Sanitary Survey Report and Sampling Plan for Ballinakill Bay

Produced by

AQUAFACT International Services Ltd

In conjunction with

The Sea Fisheries Protection Authority

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Glossary

ANOVA	Analysis of Variance
BMPA	Bivalve Mollusc Production Area
BOD	Biochemical Oxygen Demand
CD	Chart Datum
CFU	Colony Forming Unit
CSO	Central Statistics Office
ED	Electoral Divisions
Depuration	The process of purification or removal of impurities
DWF	Dry Weather Flow
EC	European Communities
E. coli	*Escherichia coli*
Fetch	The distance a wave can travel towards land without being blocked
Geometric Mean	The nth root of the product of n numbers (The average of the logarithmic values of a data set, converted back to a base 10 number).
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine environmental Pollution
GIS	Geographical Information Systems
GPS	Global Positioning System
Hydrodynamic	Forces in or motions of liquids
Hydrography	The description and analysis of the physical conditions, boundaries, flows and related characteristics of water bodies
IID	Infectious Intestinal Disease
INAB	Irish National Accreditation Board
I-WeBS	Irish Wetland Bird Survey
LAT	Lowest Astronomical Tide
Marpol 73/78	International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978. Marpol is short for Marine Pollution, 73 for 1973 and 78 for 1978.
MPN	Most Probable Number
MSD	Marine Sanitation Device
NAP	Nitrates Action Programme
NoV	Norovirus
NRL	National Reference Laboratory

OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
Pathogenic	Capable of causing disease
p.e.	Population Equivalent
Plankton/Planktonic	Pertaining to small, free-floating organisms of aquatic systems
PSU	Practical Salinity Units
REGULATION (EU) 2017/625	OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 March 2017 on official controls and other official activities performed to ensure the application of food and feed law, rules on animal health and welfare, plant health and plant protection products
RMP	Representative Monitoring Point
cSAC	Candidate Special Area of Conservation
SFPA	Sea Fisheries Protection Authority
SPA	Special Protection Area
SS	Suspended Solids
STW	Sewage Treatment Works
Suspension feeders	Animals that feed on small particles suspended in water
UKAS	United Kingdom Accreditation Service
UKHO	United Kingdom Hydrographic Office
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant
WWTW	Waste Water Treatment Works

1. Introduction

Consumption of raw or lightly cooked bivalve molluscs can results in illness due to the presence of micro-organisms, many of which are derived from faecal contamination of the marine environment. Shellfish contaminated with pathogenic microorganisms may cause infectious disease in humans and such outbreaks are more likely to occur close to our coasts where production areas are impacted by sources of human and animal faecal contamination.

The risk of contamination of bivalve molluscs with pathogen microorganisms is assessed through microbiological monitoring programmes. This assessment results in the classification of bivalve mollusc production areas, which in turn governs the level of treatment required before human consumption of the shellfish.

Under EU regulations sanitary surveys of bivalve mollusc production areas and their associated hydrological catchments and coastal waters are required in order to establish the appropriate representative monitoring points for these monitoring programmes.

Specifically under regulation (EU) 2017/625 and its subsequent implementing regulation (EU) 2019/627 there is a requirement to carry out a sanitary survey before classifying any shellfish production or relaying area. Article 56 of Implementing Regulation 627 of 219 states:

1. Before classifying a production or relaying area, the competent authorities shall carry out a sanitary survey that includes:

- an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
- an examination of the quantities of organic pollutants released during the different periods of the year, according to the seasonal variations of human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;
- determination of the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area.

2. The competent authorities shall carry out a sanitary survey fulfilling the requirements set out in paragraph 1 in all classified production and relaying areas, unless carried out previously.

3. The competent authorities may be assisted by other official bodies or food business operators under conditions established by the competent authorities in relation to the performance of this survey.

Currently the Sea Fisheries Protection Authority in conjunction with Aquafact International Ltd are conducting sanitary surveys for new bivalve mollusc production areas and for those existing classified production areas which were previously not surveyed.

This report contains the documents relevant to the sanitary survey of the bivalve mollusc production area at Ballinakill Bay, County Galway. It identifies the representative monitoring points and supporting sampling plans for pacific oysters, native oysters, mussels, razor clams, scallops and carpet-shell clams in Ballinakill Bay. It also sets out the production area boundaries in the Bay.

2. Overview of the Fishery/Production Area

2.1. Description of the Area

The western part of Ballinakill Bay (see Figure 2.1) is exposed to western/northwestern winds and depths range from +20m to intertidal areas. The eastern part of the bay is a narrow but comparatively shallow inlet opening to the northeast of the Freaghillaun-Carrigeen Island group on the northwest coast of Co. Galway between Killary Harbour to the north and Cleggan, Streamstown and Clifden Bays to the south. The bay is *c.* 10km in length and *c.*5km wide with the main channel being *c.* 880m. In the inner reaches, the harbour divides up to form a number of small shallow bays, namely Derryinver, Roeillaun, Barnaderg and Fahy Bay (see Figure 2.1). The main channel is two pronged comprising a north passage and a south passage, with depths of 10-20m. East of Freaghillaun Island, between the two channels is a depression known as Freaghillaun Deep, with depths down to 24m. There is also a smaller depression, down to 16m west of Roeillaun Bay and north of Fahy Bay. Otherwise, the harbour has a mean estimated depth of 10m with the inner harbour having an estimated mean depth of *c.* 5m. Given that the maximum tidal range is *ca* 3.5m at Spring tides, this means that this part of Ballinakill Harbour experiences a high rate of flushing on any one Spring tide and that during the period of Spring tides, the entire inner part of the harbour is completely refreshed.
The volume of the bay is estimated at 220,000,000m^3.

The catchment area (103.7km^2) of Ballinakill Harbour is drained mainly by the Dawros River (55.5%) which enters the harbour in the northeast. In the southeastern corner of the bay, the Owengarve Stream and the Owennabaunoge River flow into Barnaderg Bay. The Traheen River, Tullyboy Stream and Moyard River all flow into the harbour south of Fahy Bay. The three former rivers drain *c.* 17.3% of the catchment and the 2 latter rivers drain 11% of the catchment.

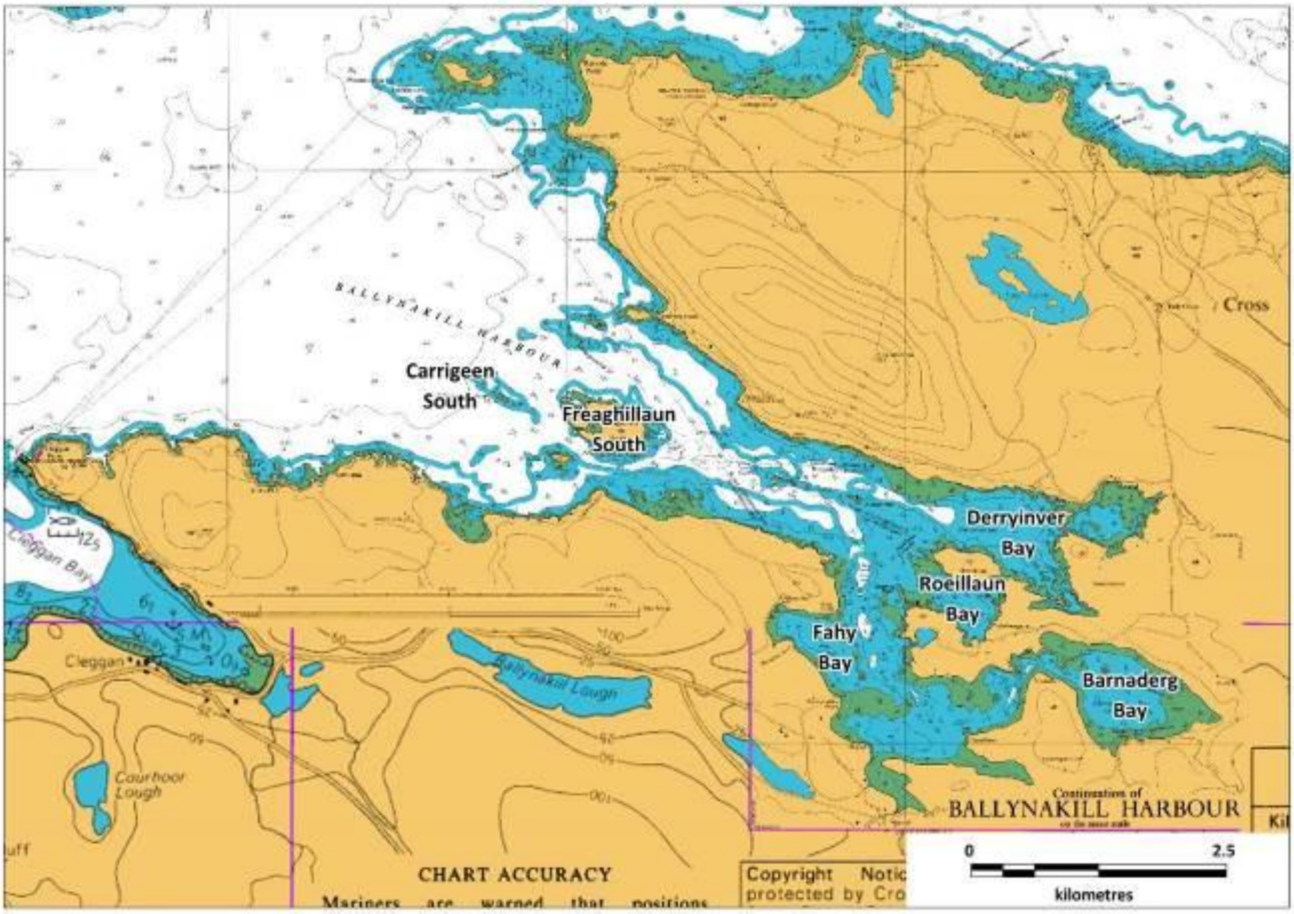


Figure 2.1: Ballinakill Harbour

In proportion to its size, Ballinakill Harbour shows great variety in the nature of the seabed (AQUAFACT, 1991a). Along the main channel the bottom is sandy and in the shallower waters nearer the shore, *Zostera* beds and muddy sand occur in many places. East of Freaghillaun, near the entrance, the Freaghillaun Deep depression, has a bottom of muddy sand with much drift weed. A number of species, such *as Astropecten irregularis, Lumbrineris gracilis, Stylaroides glauca, Ophiura ophiura* and *O. albida,* are only found in the open channels near the entrance to the harbour (Southern, 1914). Others such as *Antedon bifida, Aphrodite aculeata, Phaxas pellucidus, Ensis siliqua* and *Amphiura brachiata,* live on sandy bottom in more sheltered conditions. Many other species, such as *Anemonia viridis, Sphaerosyllis hystrix, Eusyllis tubifex, Odontosyllis gibba, Helcion pellucidum and Nerophis ophidion*, are usually associated with *Laminaria* or *Zostera*, or other sea-weeds. Many of the other species are attached to shells, stones or weeds. The smaller depression west of Roeillaun Bay and north of Fahy Bay has a sandy bottom with a thick layer of dead shells, chiefly of *Pecten maximus, Ostrea, Mya, Solen, Dosinia exoleta, etc.,* with encrusting polyzoans sponges and hydroids. There is some broken *Lithothamnium* and around the edge there is muddy sand, *Lithothamnium* and dead *Zostera* and other drift weeds. The main channels running southwards from here have a sandy mud bottom, with broken shells and much drift-weed. Fahy Bay is formed of sandy mud, shells and gravel, covered with *Lithothamnium calcareum*, sea-weeds and *Zostera*. It contains a rich fauna with *Gibbula magus* occurring in vast numbers. The muddy inner bays have somewhat brackish conditions and a correspondingly low diversity of species.

A large portion of the Ballinakill Harbour BMCPA is designated as a cSAC; the West Connacht Coast cSAC (Site Code: 002998). This cSAC is designated for the protection of bottle nose dolphins *Tursiops truncatus* and the site consists of a substantial area of marine waters from Erris Head, Co. Mayo to Knock Point, Co. Galway (see Figure 2.2). The site encompasses a diverse range of shallow marine habitats occurring in waters < 100 m deep *e.g.* reefs, islets and sedimentary basins (NPWS, 2014). The site contains physical and hydrographic features which include shallow coastal bays, areas of steep seafloor topography and complex areas of strong current flow adjacent to estuaries, coastal headlands and islands, sandbanks, shoals and reefs all of which are believed to be important for bottle nosed dolphins. The species are present throughout the year and the sighting records of bottle nose dolphins in the cSAC are significant for the west coast of Ireland and indicate widespread use of the area by individual groups of dolphins. Groups are known to alter their composition or to aggregate together within the site and comparatively high group sizes of up to 50-65 individual dolphins or more have been recorded in the site's northern and southern components. Adults closely accompanying calves are commonly observed in summer and autumn months at a number of locations within the site, and group foraging, resting or social behaviour are also regularly recorded. Individual dolphins are also known to recur within and between years at key locations within the site (*e.g.* outer Killary Harbour, off the Mullet Peninsula), indicating a degree of site fidelity to its coastal waters.

