land value (e.g. beaches) from erosion. — Identification of the most destructive wave direction is crucial — Optimum placement area must be located and be sufficiently shallow — The height of the berm is critical in calculating the reduction in wave force.
Coastal Protection	The use of geotubes to contain DM to aid in coastal erosion defence. Excavated rock can also be used as cover material.	+ Can prevent flooding and coastal erosion + Use of geotubes retains and isolates contaminants. + Reduces quantity of quarried material required + Reduces large scale transport of quarried material — The size and weight of the rock is important in the design of coastal protection structures. — Hydraulic equipment is required for geotubes.
Landfill Cover	Landfill cover is used daily to minimise odour and rodents. Substantial material is also required for a permanent cap when areas of the landfill are at capacity.	+ Should be a vast improvement in the aesthetics of the area upon completion of project. + The regeneration of plant life will revitalise wildlife. + Possible amenity and recreation areas for locals can be created. + Value of surrounding lands increase as well as the developed land itself. — Desalination will be needed to stimulate plant growth — Dewatering will be required in most cases and in all cases where hydraulic dredgers are used. — Contamination levels must be at a suitable level for the materials intended use. — Growth testing will have to be carried out to ensure that the material can support growth annually.
Capping Material	Using clean DM as a cover to envelop contaminated DM disposed in open water or as covering in solid waste landfills.	+ Provides an effective method of controlling contaminated DM within the aquatic environment. + More economical than treatment of contaminated DM + No additional costs than disposal at sea — Coarse uncontaminated material necessary. — Water depth must be acceptable. — Accurate placement is essential. — Monitoring and maintenance may be required periodically. — Organic content should be low to deter organisms. — Placement should be carried out during low wave action at a low velocity with the potential use of a diffuser.

Table C-1 Engineering Beneficial Uses of Dredge Material

Beneficial Use	Description	Advantages (+)/Disadvantages(-)
Upland Creation/Enhancement	Creating or enhancing an upland habitat usually refers to a bird habitat. This area does not have to be in an elevated area but can be located by the water or even on an artificial island.	+ Almost any material that is clean can be used. + Benefits to the environment must be compared with the losses. + Possible creation of tourist attractions and areas of conservation under the European habitat and birds directives. — Transport costs can be high, especially in rural areas. — Timing of the work may be hindered by migration patterns of certain species. — Elevation, location and the topography of the area must be appropriate.
Wetland Creation/Enhancement	DM sediment is used to create/stabilise eroding natural wetland shorelines or nourish subsiding wetlands.	+ Project would improve the overall environmental conditions onsite. + Can drastically improve flood defence and erosion issues. + Provides a soft engineering solution that can be a cheaper and more attractive option than a concrete structure. — Contamination levels must be extremely low. — Material used must be silty in nature with good organic content. — Lengthy planning involved which may disrupt dredging project. — It is easier to enhance an area of wetland than to create a wetland. — Large scale EIS must be carried out. — Biological testing, which would include numerous bioassay's, would be required.
Sediment Cell Maintenance	The 'in estuary' placement of DM during beneficial use schemes, either by trickle charging or direct intertidal placement, ensures that perturbations to an estuary's cell maintenance during essential dredged is minimised. Also known as sustainable relocation. Applies exclusively to maintenance dredging	+ Is a more environmentally friendly solution than disposal at sea + Can prevent erosion on the down-drift side of the port/harbour. + No extra equipment is required. + Contamination levels should be low as the material concerned will be recently deposited sediment. + No requirements on type of material dredged. + Can be more economical than disposal at sea — Wave environment must be assessed. — The time in the tidal cycle when the work is done must be optimised

Table C-2 Environmental Enhancement Beneficial Uses of Dredge Material

Beneficial Use	Advantages	Disadvantages
Manufactured Topsoil Fill Material Landfill Liner Road Sub-base Lightweight Aggregate Brick Manufacture Production of Ceramics	+ Beneficial alternative to dumping at sea. + Saves on quarried material + Price dependent on quality of material but generation of a profit is possible. + Some products will require no capital equipment + Some products can lock in contaminants + Provides a sustainable annual beneficial use programme + Regularly reduces disposal at sea charges	+ Dewatering is essential and a prerequisite. + Saline content and levels of pH must be evaluated. + Grading of material must be appropriate. + Some areas of public use, i.e. parks, or agricultural use may not be suitable for this material depending on the pollutants present and overall quality of the material. + Relevant technical standards must be met and adjustment in chemistry of manufactured goods must be assessed. + Optimum mixes must be found and tested. + Time frame for the availability of material decisive in construction projects to avoid costly delays. + Considerable equipment required for processing. + Transport will have to be done by trucks at delivery stage. + Constant supply of material necessary to make the project sustainable into the future. + Public prejudice against technologies/processes used to treat and manage sediments. + Lack of consist or total absence of applicable state regulations. + Intermittent, variable sediment characteristics associated with typical dredging projects. + Required development of market and acceptance of products produced from dredged sediments. + Resistance from labour groups to displacement of traditional products and associated jobs. + Long-term liability and legal responsibilities associated with produced products.

Table C-3 Agricultural and Product Beneficial Uses of Dredge Material

In addition to the above general characteristics of each beneficial use methods the specific site restrictions were identified to fully allow their consideration. For the Port of Cork these include:

- Specific sediment characteristics;
- Available dredging and transport methodology;
- Locally protected sites;
- Volumes of material;
- Local discharge points (e.g. quays);
- Timing and frequency of operations.

Land Reclamation/Improvement

Land Reclamation is perhaps the best-known technique for using dredge material and involves raising the level of land which is either just below or adjacent to the water. Land improvement is a variety of this which raises the level of already established land to prevent against flooding.

The Port of Cork has recently developed a new container terminal at Ringaskiddy and also acquired the Marino Point facility. In conjunction with its current facilitates the Port has sufficient area/capacity for its long term needs. Justification could not be made for the expense of undertaking additional reclamation, with no current demand for additional facilities/area at the Port or any other local third party. Furthermore, the impact of any reclamation is substantial as it will destroy any habitats on the bed or intertidal areas and the presence of protected European sites (e.g. Cork Harbour SPA) would deem any proposed reclamation an IROPI event.

Beach Nourishment

Beach nourishment is a technique used internationally to compensate beach material losses by placing suitable material at optimum positions. While beach nourishment is an option to help manage coastal erosion it can also prevent localised flooding, lessens the impact of storm damage by dissipating energy and maintains a wide recreational beach.

Beach nourishment generally require hydraulic dredgers, which the Port of Cork utilises regularly.

The Port has considered the use of its maintenance dredge material at a variety of local beaches such as Myrtlwille, White Bay and Loughbeg Beaches. However, no notable erosion is present at of these beaches. There is also no demand to expand these beaches for recreational purposes.

In cases where no erosion is present on a beach when sediment of a similar particle distribution to that insitu is placed it is likely to be eroded as the equilibrium has been altered. To overcome this coarser-grained material that that insitu is required to be placed. The coarsest material dredged by the Port of Cork is fine sandy silt (Reference Section B) and unsuitable for these beaches.

Additionally, even if a demand was created for sediment a detailed study would be required to be undertaken on both placement method and location to ensure the sediments did not return to the navigation areas of the estuary or affect other third parties. Should the particle size distribution of the sediments being dredged alter, then further consideration of this method could be undertaken.

Coastal Protection

No local areas of erosion within the harbour have been identified where coastal protection is required. In any case, the nature of the material in its raw form would not be beneficial for such schemes without significant processing (e.g. geotubes).

Geotubes are large ‘bags’ made from a high tensile strength woven polypropylene geotextile. Geotubes are designed to receive and retain pumped sediment while allowing water to escape through the pores of the geotube. Initially designed as a dewatering mechanism Geotubes have since evolved and are now used for containment of sediments in marine structures. Alternatively, they can be used in the retention and isolation of contaminated sediments.

When used in marine structures the geotubes form the core of the structure, replacing quarry run that has been used historically. Generally, when geotubes have been used for these purposes cost savings can be realised. However, they are only suitable for relatively sheltered locations.

With the sheltered area of Cork Harbour, no significant coastal erosion has been noted. Also, no protection works entailing revetments or breakwaters are planned locally.

Geotubes are constantly being developed. However, currently, sediment with a high fraction between 63micron and 2mm, with a D50 of approximately 300micron, is recommended. Cork Harbour has a D50 significantly less than 63microns and this is likely to render this option unfeasible. Should any change in physical characteristics be noted a ‘Hanging Bag’ test can be undertaken to categorically determine the viability of this option.

As no potential suitable projects are planned and the use of geotubes is unlikely to be technically feasible, this option was not considered further.

Wetland Habitat / Enhancement

Dredge material can be used to create/stabilise eroding natural wetland shorelines or nourish subsiding wetlands. Creating natural wetlands can benefit the natural environment greatly and can serve as a recreational/nature area. In some coastal locations, wetland habitats provide protection for important transport infrastructure and thus are being considered as methods of natural protection for modelled climate change mitigation. This is not currently an option being discussed by local stakeholders or government. Currently, dredge material is not used for wetland habitat enhancement in Cork Harbour.

There is a substantial network of wetland areas within Cork estuary. However, the majority are contained with a European protected site (SPA) and are not currently noted to be in deterioration. Further establishment of wetland areas has not been proposed by any local or national stakeholder previously. Planning and attaining such a management scheme is a complex and lengthy process. It is estimated that several years of planning and consultation in conjunction with modelling and adequate environmental assessments would be required to be undertaken, with no guarantee of a positive outcome.

Due to the inherent cost and inherent risks in undertaking such an assessment, further consideration of this option cannot be justified unless assistance and leadership is provided by a national agency.

Landfill Cover/Liner and Quarry/Mine Infilling

Dredge material may be used as a landfill cover/liner or used to fill disused quarries and mines. Assessing the suitability of materials for disposal on land, the Waste Disposal Authority gives consideration to the characteristics of the material to be disposed. In the case of dredged materials arising from maintenance dredging, the main considerations usually are particle size, contamination issues and salt and water content.

Demand for cover/liner is not expected to increase as no new landfill sites are planned locally. Other existing licensed sites are either too small in relation to quantities to be disposed, or are too remote from the site.

While the dredged material from Cork Harbour is fine in nature it does not contain sufficient clay material and therefore would be unsuitable to be used as a landfill liner.

No redundant local quarries or mines have been identified in the area.

If an arrangement could be made with the landfill operators to accept dredged material, it would be necessary to land the material either in the Port, dewater and transport to the site by road. As detailed in Section D the Port of Cork generally utilises a hydraulic form of dredging, increasing the water content many times over. Therefore to facilitate landing ashore a couple site, pipeline and dewatering lagoon will be required. Alternative plant could be utilised but would reduce efficiency and increase dredging duration. The costs of establishing such a logistical process are significantly greater than the current management process.

Furthermore, the environmental impact of substantially increased heavy vehicular traffic through the local community may be unacceptable to the local planning authority.

For the above reasons landing dredged sediment ashore for treatment and transport to a landfill site or redundant quarry is unfeasible at this time.

Manufactured Topsoil

Dredged material (in conjunction with household organic waste), can be used for agricultural or horticultural purposes. This would have the benefit of producing a regular destination for a portion of the annual material produced from dredging.

While demand for manufactured topsoil in the local area is deemed to be limited, the dredged material contains good organic content and organic retention characteristics due to the presence of a silt fraction. However, as the dredged material is not well graded with low granular content, the product would have very poor drainage characteristics; therefore making it unsuitable for use as topsoil without significant amelioration. The pH is also likely to require costly adjustment with the use of aluminium sulphate or a similar product.

In order that materials dredged from marine sources to be used in conjunction with household organic waste for agricultural or horticultural purposes, the salt and metal content must be acceptably low. The heavy metal content shown in the sediment analysis, although not high, might be considered un-acceptable for conversion to topsoil. Furthermore, the saline content would have to be reduced to allow adequate seed germination; this would require a significant duration of irrigation and management.

As outlined in the previous section, a change in the logistical dredging procedure would be required to land sediment ashore, with either additional or alternative plant required. This is not attractive economically. Furthermore, a substantial land area would be required to place and drain the dredged material; such spare land is not available within the Port.

Due to the lack of demand, technical restrictions and increased logistical costs, this proposed alternative dredged material management option is not considered feasible.

Aggregate Industry

Dredged aggregates are an attractive alternative to land-based sources. When compared with onshore quarrying activities extraction and emissions costs are less than 50%. Transport costs are less than 15% as a 5000t Trailing Suction Hopper Dredger transports the equivalent of 250 trucks. It has been estimated that, for example, 1 tonne of onshore material costs the same as the equivalent of 6 tonne from offshore.

The use of the Port of Cork maintenance dredge material for aggregates was considered however a number of current issues were identified:

- Lack of regulation of marine aggregates industry and guidance on its implementation;
- Fine nature of sediment present with the presence of organics;
- Elevated saline and pH levels;
- Mechanical dredging not undertaken by the Port;
- Hydraulic dredgers used cannot be unloaded at quays.

For the above reasons landing dredged sediment ashore at a suitable location is not deemed feasible until at least the market demand for aggregates has increased locally and suitable wharf facilitates are developed.

Recycling

Sediment Cell Maintenance

Sediment Cell Maintenance involves the 'in estuary' placement of dredged material, either by trickle charging or direct intertidal placement, to ensure that perturbations to a location from essential dredging works is minimised. This is also known as sustainable relocation and applies exclusively to maintenance dredging as this sediment is inherently mobile within the local environment. Undertaking plough dredging or water injection dredging is generally termed sediment cell maintenance as the material is retained with the local environment. The Port of Cork has included both water injection dredging and ploughing dredging within their maintenance dredging strategy to minimise the volume of sediment being removed from the harbour sediment cell and disposed of at sea. Therefore, beneficial use through sediment cell maintenance will be undertaken when these campaigns are undertaken.

Processing/Recovery

As outlined in attachment B.1(ii) the sediment dredged annually by the Port of Cork is clean uncontaminated material. Therefore, there is no benefit from processing the material, excluding dewatering and desalination, for specific beneficial uses outlined above.

Best Practical Environmental Option

After consideration of the above assessment, it is deemed that disposal at sea, at the historic disposal site, is the most appropriate method for the disposal of material from the Port of Cork for the primary dredging campaigns. This is largely due to the current disposal site providing adequate performance logistically, economically and environmentally to the satisfaction of all of the stakeholders. The current Roche’s Point placement site is well established and has been used for disposal for many decades. The studies presented in Section F demonstrates that the condition of the site has not undergone any considerable changes since 1999, since when approximately 1.25 million cubic metres have been disposed of at the site, and that the site is operating as expected.

Despite the above finding, alternative options to disposal at sea will continue to be investigated by the Port of Cork, with the goal of implementing the best social, economic and environmental dredge material management process possible.

Appendix E – Assessment of Benthic and Fisheries Impacts of Maintenance Dredging

Assessment of Benthic and Fisheries Impacts of Maintenance Dredging in Lough Mahon and the Lower River Lee

(August-September 2020)

Commissioned by: Port of Cork

Undertaken by: Aquatic Services Unit (UCC)
(February 2021)

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1 INTRODUCTION

1.1 Study Brief

As part of their application for a new round of channel maintenance dredging and dumping (from 2022-2029), the Port of Cork commissioned the Aquatic Services Unit (ASU) to undertake an assessment of the potential impacts of the proposed programme on the benthic and fisheries communities within Cork Harbour following the approach of their previous assessment in 2011 and 2012 (ASU, 2013). That study entailed pre- and post-dredging surveys at several locations in the upper harbour area stretching from the City Quays downstream to Marino Point. In the intervening period, i.e. since 2013, three annual fisheries surveys were undertaken in 2016, 2018 and 2019 comprising spring-summer trawling in the Lough Mahon area. It became clear at an early stage in 2020 that due to prolonged delays in being permitted to undertake fieldwork due to Covid-19, along with other timing constraints, that the best approach to the study would to undertake a reduced survey and rely on a combination of the new survey results and those of the previous surveys in order to assess the likely impacts of the dredging.

1.2 Study Outline

The current survey broadly follows the study approach of the original survey undertaken in 2011 and 2012 although with a reduced scope as explained previously. As with the earlier survey, the project has been designed to get a comprehensive overview of the main components of the intertidal and subtidal benthic infauna and the fish and mobile invertebrate fauna using the main shipping channel and or the intertidal sand and mud flats of Lough Mahon. The benthic macroinvertebrate communities (mainly oligochaetes and polychaete worms and bivalve molluscs) were sampled in intertidal and sub-tidal areas using cores and grabs respectively, while mobile epibenthic fauna mainly crustaceans, (shrimp and crab) and fish were sampled using beam trawls. Fish and crustaceans were also targeted using baited pots and fyke nets.

Benthic macroinvertebrates were identified, counted and their wet-weight biomass measured while fish were identified counted and measured. Mobile epibenthic crustaceans were identified and bulk weighed, with representative samples retained for size frequency analysis.

1.3 Receiving Environment

The estuary comprises a narrow channel from the City Quays as far as Blackrock Castle and after that widens out into the mud and sandy mud expanses of Lough Mahon. The intertidal area of Lough Mahon comprises mud and sandy mud flats, both north and south of the shipping channel, with narrow rocky belts in the mid to upper intertidal. There are also extensive mussel beds in places e.g. by Carrigrenan Point on Little Island. A bit off the main channel, between Marino Point and Fota, there are extensive intertidal flats, forming part of the extensive Cork Harbour SPA (Site Code:004030), which are used by waterfowl as feeding areas in the appropriate seasons. The area is immediately adjacent to the Great Island Channel SAC (Site Code: 001058) located at and east of Marino Point, the intertidal flats at Carrigrenan Point on Little Island and the Intertidal flats at Lough Mahon adjacent to Hop Island, which are also within the Cork Harbour SPA.

1.4 Sampling Areas

The original study design of 2011 and 2012 assessed 4 sampling areas (Area 1 to Area 4) and a control site (see Figure 1.1). These were: Area 1- City berths to the Marina Power Station. Area 2 - Tivoli to Blackrock Castle, Area 3 Upper Lough Mahon from Blackrock Castle to Hop Island and Area 4 - Lower Lough Mahon from Hop Island to Marino Point. The control site was located in the North Channel just south of Rossmore (Figure 1.1).

Samples were collected from Areas 2-4 during the current survey. The reduced study scope confined the intertidal sampling to upper and mid shore levels only, at each of the surveyed transects, while eliminating the lower shore position, which in the previous survey returned the lowest numbers and biomass of invertebrates at each transect. In addition, it was decided not to sample the control site at Rossmore, a decision which is explained in the Methodology Section below.

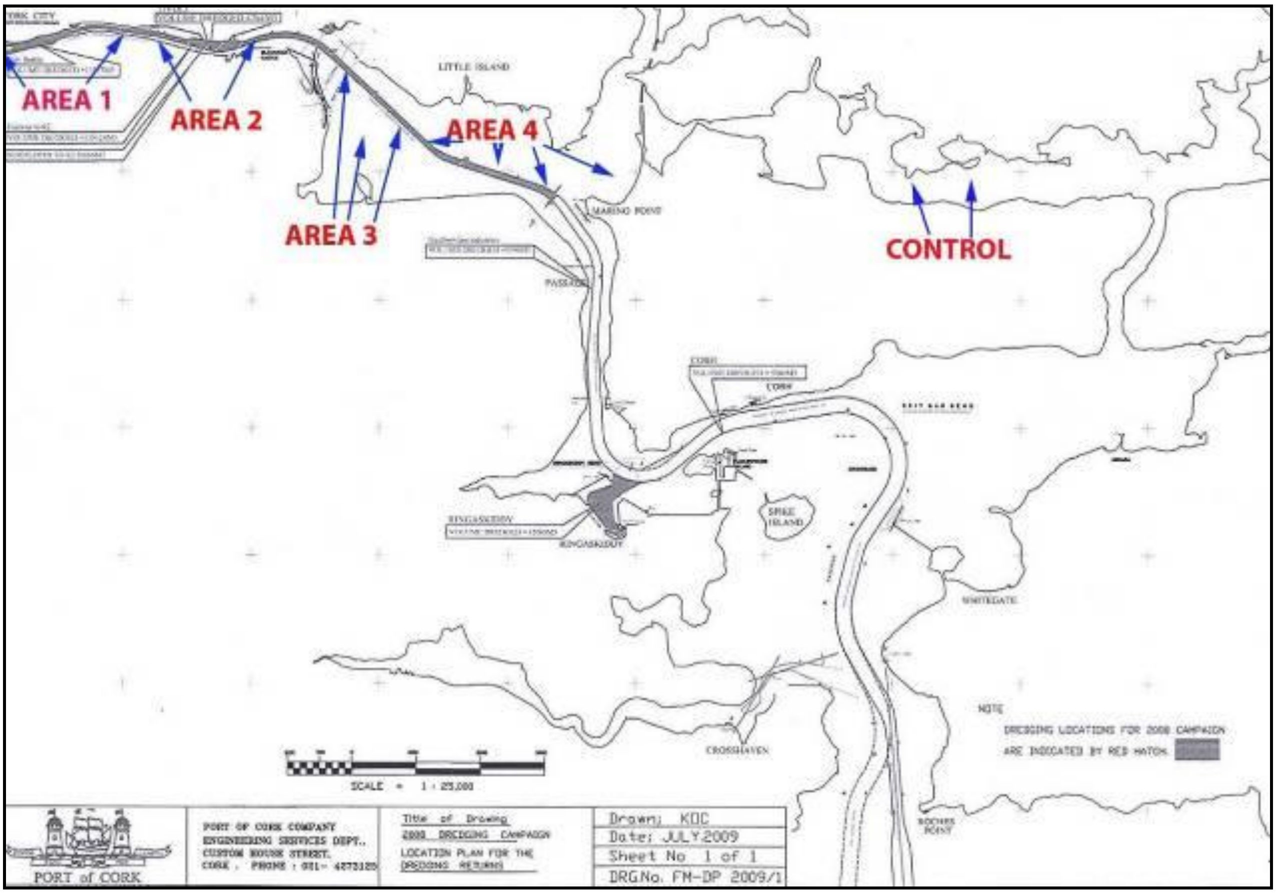

Figure 1.1: Cork Harbour Study Area from 2011 and 2012 Surveys.

2 METHODOLOGY & RESULTS - BENTHOS

2.1 Intertidal Soft Benthos Survey

Three survey areas were selected. These survey areas were:

Lough Mahon South (Hop Island)
Lough Mahon North (Carrigrenan)
Lough Mahon East (Marino Point)

In each area a single transect, oriented perpendicular to the low water line was surveyed with positions recorded and marked along the high and mid shore areas. These same transects were sampled in 2011 and 2012. During the current survey, samples were collected from only the upper and mid shore areas as these were identified as containing the highest faunal abundance and biomass in the previous surveys. In addition, results from the surveys undertaken in 2011 and 2012 indicated that no differences were noted from the controls sites at Rossmore, which is why it this area was not re-surveyed in 2020.

Field Surveys

Intertidal fieldwork was carried out on the 16th & 21st September 2020. All sampling stations were positioned using a handheld GPS (Trimble Geo-XM GPS or Garmin eTrex GPS). A list of the stations sampled is presented in Table 2.1 and displayed on a map (Figure 2.1).

Table 2.1 Positions of intertidal soft sediment biological sampling stations. All locations given in Irish Map Grid.

	Easting (m)	Northing (m)		Easting (m)	Northing (m)
Transect 1 High	173888	69535	Transect 3 High	178028	70187
Transect 1 Mid	174055	69748	Transect 3 Mid	177772	70172
Transect 2 High	176440	70956			
Transect 2 Mid	176190	70831			

Intertidal Core Sampling

Samples were collected at each site using the following methods:

3 x replicate 19cm Ø cores (Area = 0.028m^2) were taken to a depth of 20cm at each shore height. Each core was placed in a plastic bag with 2 waterproof labels and transported to the laboratory.

A surface scrape of sediment was taken for granulometric and Loss on Ignition (LOI) analyses. This sediment was carefully transferred to a pre-labelled plastic zip-lock bag for transport back to the laboratory.

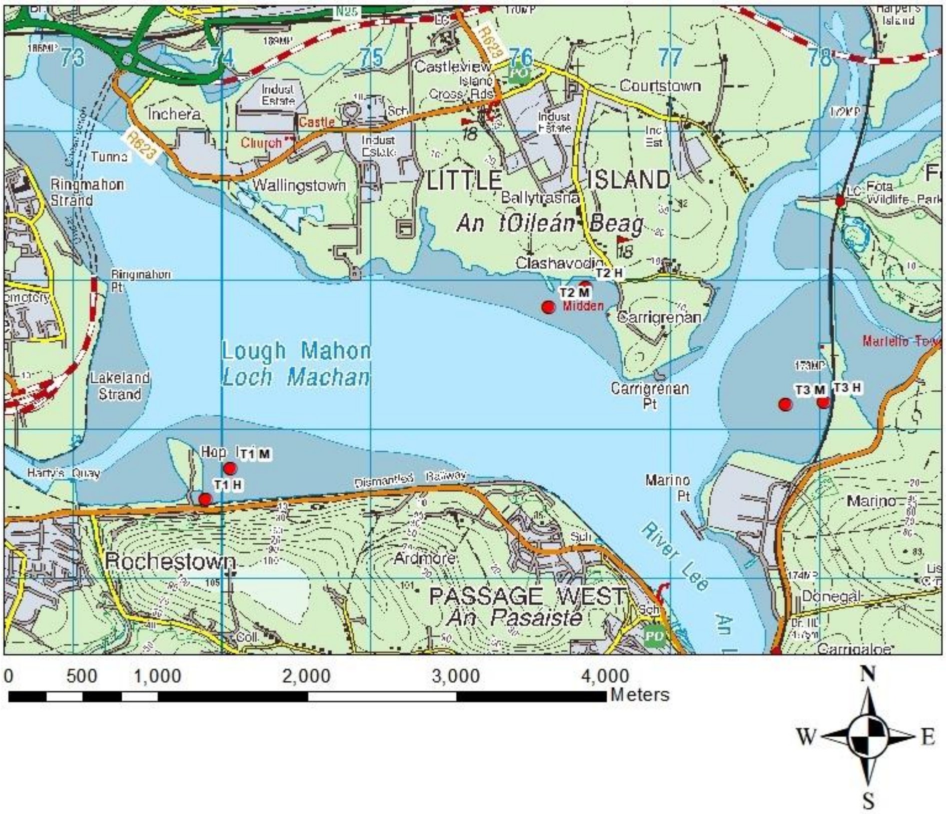

Figure 2.1: Map showing locations of intertidal soft sediment sampling positions in Cork Harbour.

2.2 Sub-tidal Soft Benthos Survey

Subtidal Grab Sampling

Three survey areas were selected. These survey areas were:

- Area 2: Tivoli Area (Marina Generating Station – Blackrock Castle)
- Area 3: Ringmahon (Blackrock Castle – Ringmahon Point)
- Area 4: Lough Mahon (From Ringmahon Point to Marino Point)

In each area a series of 3 replicate 0.045m^2 van Veen grabs were collected for faunal analysis on August 24th. Two sites were sampled in Area 2, three sites in Area 3 and one site in Area 4. An additional grab was collected for particle size and loss on ignition analyses at each site. No particle size sample was collected for Area 4 Grab Site 2. All sampling stations were positioned using a GPS (Garmin eTrex GPS). A list of the stations sampled is presented in Table 2.2 and mapped in Figure 2.2.

Table 2.2 Positions of sub-tidal soft sediment sampling stations. All locations given in Irish Grid.

	Easting (m)	Northing (m)
Area 2 G1	171842	72018
Area 2 G2	172351	72097
Area 3 G1	173268	71908
Area 3 G2	173294	71824
Area 3 G3	173205	71803
Area 4 G1	176041	69869
Area 4 G2	176035	69812

Figure 2.2 Location of grab samples collected in August 2020.

2.3 Sample Processing of Intertidal & Subtidal Samples

Granulometric Analysis

Granulometric analysis was carried out on oven-dried sediment samples from each station. The sediment was passed through a series of nested brass test sieves with the aid of a mechanical shaker after prior treatment with hydrogen peroxide to remove organic matter following the method of Holme and McIntyre (1983). The brass sieves chosen were: 4mm, 2mm, 1mm, 500µm, 250µm, 125µm and 63µm. The sediments were then divided into three fractions: % Gravel (>2mm), % Sand (<2.0mm >63µm) and % Silt-Clay (<63µm). Further analysis of the sediment data was undertaken using the Gradistat package (Blott & Pye, 2001).

Organic Matter Analysis

Organic matter was estimated using the Loss on Ignition (LOI) method. One gram of dried sediment was ashed at 450˚C for 6 hours and organic matter was calculated as % sediment weight loss.

Biological sample processing

All faunal samples were sieved on a 1mm mesh sieve within 24 hours of collection. Samples were left in 4% buffered formalin for at least 4 days in order to fix them and thereafter transferred to 70% ethanol in readiness for identification. All fauna were identified to the lowest taxonomic level possible using standard keys to north-west European fauna.

Sample biomass was undertaken on the major taxonomic groups (worms, molluscs, crustaceans and other taxa) using the blotted wet weight method. Each sample was blotted dry with tissue and weighed using a calibrated electronic balance. Results from each replicate were pooled to provide a single figure for biomass for each transect height.

Data analysis

Multivariate analysis of the faunal data was undertaken using the statistical package PRIMER v. 5 (Clarke & Gorley, 2001). Species that were present in less than one station per grid was removed from the multivariate analysis. All abundance data was fourth root transformed to reduce the importance of highly abundant species. A Bray-Curtis similarity matrix was produced and this similarity matrix was used for the cluster analysis and non-metric Multi-Dimensional Scaling (MDS) analysis.

Cluster analysis allows for creation of a 2-dimensional structure (dendogram) based on the similarity of stations to each other and allows for the identification of discrete groups based on faunal similarities.

Non-metric multidimensional scaling (MDS) was undertaken on the Bray-Curtis similarity matrix to produce an ordination. This MDS ordination was then used to identify groups of samples which have similar faunal assemblages. Each MDS ordination also produces a stress value which allows for a good interpretation of how good the two-dimensional plot represents the multi-dimensional sample relationship. Clarke and Warwick (1994) have provided guidelines on these values and their relationship with the faunal plots. These are outlined below

- Stress Value <0.05: Excellent representation of the data.
- Stress Value <0.10: Good representation of the data. Some fine detail may be misinterpreted.
- Stress Value <0.20: Useful representation of the data. Some detail may be misinterpreted.
- Stress Value >0.20: Data should be viewed with caution. The data may be randomly distributed within the ordination and may not represent the underlying dataset.

2.4 Intertidal Survey Results & Overview

Transect 1 is located along the soft sediment intertidal area adjacent to Hop Island along the southern shore of Lough Mahon. Transect 2 is located along the soft sediment intertidal area adjacent to Carrigrenan located along the northern shore of Lough Mahon. Transect 3 is located along the soft sediment intertidal area north of Marino Point located along the eastern shore of Lough Mahon. During the survey, samples were taken from the upper and mid shore areas of the transect.

Particle Size Analysis Results

Results from Particle Size analysis of sediment collected in September 2020 highlights the relatively homogenous distribution of sediment types across the shore. The sediment is dominated by poorly sorted muds, with all sites containing >80% mud (Table 2.3 & Figure 2.3). Loss on Ignition results show values typical of mud-dominated environments.

Table 2.3: Granulometry and Loss on Ignition results from all sites from the present survey.

	% Gravel	% Sand	% Mud	Textural Group	% LOI
T1 High	0.6%	5.0%	94.4%	Poorly Sorted slightly gravelly mud	4.41%
T1 Mid	1.4%	8.6%	90.0%	Poorly Sorted slightly gravelly mud	4.33%
T2 High	0.1%	11.7%	88.2%	Poorly sorted slightly gravelly sandy mud	5.96%
T2 Mid	0.6%	17.1%	82.3%	Poorly sorted slightly gravelly sandy mud	3.69%
T3 High	0.0%	15.5%	84.5%	Poorly sorted sandy mud	4.59%
T3 Mid	0.0%	7.6%	92.4%	Poorly sorted mud	4.58%

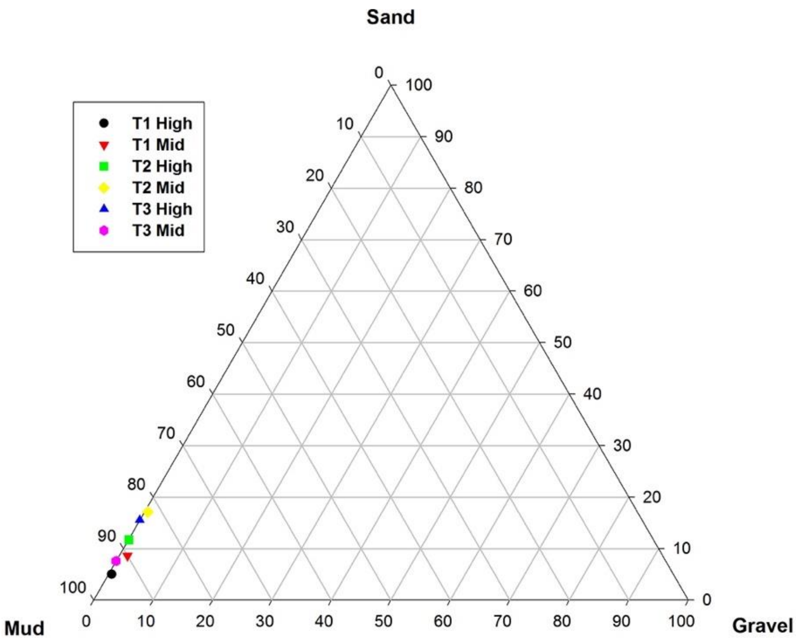

Figure 2.3: Ternary plot of granulometry results from intertidal sites in Cork Harbour.

Faunal Results

Faunal results from the present survey indicate the presence of fauna typical of sandy mud intertidal systems, dominated by polychaete worms and bivalve molluscs (Table 2.4).

Table 2.4: Fauna identified along each transect during the present survey (September 2020).

	T1 High A	T1 High B	T1 High C	T1 Mid A	T1 Mid B	T1 Mid C
Cyathura carrinata	8	3	8	-	-	-
Crangon crangon	2	-	-	-	-	-
Peringia ulvae	3	-	9	3	4	1
Scrobicularia plana	7	7	7	5	3	6
Mya arenaria	-	-	-	-	1	-
Hediste diversicolor	16	15	13	1	1	2
Nephtys hombergii	-	-	1	5	1	4
Streblospio sp.	22	7	5	-	-	5
Oligochaetae	21	16	19	9	16	23
Tharyx sp.	1	-	-	-	-	-
Polydora sp.	2	-	-	-	-	-
Arenicola marina	-	-	-	-	1	1
Capitella capitata	-	-	-	-	-	1
Heteromastus sp.	-	-	-	5	-	-
	T2 High A	**T2 High B**	**T2 High C**	**T2 Mid A**	**T2 Mid B**	**T2 Mid C**
Crangon crangon	1	1	-	-	-	1
Peringia ulvae	1	10	6	-	-	1
Scrobicularia plana	4	8	4	1	2	2
Mya arenaria	1	1	2	61	40	45
Cerastoderma edule	1	2	-	-	1	-
Hediste diversicolor	3	4	4	1	-	-
Nephtys hombergii	9	4	4	5	3	2
Oligochaetae	-	1	-	-	-	-
Arenicola marina	-	-	-	-	1	-
Tharyx sp.	-	-	-	-	-	1
	T3 High A	**T3 High B**	**T3 High C**	**T3 Mid A**	**T3 Mid B**	**T3 Mid C**
Crangon crangon	-	-	-	-	1	-
Peringia ulvae	3	-	3	5	6	-
Scrobicularia plana	2	-	3	1	-	1
Hediste diversicolor	6	9	10	5	5	2
Nephtys hombergii	9	6	5	6	6	3
Oligochaetae	-	-	1	-	-	-
Ampharetidae	-	1	-	-	-	-

Table 2.5: Primary and derived indices samples collected during the present survey (September 2020).

	T1High A	T1High B	T1High C	T1Mid A	T1Mid B	T1Mid C
Species	9	5	7	6	7	8
Abundances	82	48	62	28	27	43
Shannon-Wiener	1.81	1.46	1.75	1.65	1.33	1.49
Pielou's Evenness	0.825	0.910	0.899	0.919	0.681	0.714
Simpson Dominance	0.195	0.255	0.195	0.212	0.391	0.332
	T2High A	**T2High B**	**T2High C**	**T2Mid A**	**T2Mid B**	**T2Mid C**
Species	7	8	5	4	5	6
Abundances	20	31	20	68	47	52
Shannon-Wiener	1.56	1.75	1.56	0.413	0.611	0.604
Pielou's Evenness	0.804	0.843	0.967	0.298	0.380	0.337
Simpson Dominance	0.275	0.211	0.22	0.811	0.731	0.753
	T3High A	**T3High B**	**T3High C**	**T3Mid A**	**T3Mid B**	**T3Mid C**
Species	4	3	5	4	4	3
Abundances	20	16	22	17	18	6
Shannon-Wiener	1.24	0.865	1.38	1.25	1.25	1.01
Pielou's Evenness	0.891	0.787	0.857	0.905	0.901	0.921
Simpson Dominance	0.325	0.461	0.298	0.301	0.302	0.389

The upper shore height at Transect 1 returned the highest number of species and highest abundances in a single core (Table 2.5). Diversity and abundances were generally lower at Transect 3, although the main species present at this site were also present at the other sites. The dominant species present across all sites were the polychaetes *Hediste diversicolor* and *Nephtys hombergii*, and the molluscs *Scrobicularia plana* and *Peringia ulvae*. Large numbers of the Sand-Gaper, *Mya arenaria* were present at the mid shore height in Transect 2.

Analysis of the data shows differences between the transects, with the mid shore site at Transect 2 showing the greatest difference from the other sites (Figure 2.4 & 2.5). This was due to the higher numbers of *M. arenaria* recorded at that site. Although differences were evident between the transects, these are considered minor, with a large amount of overlap in the species present across the sites. Variation in abundance was the main driver of the differences noted in these results.

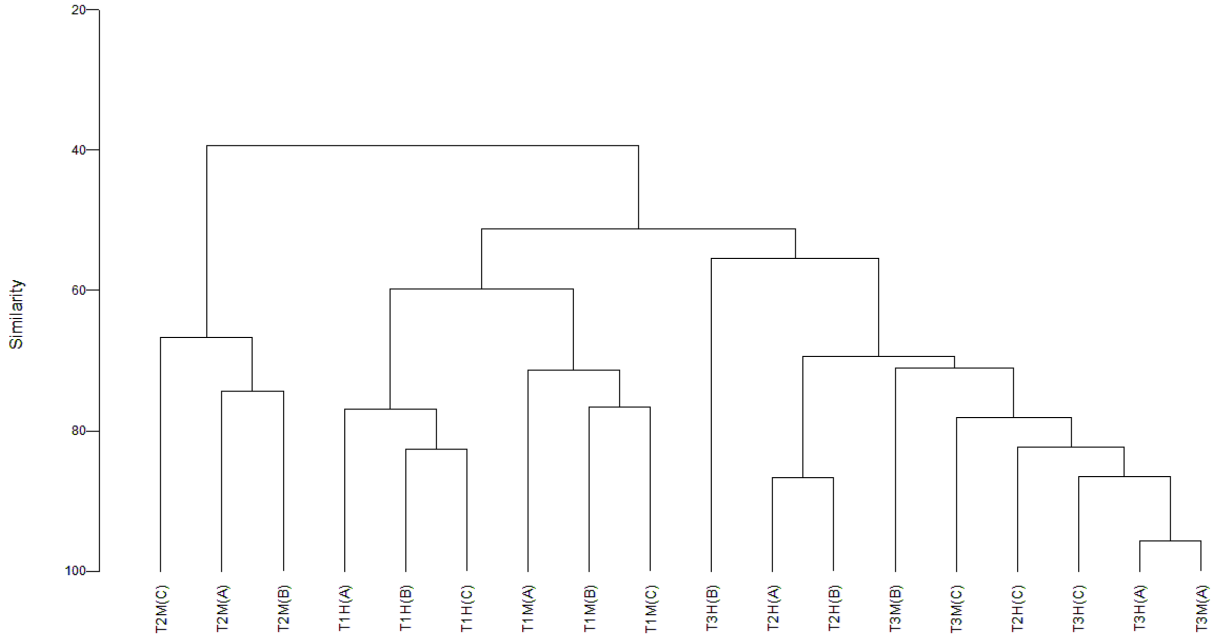

Figure 2.4: Dendogram showing the similarity between the sites and replicates collected along three transects in September 2020.

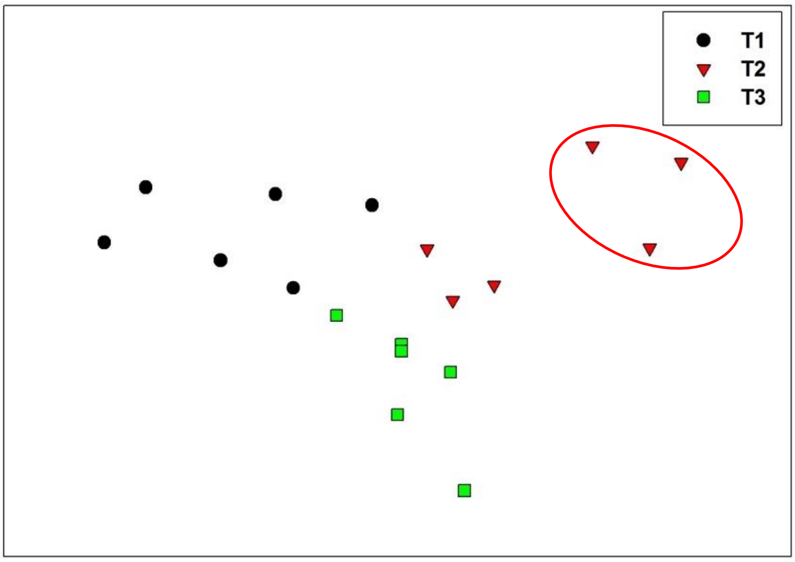

Figure 2.5: MDS plot indicating similarity of the sites and replicates collected in September 2020 showing variation between the transects [Stress = 0.11]. Replicates from T2 Mid are circled in red

A single faunal community was identified across all three survey areas - Polychaete/bivalve dominated mid-estuarine mud shores (JNCC Habitat type LS.LMu.MEst; EUNIS Code A2.31). This classification is the same as the community type identified in 2011 and 2012, although some minor differences in diversity and abundances were noted between both surveys.

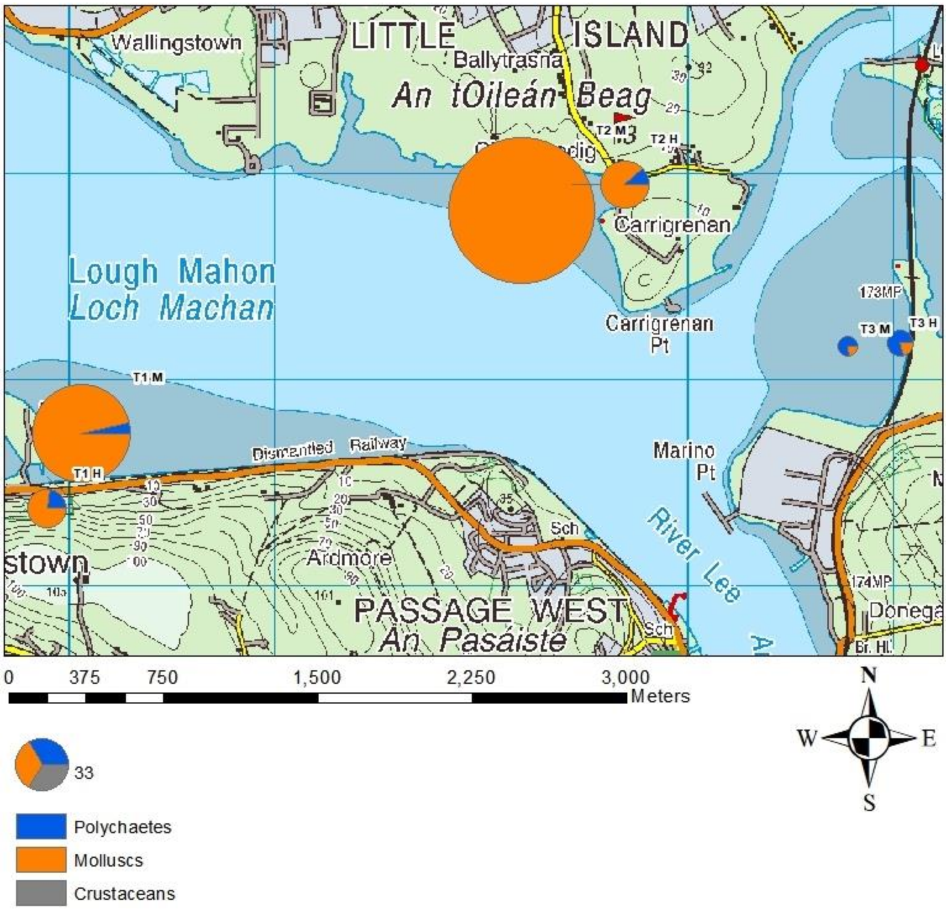

Figure 2.6: Relative biomass distribution across the three Intertidal transects.

Biomass distribution revealed large variations between the biomass at each of the three transects (Figures 2.6 & 2.7). The much-lower biomass at Transect 3 relates to several factors. Abundances and diversity at the transect were lower than at the other transects and there were lower numbers of bivalves at the site also. Large numbers of *Mya arenaria* were present at the mid-shore site at Transect 2, resulting in very high biomass for the area. Overall, high biomass levels at Transects 1 & 2 are accounted for by the high bivalve numbers present (Fig 2.8 & 2.9). Polychaete worms account for the greatest proportion of biomass at Transect 3 (Fig 2.10).

Figure 2.7: Biomass distribution at each of the sites surveyed in September 2020. Molluscs make up the highest proportion of biomass along Transects 1 & 2, with polychaetes accounting for the highest proportions in Transect 3.

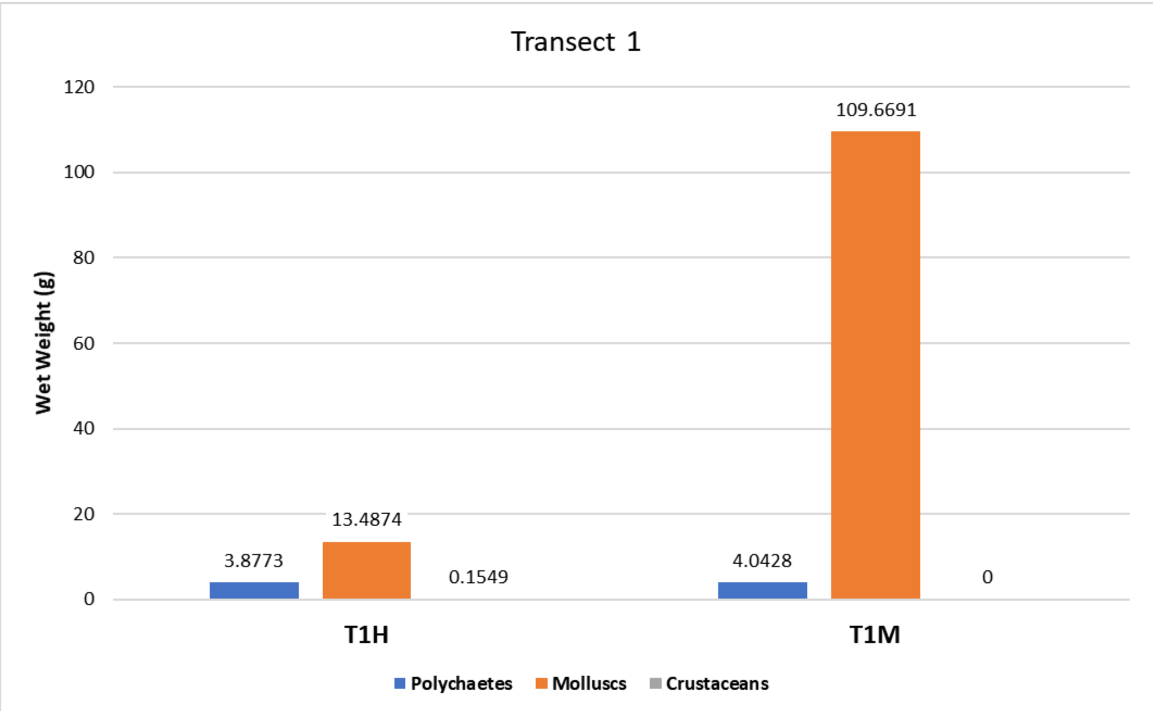

Figure 2.8: Biomass distribution across Transect 1 – September 2020.

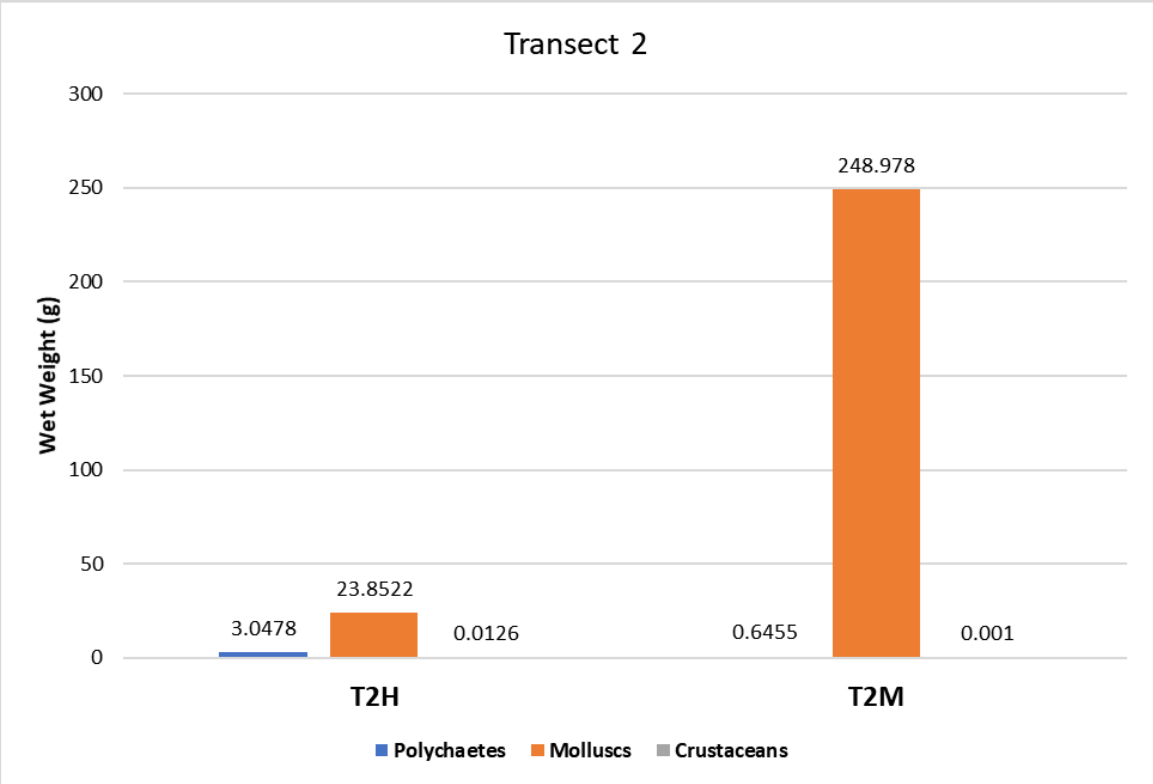

Figure 2.9: Biomass distribution across Transect 2 – September 2020.

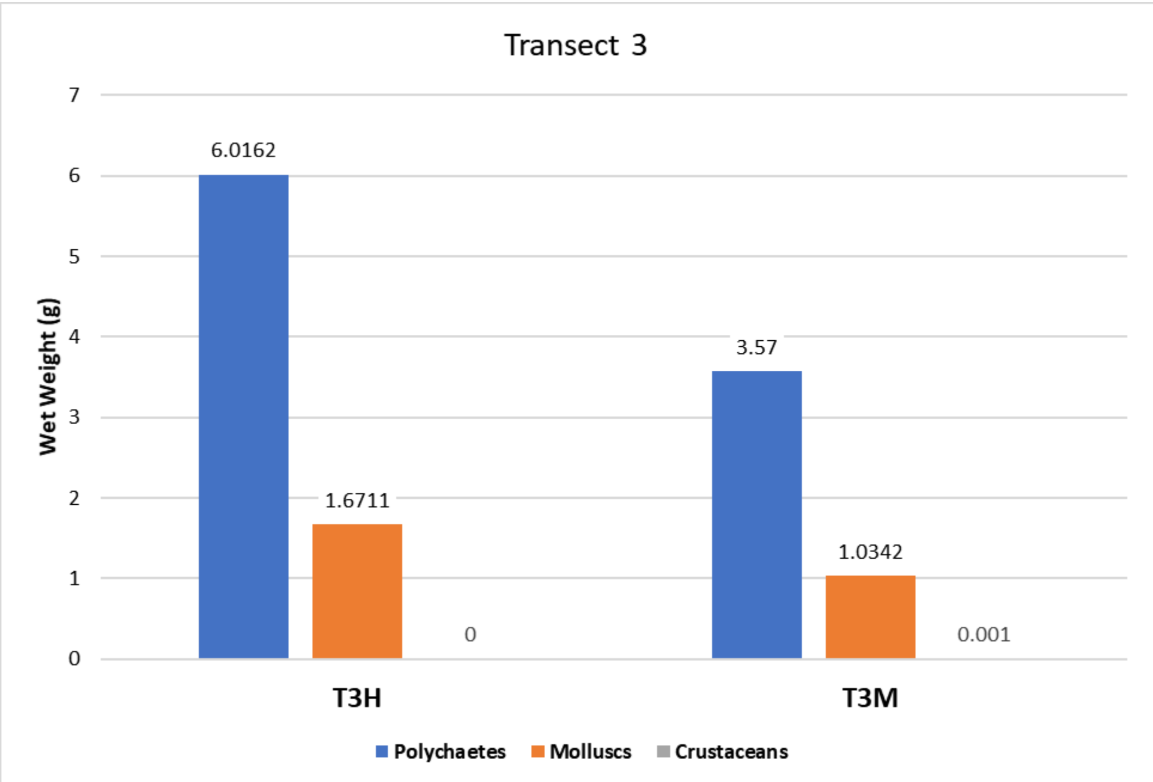

Figure 2.10: Biomass distribution across Transect 3 – September 2020.

Comparisons with Previous Surveys

Detailed analysis of the combined dataset shows differences between the present survey (2020) and previous surveys (2011 and 2012) in terms of similarity (Figures 2.11 & 2.12). Results from the present survey are distinct from the previous surveys due to differences in faunal abundances across the survey area. Differences at Transect 1 include lower numbers of *Hediste diversicolor*, Oligochaetae, *Tharyx* and *Scrobicularia plana* in the upper shore site, with similar reductions in the numbers Oligochaetae and *Streblospio* at the mid shore height. Notable differences along Transect 2 include lower numbers of Oligochaetae at the upper shore site and higher numbers of *H. diversicolor*, at both tidal heights, and the presence of large numbers of the bivalve mollusc *Mya arenaria* in the mid shore site. Transect 3 had lower numbers of Oligochaetae and no *Streblospio* which were recorded in high numbers in 2011.

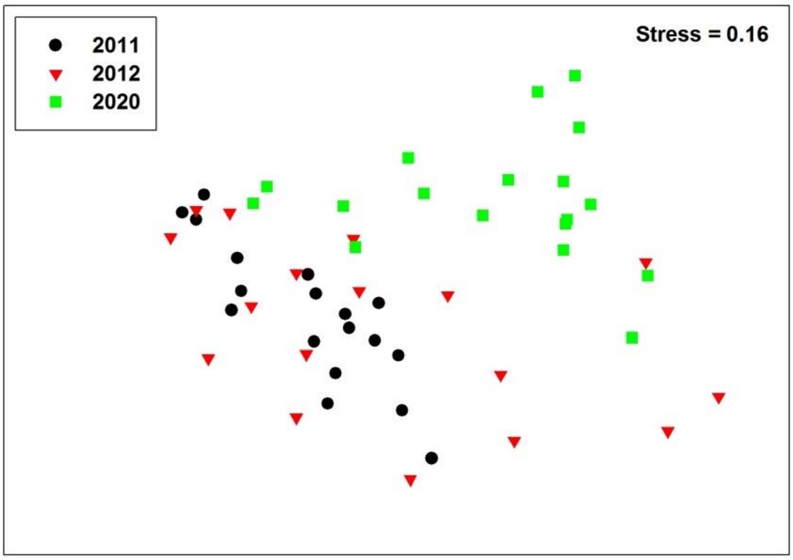

Figure 2.11: Non-metric multidimensional scaling plot indicating similarities between samples from across three years (2011, 2012 & 2020) for Transects 1-3.

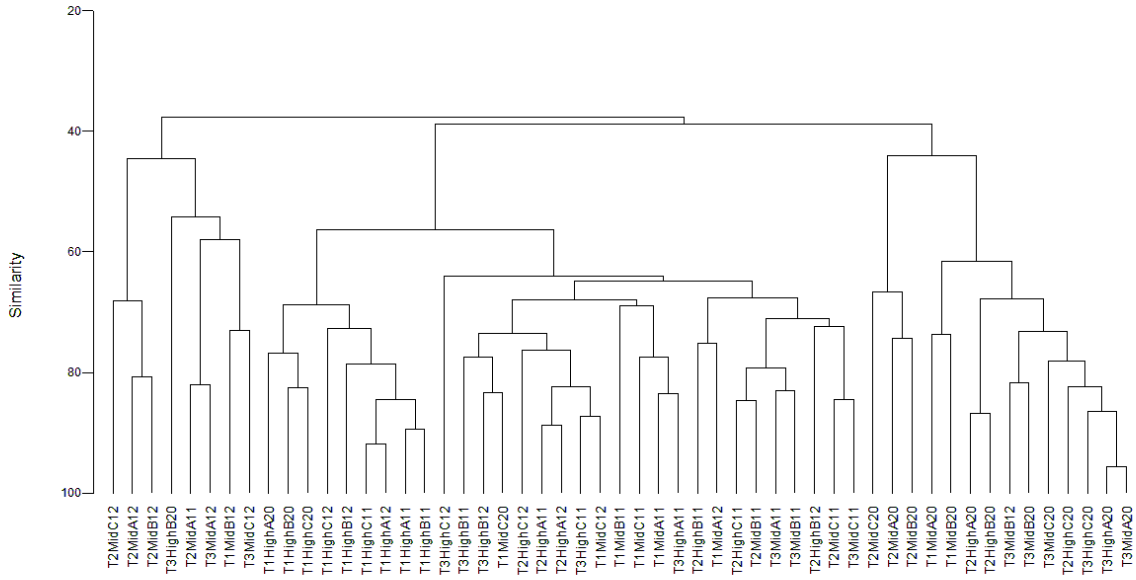

Figure 2.12: Dendogram showing the similarity between the sites and replicates collected along three transects in September 2020 with samples collected in 2011 and 2012.

Differences in faunal abundance were reflected in differences in biomass across the survey area (Table 2.6). Only one sample location showed a lower biomass, with the upper shore site at T1 returning lower biomass levels compared to surveys in 2011 and 2012. The remaining sites all showed higher biomass compared to the earlier surveys, especially at T1 Mid and T2 Mid. Further analysis of the data identified the latter differences to be associated with the sand-gaper *M. arenaria*, which was present in large numbers in T2 Mid and represented by one large individual at T1 Mid in the current survey. This variation in biomass is considered to be associated with the natural spatial patchiness of the molluscs at these sites. Changes were also noted in the increased contribution of worms to biomass levels in T3 High and Mid sample locations when compared to previous surveys, and a reduced contribution from worms at Transect 1 High. It is postulated that this is related to the spatial patchiness of the fauna in these areas.

Table 2.6: Total biomass (in grams) for each of the sites surveyed in 2020 compared to the same sites in 2011 and 2012.

	2020 (September)			
	Worms	**Molluscs**	**Crustaceans**	**Total Biomass**
T1 H	3.877	13.487	0.155	17.520
T1 M	4.043	109.670	0.000	113.712
T2 H	3.048	23.852	0.013	26.913
T2 M	0.646	248.978	0.001	249.625
T3 H	6.016	1.671	0.000	7.687
T3 M	3.570	1.034	0.001	4.605
	2011 (May)			
	Worms	**Molluscs**	**Crustaceans**	**Total Biomass**
T1 H	23.970	10.520	0.022	34.512
T1 M	3.560	6.460	0.001	10.021
T2 H	0.440	1.530	0.001	1.971
T2 M	0.000	2.540	0.001	2.541
T3 H	0.003	2.120	0.001	2.124
T3 M	0.001	2.520	0.021	2.542
	2012 (June)			
	Worms	**Molluscs**	**Crustaceans**	**Total Biomass**
T1 H	19.970	13.520	0.031	33.521
T1 M	0.070	1.860	0.000	1.930
T2 H	0.220	1.510	0.010	1.740
T2 M	28.670	0.450	0.170	29.290
T3 H	0.050	3.440	0.010	3.500
T3 M	0.001	2.010	0.050	2.061

Although differences were noted in the faunal and biomass data from 2020 when compared to 2011 and 2012 surveys, the biological community has remained the same, namely polychaete/bivalve dominated mid-estuarine mud shores. The species which were identified in previous surveys were also recorded in the present survey, although with some differences in relative abundances and biomass noted. Previous surveys from 2011 and 2012 have shown that maintenance dredging has no impact on the intertidal communities in Lough Mahon, and that is also considered for the present survey.

2.5 Subtidal Survey Results & Overview

Three of the four areas previously surveyed in 2011 and 2012 were re-surveyed during the present survey. Ongoing dredging in Area 1 meant that no samples were collected in this area. Dredging at the time of sampling adjacent to Tivoli restricted the collection of samples from Area 2 to the stretch downstream of Tivoli docks and upstream of Blackrock Castle. This was further downstream than the previous surveys in the same area, which had previously been upstream of Tivoli docks. Sample collections for Areas 3 & 4 were within the same general area of the previous sample locations. Due to the coarse nature of the sediment at Area 4, only a single sample was collected for Particle Size Analysis.

Particle Size Analysis Results

Results from particle size analysis of sediment collected in August 2020 were similar to results obtained previously, with Areas 2 & 3 dominated by muds and sandy muds, with mixed sediment dominating the downstream part of Area 4 (Table 2.7 & Figure 2.13). It wasn't possible to obtain a sample for grain size analysis at A4G2 due to the coarse nature of the sediment at that location. Loss on Ignition results reflected the sediment type present, with higher LOI values in samples from Areas 2 & 3 (dominated by mud) compared to lower levels in Area 4 (dominated by coarser sediments), Table 2.7.

Table 2.7: Granulometry and Loss on Ignition results from all sites from the present survey.