The BMCPA also overlaps a Special Protection Area (SPA): Illaunnanoon SPA (IE004221) that covers the island of Illaunnanoon (also known as Lamb's Island) and the surrounding marine waters and intertidal rocks (see Figure 2.2). It is situated at the mouth of Barnaderg Bay on the east side of Ballinakill Harbour. The site is designated for the Sandwich Tern and the site supports a nationally important population (80 pairs in 1984, 35 pairs in 1995 and 90 pairs in 2001). Other species recorded on the island in 2001 include Common Tern (20 pairs), Black-headed Gull (70 pairs) and Common Gull (12 pairs).

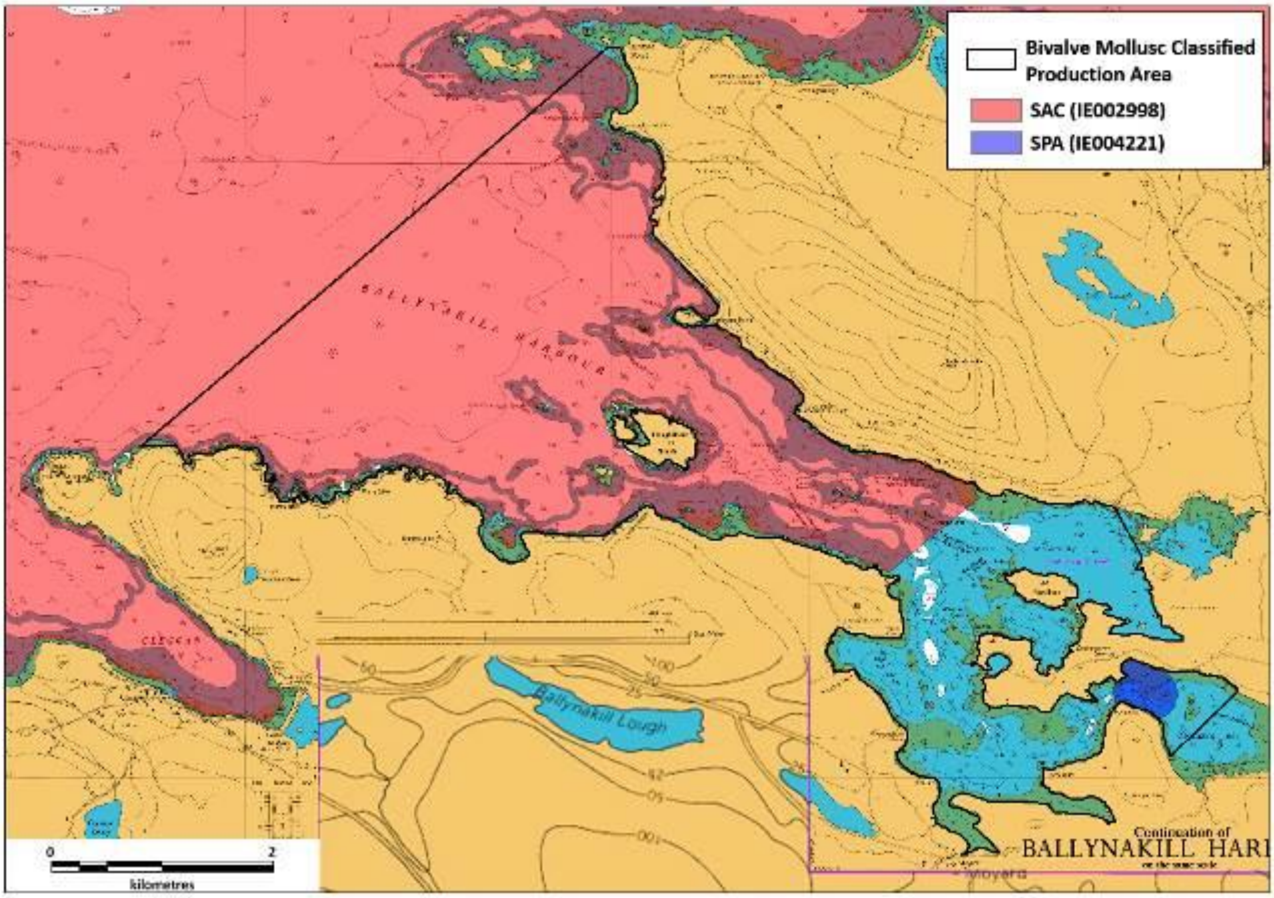


Figure 2.2: Location of Natura 2000 sites overlapping with the Ballinakill Harbour BMCPA.

Land cover within the Ballinakill Harbour catchment area is a mixture of peat bogs, land principally occupied by agriculture but with significant areas of natural vegetation, coniferous forest, natural grassland, sparsely vegetated areas, traditional woodland scrub and coniferous and broad-leafed forestry.

The population of the catchment is approximately 1,320[1]. There main villages/urban centres within the catchment are Letterfrack, Tully Cross and Moyard. The population increases in the spring and summer months due to tourists. Almost a quarter of the homes in the area are holiday homes.

[1] Calculation explained in Section 4.1.1

2.2. Ballinakill Bay Fishery

Approximately six vessels operate in the Ballinakill Harbour BMCPA for brown crab using creel pots between February and December (Marine Institute, 2015). Scallop dredging occurs towards the outer bay and there is a razor clam fishery just east of Freaghillaun South. There was a traditional native oyster fishery in the past in Ballinakill. Existing mussel, oyster and finfish aquaculture sites can be seen in Figure 2.5 and Figure 2.3 shows the fishing activity in the Ballinakill Harbour BMCPA.

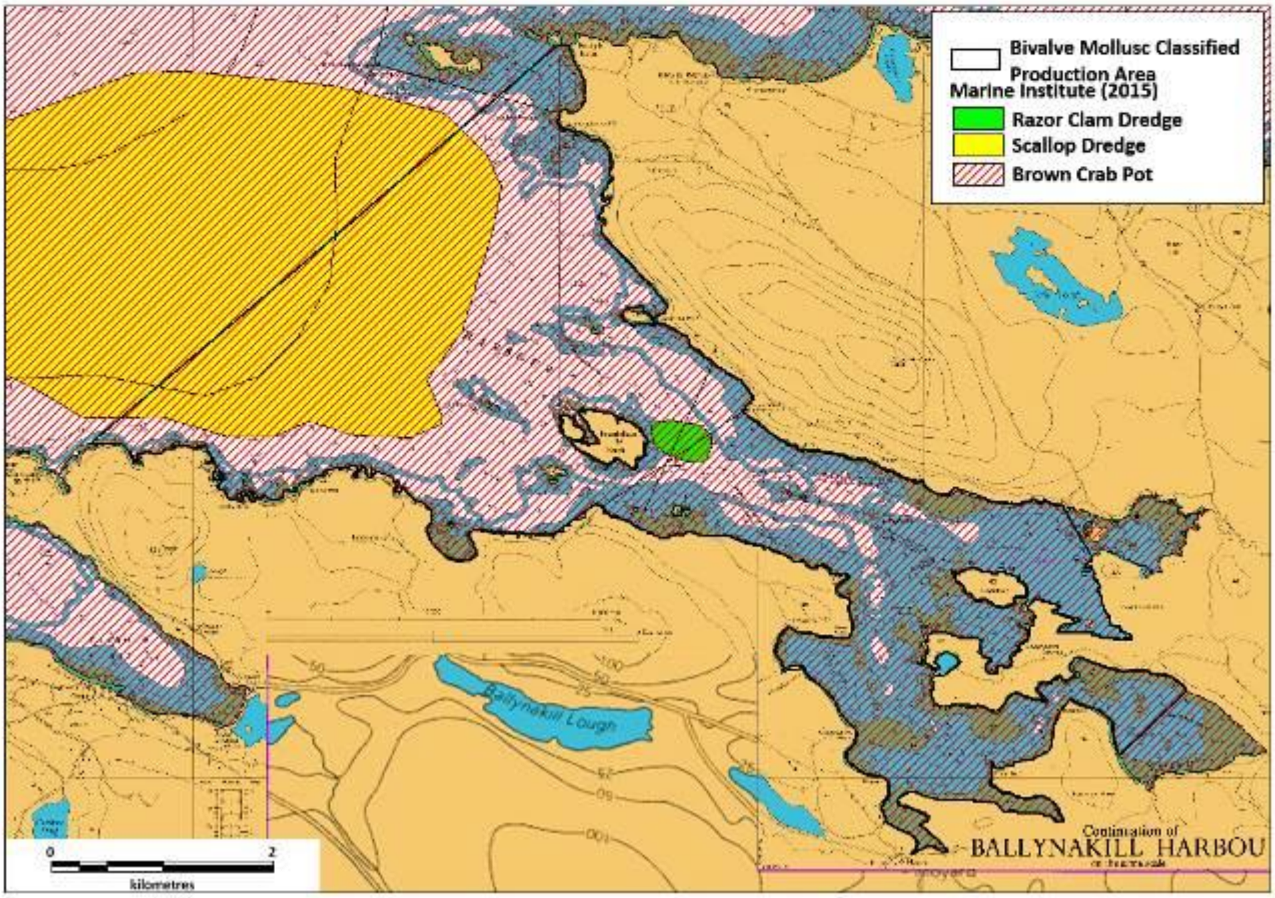


Figure 2.3: Fishing activity in the Ballinakill Harbour BMCPA (Marine Institute, 2015)

2.2.1. Location/Extent of Growing/Harvesting Area

The shellfish designated waters in Ballinakill cover an area of approximately 8.31km^2 and the Bivalve Mollusc Classified Production Area (BMCPA) covers *c.* 19.75km^2. Both can be seen in Figure 2.4. Pacific oysters, native oysters, mussels, razor clams, scallops and carpet shell clams occur in Ballinakill Harbour.

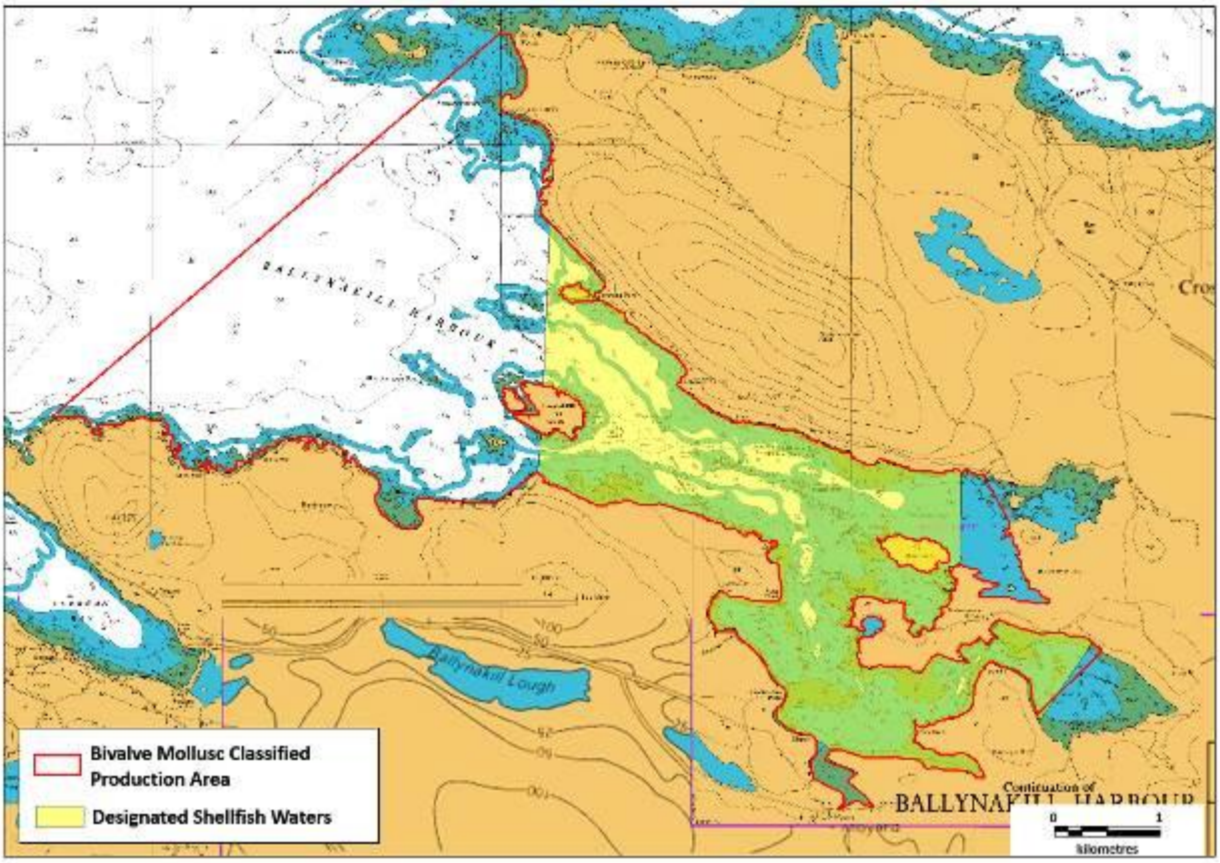


Figure 2.4: Bivalve Mollusc Classified Production Area and Designated Shellfish Waters within Ballinakill Harbour.

Figure 2.5 shows the current locations of licenced aquaculture sites within Ballinakill Harbour. There is one mussel site located in the outer harbour close to the northern shore between Letterbeg Point and Tonabinnia. All of the oyster sites are in the inner harbour area, with one close to the north shore at Derryinver Bay, one in Fahy Bay south of Ross Point, one south of Knocknahaw Point and all around Dawros Beg.

There are two salmon farm sites within the bay also, one east of Freaghillaun South and one east of Ross Point in the inner bay. Approximately 87% of the licenced area is occupied by oysters (1.7km^2), 7.7% by mussels (0.15km^2) and 5.4% by salmon (0.06km^2).

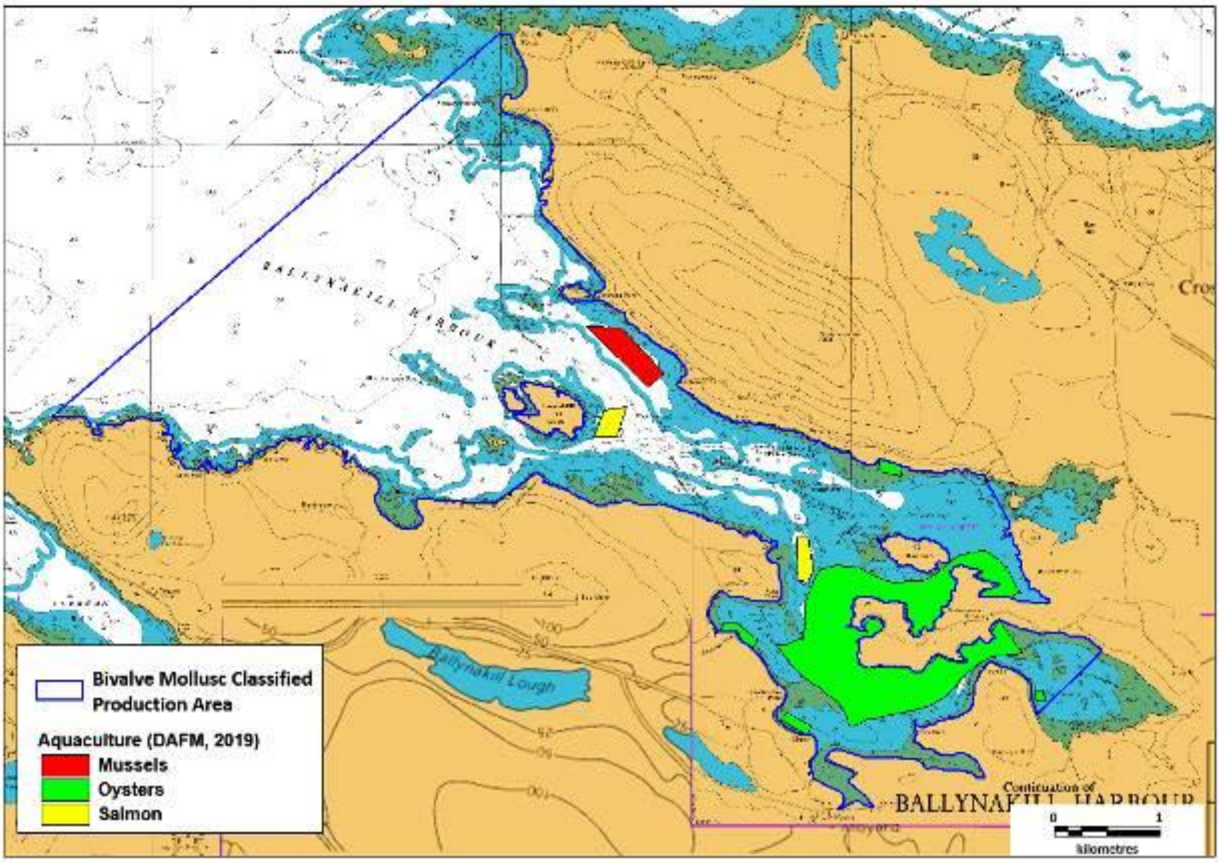


Figure 2.5: Licenced aquaculture sites within Ballinakill Harbour (Source: DAFM, 2019).

2.2.2. Description of Species

*2.2.2.1. Blue Mussels (*Mytilus edulis*)*

General Biology

Mytilus edulis is a filter feeding marine bivalve. It occurs from the high intertidal to the shallow subtidal attached by fibrous byssus threads to suitable rocky substrata. They are a gregarious species and at high densities form dense beds of one or more (up to 5 or 6) layers, with individuals bound together by their byssus threads.

Spawning is protracted in many populations, with a partial spawning in spring and a less intensive secondary spawning in summer to late August or September (Seed, 1969). Larvae spawned in spring can take advantage of the phytoplankton bloom. The secondary spawning is opportunistic, depending on favourable environmental conditions and food availability. An individual female (*ca* 7mm) can produce 7-8 million eggs, while larger individuals may produce as many as 40 million eggs (Thompson, 1979). In optimal conditions larval development may be complete in less than 20 days but growth and metamorphosis in the plankton between spring and early summer, at *c*. 10 °C, usually takes 1 month. However, it is not unusual for planktonic life to extend beyond 2 months in the absence of suitable substrata or optimal conditions (Bayne, 1965; Bayne, 1976). Newly settled mussels are termed 'spat'. Dispersion is dependent on the duration of planktonic life. Maintenance of their position in the water column by active swimming ensures that larvae can be potentially dispersed over great distances by currents.

Mytilus edulis is not listed as threatened or endangered; however, intertidal *Mytilus edulis* beds are listed as threatened or in decline in the OSPAR [Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)] List of Threatened and/or Declining Species and Habitats (OSPAR, 2008).

Distribution

Figure 2.6 shows the location of the single licenced mussel site in Ballinakill Harbour. This site covers 0.15km^2 and it is located in the outer harbour close to the northern shore between Letterbeg Point and Tonabinnia.

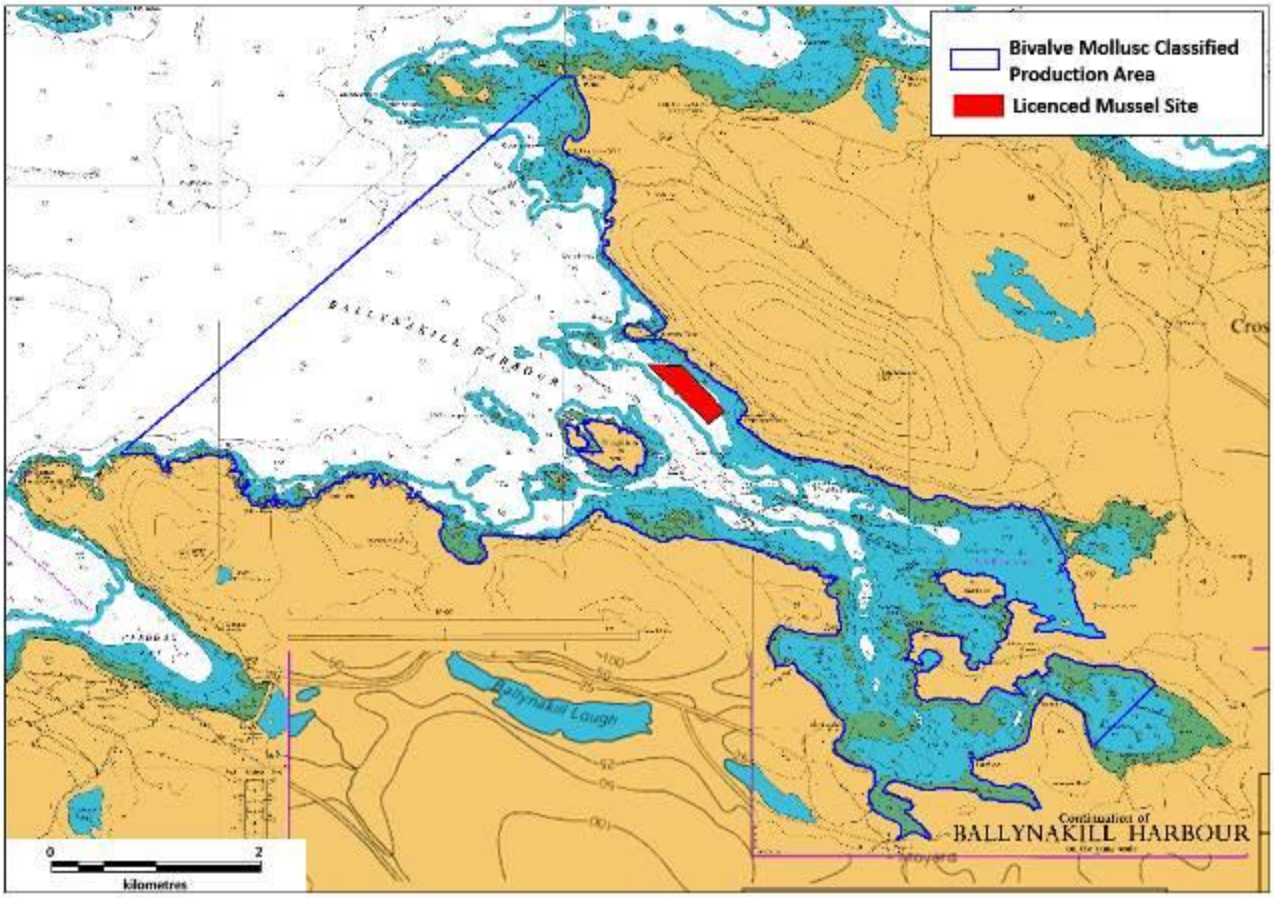


Figure 2.6: Mussel licenced sites in Ballinakill Harbour (Source: DAFM).

Fishery

The mussels in Ballinakill Harbour are in the main, cultured using longlines (Marine Institute, 2013). Long-line culture is an alternative to raft culture in areas less protected from wave action. A long-line supported by a series of small floats joined by a cable or chain and anchored at the bottom on both end is employed. Collected mussel spat on ropes or strings (droppers) are suspended on the line. From each of the lines there are a number of dropper lines (up to 5m in length). The depth of the droppers, which is directly related to the quantity of mussels being cultured, is dependent upon a number of factors; not the least of which is water depth, the flotation provide and the carrying capacity of the system.

Harvesting is intermittent and taken from one site. In harvest years, stock is lifted primarily during the summer months but harvesting can take place during other periods of the year also.

2.2.2.2. Oysters (Crassostrea gigas and Ostrea edulis)

General Biology

Pacific oysters (*Crassostrea gigas*) is native to the Indo-West Pacific region but because of successful introductions into many areas it has now a global distribution. In its native habitat it is an estuarine species preferring firm bottom substrates where it attaches to rocks and other shells. The oyster can grow up to 18 cm and the shell is usually an off white to yellow colour with a bluish grey tinge.

Pacific oysters need a temperature of above 18°C to reproduce (PMFSC [Pacific States Marine Fisheries Commission], 1996). The larvae are planktonic and spend several weeks in this phase. Then after that time, once an acceptable location has been found the oyster drops out of the plankton and attaches itself to its chosen surface, at which point it is known as ‘spat’. All pacific oysters for on-growing/farming in Ballinakill Bay are imported from external suppliers and the species does not occur naturally.

Native oysters (*Ostrea edulis*) are a native European oyster species. They are slower growing and were traditionally found in a number of bays around the Irish coast. Similarly to the pacific oyster they are an estuarine species and again prefer to settle on shell and rock surfaces.

Distribution

Figure 2.7 shows the locations of licenced oyster sites in Ballinakill Harbour. These farmed sites cover an area of 1.7km^2. All of the oyster sites are in the inner harbour area, with one close to the north shore at Derryinver Bay, one in Fahy Bay south of Ross Point, one south of Knocknahaw Point and all around Dawros Beg.