	% Gravel	% Sand	% Mud	Textural Group	% LOI
A2G1	0.9%	14.7%	84.4%	Poorly sorted slightly gravelly sandy mud	8.64%
A2G2	0.8%	4.7%	94.5%	Poorly sorted slightly gravelly mud	8.86%
A3G1	0.0%	16.0%	84%	Poorly sorted sandy mud	5.92%
A3G2	0.0%	9.5%	90.5%	Poorly sorted mud	6.53%
A3G3	0.0%	2.9%	97.1%	Poorly sorted mud	7.95%
A4G1	6.7%	71.8%	21.4%	Very poorly sorted gravelly muddy sand	3.42%

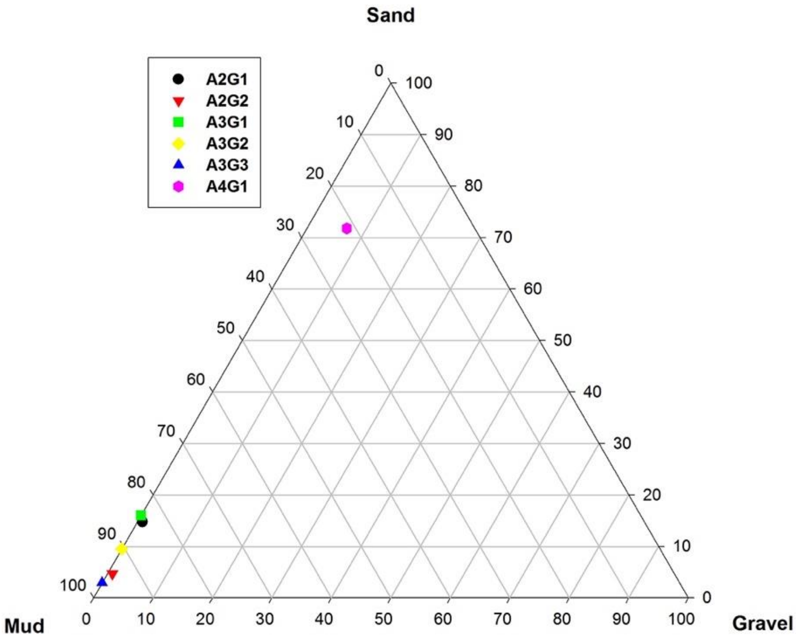

Figure 2.13: Ternary plot of granulometry results from subtidal sites in Cork Harbour.

Table 2.8: Fauna identified from the subtidal grabs from the present survey, August 2020.

	A2G1A	A2G1B	A2G1C	A2G2A	A2G2B	A2G2C	A3G1A	A3G1B	A3G1C	A3G2A	A3G2B	A3G2C	A3G3A	A3G3B	A3G3C	A4G1A	A4G1B	A4G1C	A4G2A	A4G2B	A4G2C
***Pomatoceros* sp.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-	26	-	1	100
Carcinas maenas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1	-	-	-
***Ophiura* sp.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	1	-
***Abra* sp.**	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	1	1	3	4	3	-
Pthisica marina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71	-	8	-	1	-
***Corophium* sp.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	-	4	1	-
Melita palmata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	3	7	4	2	4
***Tharyx* sp.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	13		44	21	8
***Oligochaeta* spp.**	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	28	193	32	60	25	24
Heteromastus filiformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	128	6	12
Capitellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	5	-	40	22	-
***Scoloplos* sp.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Aphroditidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Phyllodocidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	1	7	8	5	4
Spionidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	1	-		3	-
Eteone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	8	5	-
Cirratulidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	16	-	-	-	8
Ampharetidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	92	28	4
Streblospio	1	-	-	4	2	6	2	3	-	-	1	2	1	1	1	-	7	1	12	-	-
Syllidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2	4	5	4
***Nephtys* sp.**	1		2	2	-	5	-	2	-	3	3	-	3	2	3	-	-	-	-	1	-
***Harmathoe* indet.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Balanus crennatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-
Bryozoa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-
***Anemone* indet.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
***Dorididae* indet.**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-
Terebellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Nereididae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Crangon crangon	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Faunal Results

Faunal results from the current survey indicate the presence of fauna typical of muddy subtidal estuarine systems in Areas 2 & 3, and coarser estuarine systems in Area 4 (Table 2.8).

Table 2.9: Primary and derived indices samples collected during the present survey.

	A2G1A	A2G1B	A2G1C	A2G2A	A2G2B	A2G2C
Species	2	0	1	3	2	4
Abundances	2	0	2	7	3	14
Shannon-Wiener	0.693	-	0.000	0.956	0.637	1.200
Pielou's Evenness	1.000	-	-	0.870	0.918	0.864
Simpson Dominance	0.500	-	1.000	0.429	0.556	0.337
	A3G1A	**A3G1B**	**A3G1C**	**A3G2A**	**A3G2B**	**A3G2C**
Species	1	2	1	1	2	1
Abundances	2	5	3	3	4	2
Shannon-Wiener	0.000	0.673	0.000	0.000	0.562	0.000
Pielou's Evenness	-	0.971	-	-	0.811	-
Simpson Dominance	1.000	0.520	1.000	1.000	0.625	1.000
	A3G3A	**A3G3B**	**A3G3C**	**A4G1A**	**A4G1B**	**A4G1C**
Species	2	2	2	2	20	12
Abundances	4	3	4	51	229	249
Shannon-Wiener	0.562	0.637	0.562	0.0965	2.2.00	0.983
Pielou's Evenness	0.811	0.918	0.811	0.139	0.734	0.395
Simpson Dominance	0.625	0.556	0.625	0.962	0.165	0.61
	A4G2A	**A4G2B**	**A4G2C**			
Species	12	17	9			
Abundances	408	132	168			
Shannon-Wiener	1.890	2.230	1.420			
Pielou's Evenness	0.760	0.788	0.647			
Simpson Dominance	0.194	0.142	0.387			

Area 4 returned by far the highest abundances and species diversity, with much lower levels of both in replicates from Areas 2 and 3, which both had very similar results (Table 2.9). These results are very similar to results obtained in 2011 and 2012, when Area 4 also returned the highest diversity. The number of identified taxa present in each area was similar to those collected previously. In Area 2, four taxa were identified in the present survey, 0 in 2011 and 5 in 2012. There was a decrease in the number of taxa identified in Area 3 for the present survey (3 taxa) compared to 2011 (7 taxa) and 2012 (10 taxa). It should be noted, however, that the dominant taxa identified in previous surveys remained the same for the present survey i.e. *Nephtys hombergii* and *Streblospio*. Overall, the number of taxa identified in the present survey (28) was slightly lower than identified previously (33 in 2011 and 36 in 2012).

Statistical analysis of the data highlights these differences, with two distinct groupings evident (Figures 2.14 & 2.15). There was a high degree of similarity between Areas 2 and 3, with Area 4, as expected, showing distinct separation. The benthic community in Areas 2 and 3 was similar, dominated by the polychaete worms *Streblospio* and *Nephtys*, with very low abundances recorded. The benthos at Area 4 was more diverse and with higher abundances, reflecting the mixed nature of the seabed substrate in the area. A single site (A3G1C) has been classified as an outlier, as only a single taxon (Oligochaetae) was present in low numbers (3 individuals).

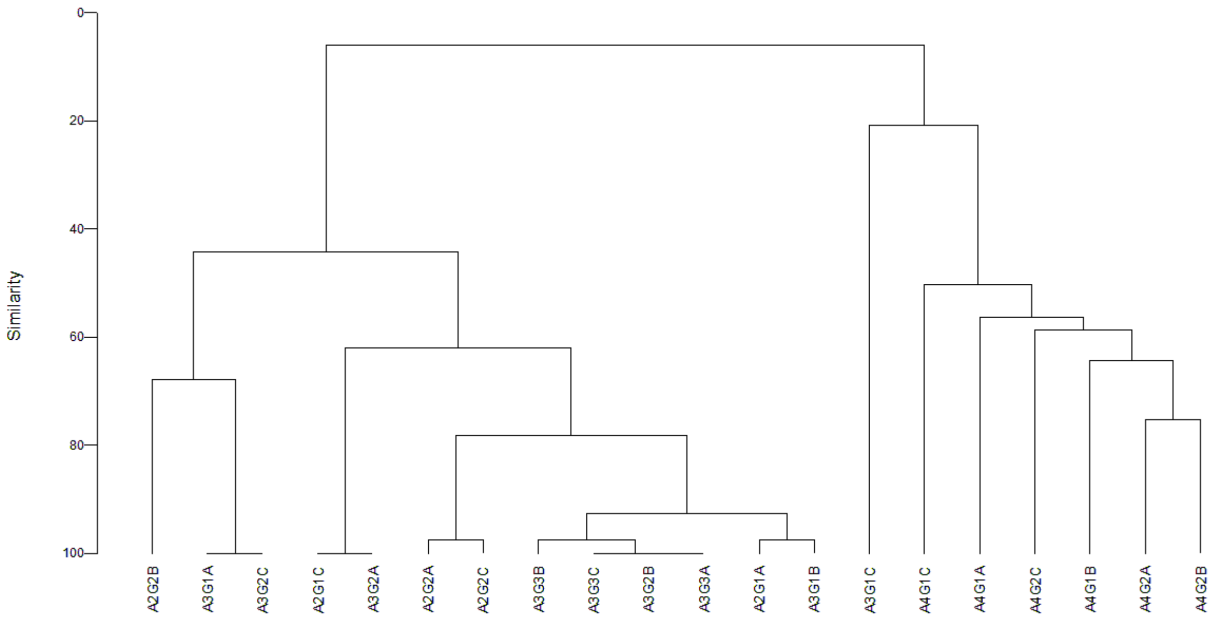

Figure 2.14: Dendogram highlighting the differences between Area 4 and Areas 2 & 3.

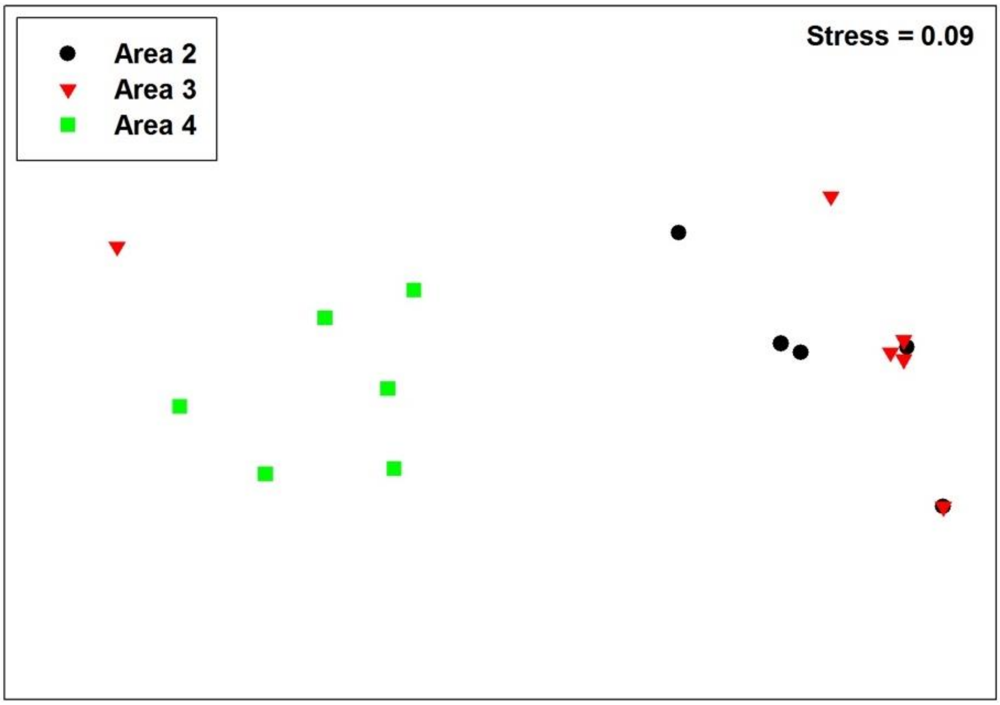

Figure 2.15: MDS plot indicating similarity of the sites and replicates collected in August 2020 showing variation between the survey areas [Stress = 0.09].

Two faunal communities were identified in the survey. In areas 2 & 3 a single faunal community – '*Sublittoral mud in variable salinity*' (SS.SMu.SMuVs) was identified. This was the same community type identified in 2011 and 2012 for Area's 1 & 2. *'*Nephtys hombergii *and* Tubificoides *spp. in variable salinity infralittoral soft mud*' (SS.SMu.SMuVs.NHomTubi) was identified in Area 3 in 2011 and 2012, and although the dominant taxa remained the same for the present survey in Area 3, a reduction in faunal diversity and abundances meant that the Area 2 community ('*Sublittoral mud in variable salinity*' (SS.SMu.SMuVs) was considered a better fit for the current survey. Area 4 has been classified as '*Infralittoral mixed sediment*' (SS.SMx.IMx), which was the same as the classification for 2011 and 2012. As with findings from previous surveys, the lack of key identifying fauna and the spatial patchiness of the fauna made further community classification of Area 4 difficult.

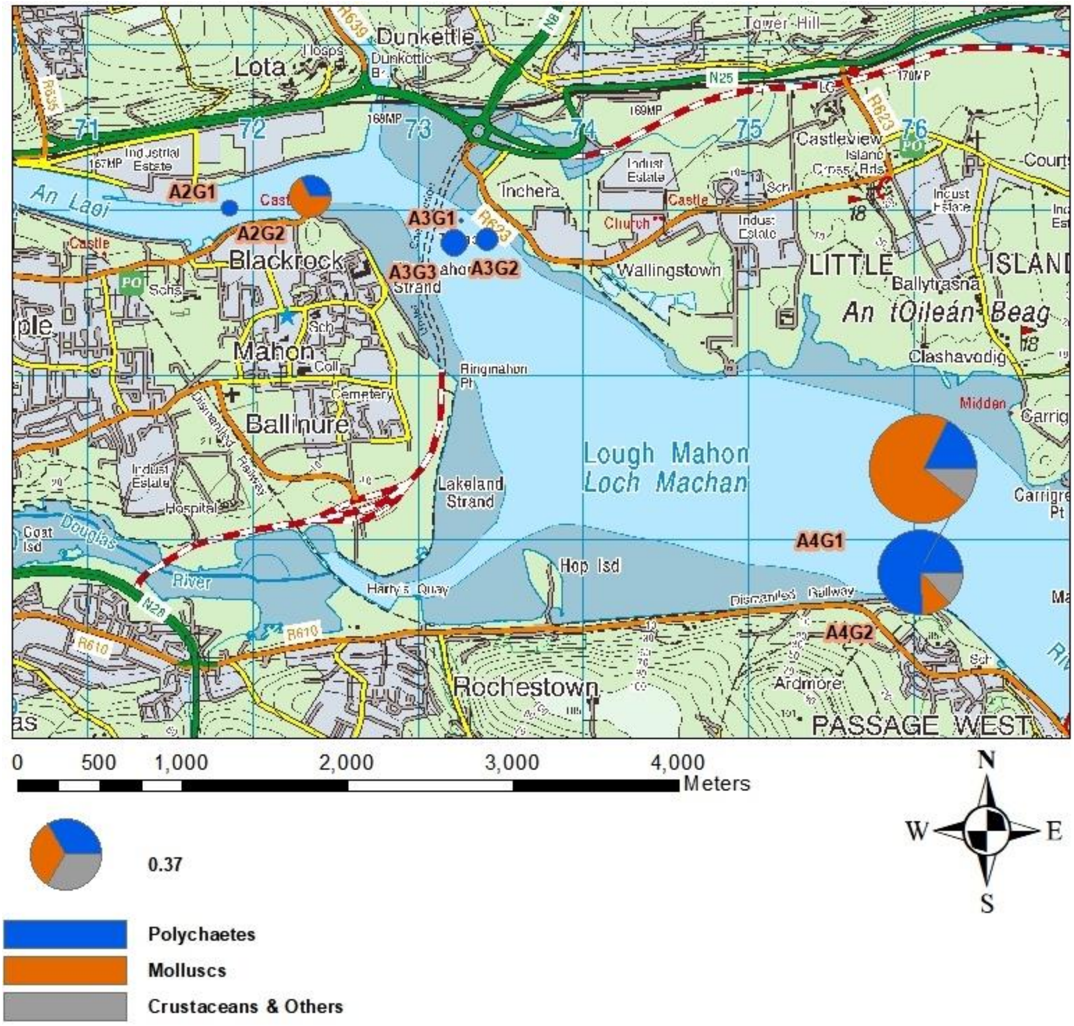

Figure 2.16: Relative biomass distribution across the three survey areas.

Biomass results from the subtidal survey mirrored these findings with a large difference between the biomass in Area 4 and in Areas 2 & 3 (Figure 2.16 & 2.17). Localised patchiness within the areas was also noted, with some variations evident between the replicates in terms of biomass (across all three areas) and the faunal grouping which constituted the biomass (present in Areas 2 and 4) (Figs 2.18, 2.19 & 2.20).

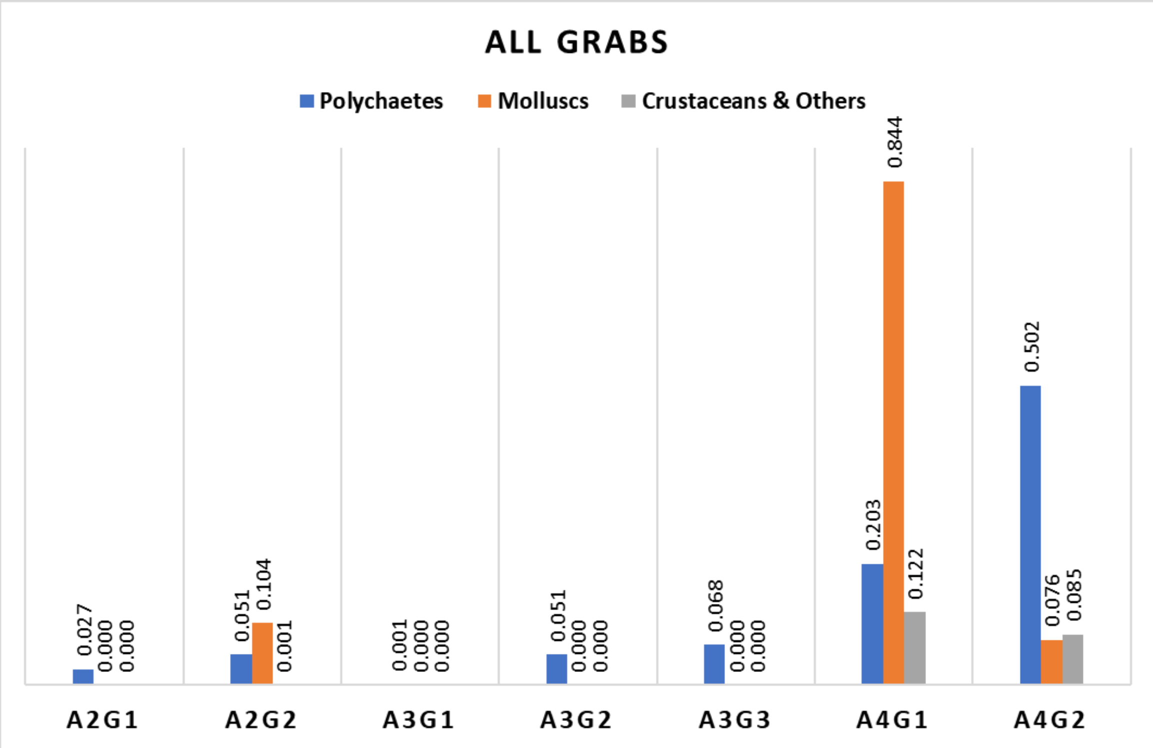

Figure 2.17: Biomass distribution at each of the sites surveyed in August 2020. The highest biomass present across the site is present in Area 4, with reduced biomass in Areas 2 and 3.

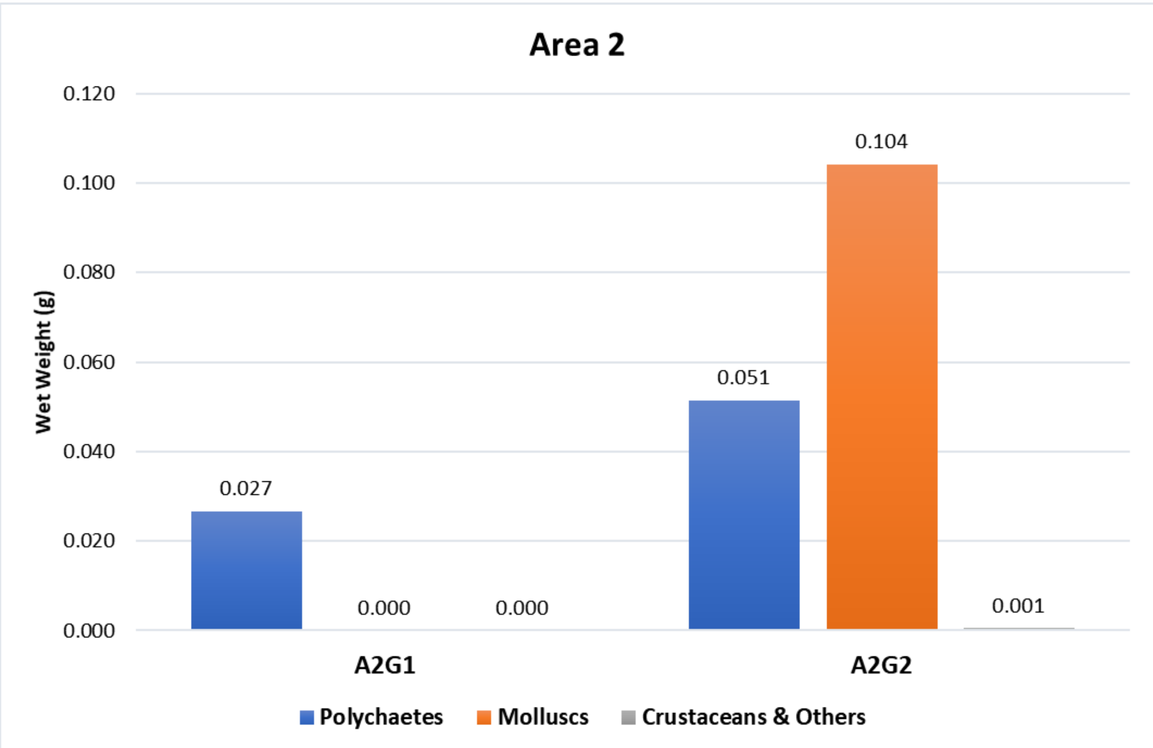

Figure 2.18: Biomass distribution across Area 2 – August 2020.

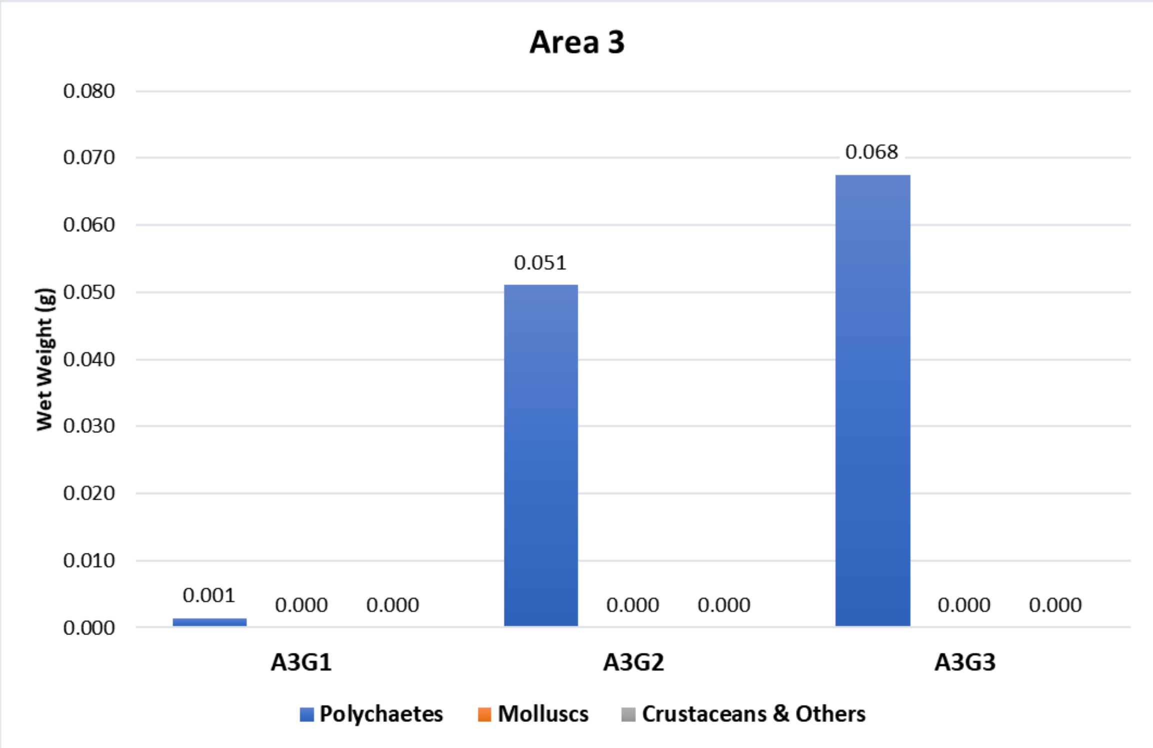

Figure 2.19: Biomass distribution across Area 3 – August 2020.

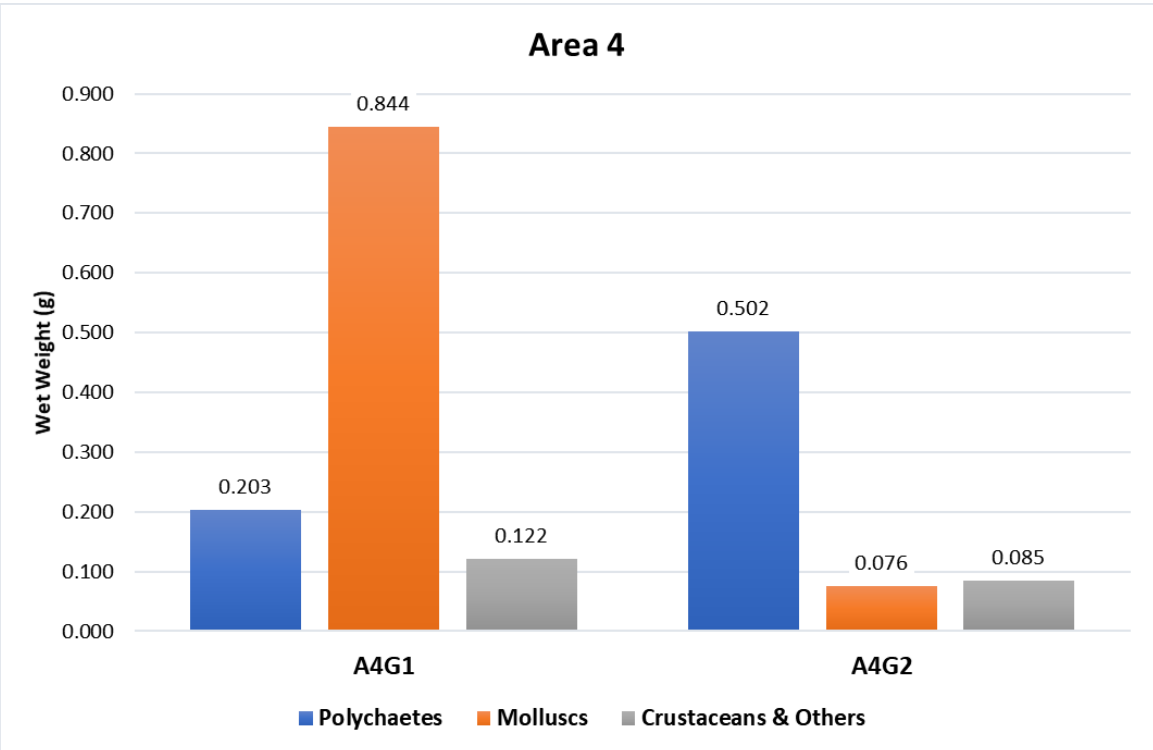

Figure 2.20: Biomass distribution across Area 4 – August 2020.

Comparisons with Previous Surveys

The present survey identified the presence of two distinct faunal communities in the main shipping channel which was largely similar to those identified in 2011 and 2012. Although some changes were noted in the community in Area 3, these related to the reduced faunal abundances present in the area, but the dominant taxa present in the area remained the same as previously identified. Surveys undertaken in 2011 and 2012 identified the same community across the survey areas before and after maintenance dredging, with recovery evident in the shipping channel immediately after maintenance dredging was completed in 2012. Results from the present survey mirror the findings from this previous survey, with 2 distinct faunal communities present. The dominant taxa identified previously remain the dominant taxa during the present survey, although some changes in abundances have been observed.

Statistical analysis of the combined dataset indicates no difference in community structure between the present survey (2020) and previous surveys (2011 and 2012) in terms of similarity (Fig 2.21a & Fig 2.22). The distinct differences in faunal structure that is present between Area 4 and the remaining areas is consistent across the years (Fig 2.21b). This consistency of results indicates the stable nature of the benthic community within the shipping channel. Differences in biomass were noted in Area 3 between the study years, with much lower biomass in 2020 when compared to previous surveys (Fig. 2.23). This is reflected in the lower faunal diversity and abundance in this area. Biomass levels in Area 2 and Area 4 were broadly similar to those identified in these areas previously.

Although differences were identified in terms of biomass and relative faunal abundances, the benthic community within the shipping channel has remained stable across the survey years. All species identified in 2020 were identified in previous surveys and the communities identified are similar to those identified previously.

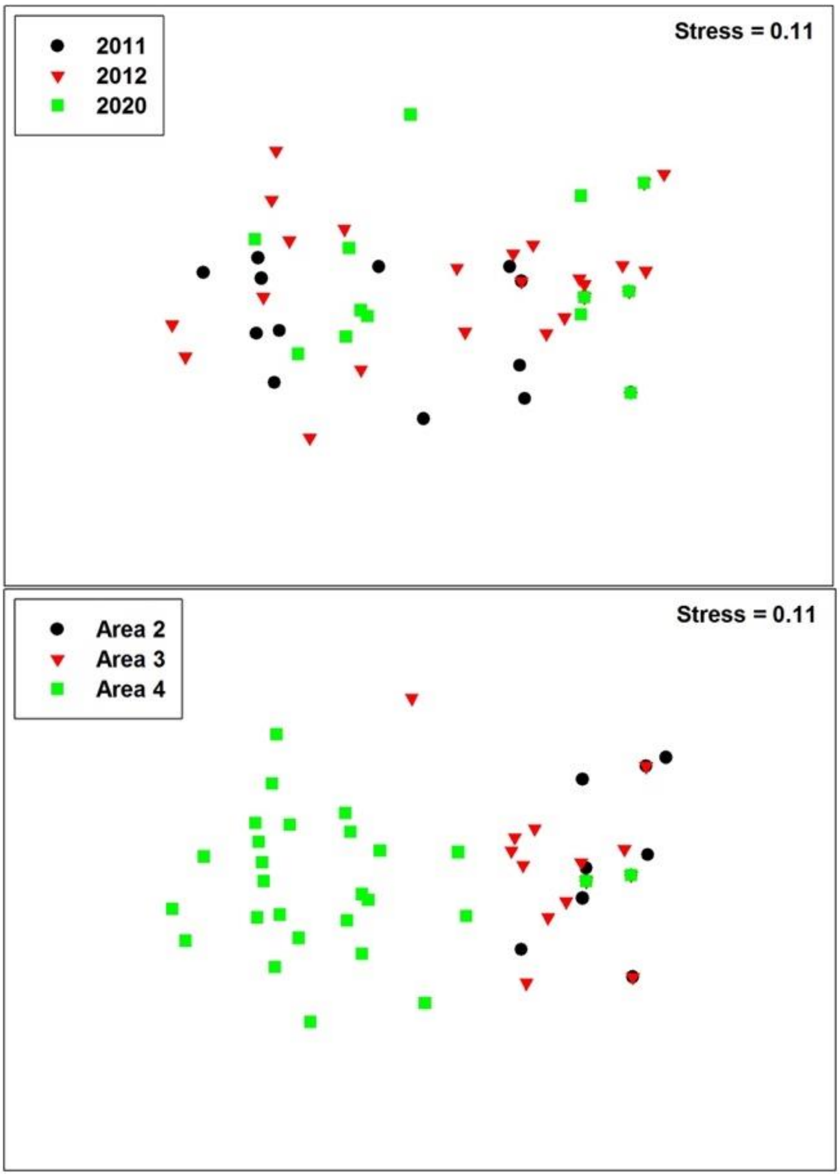

Figure 2.21: Non-metric multidimensional scaling plot indicating similarities between samples across (a) three survey years and (b) across the three survey areas. Note the lack of separation in the data between the years (a) with obvious distinction between the three areas (b).