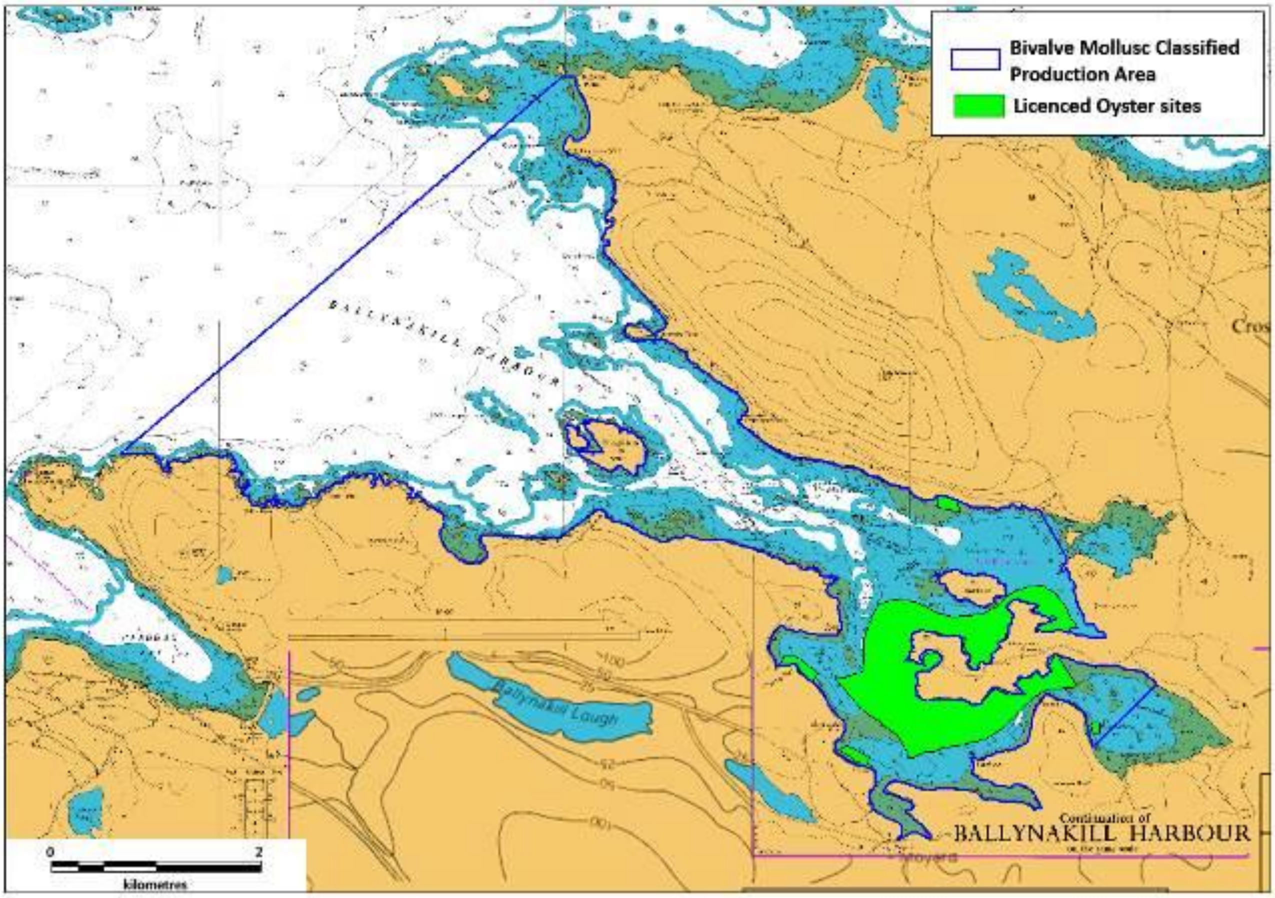


Figure 2.7: Licenced oyster harvesting sites in Ballinakill Harbour (Source: DAFM).

Fishery

Intertidal pacific oyster culture is carried out in bags on trestles in the intertidal zone. There are three oyster companies within the bay with an average annual production of 60 tonnes combined. Harvesting takes place all year round.

Native oysters are currently constrained to the site at Dawros. A wild fishery once existed here but is no longer commercially viable with no significant market size wild stocks remaining. The site licence holder though has imported young native oyster seed for on growing using bags and trestles and is currently growing these oysters to market size. It is envisaged that production may not amount to more than one tonne per year. Harvesting may be all year around depending upon market demand.

*2.2.2.3. Razor Clam (*Ensis *spp.)*

General Biology

Razor clams live in soft sand and mud around the low tide mark. They bury themselves in the sediment using their powerful muscular foot with only a siphon protruding from their vertical burrow. They are filter/suspension feeders and use their siphon to filter plankton out of the water column.

Distribution

The Inshore Fisheries Team of the Marine Institute's Fisheries Ecosystems Advisory Services surveyed the razor clam beds in Ballinakill Harbour in 2016 (FEAS, 2016). The razor clam distribution in Ballinakill Harbour can be seen in Figure 2.8 below. This bed was surveyed on September 14th 2016 aboard MFV Rosanne using a hydraulic dredge. Dredge efficiency was high in the relatively clean loose sand especially on the northern shore. Catches were clean with little dead shell or by-catch. Mixed sediments occurred on the south shore. Mud substrates in the middle channel of the bay are devoid of razor clams. Biomass ranged from 0.1 to 2.93kg/m^2. Average length of *Ensis arcuatus* was 131±17mm and average length of *E. siliqua* was 174±28mm. The biomass of *E. arcuatus* was estimated to be 111 ± 90t in the surveyed area (0.279km^2) and 162 ± 137t in the extended survey area (0.363km^2, potential distribution). The biomass of *E. siliqua* was estimated to be 3t in the surveyed area (0.279km^2) and 3.5t in the extended survey area (0.363km^2). Figure 2.9 and Figure 2.10 show the biomass densities of *E. arcuatus* and *E. siliqua* over the surveyed zone and extended zone in Ballinakill Harbour.

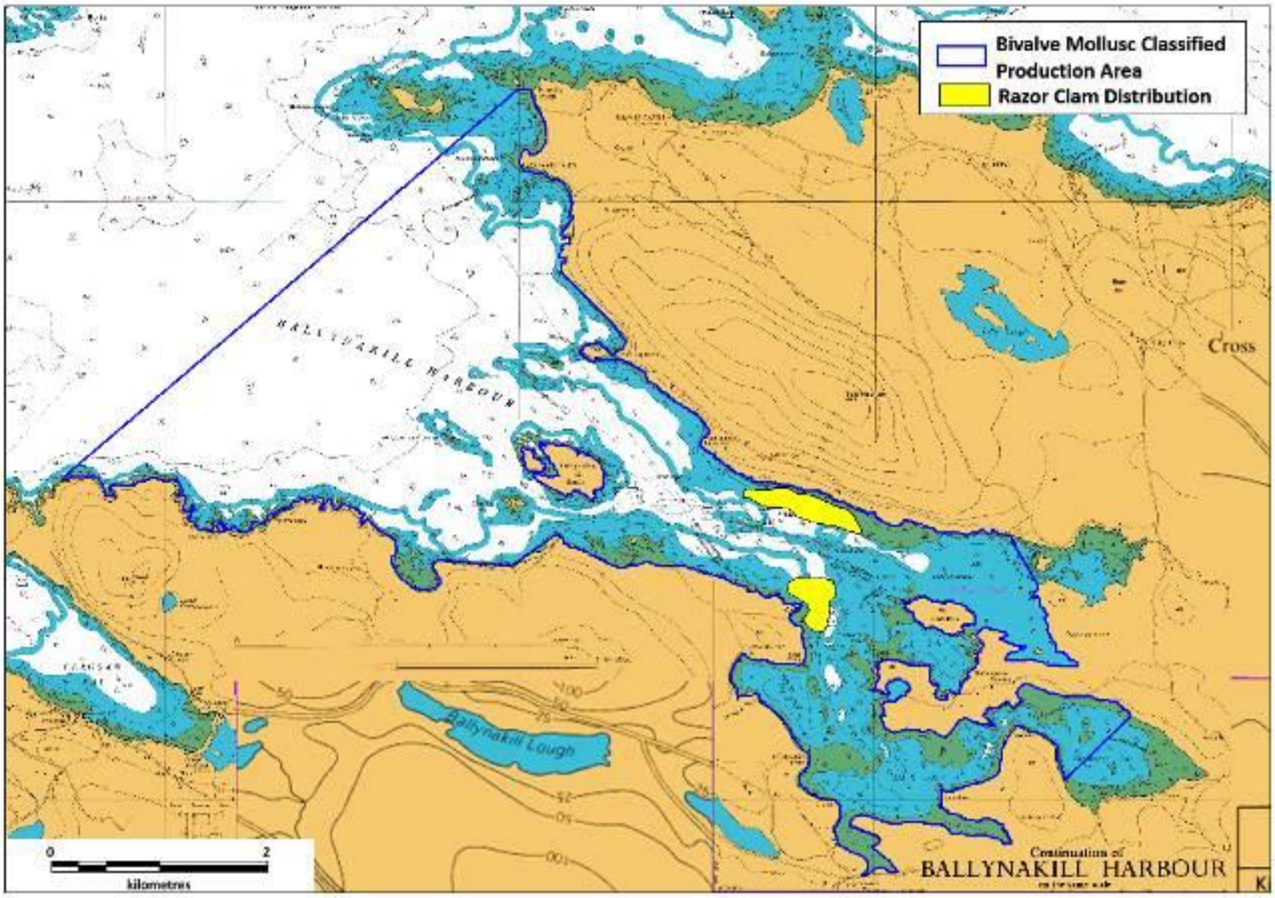


Figure 2.8: Razor clam distribution in Ballinakill Harbour (FEAS, 2016).

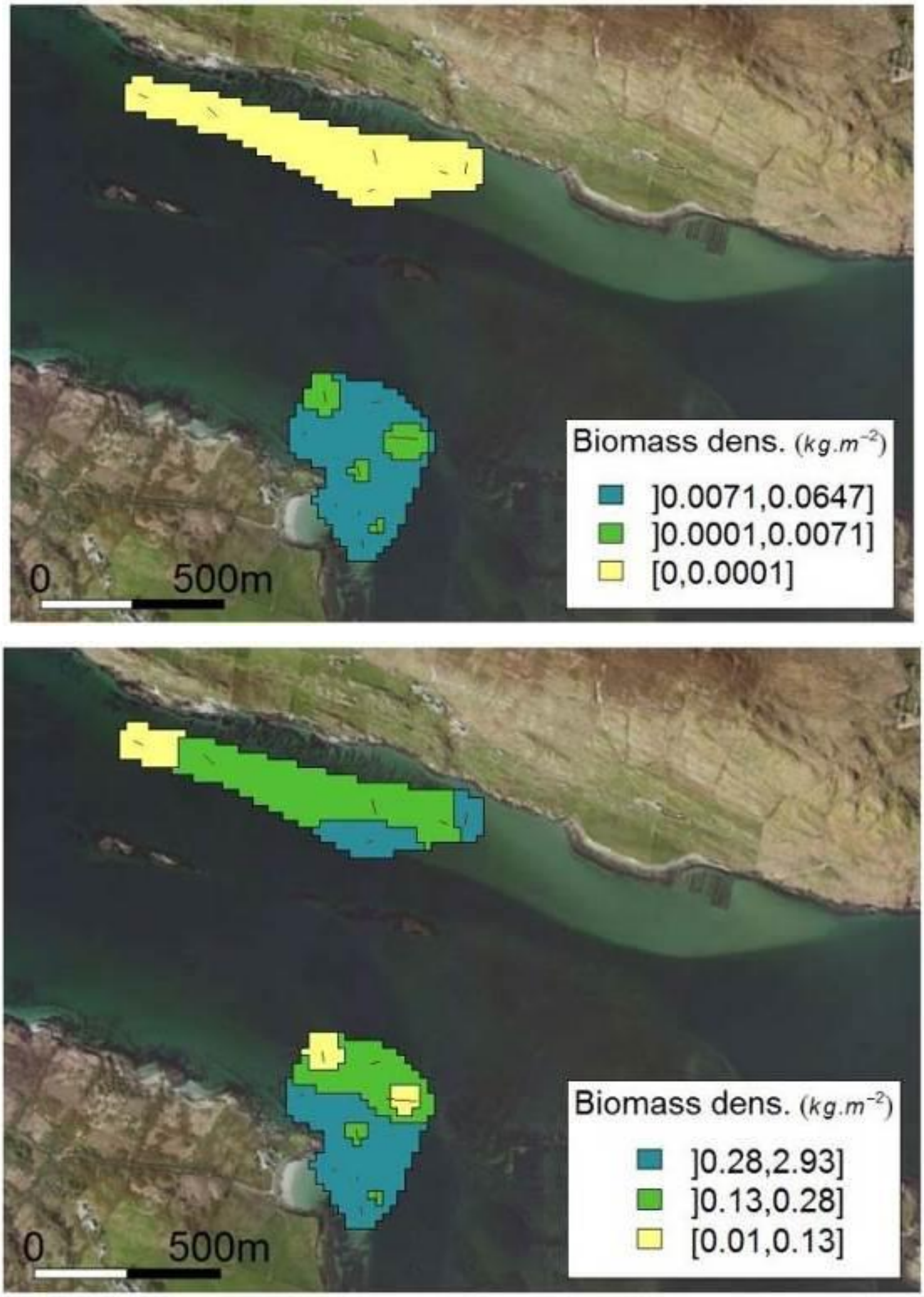


Figure 2.9: Biomass density of *E. arcuatus* (top) and *E. siliqua* (bottom) over the surveyed zone (0.279km^2) in Ballinakill Harbour.

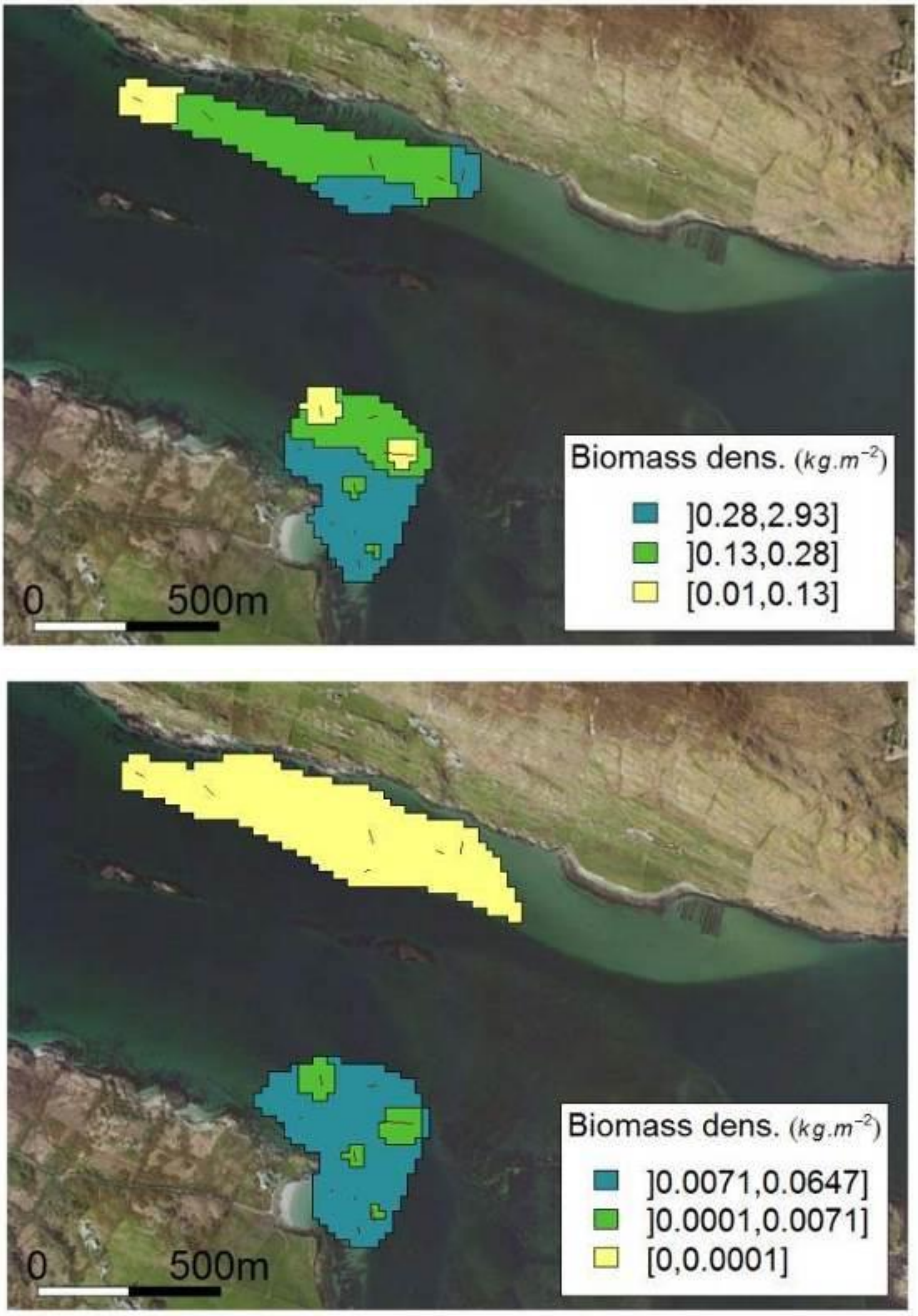


Figure 2.10: Biomass density of *E. arcuatus* (top) and *E. siliqua* (bottom) over the extended zone (0.363km²) in Ballinakill Harbour.

This area was also surveyed more recently in April 2018 (FEAS, 2019). The most abundant species present was *Ensis magnus* with lower densities of *E. siliqua*. The area surveyed was 0.48 km^2. No fishery had recently occurred in the area. Figure 2.11 shows the distribution of razor clams in 2018.

The total biomass of *Ensis magnus* in the bay in April 2018 was 85 tonnes. Approximately 84 tonnes was over 100 mm in shell length. This estimate is lower than the 111 tonnes estimated in 2016 over a smaller area and much lower than the biomass extrapolated to the area of potential habitat available from the 2016 survey. The size distributions are similar in both surveys. The 2018 estimate is more precise than that of 2016 although in both cases the estimates are uncertain. This is largely due to the way the stock is distributed along a narrow strip of sand along the north shore in particular making interpolation and estimation difficult. The biomass of *Ensis siliqua* was 5 tonnes.

The size distribution was skewed towards larger size classes typical of unexploited razor clam stocks.

Figure 2.11. Distribution of razor clams in Ballinakill Harbour in April 2018.

Fishery

The fishery is generally operated by a small number of licenced fishing vessels and the fishery is normally exploited during the summer and autumn periods. The fishing is carried out in the summer/autumn period, but it is intermittent and subject to a locally agreed management plan. Fishing or the harvestable tonnage is based on the Marine Institute stock survey which is carried out annually.

Catch advice for 2018, was 15% of biomass or 13 tonnes for *E. magnus* and 1 tonne for *E. siliqua* (latest MI survey)

*2.2.2.4. Pulled Carpet Shell Clams (*Venerupis corrugata*)*

General Biology

The Pullet Carpet Shell lives burrowed in sand and silty mud. It is a lamellibranch bivalve mollusc that filters water through its 2 siphons (one in and the other out) catching organic matter (detritus) and phytoplankton as food. The gills are two pairs of plates composed of filaments. *Venerupis corrugata* lies buried in sand, gravel or mud bottoms, usually from the low tide mark to a depth of 40 m. Its sexes are separate, although hermaphrodites can be found infrequently. Reproduction is external and takes places mainly during summer in the wild, and/or in hatcheries. The larvae swim freely for 10-15 days before settling as spat of about 0.5 mm on a sand and silty mud substrate (FAO, 2019).

Distribution

Figure 2.12 show the location of Pulled Carpet Clams in Ballinakill Bay. As Pulled Carpet Shell Clams are a by catch of the Razor Clam fishery, the beds are also in the same locations as the Razor Clams.

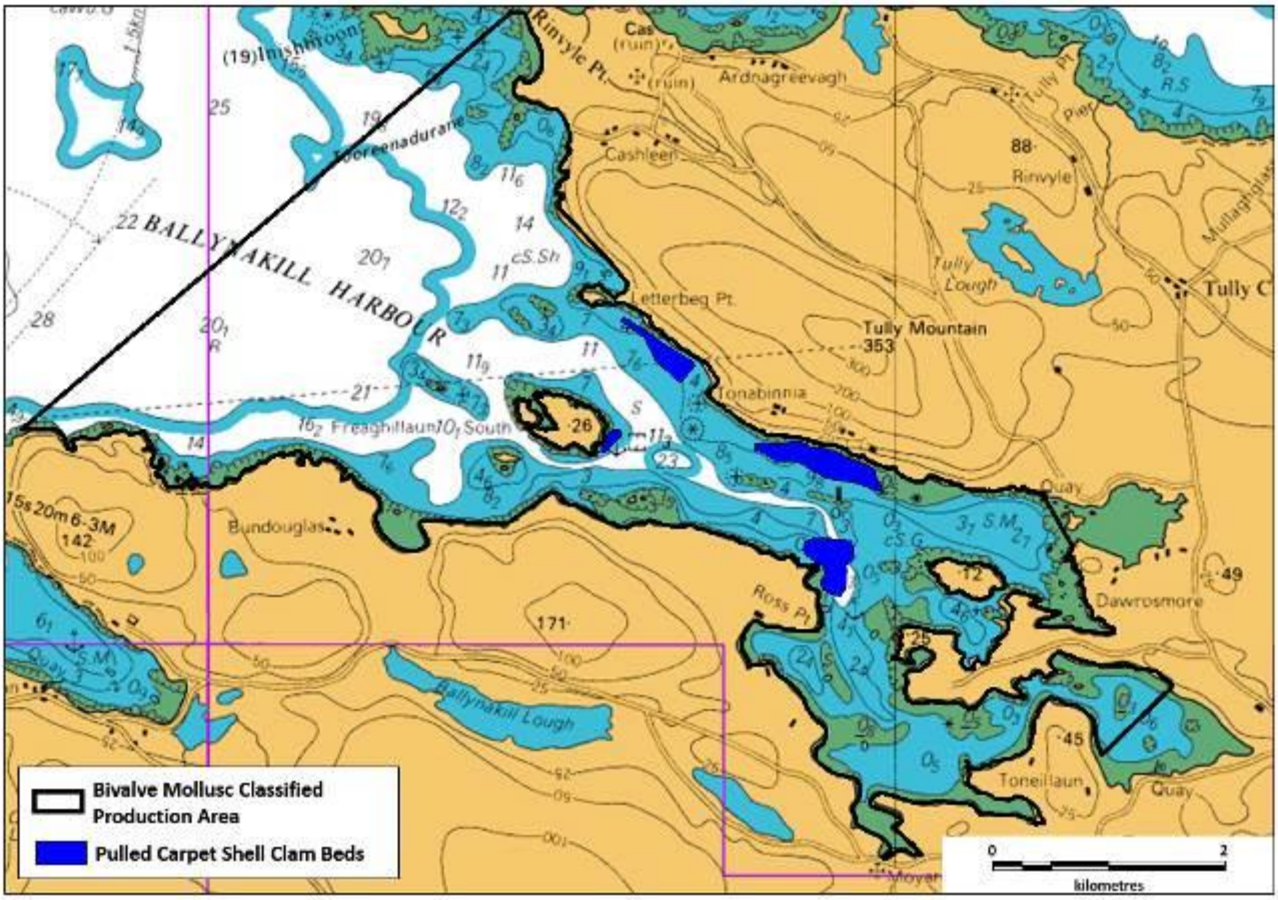


Figure 2.12 Pulled Carpet Shell Clams.

Fishery

A by-catch fishery exists for this species in Ballinakill Bay and small amounts are landed alongside razor clams. The species is found in the same bed areas as the razor clams. During the seasonal opening of the razor clam fishery amounts of up to 200 kg per week can be landed as a by-catch. A specific management plan is set out each year for the razor clam fishery and by default, the carpet shell clams fall under the same scope.

*2.2.2.5. King Scallops (*Pecten maximus*)*

General Biology

King Scallops are filter feeders which can be found anywhere from just below low water to depths exceeding 100m. They prefer sediments consisting of sand, gravel and mud. Scallops are hermaphrodites releasing male and female gametes separately into the surrounding water column. Spawning is synchronised with other scallops in the area. Eggs develop into free swimming larvae over a period of 24-48hrs and migrate to the surface where they stay for three or more weeks. Larvae eventually settle onto the seabed, where they become attached to the substrate and metamorphose into their adult form.

Distribution

Figure 2.13 shows the location of the Scallop dredge fishery within Ballinakill Bay. The main extent of the fishery is located outside of the Ballinakill BMPA; however, it extends into the mouth of the bay.