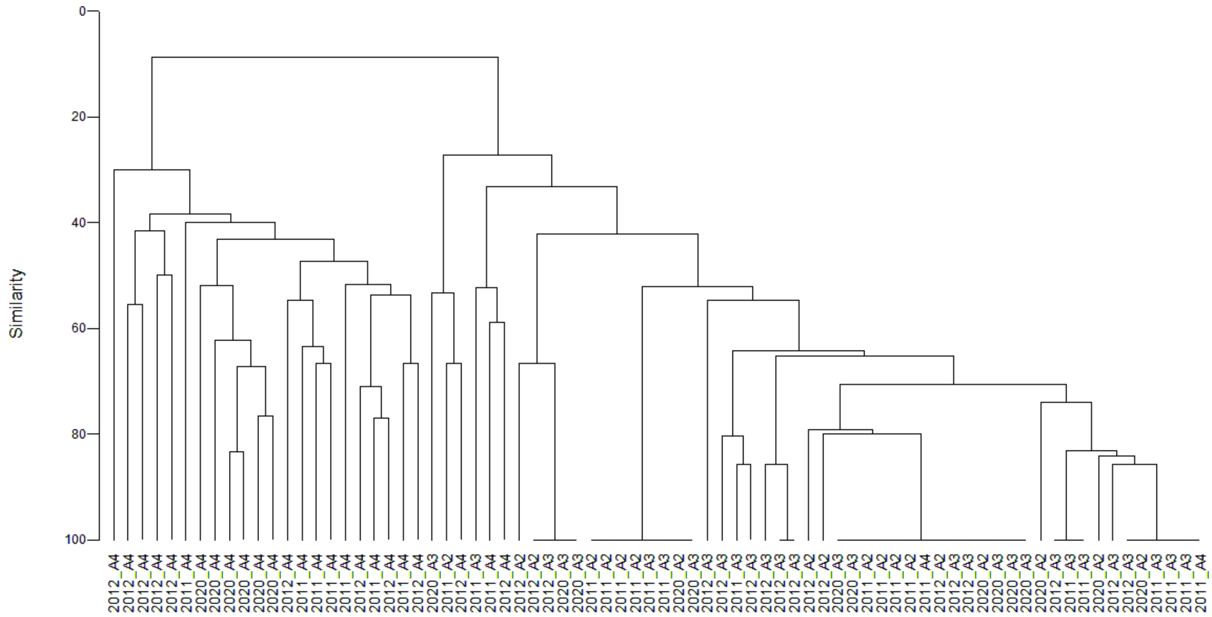

Figure 2.22: Dendogram showing the similarity between the sites and replicates collected along three transects in August 2020 with samples collected in 2011 and 2012.

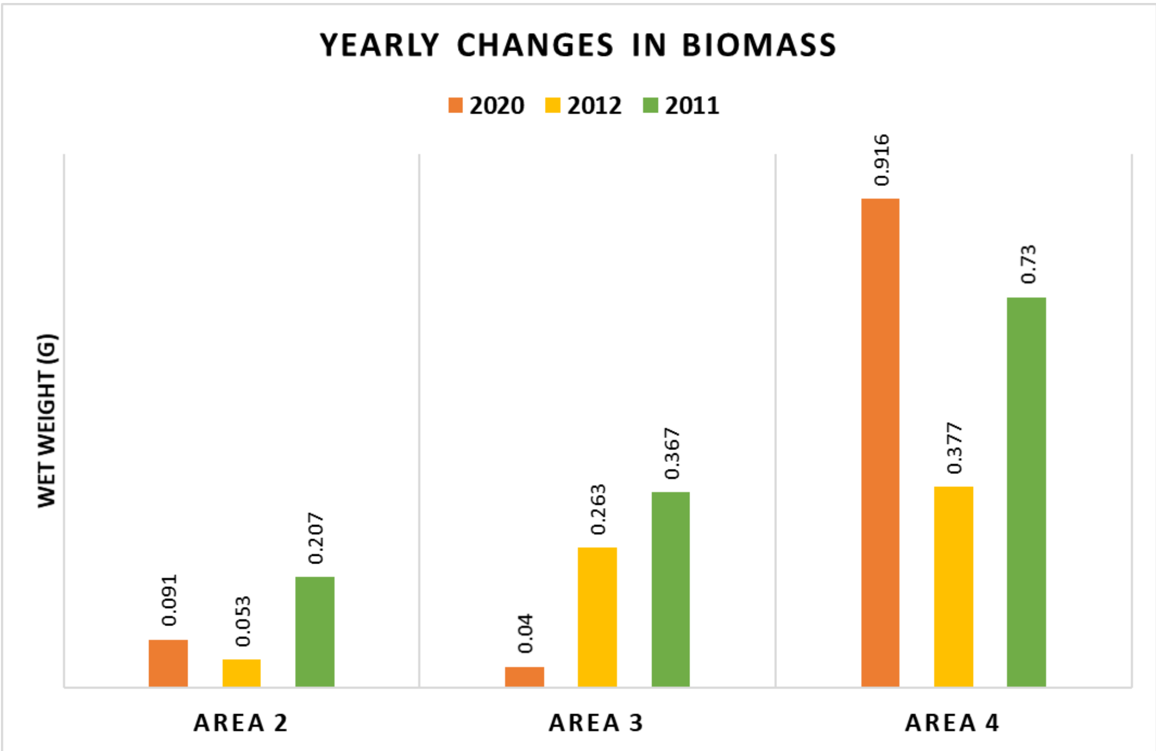

Figure 2.23: Comparison of biomass across the years from 2011, 2012 and 2020. Average weights per grab for each of the areas.

2.6 Dredging impacts

Dredging activities impact on the benthos in two ways:

1. Direct removal of habitat within the dredge footprint
2. Increased turbidity and sedimentation associated with dredging activities

The most significant impact of dredging is the direct removal of sediment from the areas to be dredged. This will result in significant reductions in the number of species, individuals and biomass in areas which have been subjected to dredging events. These reductions include a 30% - 70% for species number, between 40% and 95% for abundances and 80% - 90% for biomass levels post dredging (from Newell *et al.,* 1998). However, these impacts are expected to be localised within the direct footprint of the dredge area.

The significance of this impact is dependent on several factors; such as the sediment type, biological community, frequency of dredging etc. Within the areas to be dredged, much of the benthos is characterised by the presence of sandy muds and muddy sands (these dominate Areas 1-3). The downstream portion of Area 4 is characterised by coarser mixed sediment. Sub-tidal estuarine communities which inhabit sandy mud habitats are typically dominated by fast growing, opportunistic species (such as *Nephtys* and *Streblospio*). As a result the faunal communities in these areas (Area's 1-3) are expected to recover rapidly (within 12-18 months) once dredging is completed (from Newell *et al.,* 1998). The seaward end of Area 4 consists of mixed sediments, with more established fauna present. Direct removal of this habitat will result in a longer recovery period (2-4 years) following completion of dredging (from Newell *et al.,* 1998).

The benthos in the areas to be dredged in Cork Harbour are subjected to regular maintenance dredging and as a result, the benthic communities present are well adapted to rapid recovery after dredging events. A baseline survey was undertaken in 2011, prior to maintenance dredging taking place in the 2011/2012 season. Results indicated that the benthos in all areas subjected to maintenance dredging were in the process of recovery within 6 months following cessation of dredging. This timescale is consistent with previous studies on the recovery of sub-tidal dredged sediments in estuarine conditions (Bonsdorff, 1980; Clarke *et al,* 1990 in Newell *et al.*, 1998)

The system in Cork Harbour is a turbid system and subjected to regular increases in turbidity following heavy rainfall and strong tides. The benthic communities present in this system are adapted to increases in turbidity and as a result, impacts associated with increased turbidity are expected to be negligible. No impacts are expected on the intertidal communities from the maintenance dredging of the shipping channel. Previous surveys in 2011/2012 indicated no impact from maintenance dredging on the intertidal communities, and modelling undertaken by RPS in 2020 (RPS, 2021) indicated that only small areas of the intertidal would be subjected to between 1 – 2.5mm of sediment deposition, but most of the intertidal and subtidal area within Lough Mahon and the North Channel would have accumulated deposits of sediment of only between 0mm and 1mm as a result of the dredging campaign. These levels of sedimentation would be considered small. Consequently, there are expected to be no adverse impacts on the intertidal areas of the Cork Harbour SPA or the North Channel SAC.

3 METHODOLOGY & RESULTS – FISHERIES

3.1 Methods

Fieldwork for the fisheries study was undertaken on August 24th and 25th 2020. Three fisheries survey methods were employed: (i) trawling using a 2m beam trawl (Plate 3.1), (ii) potting for green crabs using 4 strings of 5 pots each baited with white fish offal (Plate 3.1) and (iii) 5 single fyke nets (not shown). The pots were deployed near the Tivoli Docks, at the top of Lough Mahon 650m seaward of the entrance to the Glashaboy Estuary, off Little Island 550m NE of Ring Mahon Point and 1.2km SE of Ringmahon Point. In each case the pots were either in or beside the shipping channel (Figure 3.1). Five single fyke nets were deployed, one between Blackrock Castel and the Glashaboy Estuary, 650m SE of the Glashaboy Estuary entrance, 85m east of Ring Mahon Point, and two at either side of the channel 1.6km WNW of Marino Point (Figure 3.1). All fykes were along the side slopes of the dredged channel. Finally, three successful trawls tows were completed in the lower third of Lough Mahon between Marino Point and Little Island (Area 4), all in the dredged channel (Figure 3.2). Another trawl was attempted in the upper half of Lough Mahon (Area 3) but it filled with mud and couldn't be processed. Pots and fykes were deployed on August 24th and retrieved 24 hours later. The GPS positions in Lat Long are listed for all the survey points in Table 3.1.

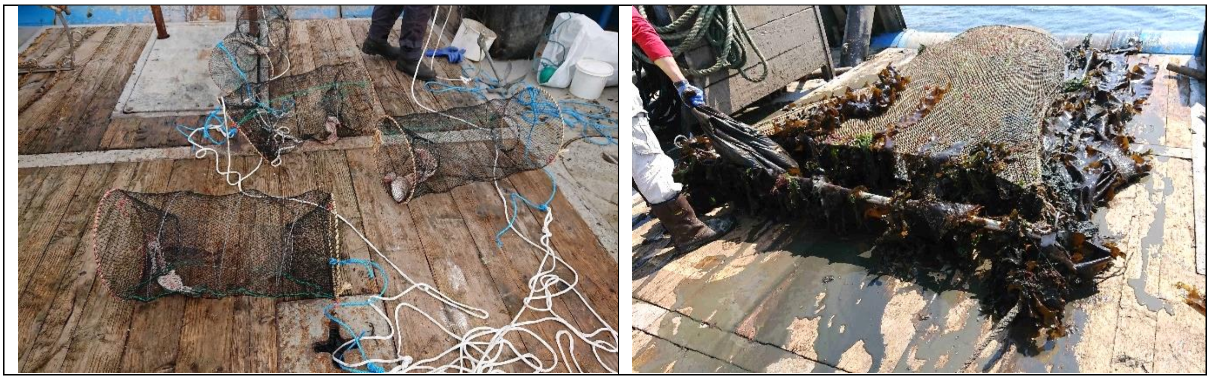

Plate 3.1 Rigged and baited crab pots (left), 2m beam trawl from the 2018 survey in (right)

Figure 3.1: Positions of crab pots (pink markers) and fyke nets (blue markers) August 2020

Figure 3.2: Positions of 3 beam trawl tracks in Area 4, August 2020.

Table 3.1 Positions of crab pots, fyke nets and beam trawls (in degrees Lat. Long.) August 2020

Fishing Gear	Latitude	Longitude
Pot 1	51.901094°N	-8.408037°W
Pot 2	51.899841°N	-8.388756°W
Pot 3	51.893905°N	-8.383099°W
Pot 4	51.887724°N	-8.372906°W
Fyke 1	51.902028°N	-8.401330°W
Fyke 2	51.899459°N	-8.389351°W
Fyke 3	51.890797°N	-8.377430°W
Fyke 4	51.881101°N	-8.354624°W
Fyke 5	51.883651°N	-8.355137°W
Trawl 1 A4 in	51.881601°N	-8.350975°W
Trawl 1 A4 out	51.883036°N	-8.358056°W
Trawl 2 A4 in	51.881965°N	-8.351234°W
Trawl 2 A4 out	51.883203°N	-8.359489°W
Trawl 3 A4 in	51.883948°N	-8.361709°W
Trawl 3 A4 out	51.885950°N	-8.367378°W

3.2 Results

Crab Pots

All four strings of crab pots collected similar total weights of green crab (*Carcinus maenas*) – Table 3.2. In fact, it is debatable whether they could have actually held any more animals (Plate 3.2).

Table 3.2: Weight in kilos of green crab (*Carcinus maenas*) in each 5-pot string at four locations in Lough Mahon (August 24th-25th 2020)

	Pot string 1	Pot string 2	Pot string 3	Pot string 4
Pot 1	6.1	27.5	26.6	9.4
Pot 2	11.3	18.5	17.9	20.3
Pot 3	21.5	14.9	17.4	17.0
Pot 4	21.2	17.0	14.6	11.9
Pot 5	25.5	7.0	12.6	9.8
Total	**85.6**	**84.9**	**89.1**	**68.4**

In the original study in 2011 and 2012 a different pot type was used to catch crabs. These were laid out in strings of 10 per site from the city quays down to Tivoli docks. They were also baited with fish offal and left in place for 24 hours. The maximum total catch in any one string was 17kg compared to nearly 90kg in the current study. The reason for this is believed to be the type of pot itself which in 2020 may have been more efficient, although the amount of bait and seasonal differences in sampling may also have affected the results. In any case, the high and remarkably consistent total weight of crabs taken in the four strings of pots deployed throughout Lough Mahon in August 2020, suggests that there was a very high density of green crabs present throughout the study area, pointing to a healthy stock of this key species within the area.

Plate 3.2 A crab pot with catch of green crab (*Carcinus maenas*) and remnants of bait (25-8-2020)

Fyke Nets

Unlike the crab pots, fyke nets were not baited. They caught mainly green crab and a small number of fish (Table 3.3). The location of fyke nets, effectively in open water, is suboptimal and they are more traditionally operated in narrow riverine channels or lake margins i.e. in non-tidal waters. A longer deployment might have resulted in a higher catch and a wider variety of species. The pollack was netted in the fyke leader net and hadn't swan into the net chambers. Five-bearded rockling was the fish species most frequently taken in fyke nets deployed in the 2011 and 2012 surveys but was only present in one in 2020. In the original 2011 and 2012 study, the seven fyke nets deployed from the City Quays to the end of Lough Mahon, on average captured 4.3-6.7kg of green crab (max 11.3kg), i.e. significantly more than in the current study. They also tended to catch more fish species but again the numbers were very low. The main reason thought to account for these differences is that the fyke nets deployed in the earlier study were double ended and probably were able to fish actively regardless of the direction of the tide, whereas those deployed in the current study were single fyke nets and probably only fished during either ebb or flood tides. In any case, it would seem that, overall, fyke nets are not a particularly productive survey method for this type of study.

Table 3.3: Weight in kilos of green crab (*Carcinus maenas*) in each pot at five locations in Lough Mahon (August 24th-25th 2020)

	Fyke 1	Fyke 2	Fyke 3	Fyke 4	Fyke 5
Green Crab	0.8kg	1.9kg	1kg	0.75kg	1.05kg
Pollack	1 (17cm)	1 (15cm)			
Flounder		1 (12cm)			
5-bearded Rockling			1 (13cm)		

Trawling

Three trawl tows were undertaken in the lower third of Lough Mahon (Area 4) on the 24th of August (Plates 3.3-3.5) and more fish were taken in each than in any of the trawls undertaken previously in this area (Area 4) or in the upper section of Lough Mahon (Area 3), either in the original 2011 and 2012 surveys or the follow up surveys in 2016, 2018 and 2019 (Tables 3.4 and 3.5). In terms of diversity there were 19 species of fish taken in the three trawls. This compares with 10 taken in many more trawls in 2011 (80% in common), 20 taken in 2012 (75% in common), 14 taken in 2016 (86% in common), 16 taken in 2018 (75% in common) and 10 species taken in 2019 (100% in common) in Areas 3 and 4. Of the species taken in 2020, only pouting (*Trisopterus luscus*) had not been recorded previously. Indeed, one would expect to find all these common species in English, northern French, Belgian and Dutch estuaries also. Moreover, the most abundant invertebrates (green crab and brown shrimp) would be expected to be among the most abundant invertebrates in these estuaries also, forming very important parts of the food web. The higher fish numbers taken in the current survey may be partly explained by modifications made to the beam trawl introduced in 2020.

A comparison with the fish recorded by Inland Fisheries Ireland (IFI) in Lough Mahon in October 2010 (Kelly, *et al*., 2011) is shown in Table 3.6. IFI used 3 fishing gear types: beach seine from the shore (6 locations), fyke nets (6 locations) and beam trawls (6 locations). In total they recorded 16 fish species, 10 of which were only recorded in the shoreline beach seines, which may explain why the IFI and current survey only had 9 species in common (i.e. 56%). In terms of actual numbers of individuals, the highest by far (sprat and sand gobies) were taken in beach seines.

What is clear from the current 2020 results is that Cork Harbour is an important nursery area for juvenile flatfish including dab, sole and plaice (Figures 3.3, 3.5, 3.7) and for young gadoids, in particular whiting (Figure 3.9). Other species also frequently encountered in trawls and which maybe even more estuarine dependent include black goby, sand goby, and Nilsson's pipefish (Figures 3.10, 3.11, 3.13). Also frequently recorded, although generally present in smaller numbers, included species such as dragonet and pogge (Figures 3.14, & 3.15).

In the case of a few of the more numerous species recorded, i.e. dab, sole, plaice and goby, size distribution graphs from previous trawl surveys have also been included to show the effect of the month of the sampling on the size distribution of the fish (Figures 3.4, 3.6, 3.8, 3.12), where the later sampling month in 2020 (August 24th) resulted in a shift to relatively proportions of larger fish.

An examination of the size distribution graphs in general shows that the majority of fish present were in the 0+ fish, i.e. within the first year of life, with much fewer older fish, something which is clear in the graphs for dab (Figure 3.3) and sole (Figure 3.5). An apparent anomaly in the data in relation to sole is that the 2016 sole taken in Area 4 in 2016 (Figure 3.6) were all older larger fish, probably in their second year, with apparently no young-of-the-year fish, while the 2020 sole taken in the same area are dominated by young-of-the-year fish (Figure 3.5). Overall, the current and previous trawl results point to Cork Harbour, especially its upper reaches around Lough Mahon, as an important nursery ground for several common commercial species. These results suggest that there is likely constant, seasonally directed, exchange between upper harbour juvenile stocks and outer Harbour and coastal adult stocks, in the case of many species. In that way, the larvae of species such as flounder, dab, plaice, sole that spawn in marine waters, will drift into estuaries replenishing emigrants on a yearly basis. Fish enter estuaries for a wide variety of reasons which often interact. These may include more favourable temperatures, good food resources and lower predator pressure.

Summarised details of the biology and estuarine dependency of the 19 species recorded in the current survey are presented in Tables A1 and A2 in Appendix 1.

Crangon and Green Crab

The two most abundant mobile invertebrate species taken in the survey area were green crab, also known as shore crab (*Carcinus maenas*) and the brown shrimp (*Crangon crangon*). Other important species included prawn, mainly *Palaemon serratus*, and the peacock fan worm (*Sabella pavonina*). Green crab and *Crangon* are key food web structuring species in estuaries and shallow inshore environment (Selleslagh and Amara, 2008) where they are extremely important predators of juvenile fish but also, in the case of *Crangon* in particular can form part of the diet of older fish also (Amara *et al.*, 2001). Both species have a broad salinity tolerance range which allows them to penetrate the Lower Lee estuary at least to the City Quays, in the case of green crab. *Crangon* may have more than one year-class present in a population, although juveniles would seem to overwhelmingly dominate (Oh, *et al.,* 1999). *Crangon* may spawn more than once in a season with spawning at Irish latitudes perhaps extending from early spring into early summer (see Campos and Van der Veer, 2008). The size distribution of *Crangon* taken in August 2020 in Trawl 2 of Area 4 (Figure 3.16) points to just one main size class, whereas previous assessments suggested more than one year-class or perhaps the progeny of more than one or partially overlapping spawnings (Figure 3.17).

No size distribution was undertaken for green crab because it wasn't possible to process them on board and they were returned live to the Lough. As the current potting survey and previous surveys in Lough Mahon have shown green crab are a major component of the Cork Harbour food web. These crabs are opportunist predators consuming a wide variety of worms, bivalves and other crustaceans such as *Crangon*, they are also cannibalistic. They will vary their diet from place to place within the same waterbody depending on the local abundance of prey items tending to go for the most easily captured and highest energy content items available (Baeta *et al.,* 2005). Green crabs in turn form part of the diet of larger fish and shore birds.

Table 3.4 Fish and invertebrates taken in three 2m beam trawls in the lower end of Lough Mahon (August 24th, 2020)

Common Name	Scientific Name	Trawl 1 Area 4	Trawl 2 Area 4	Trawl 3 Area 4
Green crab	*Carcinus maenas*	1kg	4.9kg	1kg
Brown shrimp	*Crangon crangon*		1.2kg	0.21
Hermit crab	*Pagurus bernhardus*	+		
Harbour swimming crab	*Liocarcinus sp.*	+		
Small spider crabs	*Majiidae*		3	
Prawn	*Palaemon serratus*	0.85kg	1.55kg	0.2
Common starfish	*Asterias rubens*	+	0.7kg	
Peacock worms	*Sabella pavonina*	++	+++	++
Sponge	*Suberites sp.* (?)	+	0.1	
Hydroids indet			+	
Ascidians indet			4	
Sea slugs			3	
Feather star	*Antedon* sp.	++		
Common whelk	*Buccinum undatum*		+	
Anemones indet.			++	
Flounder	*Platichthys flesus*	2	7	5
Dab	*Limanda limanda*	22	94	114
Plaice	*Pleuronectes platessa*	4	4	50
Sole	*Solea solea*	6	35	308
Pollack	*Pollachius pollachius*	1		
Whiting	*Merlangius merlangus*	22	7	19
Cod	*Gadus morhua*		1	
Poor cod	*Trisopterus minutus*		1	2
Pouting	*Trisopterus luscus*	3		2
5-bearded Rockling	*Ciliata mustela*	2	10	2
Sand Goby	*Pomatoschistus minutus*	~110 (0.3kg)	373 (1kg)	92 (0.28kg)
Black Goby	*Gobius niger*	7	69	5
Butterfish (Gunnel)	*Pholis gunnellus*	2	1	
Pogge (Hooknose)	*Agonus cataphractus*		16	2
Dragonet	*Callionmys lyra*	8	33	2
Grey Gurnard	*Eutrigla gurnardus*		1	6
Greater pipefish	*Syngnathus acus*		6	
Nilsson's pipefish	*Syngnathus rostellatus*	1	4	42
Eel	*Anguilla anguilla*		2	

Table 3.5: Numbers of 28 species of fish taken in all beam trawls in Areas 3 & 4 (Lough Mahon) from 2011 to 2020.

	Common Name	2011	2012	2016	2018	2019	2020
1	Sand Goby	48	18	31	3	1	575
2	Sole		3	53	11		349
3	Dab	2	29	1	20	61	231
4	Plaice	31	49	3	134	6	58
5	Nilsson's pipefish		29	24	5	12	47
6	Black Goby	11	3	6			81
7	Hooknose/Pogge	20	9	7	3	3	18
8	Dragonet		9			4	43
9	Whiting		1	1			48
10	Flounder	7	7		10	8	14
11	Butterfish/Gunnel)	2		8	5	7	3
12	Greater pipefish	2	1	7		4	6
13	5-bearded Rockling		1	2			14
14	European eel				8		2
15	Grey gurnard		1				7
16	Cod		1		2	2	1
17	Poor cod				1	2	3
18	Pollack		1	2	1		1
19	Pouting						5
20	Worm pipefish			3	1		
21	Sea scorpion			1	2		
22	Transparent Goby		2				
23	Corkwing wrasse	1	1				
24	Thornback Ray		1		1		
25	Common Goby	1					
26	Conger eel (larva)		1				
27	Spratt		1				
28	John Dory				1		
Total Individuals (all trawls)		**125**	**168**	**149**	**208**	**110**	**1506**
Species Total (all trawls)		**10**	**20**	**14**	**16**	**11**	**19**
% in common with 2020 species		**80%**	**75%**	**86%**	**75%**	**100%**	**100%**

Table 3.6: Fish recorded by Inland Fisheries Ireland (Kelly *et al.,* 2011) from Lough Mahon (Black Rock Castle to Ballynoe/Rushbrook) October 2010 in decreasing order of abundance

Scientific Name	Common Name	Beach Seine (6)	Fyke net (6)	Beam trawl (6)	Total
Sprattus sprattus	Sprat	4118	-	-	4118
Pomatoschistus minutus	Sand goby	348	-	17	365
Gobiusculus flavescens	Two-spotted goby	69	-	-	69
Atherina presbyter	Sand smelt	35	-	-	35
Gadus morhua	Cod	-	33	-	33
Platichthys flesus	Flounder	8	3	2	13
Pleuronectes platessa	Plaice	7	-	3	10
Trachurus trachurus	Scad	5	-	-	5
Anguilla anguilla	European eel	-	2	-	2
Chelon labrosus	Thick lipped grey mullet	2	-	-	2
Pomatoschistus microps	Common goby	2	-	-	2
Callionymus lyra	Common dragonet	-	-	1	1
Ciliata mustela	Five-bearded rockling	-	1	-	1
Pholis gunnellus	Gunnel (Butterfish)	1	-	-	1
Spinachia spinachia	Fifteen-spined stickleback	1	-	-	1
Syngnathus acus	Greater pipefish	1	-	-	1

Plate 3.3: Contents of Trawl 1 Area 4, August 24th, 2020

Plate 3.4: Contents of Trawl 2 Area 4, August 24th, 2020

Plate 3.5: Contents of Trawl 3 Area 4, August 24th, 2020 (note that mud was washed out of the trawl before this photo was taken.

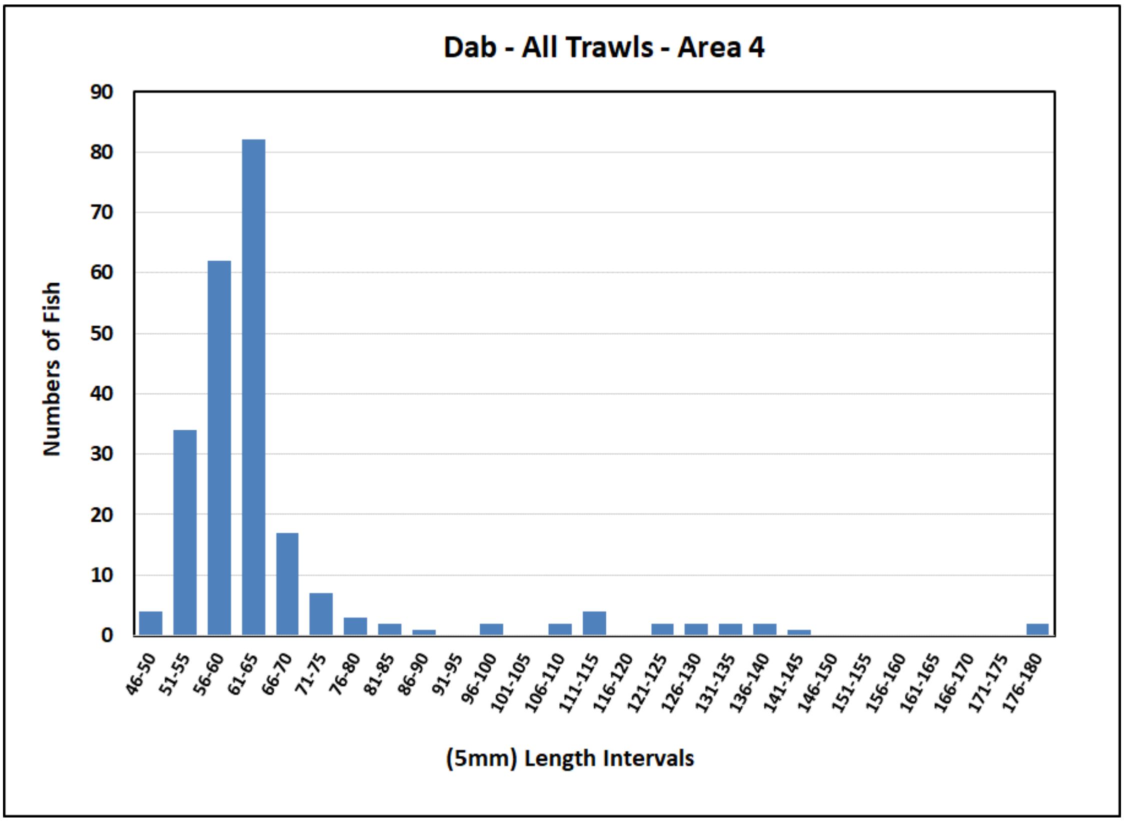

Figure 3.3: Size distribution of dab taken in 3 trawls in Area 4 (August 24th 2020)

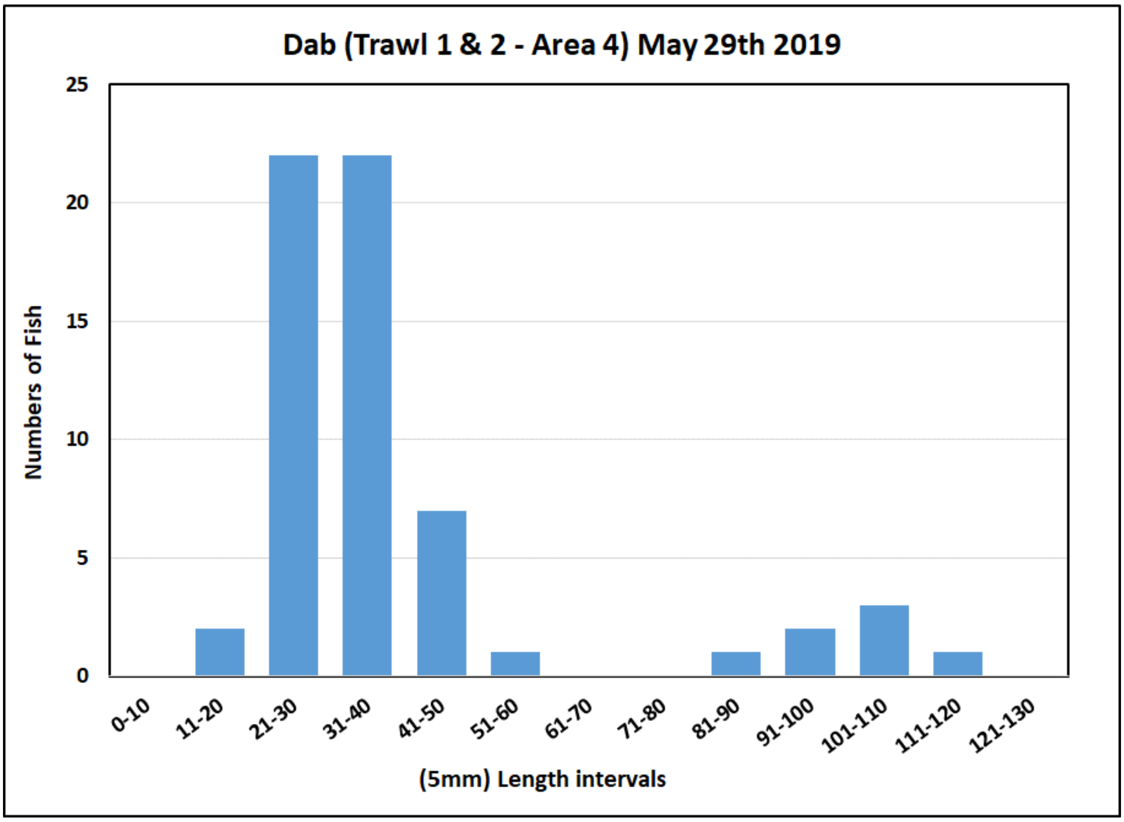

Figure 3.4: Size distribution of dab taken in 2 trawls in Area 4 (May 29th, 2019)