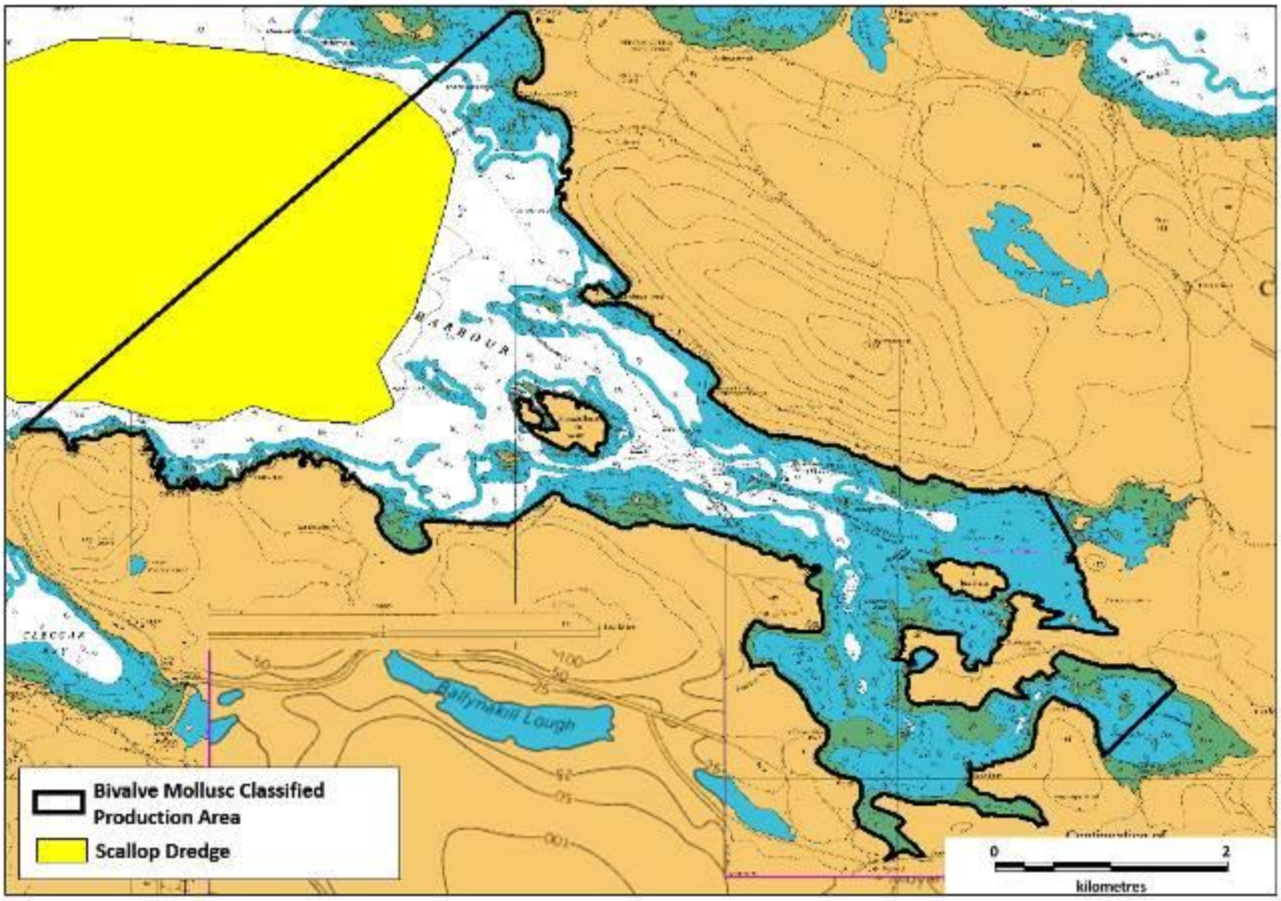


Figure 2.13: Scallop Dredge Fishery.

Fishery

A small fishery exists for wild scallops in the outer approaches of the Ballinakill production area with additional beds laying outside the boundary also. This fishery is exploited intermittently and by no more than one to two boats using towed dredges. Harvesting has not taken place since April 2018 but when the fishery is active, there is no specific seasonality with vessels harvesting from any of the months from January through until August/September.

3. Hydrography/Hydrodynamics

3.1. Simple/Complex Models

On a rising tide, sea water enters Ballinakill Harbour from the southern and fill into the inner parts of the bay. In the narrower parts of the bay and in their deeper parts is where maximum current speeds occur. Marine Computational Services Ltd. developed a hydrodynamic model for Ballinakill Harbour in 1991. Figure 3.1 shows outputs from this hydrodynamic model at mid flood, high water, mid ebb and low water. It can be seen that on a flooding tide water flows into the bay around Freaghillaun South with the strongest currents (30 – 40 cms.sec) flowing south into Fahy Bay and on into Barnaderg Bay. On an ebbing tide, flows in the northern part of the bay *i.e.* in Derryinver Bay, flows are in a westerly direction while in the southern part *i.e.* Barnaderg Bay flows are initially in a westerly direction by head northwest in Fahy Bay and combine with the water flows exiting from Derryinver Bay to flow in a westerly direction out of the bay. As can be seen on Figure 3.1, there is little water movement at both high and low water.

3.2. Depth

In the inner reaches, the harbour divides up to form a number of small shallow bays, namely Derryinver, Roeillaun, Barnaderg and Fahy Bay. Depths in these bays reach a maximum depth of 3 to 5m. The main channel is two pronged comprising a north passage and a south passage, with depths of 10-20m. East of Freaghillaun Island, between the two channels is a depression known as Freaghillaun Deep, with depths down to 24m. There is also a smaller depression, down to 16m west of Roeillaun Bay and north of Fahy Bay. Otherwise, the harbour has a mean depth of 5m. Figure 3.2 shows water depth in the area.

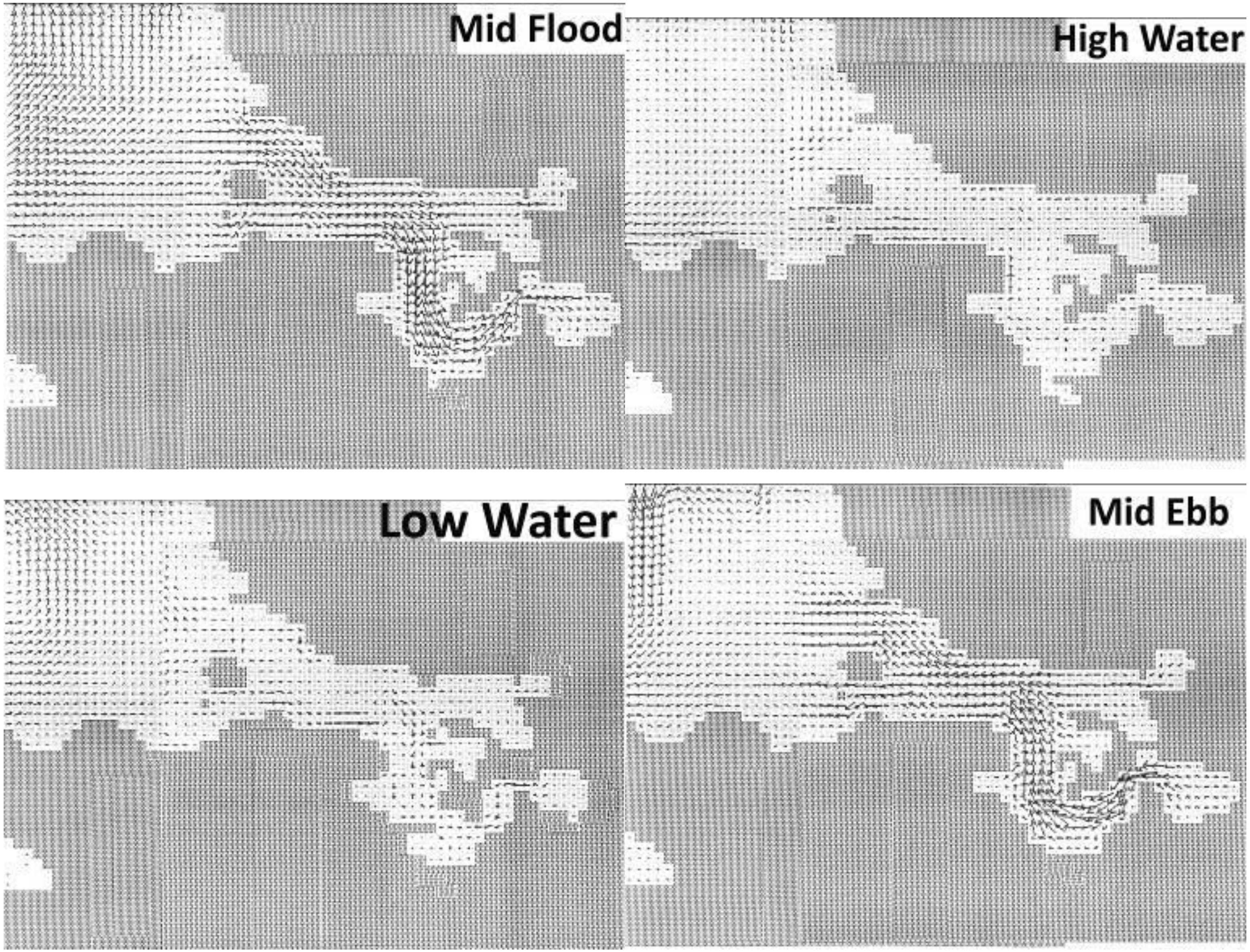


Figure 3.1: Model outputs at mi high water, mid ebb and low (MCS, 1991).

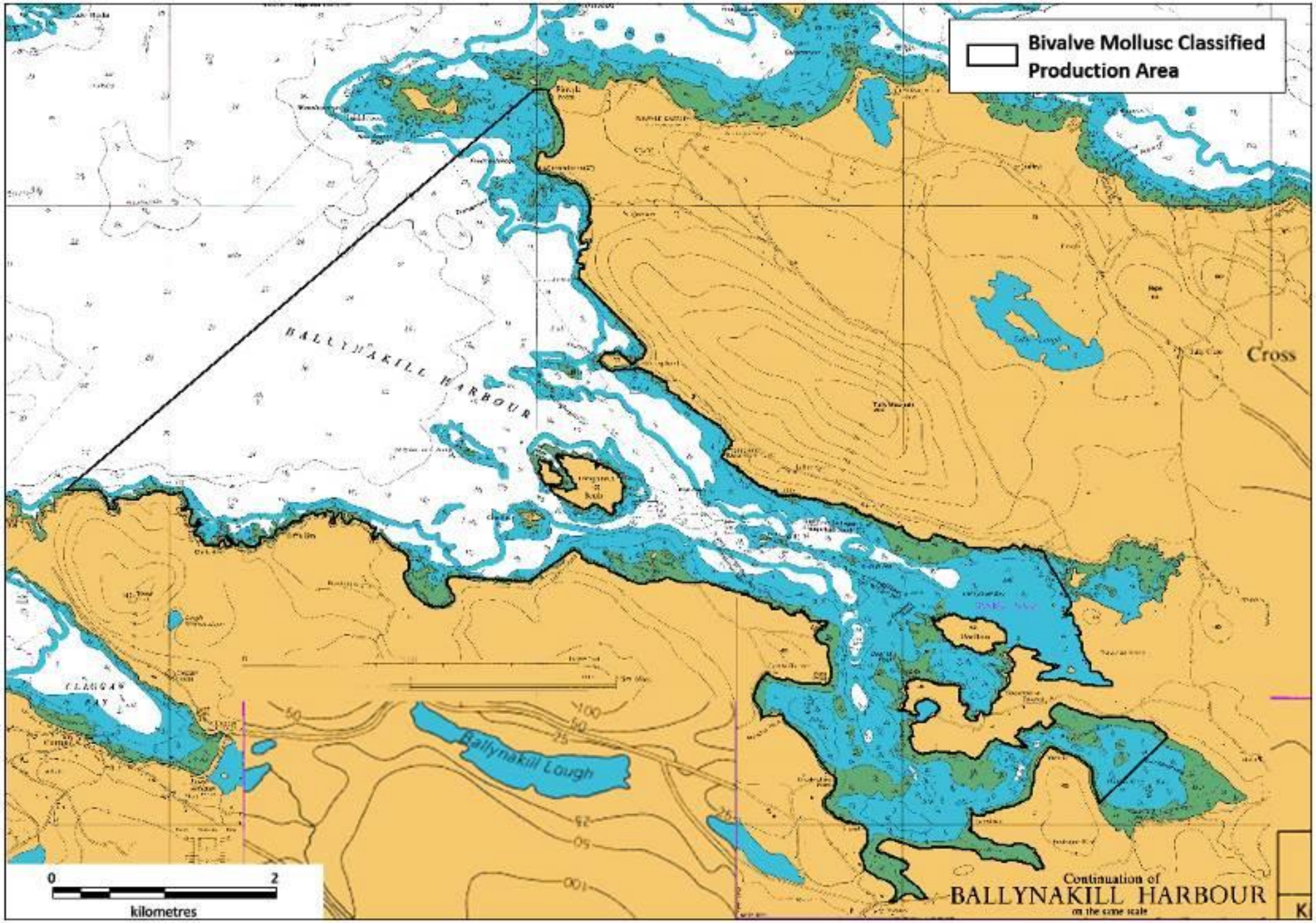


Figure 3.2: Depths in Ballinakill Harbour.

3.3. Tides & Currents

Predicted spring and neap tidal ranges in Ballinakill Harbour are in the region of 3.6 and 1.5m respectively (AQUAFACT, 1991b). Surface and bottom tidal currents are strongest in the main channel with velocities up to 1kn (0.55m/s) and 0.6kn (0.32m/s) for 1 and 10m depths, respectively. While surface currents are at a maximum during the mid-flood tide, the timing of the stronger off-bottom currents occur across a broader spectrum of the tidal cycle (AQUAFACT, 1991a). These velocities compare well with those featured in British Admiralty Chart No. 2706 for the area where velocities of 1kn are recorded on an ebb tide north of Freaghillaun South and velocities of 1.5kn on a flooding tide (0.75m/s) outside the entrance to Ballinakill Harbour (see Figure 3.3).

The direction of tidal flow during the ebb tide seems to be quite variable and it is possible that wind effects accounts for some of the variation at least at the surface (AQUAFACT, 1991a). Conditions are most variable during the period just after high tide. The main direction of water flow at all water depths is to the west or south west during the mid-ebb period while off-bottom waters take on a more southerly aspect as low water is approached. Current flows during a flooding tide are mainly easterly or southeasterly in direction for all water depths.

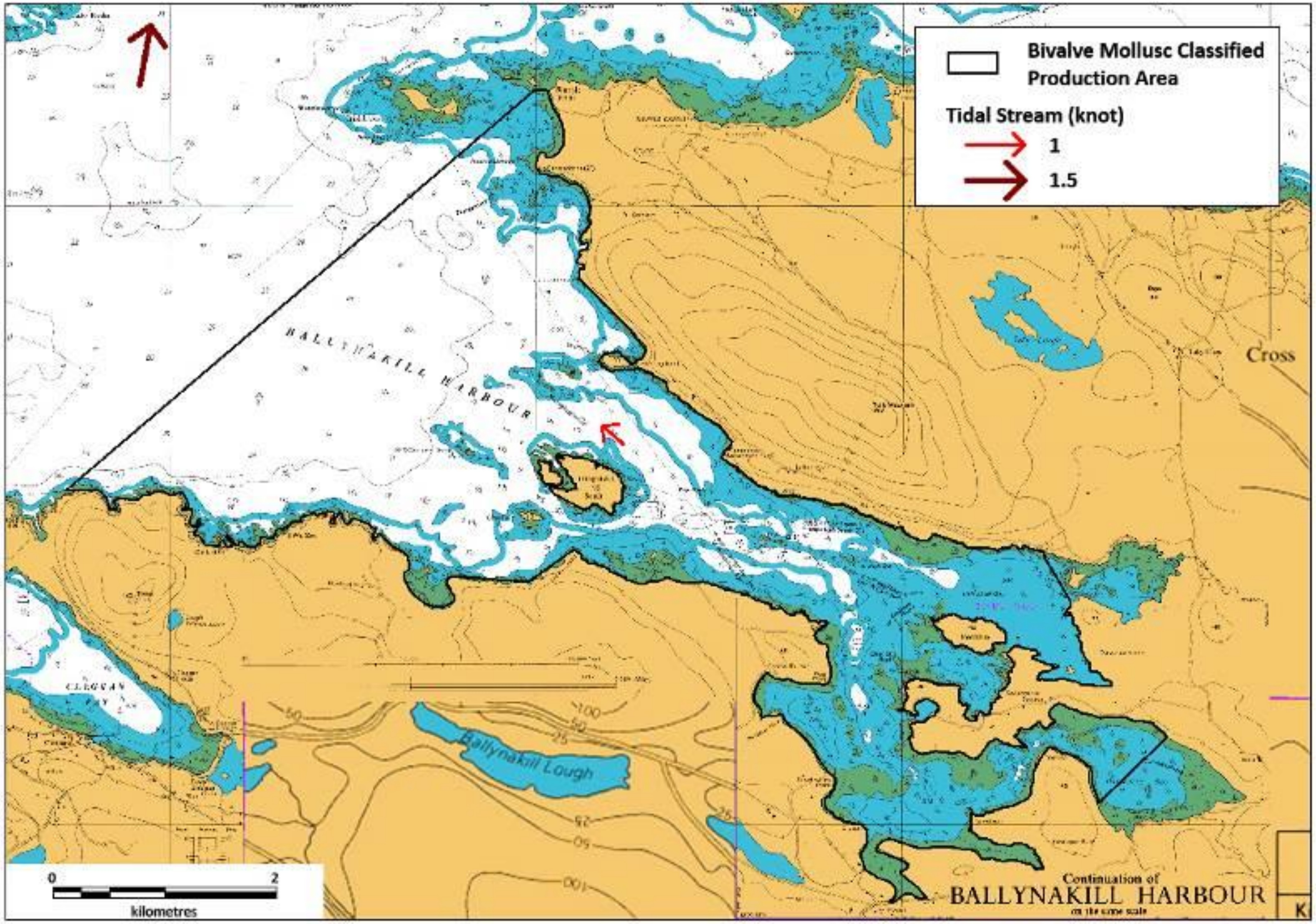


Figure 3.3: Tidal streams within Ballinakill Harbour (Admiralty Chart 2706).

3.4. Wind and Waves

Wind data from 2014 to 2018 from the Mace Head station (Co. Galway, located approximately 28km south of Ballinakill Harbour) are displayed in Table 3.1 below and wind roses for each year can be seen in Figure 3.4 below. In 2014, 31% of the wind came from the southwest, while 23% can from the west and 15% from the east. The strongest winds came from the west (19.7kn). In 2015, 38.5% of the wind came from the west, 23% from the west-southwest and 15% from the west-northwest. The strongest winds (21.9kn) came from the west-southwest. In 2016, 38.5% of the wind came from the southwest and 15% came from each of the following directions: the west-southwest, south-southwest and south. The strongest winds (18.1kn) came from the south-southwest. In 2017, 31% of the winds came from the southwest, with 23% coming from the south-southwest and 15% coming from the west and the south. The strongest winds (17.3kn) came from the southwest. In 2018, 38.5% of the wind came from the southwest and 15% came from each of the following directions: the west-southwest, south-southwest and south-southeast. The strongest winds (20.3kn) came from the southwest. It can be seen from these data that the prevailing wind direction is southwest.

Table 3.2 shows the seasonal averages from 2014 to 2018. Seasons were selected by grouping the results from the following periods: spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Seasonal averages over the past 5 years indicate that winds are typically strongest in the winter months (18.1kn), followed very closely by autumn (15.0kn), decreasing to 13.5kn in spring and 12.7kn in summer.

Table 3.1: Wind speed and direction data for Mace Head from 2014-2018 (Source: Met Eireann, 2019a; 2019b).

	2014		2015		2016		2017		2018	
Month	**Mean Speed (knots)**	**Max 10-min Mean Direction (°)**	**Mean Speed (knots)**	**Max 10-min Mean Direction (°)**	**Mean Speed (knots)**	**Max 10-min Mean Direction (°)**	**Mean Speed (knots)**	**Max 10-min Mean Direction (°)**	**Mean Speed (knots)**	**Max 10-min Mean Direction (°)**
January	18.8	216	21.9	240	17.3	227	14.3	184	20.3	220
February	21	280	15	270	18.1	206	17.1	194	16.5	227
March	14.5	214	17	260	14.8	215	14.5	211	13.3	167
April	12.3	80	11.9	270	13.6	216	11.7	265	13.4	178
May	13.2	270	16.2	290	11.3	173	12.2	186	11.9	202
June	9.4	90	12.8	200	11.3	248	15	211	10	230
July	10.7	200	14.7	250	12.7	253	12.8	234	10.3	248
August	14.1	220	13.9	180	15.3	217	13.9	230	14.2	231
September	9.1	220	12.5	290	16.1	217	15.7	222	15.3	243
October	17.1	290	12.4	240	12.3	148	17.3	226	16.2	228
November	13.9	180	20.9	280	12.9	211	15	263	17.6	163
December	19.7	270	21.8	260	16.8	185	16	240	16.3	192

Degrees Direction Key: 0°/360° = N; 23° = NNE; 45° = NE; 68° = ENE; 90° = N; 113° = ESE; 135° = SE; 158° = SSE; 180° = S; 203° = SSW; 225° = SW; 248° = WSW; 270° = W; 293° = WNW; 315° = NW; 338° = NNW.

.

Table 3.2: Seasonal averages (knots) for Mace Head wind data (Source: Met Eireann, 2019a; 2019b).

Season	2014	2015	2016	2077	2018	5-year Average
Winter	19.8	19.6	17.4	15.8	17.7	18.1
Spring	13.3	15.0	13.2	12.8	12.9	13.5
Summer	11.4	13.8	13.1	13.9	11.5	12.7
Autumn	13.4	15.3	13.8	16.0	16.4	15.0

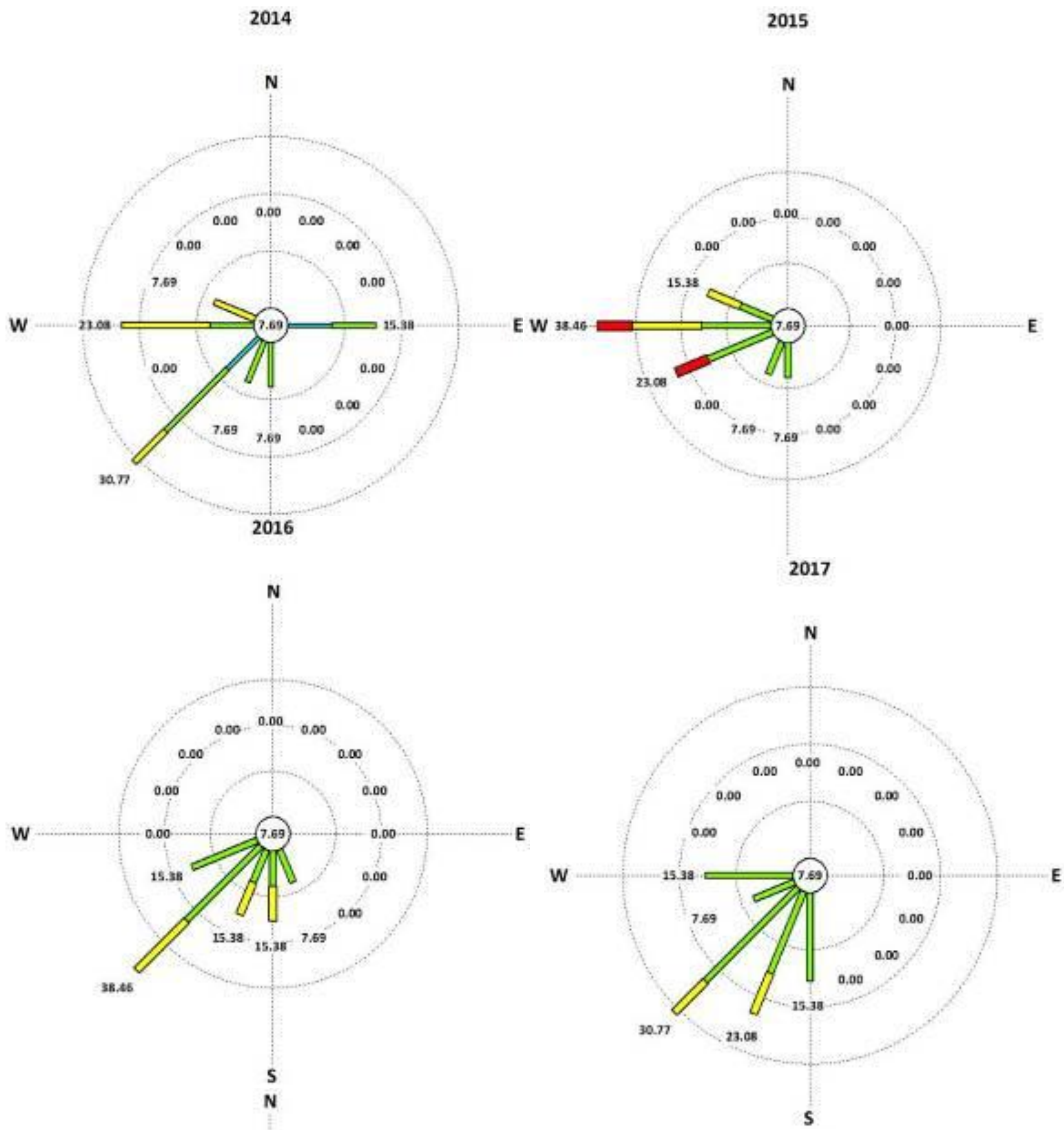
Wind conditions affect the hydrodynamic conditions in an area by generating wind-induced currents and waves. Of these phenomena, wind-induced waves are an important factor in the process of sediment resuspension and transport. Wind waves are produced by the local prevailing wind. They travel in the direction of the prevailing wind, *i.e.* a southwesterly wind will produce northeasterly moving waves. The height of wind waves depends on:

- the strength of the wind,
- the time the wind has been blowing and
- the fetch.