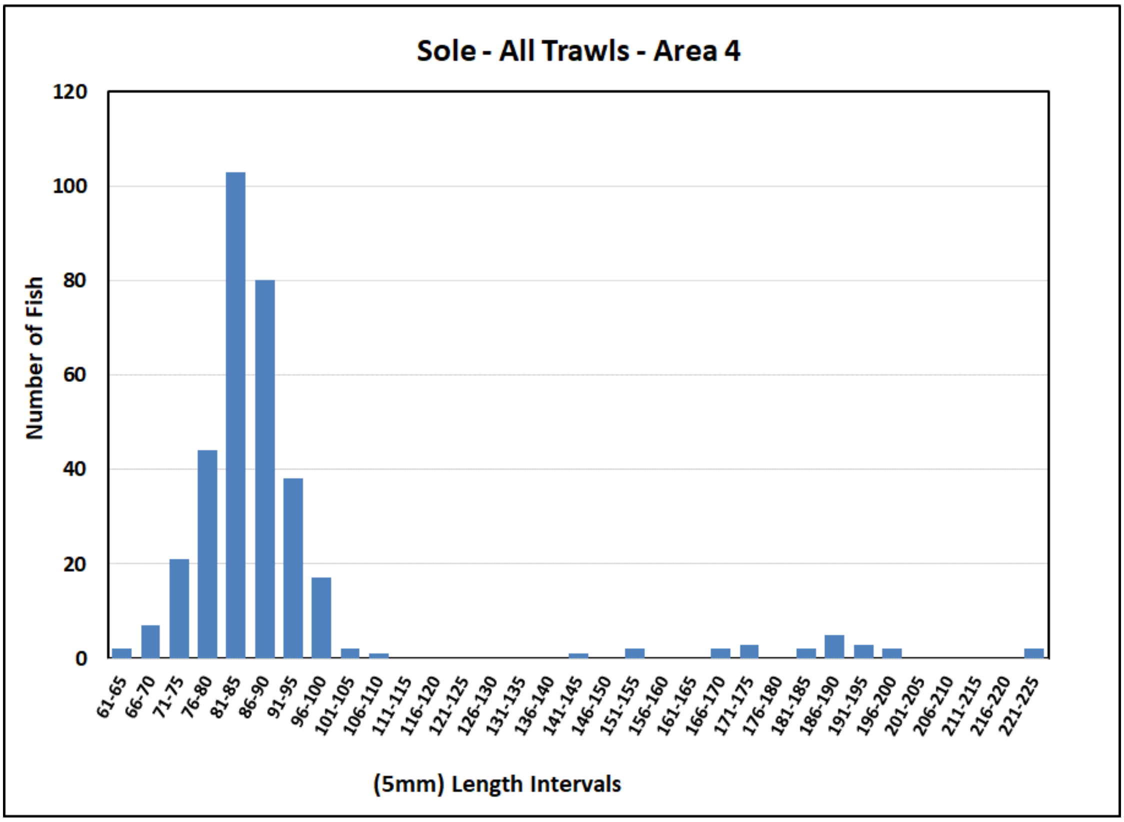

Figure 3.5: Size distribution of sole taken in 3 trawls in Area 4 (August 24th 2020)

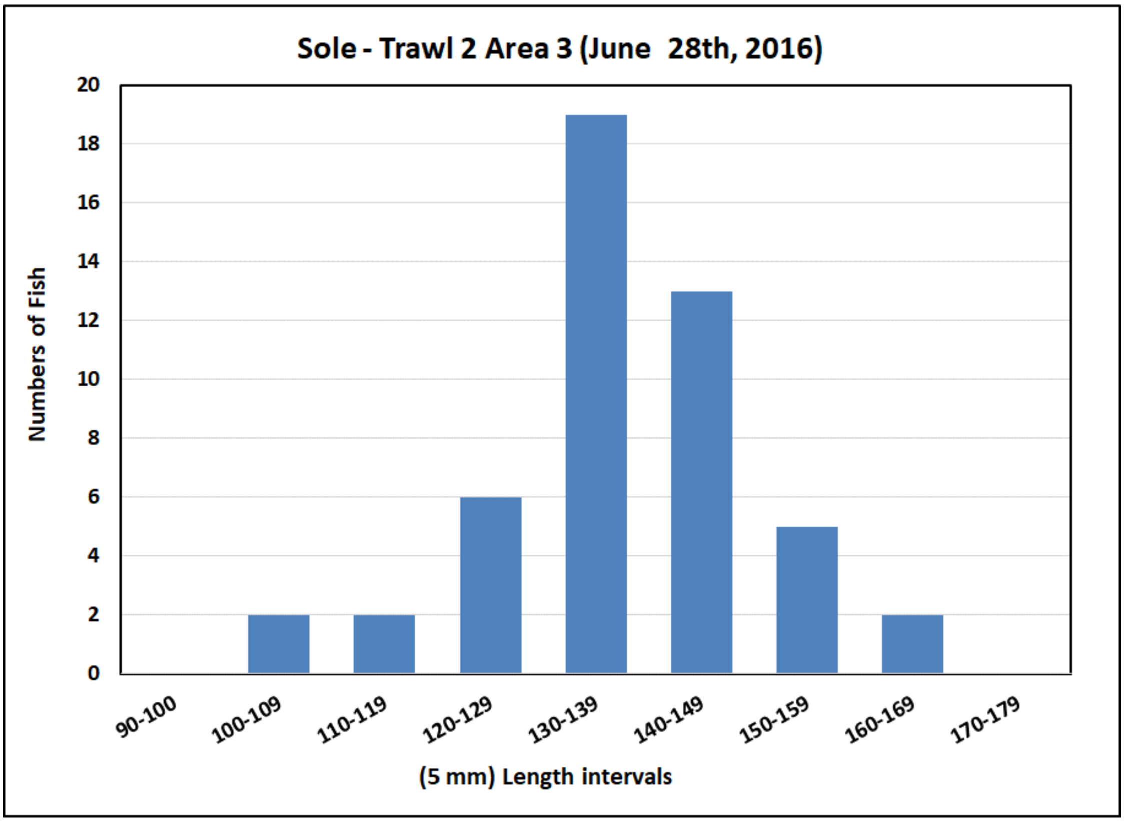

Figure 3.6: Size distribution of sole taken in 1 trawl in Area 4 (June 28th 2016)

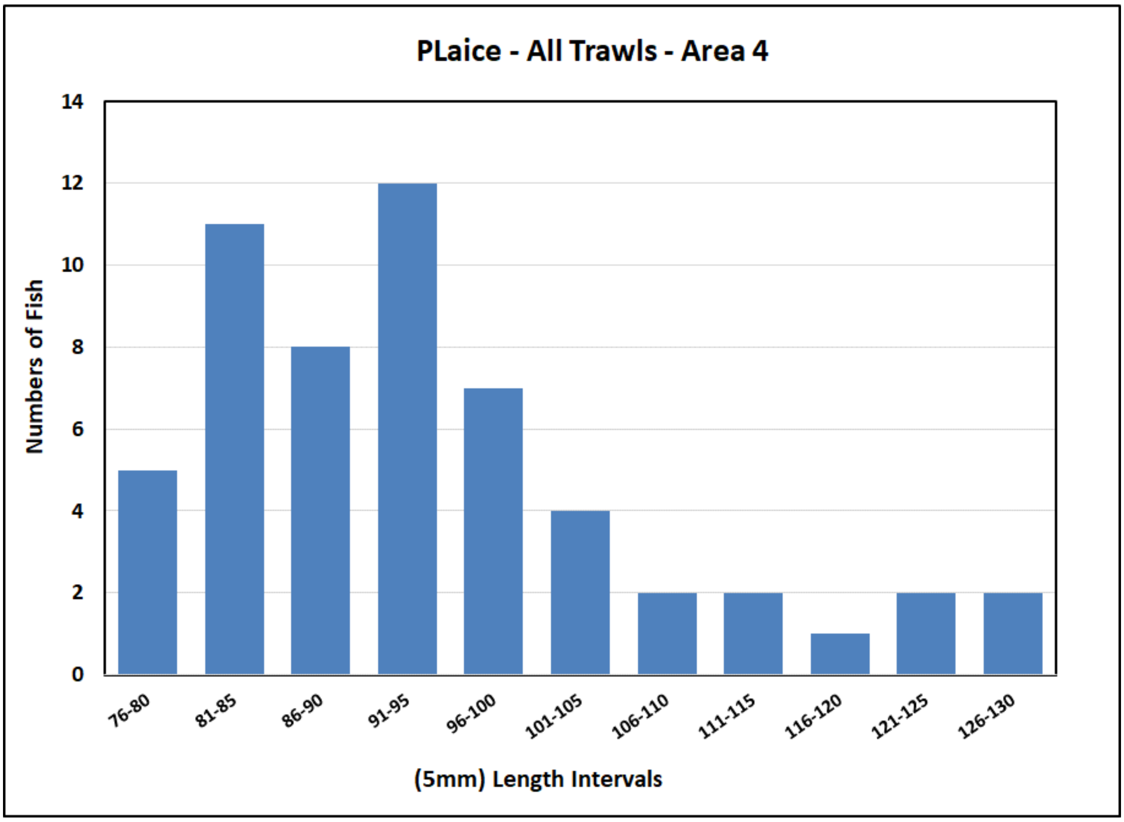

Figure 3.7: Size distribution of plaice taken in 3 trawls in Area 4 (August 24th 2020)

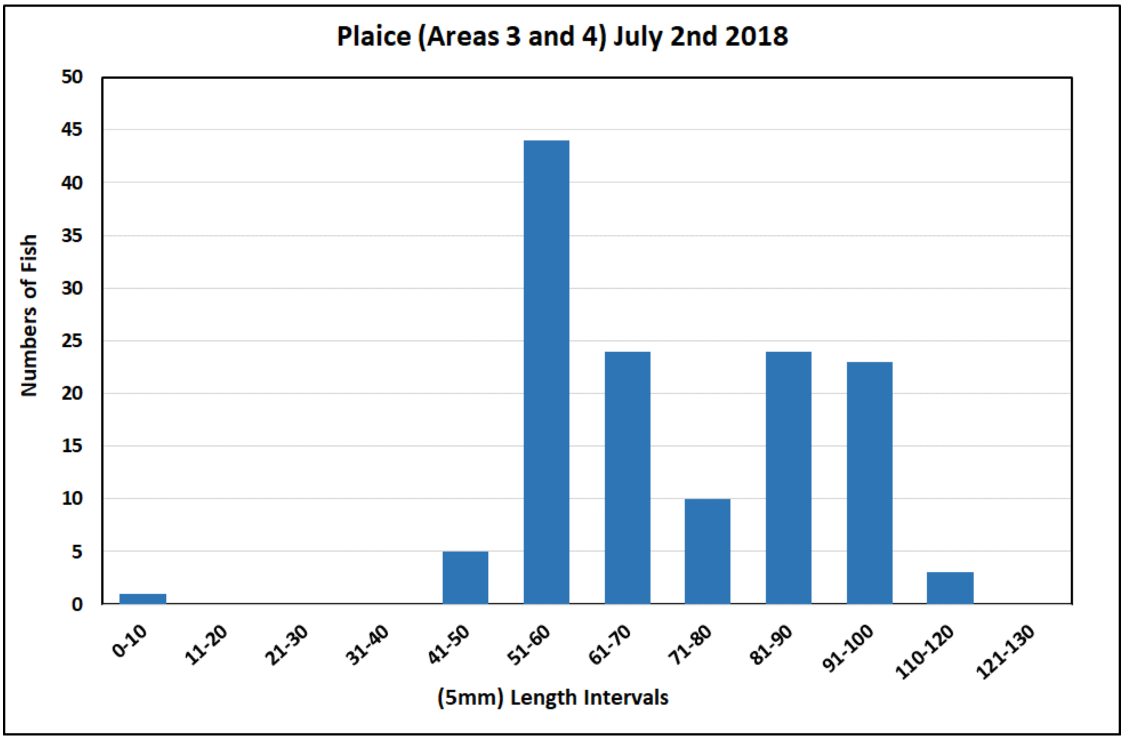

Figure 3.8: Size distribution of plaice taken trawls in Areas 3 and 4 (July 2nd, 2018)

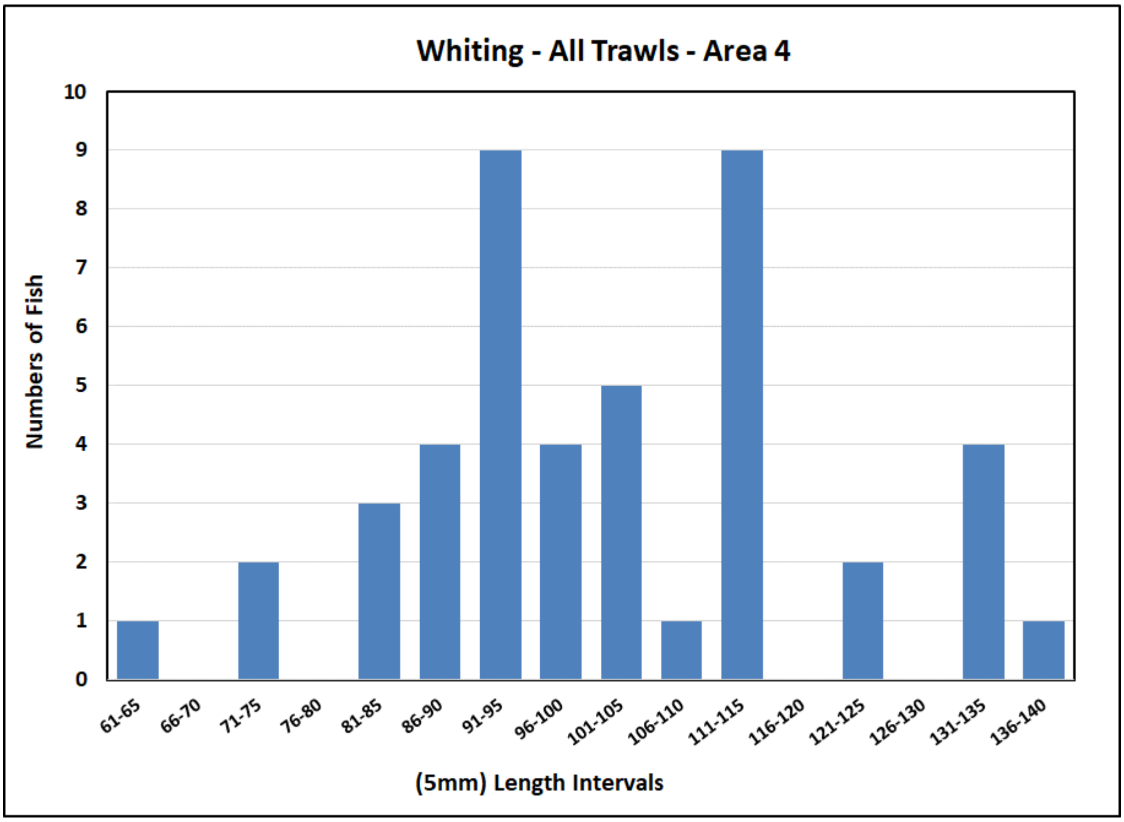

Figure 3.9: Size distribution of whiting taken in 3 trawls in Area 4 (August 24th 2020)

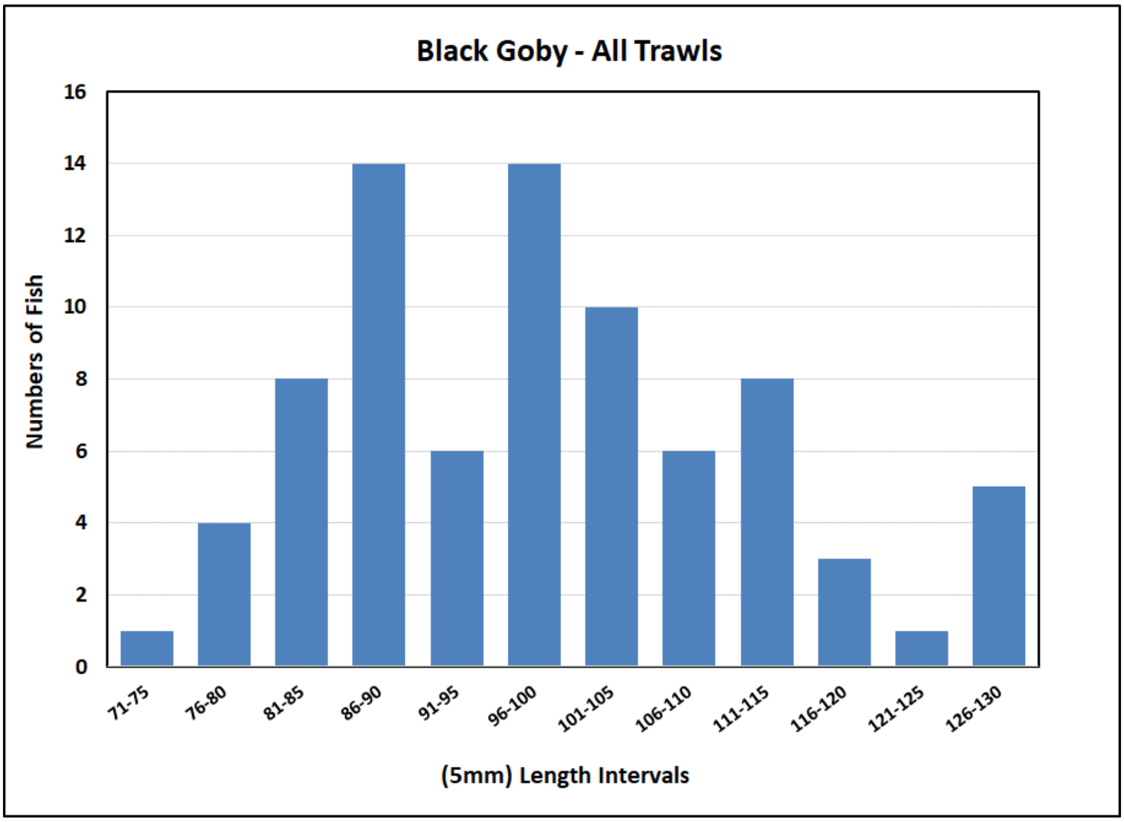

Figure 3.10: Size distribution of black goby taken in 3 trawls in Area 4 (August 24th, 2020)

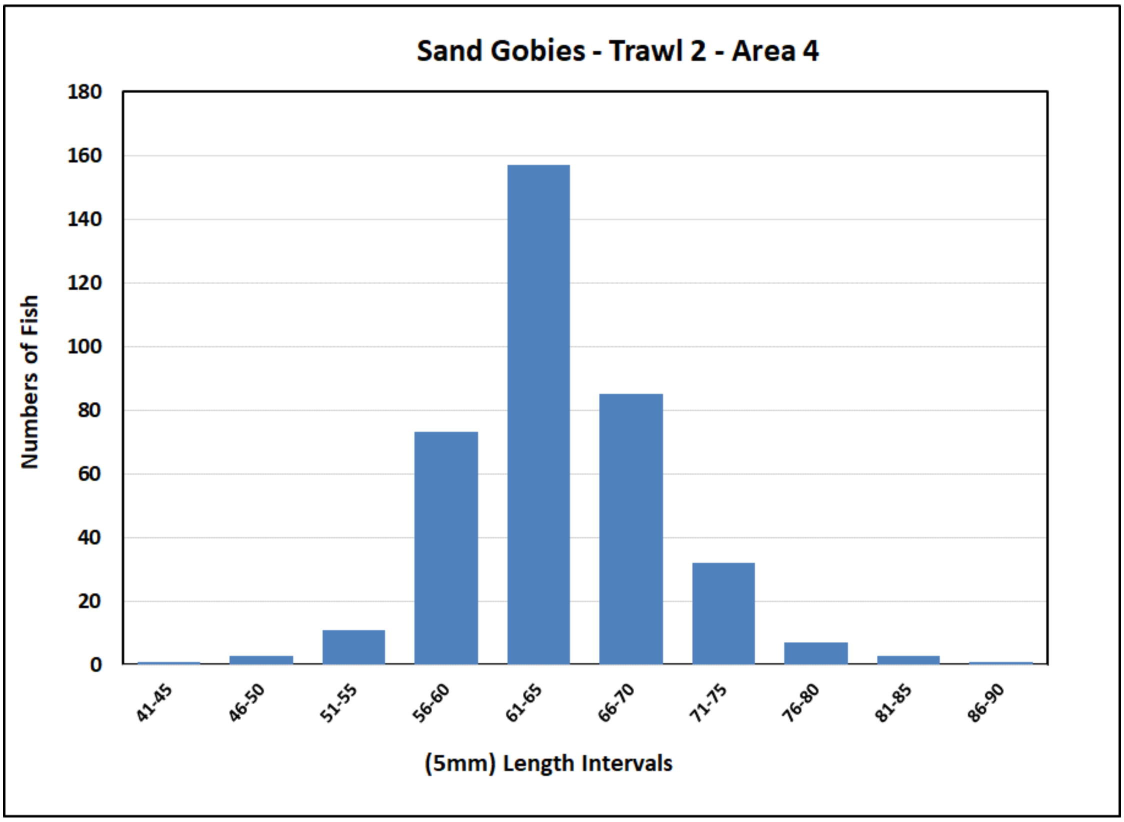

Figure 3.11: Size distribution of sand goby taken in Trawl 2 in Area 4 (August 24th 2020)

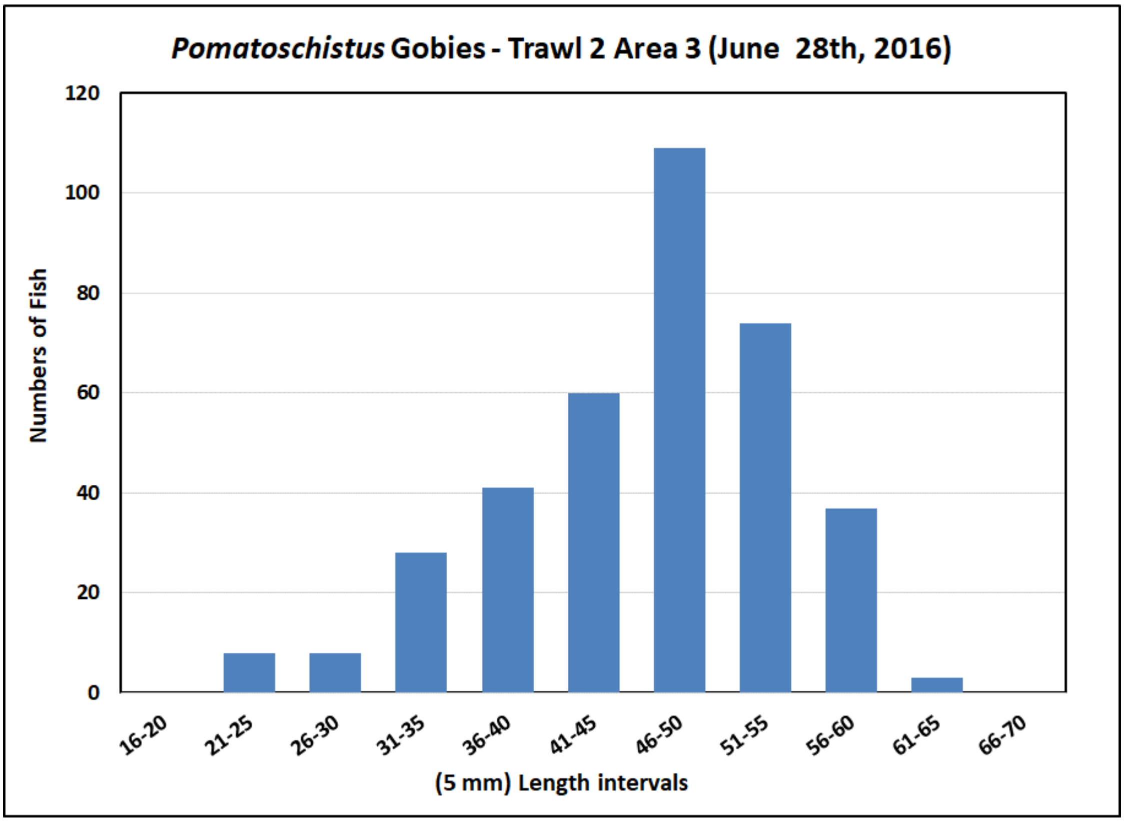

Figure 3.12: Size distribution of *Pomatoschistus* gobies (mainly sand goby) taken in Trawl 2 in Area 3 (June 28th, 2016)

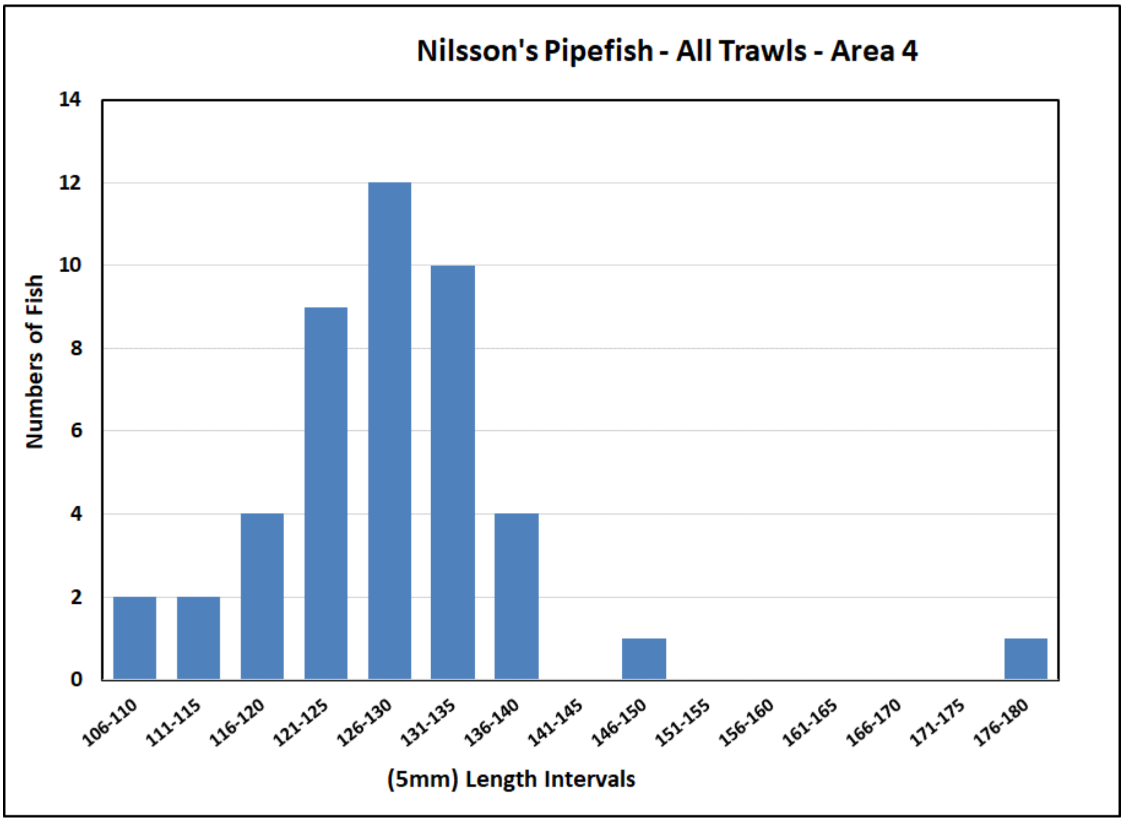

Figure 3.13: Size distribution of Nilsson's Pipefish taken in 3 trawls in Area 4 (August 24th 2020)

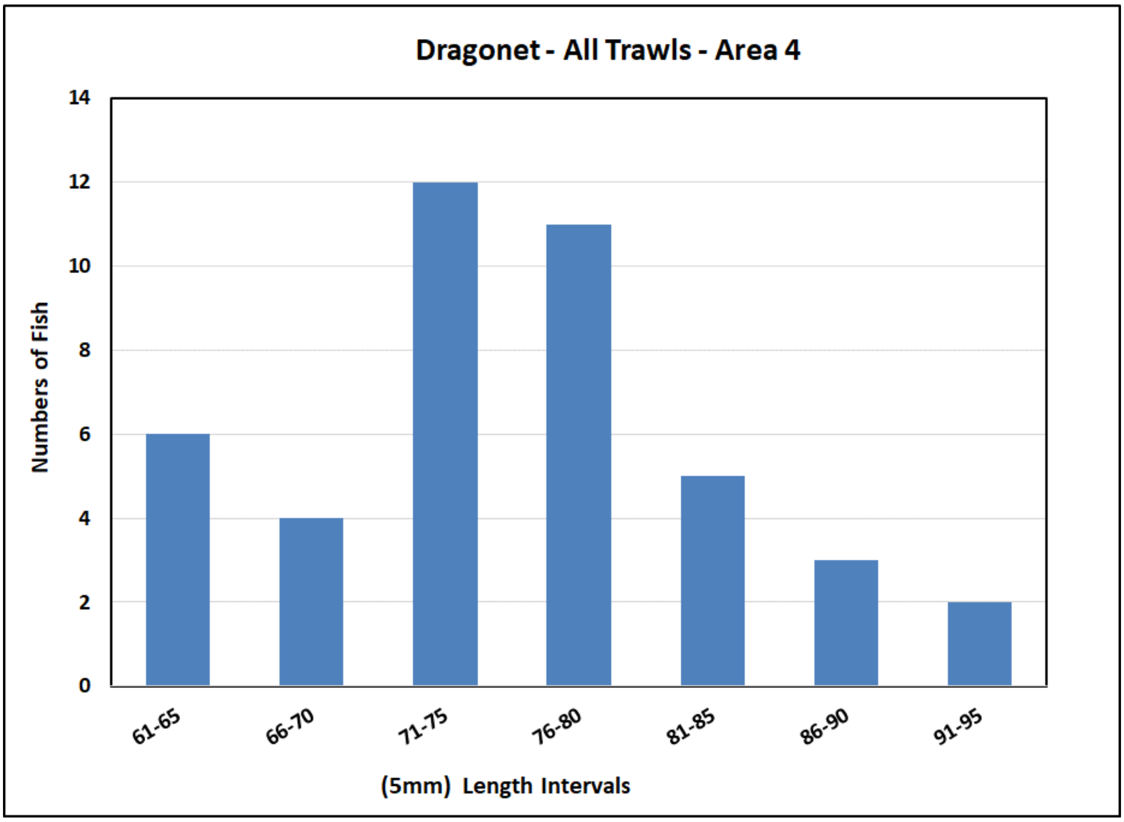

Figure 3.14: Size distribution of Dragonet taken in 3 trawls in Area 4 (August 24th, 2020)

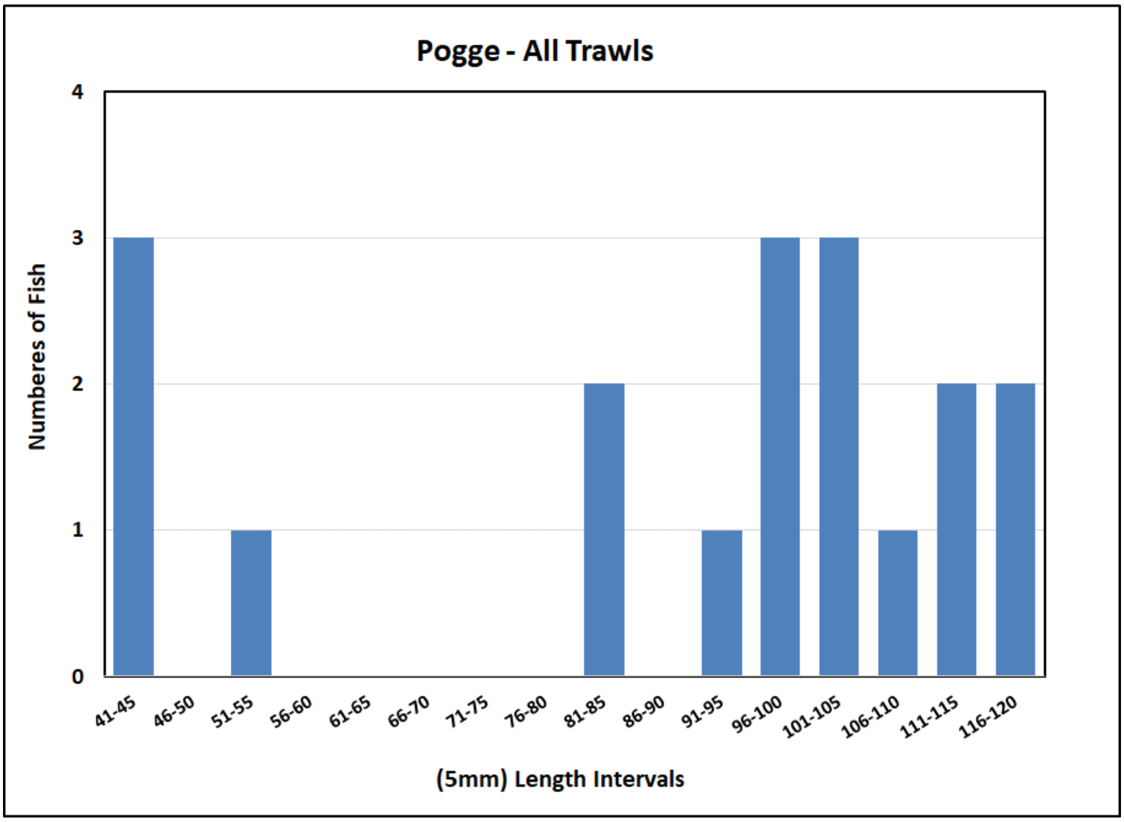

Figure 3.15: Size distribution of Pogge taken in 3 trawls in Area 4 (August 24th 2020)

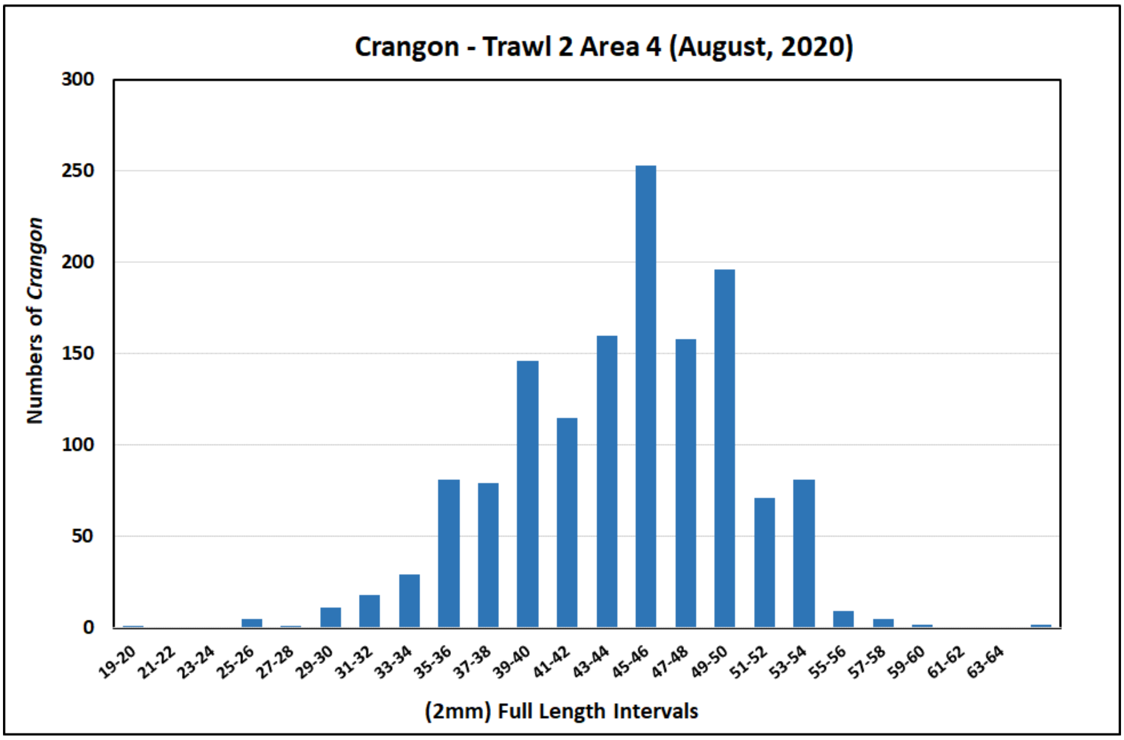

Figure 3.16: Size distribution of Crangon taken in Trawl 2 in Area 4 (August 24th, 2020)

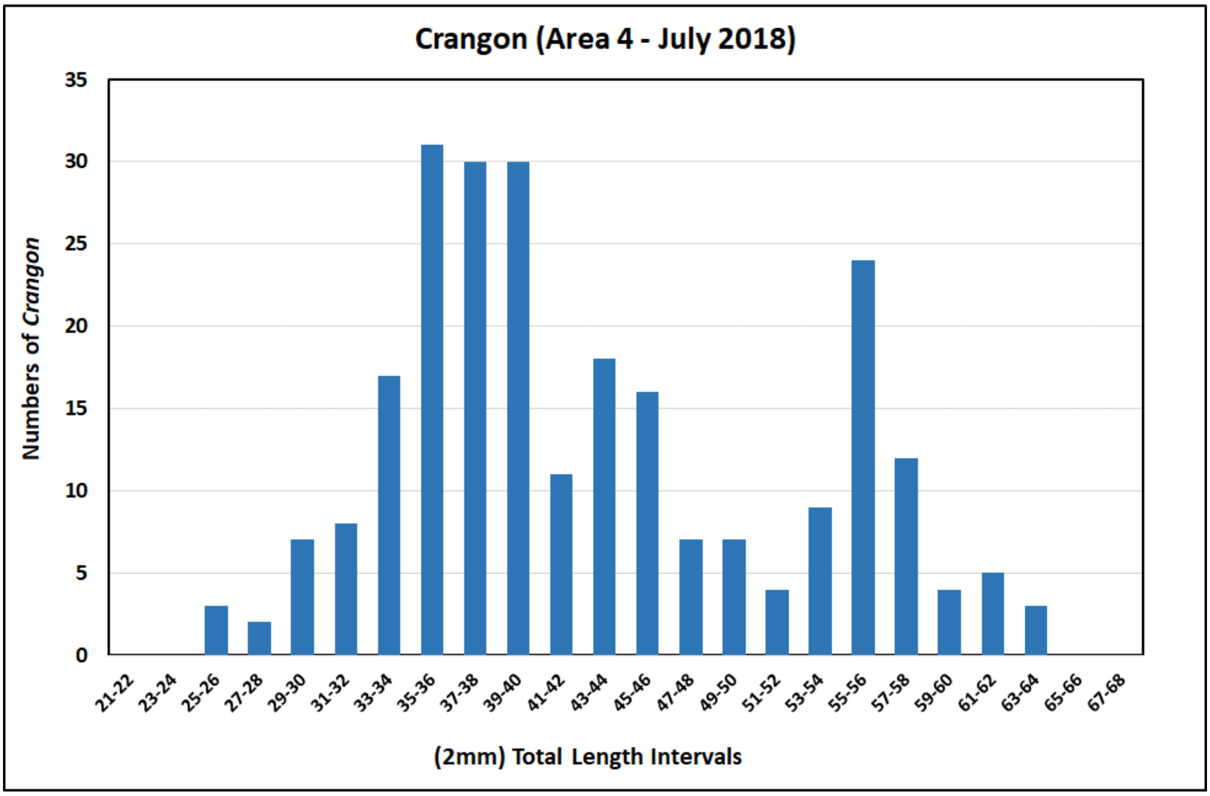

Figure 3.17: Size distribution of Crangon taken in Area 4 (July 2nd, 2018)

3.3 Dredging Impacts

Overview

Dredging of the fairways and berths will give rise to the removal of the surface layer of bottom sediments along with the associated buried infauna. It will also result in the entrainment of fish and mobile epibenthic invertebrates such as *Crangon* and green crabs that are closely associated with the bottom. During the dredging the bottom sediments will be resuspended into the water column causing elevated suspended solids concentrations in the water column in the vicinity of the dredger which will quickly dissipate as a result of tidal mixing and dilution with distance from the dredger. Finally, resuspended sediment will settle around the general harbour area during the dredging period.

Entrainment

Trailer Suction Hopper Dredgers (TSHD) when sucking up sediment with their powerful pumps will also suck up fish and mobile invertebrates living on or close to the sediment surface. Although any species and any size of fish can be entrained, the highest numbers tend to be those which live closest to the bottom e.g. juvenile flatfish, which in the case of Lough Mahon and the Lee Estuary would be flounder, plaice, dab and sole. Also, in this category, would be sand and common gobies, black goby, dragonet and pogge. Gadoids such as whiting, cod, poor cod etc. while still susceptible, are likely to be less so than the previous species because, while they do frequently feed on the bottom they are not as closely associated with it as flat fish and the other species listed. Pelagic species such as sprat and mackerel and to a lesser extent mullet and bass as well, are also less at risk of entrainment, as they occur generally farther up in the water column. However, if the pumps are still pumping as the drag head is raised from the bottom, e.g. in preparation for dredging a new line, then all fish in proximity to the drag head, even in the water column, would be susceptible to entrainment. In general, these impacts are thought likely to be relatively minor to moderate in overall terms, for the following reasons: (i) all the species involved are widespread and common within the study area, (ii) the vast majority of the subtidal and extensive intertidal area of Lough Mahon will remain untouched by the dredging and all these species of fish and invertebrate will be abundant in those areas also, (iii) the majority of the species involved have short life cycles, with high reproductive rates, with many also having very wide diet ranges. Therefore, taken in the round these, aspects of their biology and their distribution would indicate that the affected species have the power of rapid recolonisation and replacement, which should be largely completed within one year of dredging.

More valuable species such as salmon would be most susceptible to entrainment in the narrow channel areas between the City Quays and Tivoli Docks. Smolts from the River Lee tributaries below the Inniscarra Dam (i.e. the Bride, Shournagh and Martin), as well as smolts reared in the ESB Hatchery at Carrigadrohid would be migrating from the end of March to early May, with the hatchery smolts (50,000-80,000/annum, depending on the levels of brood stock) migrating earlier in this window. A tracking study (Moore *et al.,* 1998) has shown that once smoltified and ready to go to sea smolts tend to move seaward quickly, swimming actively and moving with the tide, mainly at night and during ebb tide within the main flow, and close to the surface. In the lower estuary, they tend to migrate both day and night. During flood tides they move to the sides of the channel and closer to the bed of the estuary in order to avoid being pushed backwards. However, smolts continue to actively swim and can move at speeds up to 1.5km per hour seaward on ebb tides and about 0.5km per hour during flood tides. These observations would suggest that during dredging, even in the narrowest parts of the channel in the stretch from the City Quays to Blackrock Castle, that smolts would only ever be in potential contact with the dredger for short periods during the strongest period of the flood tide toward the edges of the channel, probably mainly at night. Even during such periods given, that the dredger is only dredging actively for about 30minutes in every 2.5hours (RPS, 2020), and the channel is 105m to 290m wide compared to the active suction field of the dredger (~4-5m), there would be very limited overlap between the paths of the dredger and the movement of the smolts at any one time. Moreover, the extended period over which smolts, migrate (6-8weeks at least) compared to the time the dredger would be active in the narrow upper part of the estuary, (1-2 weeks) further reduces the overlap between migrating population and dredging. All in all, this would suggest that, at a population level, dredger-associate mortality of smolts is likely to be a very small fraction of overall natural smolt mortality caused by avian and other predators and other natural causes.

Adult salmon return to the Lee catchment throughout the summer and early autumn months, probably from May/June to September/October i.e. over an extended period, so the risk of entrainment though still possible in the narrow sections of the channel is very unlikely to be an issue at the population level because of the limited time overlap between dredging in narrow City Quays to Blackrock Castle and the extended migration period of the adults. Moreover, the combination of the localised area of active dredging i.e. around the dredger drag head, versus the width of the channel, further considerably reduces the potential encounters between the dredger and migrating fish. In addition, as previously noted, dredging is a stop-start rather than a continuous process and RPS (RPS, 2020) have estimated that in every 24hr period of the dredger would undertake 8 dredging events each consisting of 2 hours and 10 minutes (75%) steaming to and from the dumpsite and the other 50minutes (25%) loading. The latter comprising just 30minutes dredging and 20minutes manoeuvring. That would leave overall 75% of the time spread over 8 events during which salmon could migrate upriver past the dredging area without any chance of entrainment by the dredger. Therefore, the likelihood of any significant numbers of salmon smolts or adults being entrained by the dredging operation is considered to be non-significant at the population level for the River Lee catchment.

Suspended Solids

RPS (2020) have modelled the evolution of suspended solids into the water column caused by the dredger and how that plume dissipates over a tidal cycle. This has shown that concentrations can reach a maximum of about 425mg/l milligrams per litre when dredging is being undertaken in the narrow City Quays to Blackrock section of the estuary and around 350mg/l for dredging in the Lough Mahon area. In each case the highest concentrations are within a few hundred meters of the dredger dropping off rapidly due to tidal mixing and dilution eventually dropping below 4mg/l above background at distances of 1-2km. Each loading event is associated with its own plume envelope which is tidally drawn toward the lower harbour expanding and diluting as it travels, with highest residual concentrations focused along the line of the shipping channel dropping rapidly as the plume spreads laterally toward the shallow subtidal and intertidal sand and mud flats. The levels of suspended solids are not high enough to cause mortalities in fish, especially as fish are mobile and likely to avoid the areas of highest concentrations thereby reducing their time of exposure. Those likely to be exposed to the highest concentration, i.e. bottom dwelling species such as flat fish and gobies are likely to be among the most tolerant to high levels of suspended solids, as their habitats on fine silts and muds are naturally turbid. Migrating species such as salmon are known to pass through estuaries where the turbidity maximum can be even higher than the solids levels predicted by the RPS model, so the dredging is not expected to delay either inward or outward migration of this species. Overall, the spatially patchy nature of the increased levels of suspended solids associated with dredging are unlikely to have any significant adverse impacts on the fish population within the Lower Lee or Lough Mahon areas.

Conclusion

The proposed dredging will result in the entrainment of juvenile flatfish and near bottom dwelling species such as gobies, dragonet and pogge, along with a range of mobile epibenthic species, particularly, green crab and *Crangon* (brown shrimps). Due to a reservoir of such species in adjoining areas within Lough Mahon, combined with aspects of the general and reproductive biology of most of these species it is expected that the effect of entrainment will be minor to moderate in terms of impact, with recovery likely to be largely completed within one year. The possibility of entrainment of more valuable species such as salmon smolts or adults cannot be ruled out entirely in the narrow City Quays to Blackrock Castle stretch of the upper dredge area. However, the extended migration period of both smolts and adults, combined with the spatially confined area of influence of the active drag head relative to the width of the channel, as well as the stop-start nature of dredging, indicate that any entrainment will not be significant at the population level for salmon.

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5 APPENDICES

Appendix 1 Ecological Details of Fish Taken in 2020 Trawls in Lough Mahon

			Functional Groups Categories			
	Common name	**Scientific name**	**EUFG**	**FMFG**	**RMFG**	**Freq.**
1	Dab	*Limanda limanda*	MM	Bmi, BMa	Op	0.37
2	Plaice	*Pleuronectes platessa*	MM	Bmi, BMa	Op	0.45
3	Flounder	*Platichtys flesus*	MM	Bmi, BMa	Op	0.79
4	Sole	*Solea solea*	MM	Bmi, BMa	Op	0.84
5	Cod	*Gadus morhua*	MM	HZ,HP,	Op	0.45
6	Pollack	*Polacchius pollachius*	MM,MS	HP	Op	0.32
7	Whiting	*Merlangius merlangus*	MM,MS	HP	Ob	0.39
8	Pouting	*Trisopterus luscus*	MM	Bmi, Bma, HP	Op	0.32
9	Poor cod	*Trisopterus minutus*	MS			0.24
10	Sand Goby	*Pomatoschistus minutus*	ES, MM	Bmi	Og	0.66
11	Black Goby	*Gobius niger*	ES	Bmi, HP	Og	0.63
12	Butterfish	*Pholis gunnellus*	ES,MS	Bmi, Bma	Og	0.37
13	Hooknose (pogge)	*Agonus cataphractus*	ES,MS	Bmi, Bma	Ov	0.26
14	Greater pipefish	*Syngnathus acus*	ES,MM,MS	Bmi	Os	0.61
15	Nilsson's pipefish	*Syngnathus rostellatus*	ES	HZ,HP,	Os	0.37
16	5-bearded Rockling	*Ciliata mustela*	MM	Bmi, BMa	Op	0.39
17	Grey gurnard	*Eutrigla gurnardus*	MM,MS	Bmi, BMa, HP	Op	0.45
18	Dragonet	*Callionymus lyra*	MS			0.39
19	European eel	*Anguilla anguilla*	C			0.87

Table A1 List of fish species taken in Cork Harbour Survey during 2020 along with their respective Estuarine Functional Group (EUFG), Feeding Mode Functional Group (FMFG) and Reproductive Mode Functional Group Categories (RMFG) from Franco et al., (2008) - see Table A2 below for legend.

Functional Groups	Functional Group Categories	Definition
EUFG **(Estuarine Functional Group)**	C = Catadramous	Live in freshwater but regularly use estuaries as pathways of migration to the sea, where they reproduce
	ES = Estuarine Species	May breed in the estuary; highly euryhaline species, able to move throughout the full length of the estuary
	MM = Marine Migrant	Spawn at sea and regularly enter estuaries in large numbers; highly euryhaline species, able to move throughout the full length of the estuary
	MS = Marine Straggler	Spawn at sea; usually associated to coastal marine waters, enter estuaries accidentally in low numbers; predominantly stenohaline species, occur most frequently in the estuary lower reaches
FMFG **(Feeding Functional Group)**	Bmi = Microbenthivores	Feed mainly on benthic, epibenthic and hyperbenthic fauna, with prey size <1cm
	Bma =Macrobenthivores	Feed mainly on benthic, epibenthic and hyperbenthic fauna, with prey size >1cm
	HP =Hyperbenthivores/Piscivores	Feed just over the bottom, predominantly on larger mobile invertebrates living over the bottom and fish.
	HZ = Hyperbenthivore/Zooplanktivore	Feed just over the bottom, predominantly either on smaller mobile invertebrates living over the bottom and zooplankton.
	PL = Planktivores	Feed predominantly on zooplankton and occasionally on phytoplankton in the water column, mainly by filter feeding
RMFG **(Reproductive Functional Group)**	Op = Oviparous with PELAGIC EGGS	Buoyant pelagic eggs
	Ob = Oviparous with BENTHIC EGGS	Demersal eggs settling on the substratum
	Ov = Oviparous with ADHESIVE EGGS	Demersal eggs, adhesive or attached to substratum or vegetation.
	Og = OVIPAROUS GUARDERS	Post-fertilization parental care of eggs by guarding them externally
	Os = OVIPAROUS SHELTERERS	Post-fertilization parental care of eggs by sheltering them in a part of their body

Table A2 Explanation of Functional Group abbreviations and categories as given in Appendix 1 of Franco *et al.,* (2008)

Appendix F – A Review and Analysis of the Water Monitoring Data around the Port of Cork

A Review and Analysis of the Water Monitoring Data Around The Port of Cork Before During and After the Dredging Campaign in 2020

Port of Cork
April 2021

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Contents

Analysis and Report by Michael Cunningham BSc (Analytical Science)

Executive Summary

The Port of Cork undertook a water quality monitoring campaign, (initially) utilising three monitoring buoys, from August 2020 to ascertain the baseline conditions within the estuary and also, assess and quantify any impact a planned maintenance dredging campaign had on the fluctuations in recorded levels. The observations and conclusions reached would inform the Port on the appropriateness of a summer closed period, where dredging is currently restricted.

Baseline Levels

The turbidity data, from the non-dredging periods, increases in a seaward direction, from an average of 11.59 to 38.86NTU for Buoy 11 to Buoy RA-24 respectively. The reason for this natural variability is not clear; it may be due to the more exposed location of Buoy RA-24. Also an increasing influence of salt water at this site on materials in colloidal suspension would result in flocculation, thereby increasing the turbidity.

The increase in turbidities as the season progressed into winter is part of the normal seasonal variation and is most likely due to increase rain, run-off and storms.

The data also show that the mean dissolved oxygen saturation (%), when there is no dredging, increases slightly in a seaward direction, giving readings of 90.0% and 91.1% from Buoy 11 to Buoy RA-24 respectively.

Influence of Dredging on Turbidity

There was a statistically significant reduction in turbidity during the dredging of the harbour in the vicinity of Buoy 11 and again in the vicinity of Buoy RA-24.

Influence of Dredging on Dissolved Oxygen Saturation (%) Levels

Dissolved oxygen saturation (%) is slightly reduced during dredging at both buoys but was more so at Buoy 11. This effect may be due to the exposure of anoxic sediments by the dredging process. Despite this, dissolved oxygen saturation (%) conformed to S.I. No. 272/2009 at all times while dredging was ongoing.

Overall Conclusion

During dredging a reduction in ambient turbidity levels occurred (and by implication, Total Suspended Solids) at Buoys 11 and RA-24. There was also a slight reduction in dissolved oxygen saturation (%) at these two buoys. The data is consistent with anoxic sediments reducing the dissolved oxygen saturation (%) levels slightly, when they are exposed by the dredging.

There were no recorded exceedances of dissolved oxygen saturation (%) levels at any of the buoys that would not satisfy the requirements of S.I. No. 272/2009 - European Communities Environmental Objectives (Surface Waters) Regulations 2009.

Overall, the method of dredging, using a Trailing Suction Hopper Dredger, where overflow was not permitted, yielded an imperceptible turbidity footprint within the natural variability of turbidity (NTU) and Total Suspended Solids (TSS), in Cork Harbour.

Water Quality Monitoring in Port of Cork

Three water quality monitoring buoys, designated Buoy 24, Buoy11 and Buoy RA were deployed to Cork harbour in August 2020 to monitor water quality conditions during a dredging campaign from August to October 2020. The buoy positions were chosen based on where the majority of dredging was being undertaken. Each was equipped with an Aqua TROLL 500 Multi-parameter Sonde which monitored the following parameters…

Water Temperature (^{o}C)
Specific Conductivity (uS/cm)
Actual Conductivity (uS/cm)
Salinity (PSU)
Resistivity (ohm x cm)
Total Dissolved Solids (ppm)
Density of Water (g/cm3)
Dissolved Oxygen Concentration (mg/L)
Turbidity (NTU)

From the temperature, salinity and dissolved oxygen measurements, the Dissolved Oxygen Saturation (%) was calculated (commonly referred to as DO %). Also, from the turbidity readings, the Total Suspended Solids (mg/L) were calculated.

The buoys were initially deployed at the following locations…

BUOY	LATITUDE	LONGITUDE
24	51.9012670	-8.4308450
11	51.9015670	-8.3973600
RA	51.8362430	-8.3244750

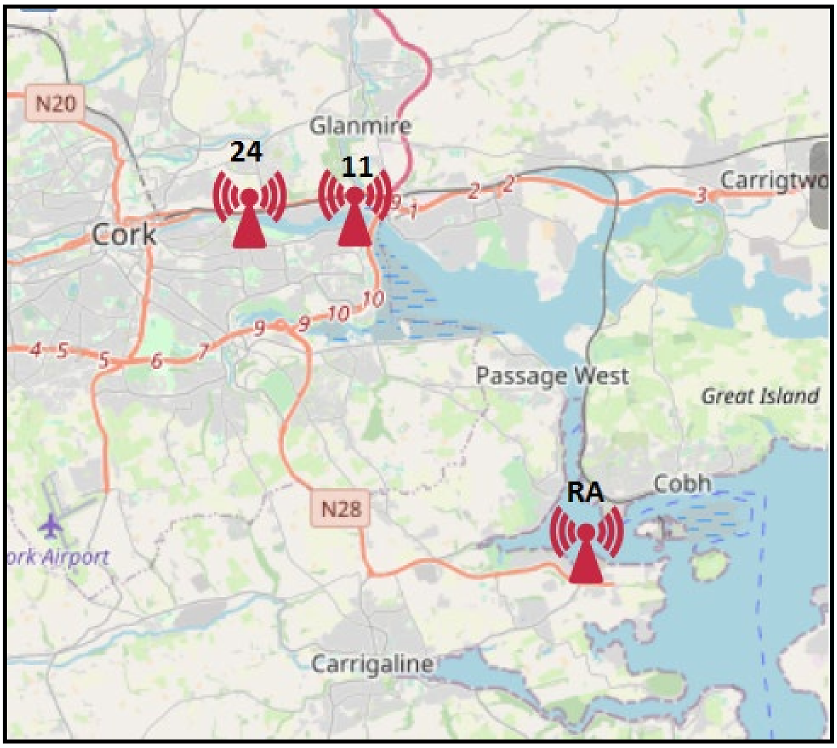

Figure 1, Positions of Buoys 24, 11 and RA

Details of the position of the Buoys are as follows…

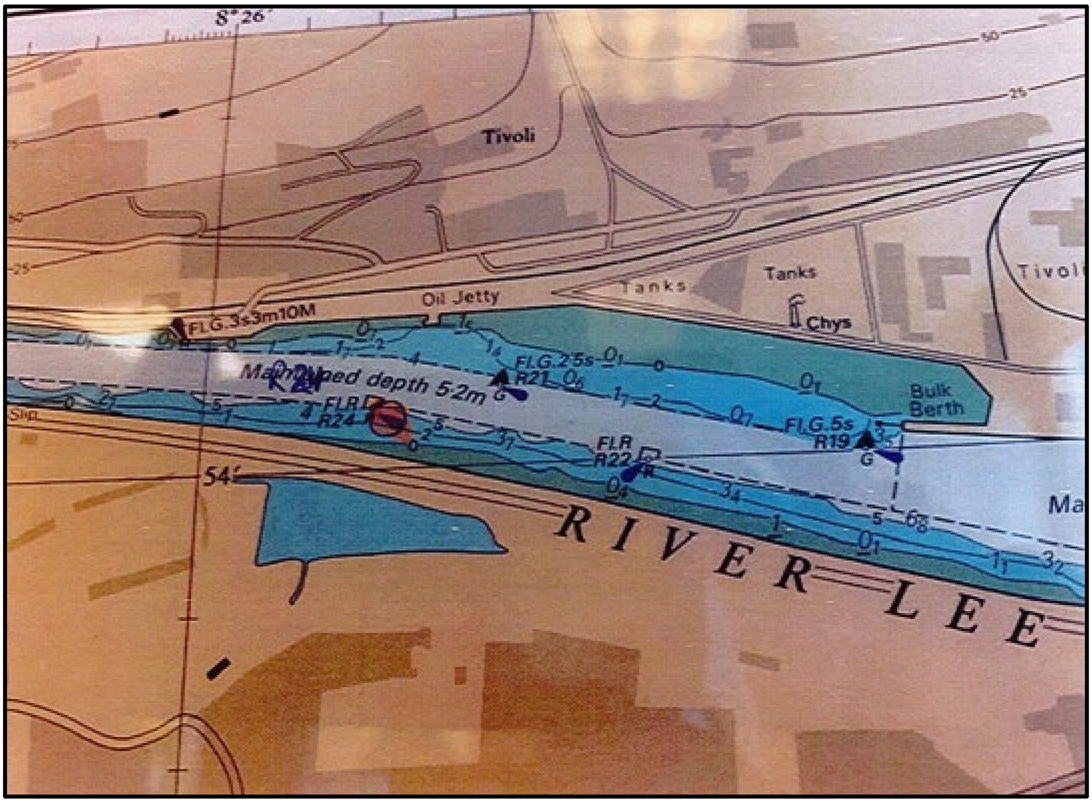

Figure 2, Details of the initial position of Buoy 24

Figure 3. Details of the position of Buoy 11

Figure 4. Details of the position of Buoy RA-24

On the 19.08.2020 at 22:06 monitoring Buoy RA was sunk due to Storm Ellen, leaving the outer harbour without a monitoring station. To fill this gap, Buoy 24 was towed to the original position of Buoy RA; it started transmitting from its new location at 16:23 on the17.09.2020. The new position is 51.8367778, -8.3234167.

The data from Buoy 24, after 17/09/20, was combined with the Buoy RA data and is hereafter referred to as Buoy RA-24.

The earlier data from Buoy 24 was of too short a duration, and insufficient to constitute a valid comparison to Buoys 11 and RA-24 data; it was therefore not considered in the rest of this report.

All relevant positions and times are as follows…

BUOY	LATITUDE	LONGITUDE	Start monitoring	End Monitoring
11	51.9015670	-8.3973600	12/08/2020 13:04	08/03/21
RA	51.8362430	-8.3244750	12/08/2020 12:35	19/08/2020 22:06
RA-24	51.8367778	-8.3234167	17/09/2020 16:23	08/03/21

Dredging

A dredging campaign was carried out, in Cork Harbour, by the Trailing Suction Hopper Dredger *TACCOLA* between 18/08/20 and 06/10/20. Dredging occurred at the following locations (in alphabetical order) Cobh Turning Circle, Fairway – Blackrock, Fairway – City, Fairway - Passage West, Fairway – Tivoli, Haulbowline Industries, Horgan's Wharf, IFI Jetty, North Custom House Quay, Ringaskiddy Basin, Ringaskiddy Deep Water Berth, South Jetties, Tivoli Container Terminal and Whitegate berth.

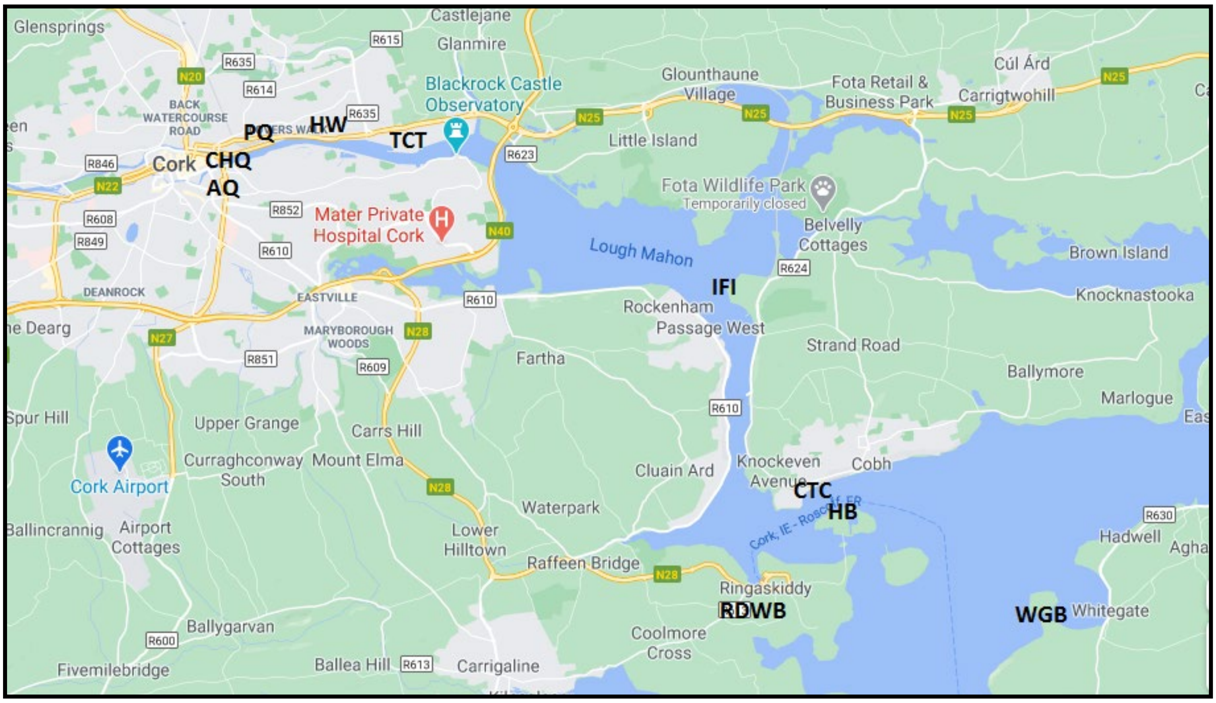

Figure 5. The locations at which dredge material was removed. The initials of the site names are included.

Monitoring Buoy 11

Monitoring Buoy 11 started transmitting on 12/08/2020 at 13:04, and was finally removed from the harbour on the 08/03/2021.

To facilitate dredging it was removed ashore on the 14/09/2020 at 09:18am and was returned to position on 18/09/2020 at 09:14. The data from this period are spurious and were therefore removed from the record.

The statistics (maximum value, minimum value, average and standard deviation) for the raw, unsorted data from this buoy is as follows…

	Water Temperature (Celsius deg.)	Specific Conductivity (uS/cm)	Actual Conductivity (uS/cm)	Salinity (PSU)	Resistivity (ohm*cm)	Total Dissolved Solids (ppm)	Density of Water (g/cm3)	Dissolved Oxygen Concentration (mg/L)	Dissolved Oxygen Saturation (%)	Turbidity (NTU)	Total Suspended Solids (mg/L)
Max	26.830	48.935	38.629	31.857	1074.7	31.807	1.024	11.380	126.06	578.71	636.58
Min	4.220	0.000	0.000	0.000	0.003	0.000	0.997	3.720	44.692	0.020	0.022
Average	11.186	21.843	16.359	13.416	0.161	14.198	1.010	8.585	83.702	13.763	15.139
Std Dev	3.785	14.464	11.365	9.443	8.074	9.402	0.007	1.461	6.085	14.503	15.953

Turbidity

A dredging campaign was carried out, in Cork Harbour, by the Trailing Suction Hopper Dredger *TACCOLA* between 18/08/20 and 06/10/20.

Given that the suction heads act in a manner, similar to a vacuum cleaner, the actual removal of bottom sediment would cause very little turbidity. In other circumstances, some turbidity would be generated by liquid overflow from the vessel, if that was permitted to happen; however it was stated that **overflow did not occur**; this would explain the absence of a dredging turbidity footprint.

The turbidity time series for Buoy 11 is as follows…

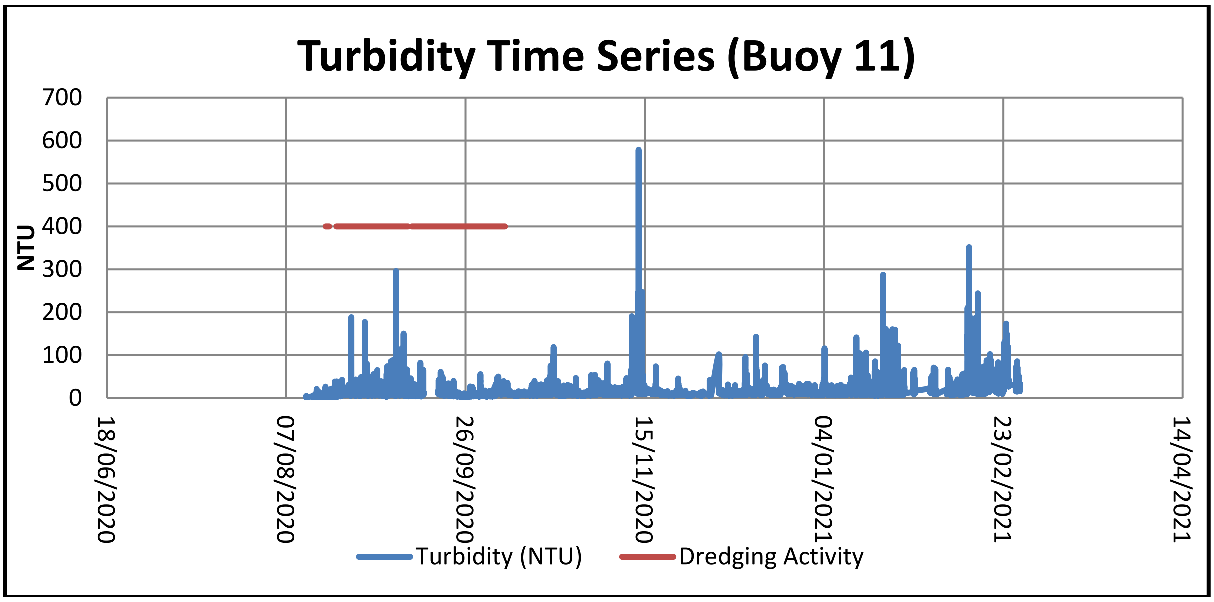

Figure 6. Turbidity time series at Buoy 11; the red line indicates when dredging was ongoing.

It is immediately evident that the data could be described as spiky. Spurious spikes can occur for a variety of reasons and it is normal practice to remove, what is referred to as 'instantaneous spikes'. These are spikes that go straight up and down, they don't have a shoulder which would indicate a genuine turbidity event, and they are 10x larger than the value of either of their neighbours. When the instantaneous data is removed, the graph is as follows.

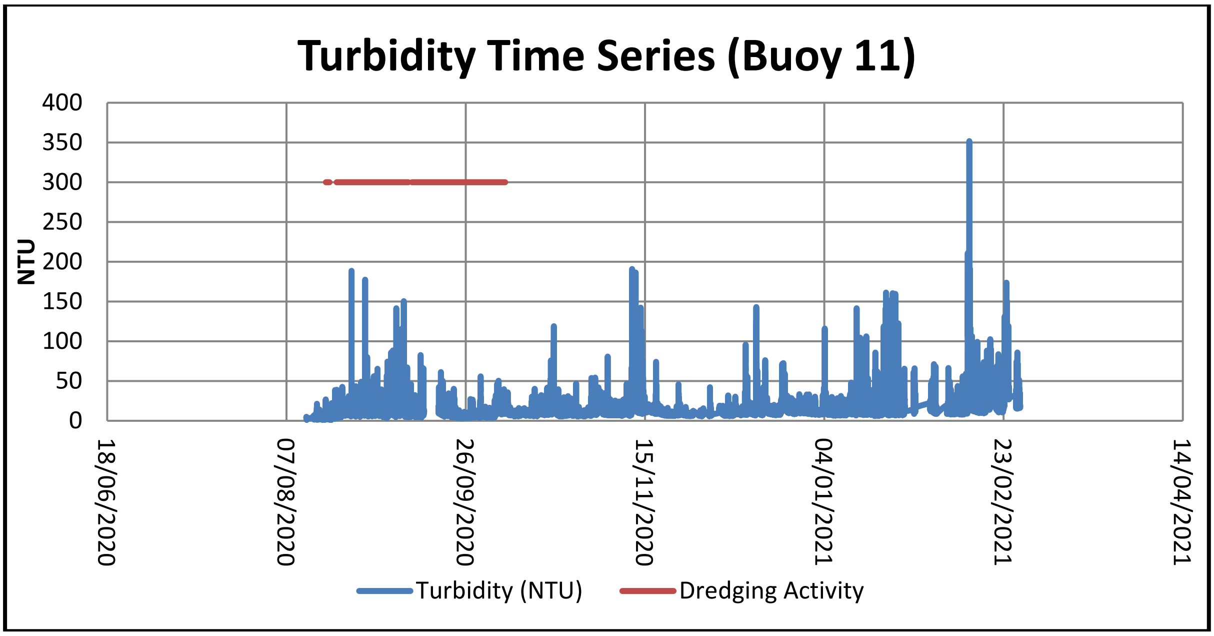

Figure 7. Turbidity time series with instantaneous spikes removed.

Monitoring started 12/08/2020 and immediately the turbidity started to rise. Dredging started 18.08.20 and the rise in turbidity continues at the same rate. These wedge-shaped structures in turbidity data usually indicates a temporary build-up of fouling on the turbidity sensor window and are usually caused by a failing or inefficient wiper. To facilitate dredging in that area, the buoy was removed ashore on the 14/09/2020 and was returned to position on 18/09/2020. In the interim the buoy and sonde would have received maintenance. Once back in the water, the turbidity remained low throughout the remainder of the dredging period.

A closer look at the period before during and after dredging is as follows…

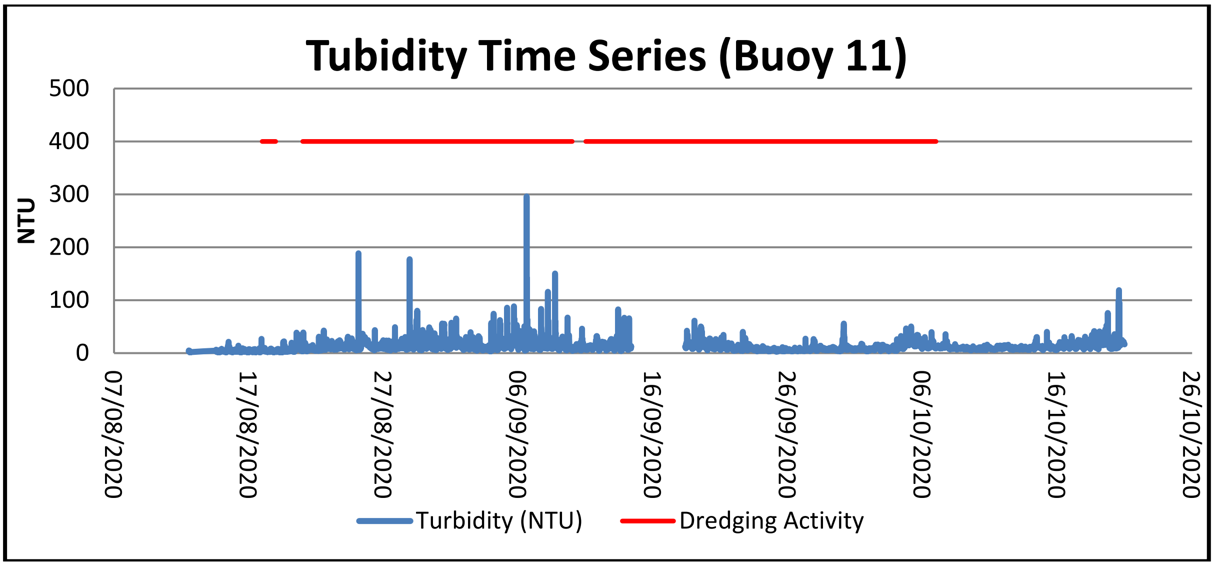

Figure 8. Turbidity during dredging period

If we wish to statistically compare the turbidity readings between the dredge and non-dredge times, we need to see how the data is distributed. If the data has a normal distribution, we can compare the differences in the mean values use a 'student's t-test'.

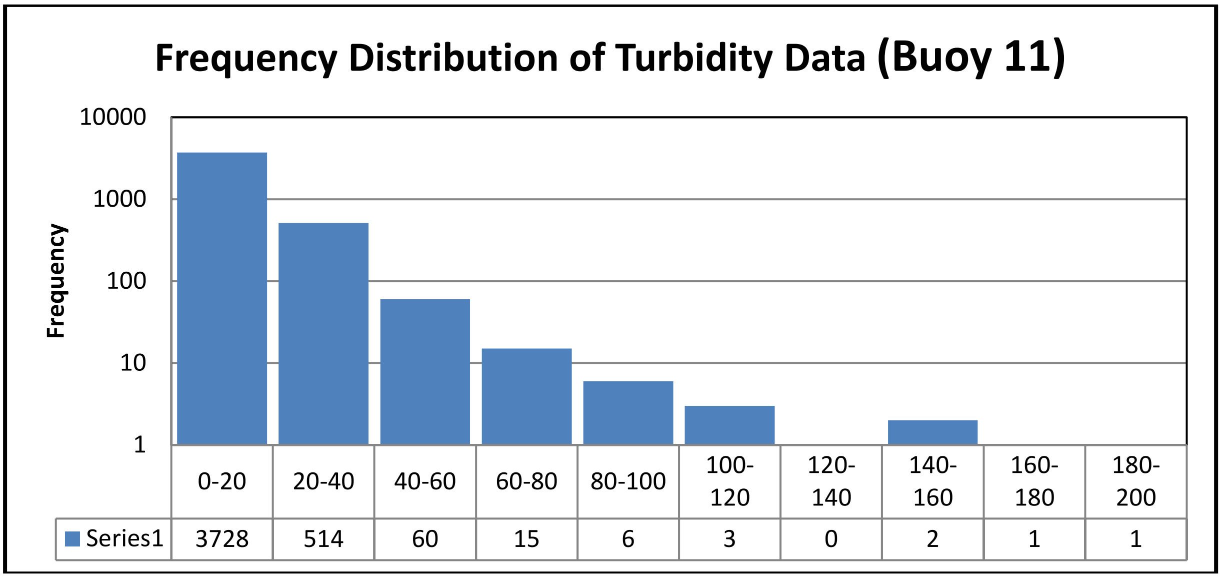

Figure 9. Frequency Distribution of the Turbidity Data. Please note the logerithmic Y axis. These data are heavily skewed and are not 'normal'.

The data is heavily skewed and it is not 'Normal' (please note the logarithmic Y axis). In order to carry out common parametric statistical tests on these data they need to be transformed to a '*Normal Distribution*'.

It is a common practice to normalise such data by using a Natural Logarithm or Box-Cox Transformation.

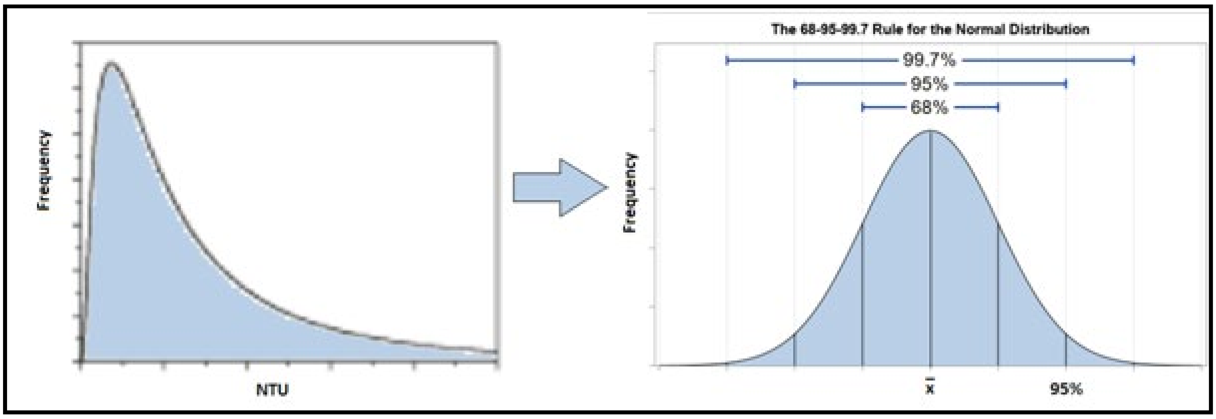

Figure 10. Conversion of non-normal data to an approximate normal distribution

Natural Log Transformation

Box-Cox transformation is a common and valid method for converting a non-normal data set to a normal distribution; however we would have to use two different λ values for the dredge turbidities and the non-dredge turbidities. This would introduce invalid differences into the data sets and would invalidate any tests of difference we would perform. We therefore went with Natural Logarithm Transformation.

The statistical breakdown of the natural log transformed data is as follows…

Natural Log Transformed Data		
	Dredge	**No Dredge**
Max	5.24	5.86
Min	0.43	0.14
Range	4.81	5.72
Mean	2.37	2.45
Std Dev	0.56	0.57
n	6,016	18,198

The frequency distribution of the two data sets is as follows…

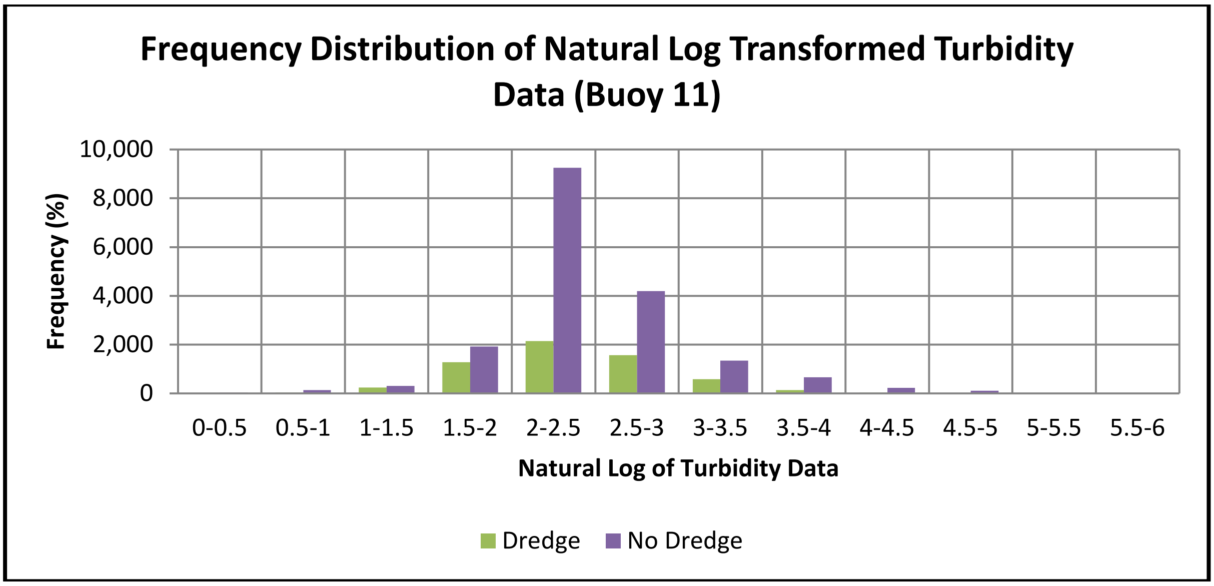

Figure 11. Frequency Distribution of Natural Log Transformed Turbidity Data (Numbers)

To make a comparison easier, the frequency numbers were converted to percentages.

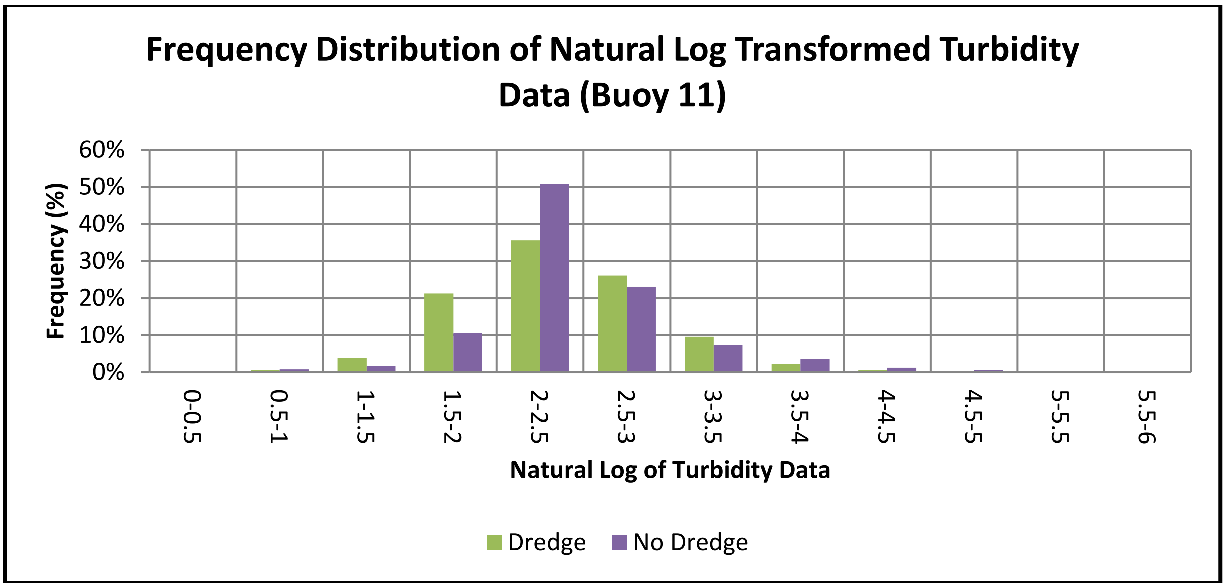

Figure 12. Frequency Distribution of Natural Log Transformed Turbidity Data (Percentages)

The dredge data seems to be weighted to the lower side of the graph, and the mean value for the dredge turbidities is lower than for the non-dredge period but is it significant?

A Student's T-test was carried out to test the hypothesis that the mean of the non-dredge data is larger than the dredge data. An unpaired, one-tailed, two samples of unequal variance t-test yielded a probability value of $p = 1.36327 \times 10^{-22}$. If $P > 0.5$, there is no significant difference. However this result indicates that these data are significantly different in more than 99.9% of cases.

Conclusion

Turbidities during dredging were reduced; this appears to be due to the type of dredger used (Trailing Suction Hopper Dredger) and the manner in which it was used (no overflow permitted).

All turbidities measured were within the natural variability of the harbour environment, and the increase in turbidities as the season progressed into winter, is part of the normal seasonal variation and is most likely due to increase rain, run-off and storms.

Total Suspended Solids

The Aquatic Services Unit (ASU), part of Cork University prepared the following calibration curve; it indicated a 1.0:1.1 ratio between NTU and Total Suspended Solids...

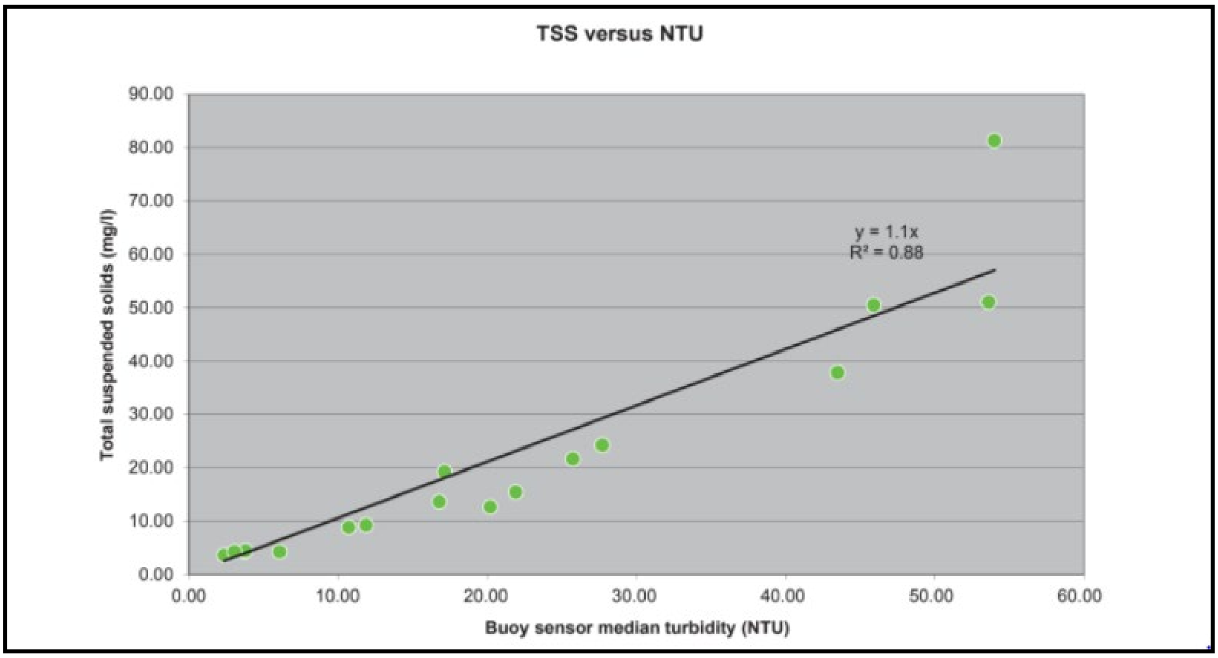

Figure 13. Calibration Graph for the conversion of NTUs to TSS (mg/l)

Given the straight forward relationship between NTUs and TSS, the analysis and conclusions of the turbidity data will be mirrored by the TSS data, as a consequence, no further comment on total suspended solids is necessary.

Oxygen

The Dissolved Oxygen Content (DO) of water is determined by quite a number of factors; these include, water temperature, salinity, atmospheric pressure, hydrostatic pressure, physical agitation of the water, the presence of phytoplankton and the presence of organic matter.

For regulatory purposes (e.g. S.I. No. 272/2009), dissolved oxygen saturation (%) levels are chosen, over oxygen concentration, as metabolic demand for oxygen increases in poikilothermic organisms as temperature increases; it therefore more closely reflects the availability of oxygen.

The oxygen saturation levels (%) are calculated from the dissolved oxygen content (do), the water temperature and the salinity; a slight error in the reading of any of these three parameters will give an erroneous value for the percentage oxygen saturation (%) levels.

If either the salinity or the temperature sensor is reading low, this will reduce the apparent percentage oxygen saturation. Errors in temperature readings will have a larger effect on the apparent percentage oxygen saturation than errors in salinity readings. The problem could be further compounded by an oxygen sensor reading low; some form of calibration is essential.

Oxygen content of water decreases as temperature and/or salinity rise. As can be seen from the graphs below, oxygen content increased from August as winter approached; this was due to the fall in water temperature.

The time series of Dissolved Oxygen Concentration (mg/l) at Buoy 11 is as follows…

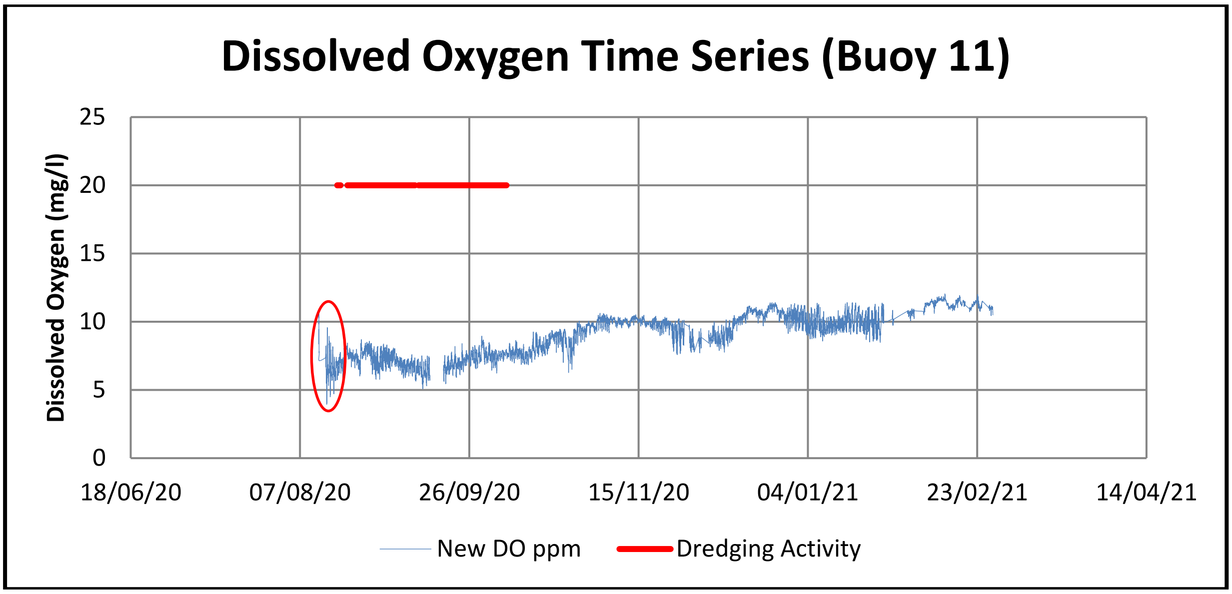

Figure 14. Dissolved Oxygen Concentration (mg/L) with respect to date; spurious data is circled in red.

There appears to be spuriously high and low readings (circled in red) between 12/08/20 and 17/08/20 (0:00) and may have been related to some initial installation issue.

The same aberrant pattern, relating to the oxygen data was apparent when oxygen was plotted against temperature, also when oxygen was plotted against salinity, and because oxygen saturation (%) is a composite figure derived from oxygen concentration, temperature and salinity, it was apparent in the oxygen saturation (%) time series. These aberrant data, in their respective graphs are shown in Appendix I. Hereafter, for clarity, the oxygen data between 12/08/20 and 17/08/20 have been removed.

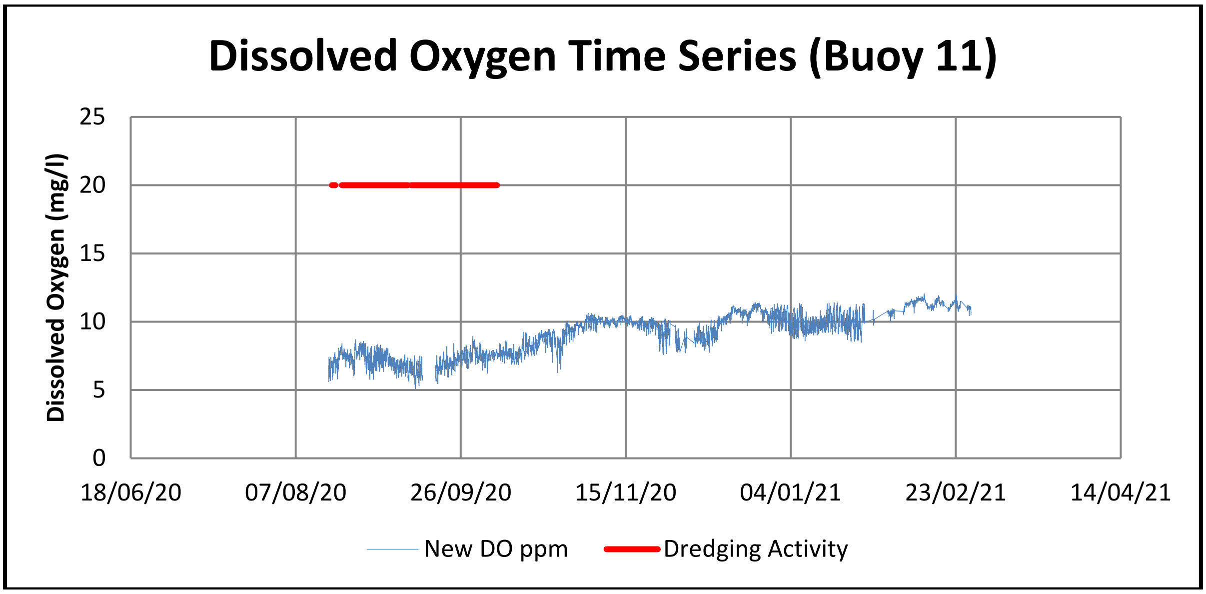

Figure 15. Dissolved Oxygen Time Series with spurious data removed.

The temperature time series is as follows…

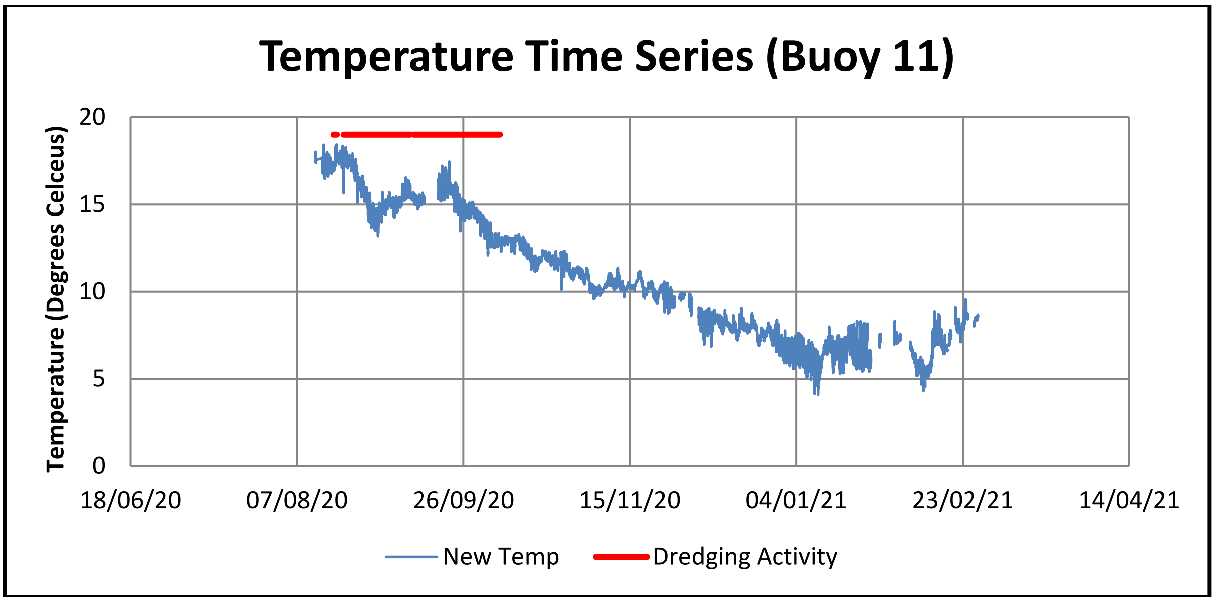

Figure 16. Temperature Time Series

As would be expected, temperature readings dropped as winter approached. The dip in temperature beginning at about 22/08/2020 and going on to 30/08/2020 appears to be associated with the rain of Storm Ellen and the subsequent runoff.

The Effect of Temperature on Oxygen Content

Water is a polar solvent but oxygen (O_2) is a non-polar gas. Generally speaking, non-polar molecules do not dissolve in polar solvents. However, through an interaction, referred to as a Dipole-Induced Dipole, water molecules interact with the oxygen molecules causing an uneven distribution of electrons within the oxygen molecule – this makes the oxygen molecule slightly polar, allowing it to dissolve in the polar water. Cold water molecules don't vibrate as much as warm molecules, so there is greater interaction between the water and the oxygen molecules when the temperature is lower. As the temperature increases, these interactions decrease because of the increased vibration, therefore less oxygen dissolves in the warmer water. The close relationship between water temperature and oxygen concentration is evident in the following graph.

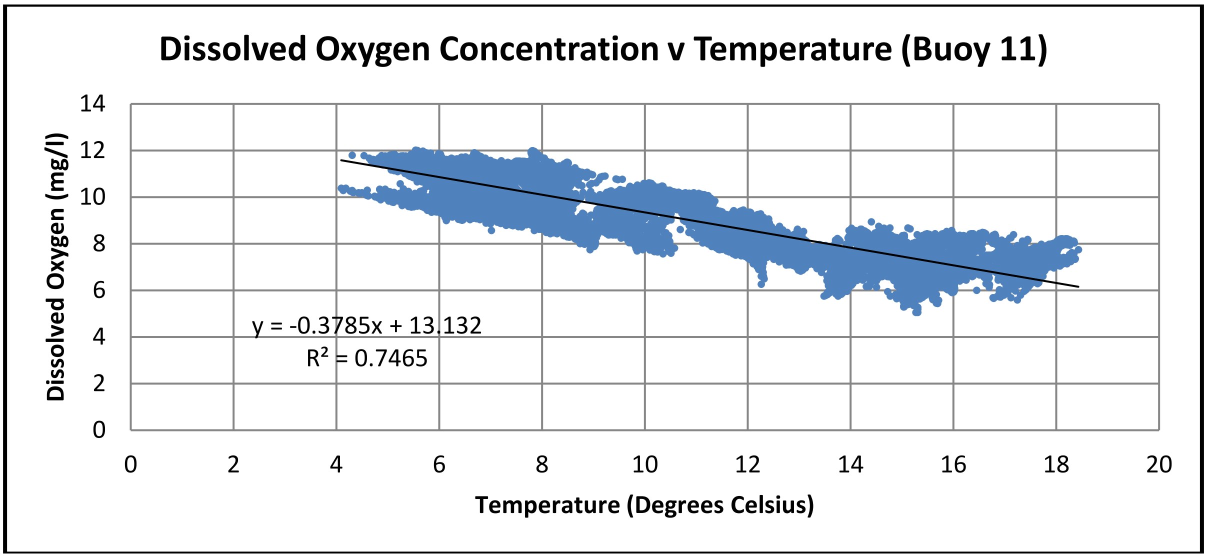

Figure 17. Dissolved O2 versus Temperature

The salinity time series is as follows…

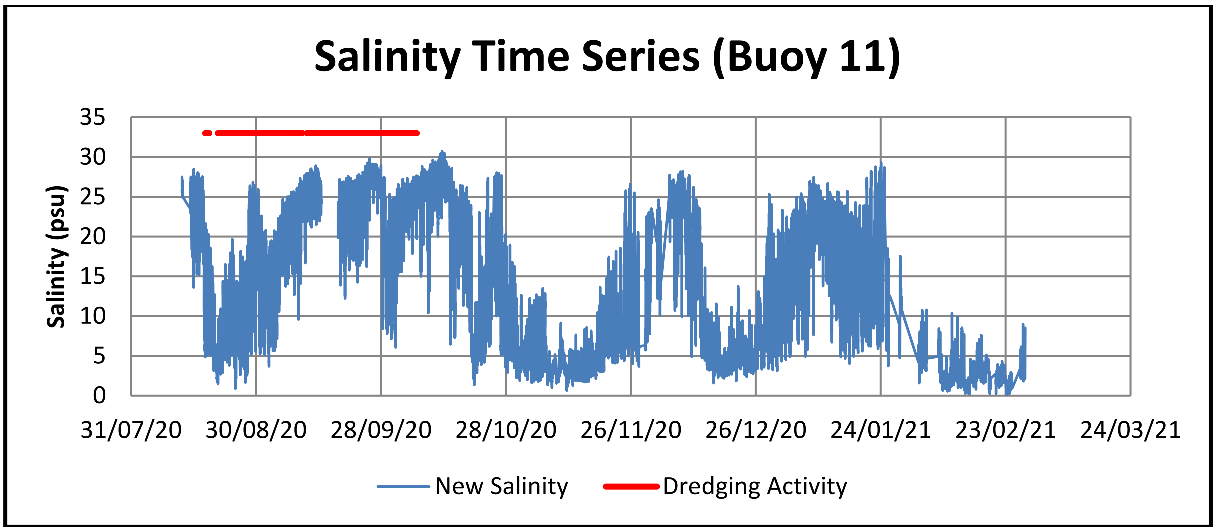

Figure 18. Salinity Time Series

Salinity varies widely at Buoy 11. The vertical grid lines on the graph are spaced at 29.5 days apart (one lunar month) and there does not appear to be any discernible pattern related to the monthly tidal cycles.

The Effect of Increased Salinity

Increasing salinity reduces the solubility of oxygen in water. When salt dissolves in water, water molecules cluster around the dissociated sodium and chlorine ions, creating what is referred to as, a hydration sphere. The more salt in the water, the more water molecules that are taken up with creating hydration spheres. The more water molecules that are taken up with creating hydration spheres, the fewer free water molecules there are available, to interact with the oxygen molecules; therefore oxygen solubility decreases. The relationship between salinity and oxygen concentration is evident in the following graph.

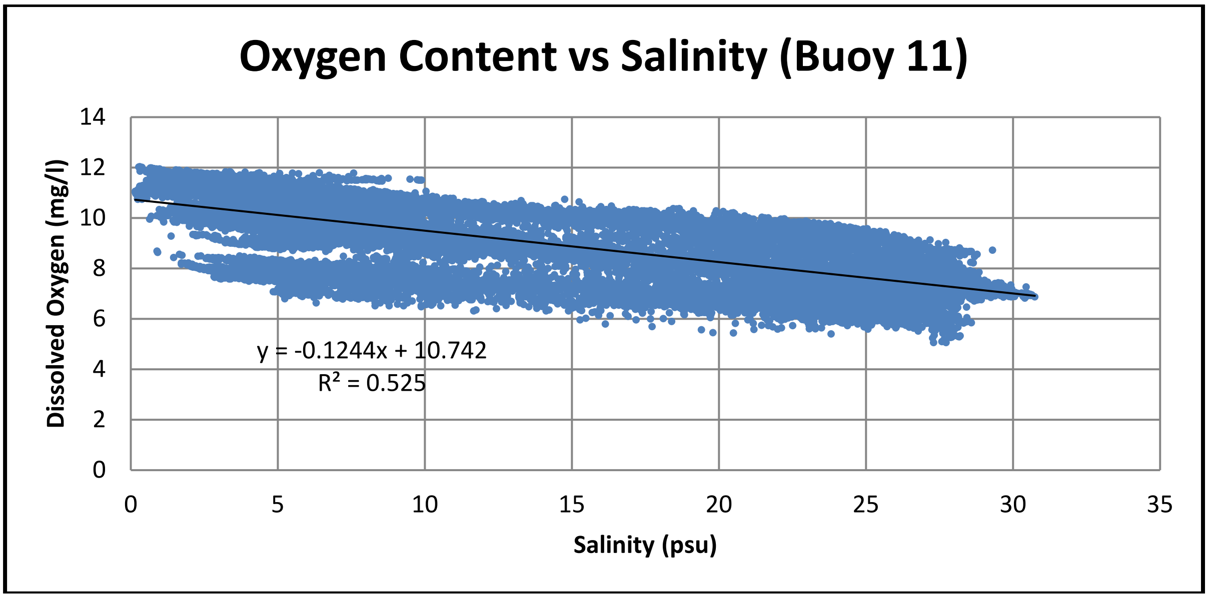

Figure 19. Oxygen Content v Salinity

The dissolved oxygen saturation (%) time series is as follows…

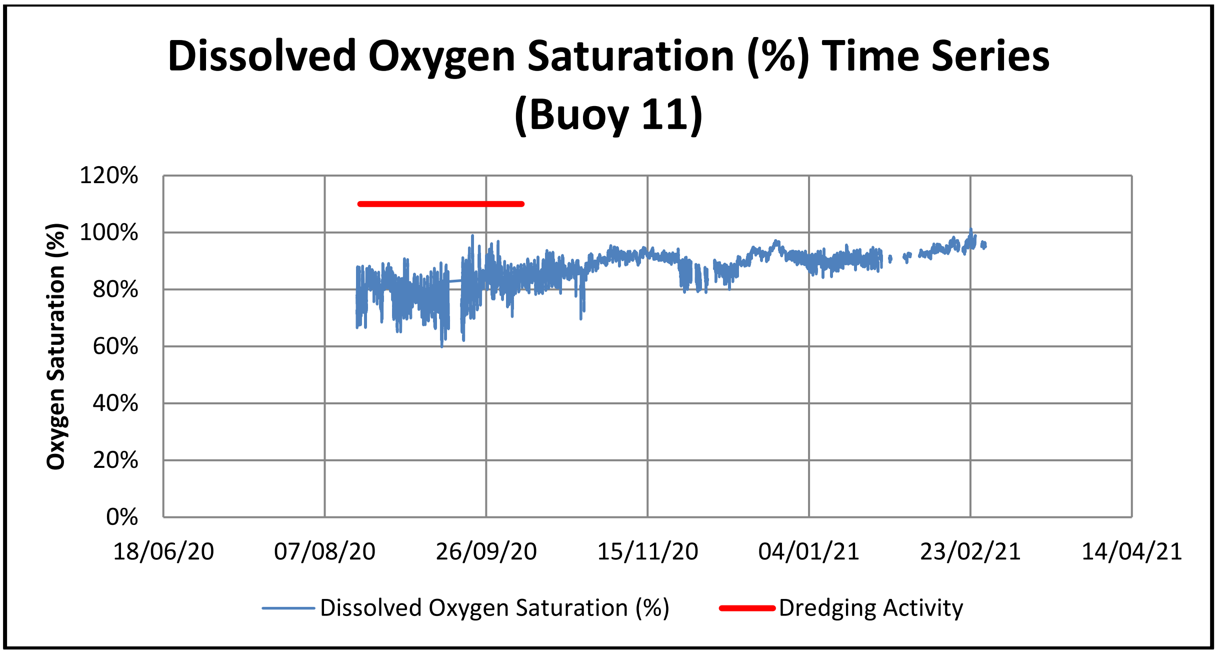

Figure 20. Dissolved Oxygen Saturation (%)

As temperature drops with the approach of winter, percentage dissolved oxygen saturation increases, from about 80% to just under 100%.

The statistical breakdown the Oxygen Saturation (%) data, over the entire period was as follows.

Dissolved Oxygen Saturation (%)	
Max	101.3%
Min	59.8%
Mean	87.6%
Std Dev	6.2%
n	23,791
n<70%	226
Percentage <70% Saturation	0.95%

S.I. No. 272/2009 - European Communities Environmental Objectives (Surface Waters) Regulations 2009, defines 'Transitional Waters' as follows…

"transitional waters" are bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows

The Port of Cork waters are by definition transitional waters.

For **summertime only**, (there are no winter standards) S.I. No. 272/2009 stipulates that for 95% of the time, dissolved oxygen saturation (%) should fall within the following limits; the limits are salinity dependent…

DO Saturation Limits	Salinity	
	0 psu	35psu
Dissolved oxygen lower limit	95%ile >70% saturation	95%ile >80% saturation
Dissolved oxygen upper limit	95%ile <130% saturation	95%ile <120% saturation

The frequency distribution of the dissolved oxygen saturation (%), for the entire monitoring period is as follows…

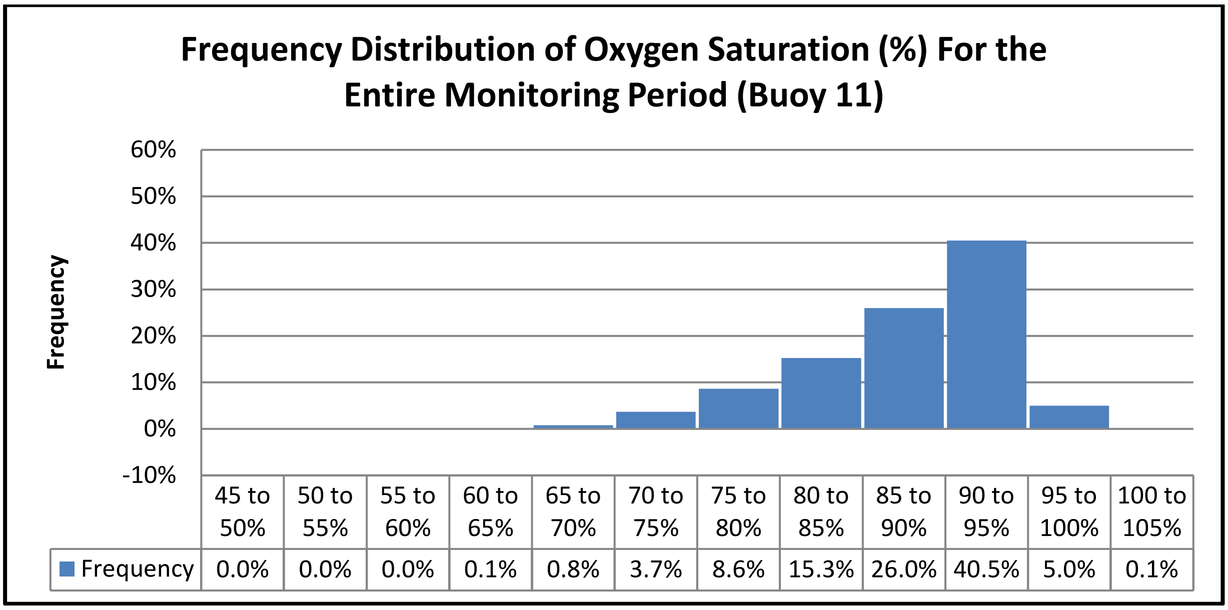

Figure 21. Frequency Distribution of Oxygen Saturation (%) for the Entire Monitoring Period. The x axis is the percentage oxygen saturation levels, and the y axis is the relative frequencies. Only 0.9% of readings were less than 70% Saturation.

When the data is separated according to when dredging is ongoing and when it was not, the statistics were as follows.

	No Dredging	Dredging Ongoing
Max	101.3%	99.0%
Min	66.2%	59.8%
Mean	90.0%	80.5%
Std Dev	4.2%	5.4%
n	17,774	6,017
n<70%	35	191
Percent <70% Saturation	0.20%	3.17%

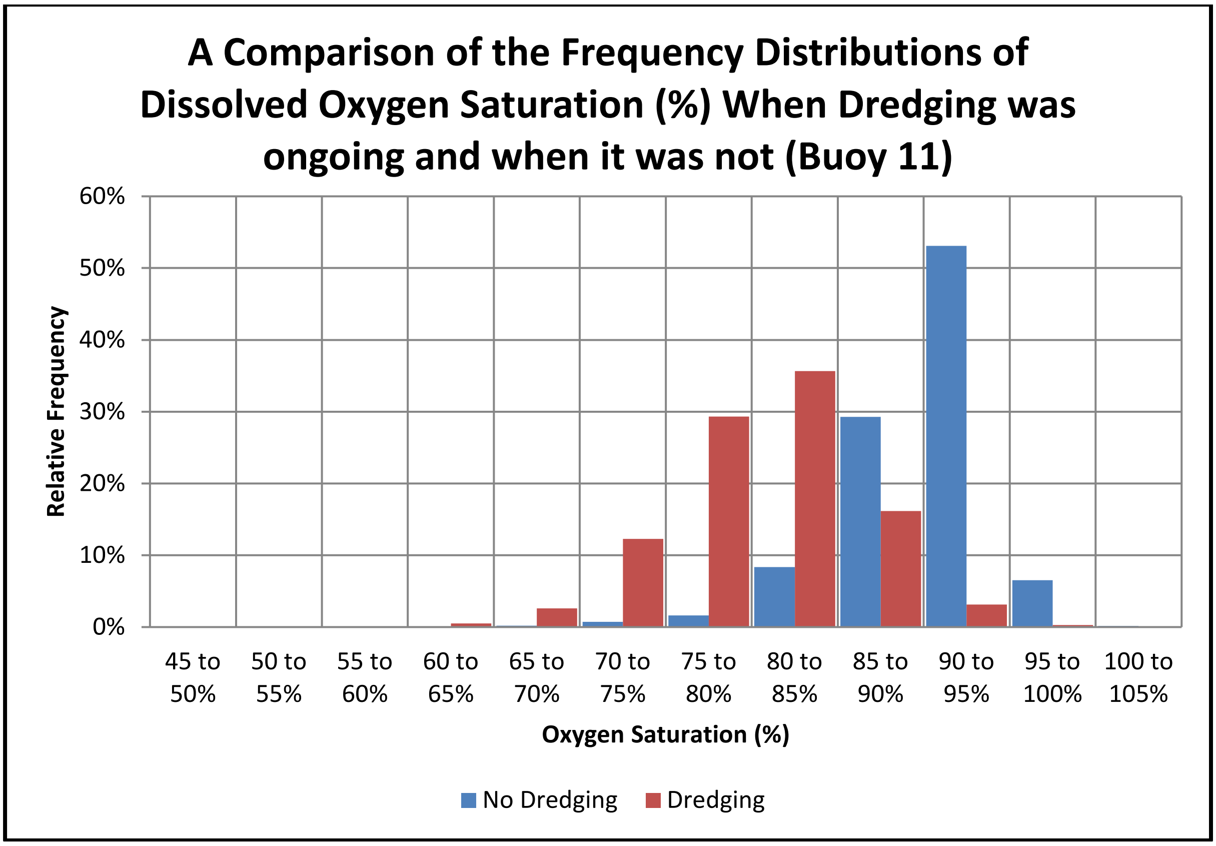

Figure 22. A Comparison of the Frequency Distributions of Dissolved Oxygen Saturation (%) when Dredging was ongoing and when it was not.

A Student's T-test was carried out to test the hypothesis that the mean of the non-dredge data is larger than the dredge data. An unpaired, one-tailed, two samples of unequal variance t-test yielded a probability value of $p = 0$ (whatever the lower limit is in Excel). If $P > 0.5$, there is no significant difference. However this result indicates that these data are significantly different in more than 99.9% of cases.

It would appear that for dissolved oxygen saturation (%) during the dredging period, 3.17% of readings are below the 70% saturation level, which is within of the 5% permitted by S.I. No. 272/2009.

Conclusion

There is a statistically significant (>99.9%) drop in dissolved oxygen saturation (%) during dredging. However, levels dropped to below 70% saturation on only 3.17% of occasions while operations were ongoing indicating that conditions complied with the stipulations of S.I. No. 272/2009.

Statistical Breakdown of the Final Buoy 11 Dataset

When all aberrant data was removed, the statistical breakdown of the residual data was as follows…

	Temperature	Specific Conductivity (uS/cm)	Actual Conductivity (uS/cm)	Salinity (PSU)	Resistivity (ohm*cm)	Total Dissolved Solids (ppm)	Density of Water (g/cm3)	Dissolved Oxygen Concentration (mg/L)	Dissolved Oxygen Saturation (%)	Turbidity (NTU)	Total Suspended Solids (mg/L)
Max	18.43	48.93	38.63	30.74	0.45	31.81	1.024	12.05	101.3%	351.71	386.88
Min	4.09	0.32	0.22	0.15	0.00	0.21	1.000	5.07	59.8%	1.15	1.27
Mean	10.72	22.33	16.72	13.23	0.01	14.51	1.010	9.11	87.6%	13.87	15.26
Std Dev	3.59	14.25	11.23	9.01	0.02	9.26	0.007	1.54	6.2%	13.40	14.74
n	23,544	23,607	23,607	23,607	23,607	23,607	23,607	23,607	23,544	23,606	23,606

Monitoring Buoy RA-24

Buoy RA-24 is located in the outer harbour in the vicinity of Ringaskiddy. Dredging in the proximity of the buoy occurred at Cobh Turning Circle, Haulbowline Industries, IFI Jetty, Ringaskiddy Basin, Ringaskiddy Deep Water Berth and Whitegate berth. Dredging at these sites occurred on the following dates; 18/08/2020, 18/09/2020 and daily from 20/09/2020 to 06/10/2020.

The statistics (Maximum value, minimum value, average and standard deviation) for the raw, unsorted data from this buoy is as follows…

	Water temperature (Celsius deg.)	Specific Conductivity (uS/cm)	Actual Conductivity (uS/cm)	Salinity (PSU)	Resistivity (ohm*cm)	Total Dissolved Solids (ppm)	Density of Water (g/cm3)	Dissolved Oxygen Concentration (mg/L)	Dissolved Oxygen Saturation (%)	Turbidity (NTU)	Total Suspended Solids (mg/L)
Max	19.05	52.43	43.43	33.24	42.01	34.08	1.0259	13.79	1.76	687.37	756.11
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.9984	6.60	0.59	0.00	0.00
Mean	9.84	39.96	28.83	24.39	0.01	25.98	1.0193	8.91	0.91	47.77	52.55
Std Dev	2.88	8.21	7.24	5.54	0.36	5.34	0.0042	0.91	0.05	37.21	40.93
n	23,575	23,575	23,575	23,575	23,575	23,575	23,575	23,575	23,575	23,575	23,575

Turbidity

The turbidity time series indicating when dredging occurred is as follows…

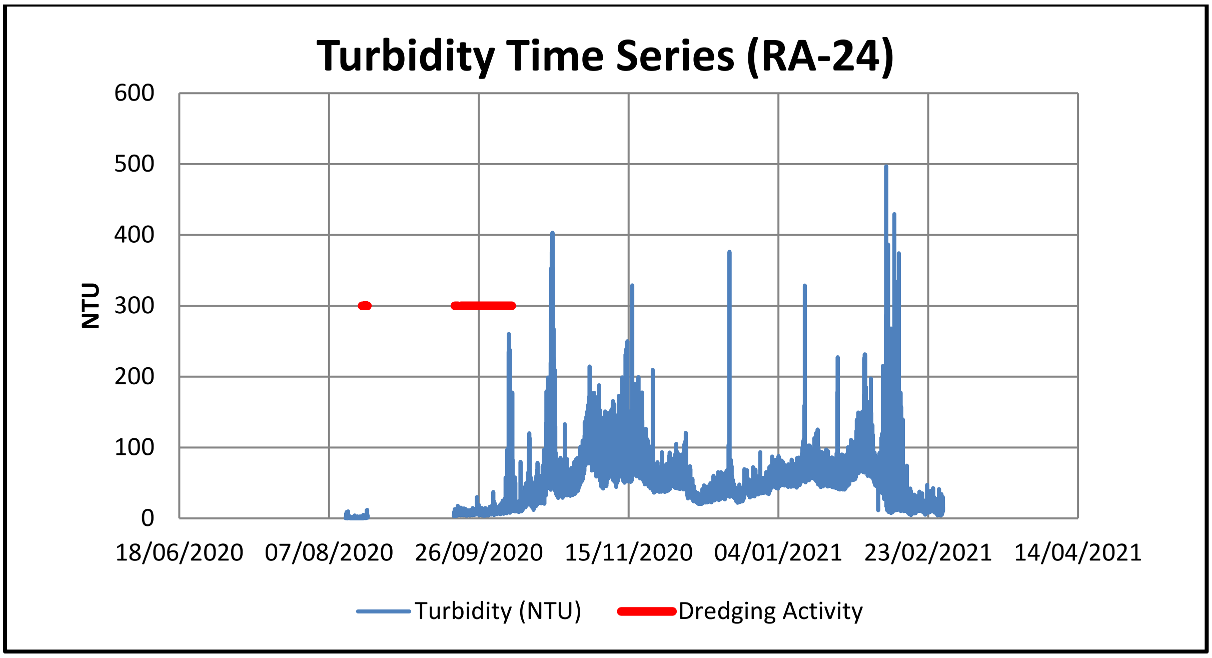

Figure 23. Turbidity time series for Buoy RA-24. The red line indicated when dredging was ongoing in the locality.

These non-normal data were separated into dredging and non-dredge data, then subjected to Natural Log Transformation to normalise the data.

	Dredging	No Dredging
Max	5.5618	6.2082
Min	-1.7148	-4.6052
Mean	2.1221	3.6634
Std Dev	0.6650	0.9707
n	2,614	20,953

The data were then converted to percentages and are compared in the graph below…

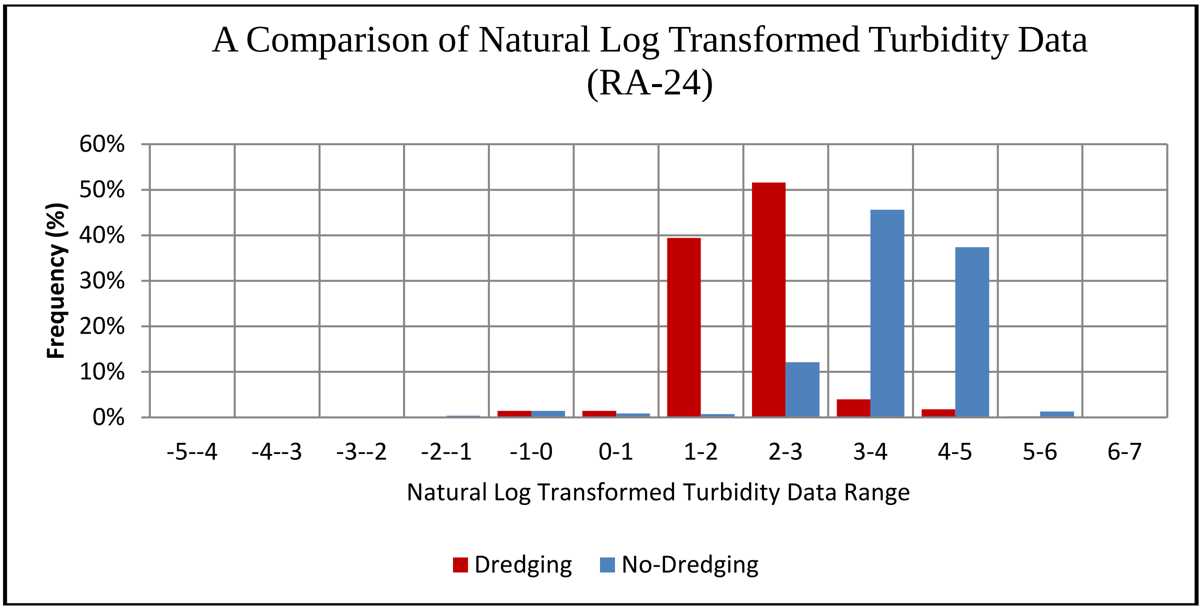

Figure 24. A Comparison of Natural Log Transformed Turbidity Data.

There was a considerable difference in the means with the non-dredging data appearing to be larger.

A Student's T-test was carried out to test the hypothesis that the mean of the non-dredge data is larger than the dredge data. An unpaired, one-tailed, two samples of unequal variance t-test yielded a probability value of p = 0 (Excel returned this value as the difference was so large). If P >0.5, there is no significant difference. However this result indicates that these data are significantly different in more than 99.999% of cases.

Conclusion

There was a statistically significant reduction in turbidity during the dredging of the harbour in the vicinity of Buoy RA-24.

The increase in turbidities as the season progressed into winter is part of the normal seasonal variation and is most likely due to increased rain, run-off and storms.

Oxygen Data From Buoy RA-24

The dissolve oxygen time series for Buoy RA-24 was as follows…

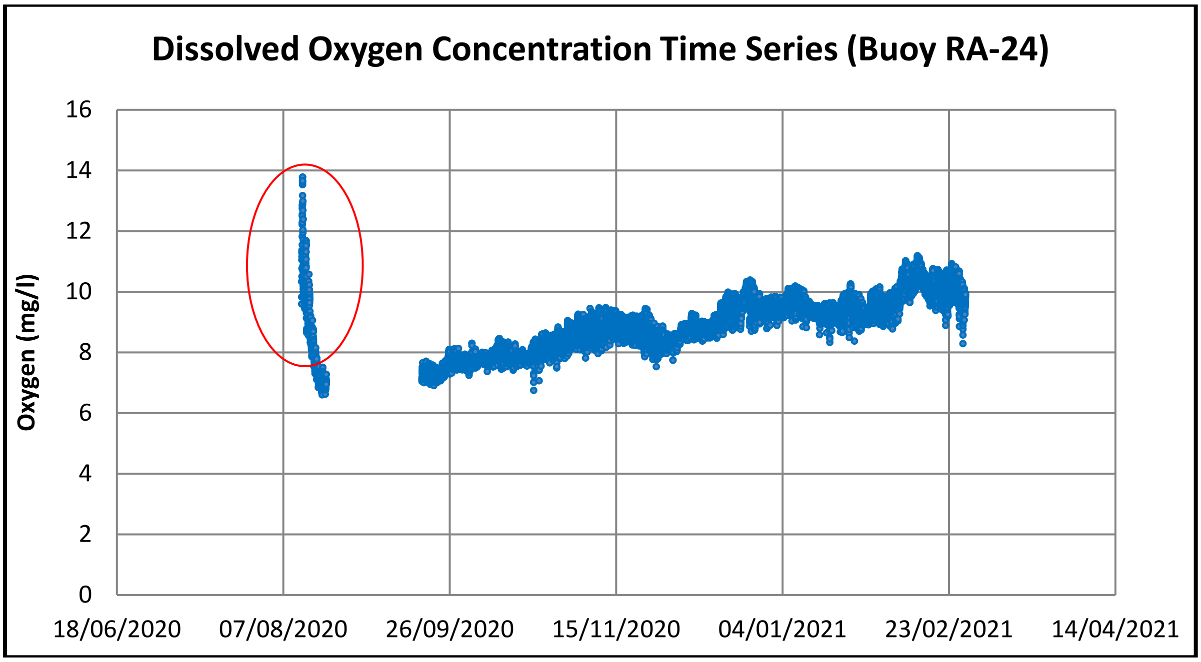

Figure 25. Dissolved Oxygen Time Series; aberrant data circled in red.

It is apparent that something is amiss with the oxygen concentration readings from 12/08/200 to 17/08/2020 (circled). Similar spurious data are evident in the graphs of the oxygen saturation time series, the dissolved oxygen versus temperature and dissolved oxygen versus salinity graphs. For clarity, these graphs are not included here, in the main body of the text, but can be referred to in Appendix II.

When the DO data from the 12th to the 17th of August was removed, the expected patterns and relationships between these parameters was observed.