The following conclusions were drawn from the results of a wave climate study developed for Ballinakill Harbour (AQUAFACT, 2001):

- The wind speed and direction are the major influences on wave generation within the Bay.
- Based on the predictions for the 50-year wind (70 kph) blowing from the south, the maximum wave height likely to occur would be in the region of 1.03m with a period in the region of 3.63s.
- Based on the predictions for the 50-year wind (70 kph) blowing from the south-southwest, the maximum wave height likely to occur would be in the region of 1.2m with a period in the region of 3.85s.
- Based on the predictions for the 50-year wind (70 kph) blowing from the south-southeast, the maximum wave height likely to occur would be in the region of 0.9m with a period in the region of 3.39s.

Based on these predicted wave heights, it is only the shallower (*i.e.* ≤ 2m) southern parts of Ballinakill Bay and where fetch distances are sufficiently long (fetch lengths in both Barnaderg and Dawros Bays are too short) that will experience re-suspension of bottom sediments and this material will be carried in a northeasterly direction across the bay to areas that are not used for any shellfish production. As this part of Ballinakill Bay is distant from where the major source of faecal pollution occurs *i.e.* the Sruffanboy Stream in Inner Barnaderg Bay, the possibility of significant levels of *E.coli* occurring the sediments is low. The potential therefore of possible wind-induced re-suspension of sediments affecting shellfish production sites in Ballinakill Bay is considered extremely low.



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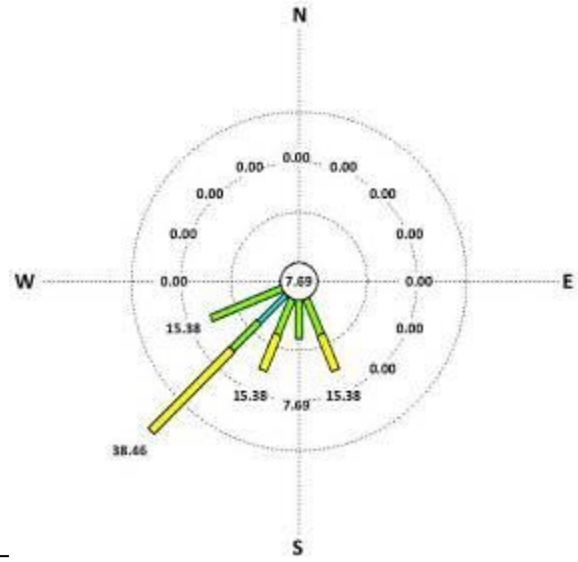
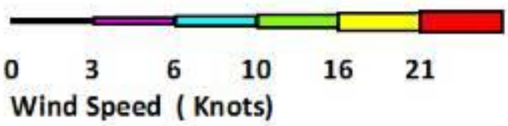
to 2018 (Source: Met Eireann, 2019a; 2019b).





3.5. River Discharges

Ballinakill Harbour drains a catchment of 103.7km^2. The main freshwater flow comes from the Dawros River to the north eastern end of the bay, which drains *c.* 55.5% of the catchment (see Figure 3.5). The Polladirk River, Kylemore River, Mweelin River, Shanaveagh River and Kylemore Lough all flow into the Dawros River. In the southeastern corner of the bay, the Sruffanboy Stream, Owengarve Stream and the Owennabaunoge River flow into Barnaderg Bay. The Traheen River, Tullyboy Stream and Moyard River all flow into the harbour south of Fahy Bay. The three former rivers drain *c.* 17.3% of the catchment and the 2 latter rivers drain 11% of the catchment. Ballinakill Lough is located on the southern side of the bay and drains a catchment of 14km^2 (13.5% of the total catchment), which then flows into the southwestern end of Ballinakill Bay. The remaining 2.6% of the catchment drains from small streams on the southern slope of Tully Mountain located on the northern shore of the bay. No flow data are available.

The current (2010-2015) WFD status of Ballinakill Harbour and its associated freshwater sources can be seen in Figure 3.6. Of the river and lake systems flowing directly into the Ballinakill Harbour BMCPA, the Dawros is of High status, the Owengarve Stream, Owennabaunoge and Traheen Rivers are of Good status and the rest are unassigned. The tributaries of the Dawros River have either a Good or High status and Ballinakill Lough and Kylemore Lough are both of Good status. The coastal waters of Ballinakill Harbour itself are unassigned.

The Owengarve Stream, Owennabaunoge and Traheen Rivers are at risk of not meeting their WFD objectives as is the Kylemore River while the Tullyboy and Moyard are under review.

During periods of high rainfall when the rivers are in flood, three features of the flows in the harbour will be affected:

1. The flushing rate of the bay will increase as the excess water has to be either emptied out of the bay or absorbed into the sea water and
2. As the tide fills, the fresh water will be backed up by the rising tide and a steep salt wedge will form and surface flows will decrease in velocity
3. As the tide ebbs, this salt wedge will decrease in terms of steepness and it will also spread out over a greater area of the bay and flows will increase in velocity.

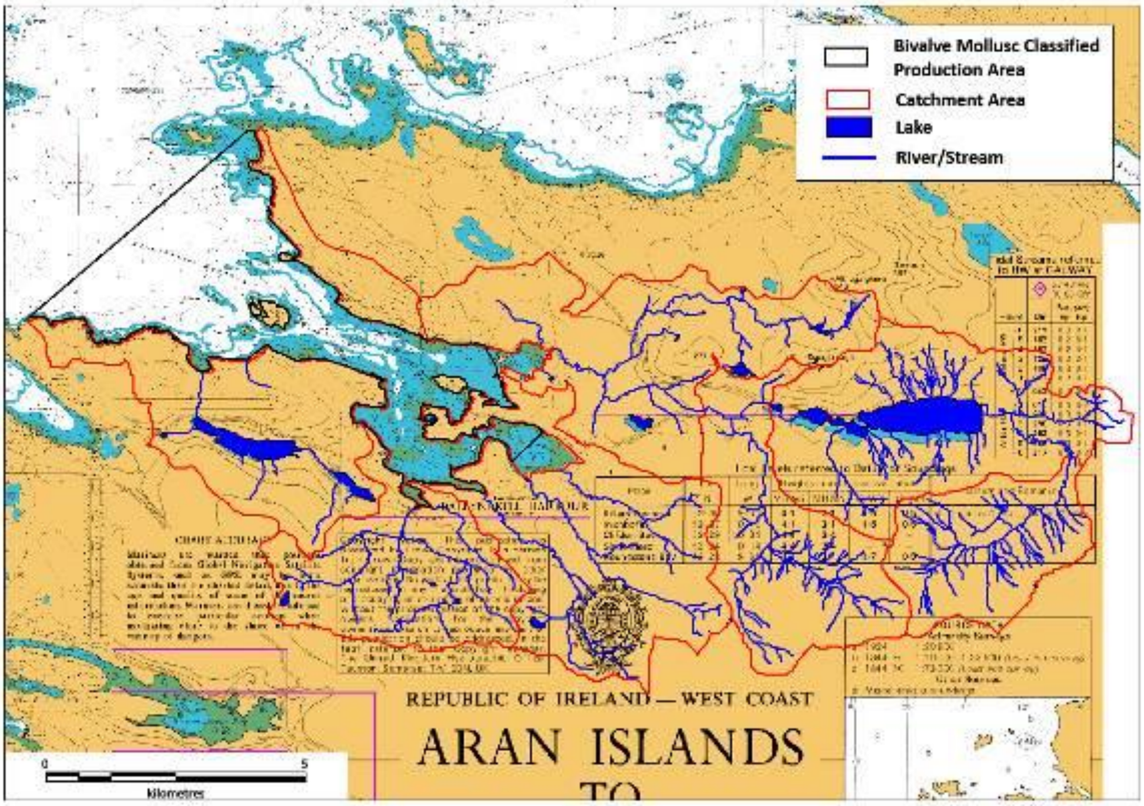


Figure 3.5: Rivers, streams and lakes in the catchment area (Source: EPA, 2019).

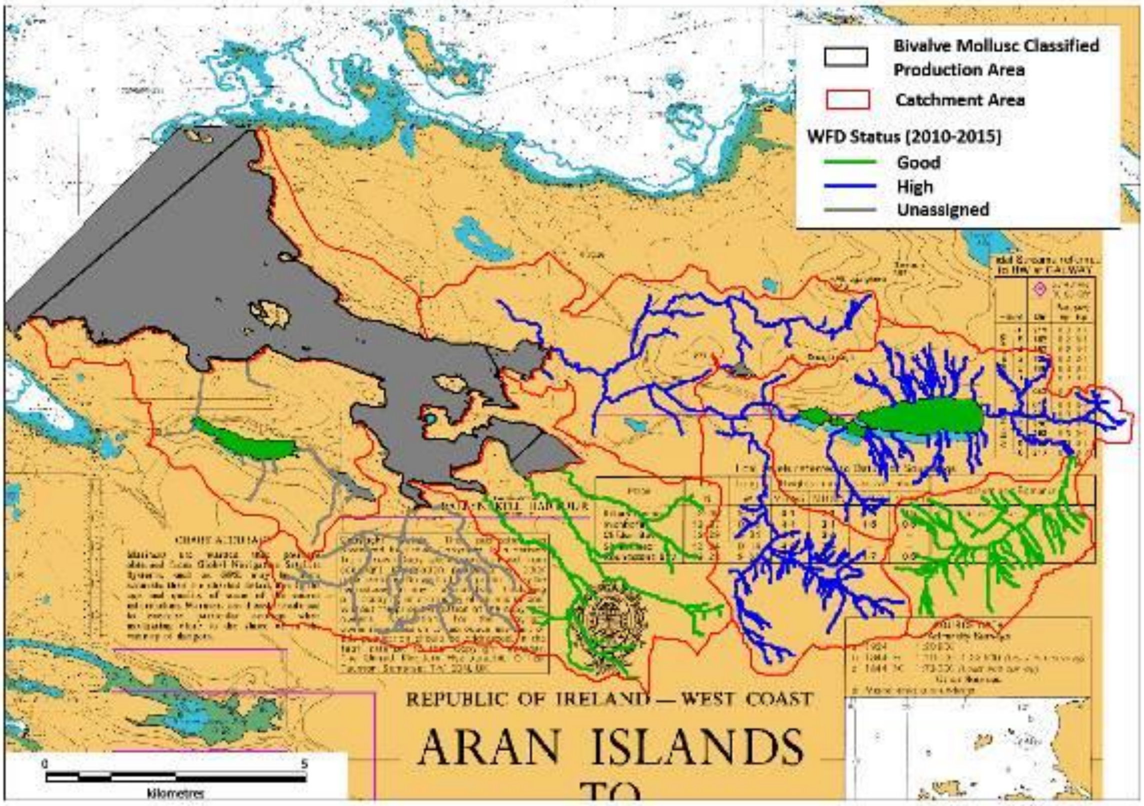


Figure 3.6: WFD Status of the coastal, transitional, lake and river waterbodies in the catchment area (Source EPA, 2019).

3.6. Rainfall Data

3.6.1. Amount & Time of Year

Figure 3.7 shows the average monthly rainfall data for Ireland (Met Eireann, 2019c) from 1981 to 2010. The wettest months in the Ballinakill Bay region over this 30-year period were October to January with the driest months from April to July. Table 3.5 shows the 30-year average monthly rainfall at the Belmullet station which is located *c.* 68km north of Ballinakill Harbour BMCPA (Figure 3.9 shows the location of the Belmullet station). During the period 1981 to 2010, average rainfall at Belmullet was lowest in May (70.4mm) and highest in October (145.9mm). The greatest daily total ranged from a low of 25.6 in March to a high of 79.6mm in October. Table 3.6 shows the seasonal averages at Belmullet from 1981 to 2010. Lowest average rainfall over the 30 year period was in spring (80.5mm) with the highest average rainfall experienced in autumn (127.2mm).

Table 3.3: Monthly average rainfall at Belmullet from 1981 to 2010 (Source: Met Eireann, 2019d).

Month	Average Rainfall (mm)	Greatest Daily Total (mm)
January	134.0	44.7
February	97.1	31.3
March	99.2	25.6
April	72.0	25.9
May	70.4	42.2
June	72.1	38.9
July	79.0	33.2
August	101.9	49.5
September	101.8	62.6
October	145.9	79.6
November	134.0	43.0
December	137.4	41.7
Year	1244.8	79.6

Table 3.4: Average seasonal rainfall values (mm) from 1981-2010 at Belmullet (Source: Met Eireann, 2019d).

Season	Average
Spring	80.5
Summer	84.3
Autumn	127.2
Winter	122.8

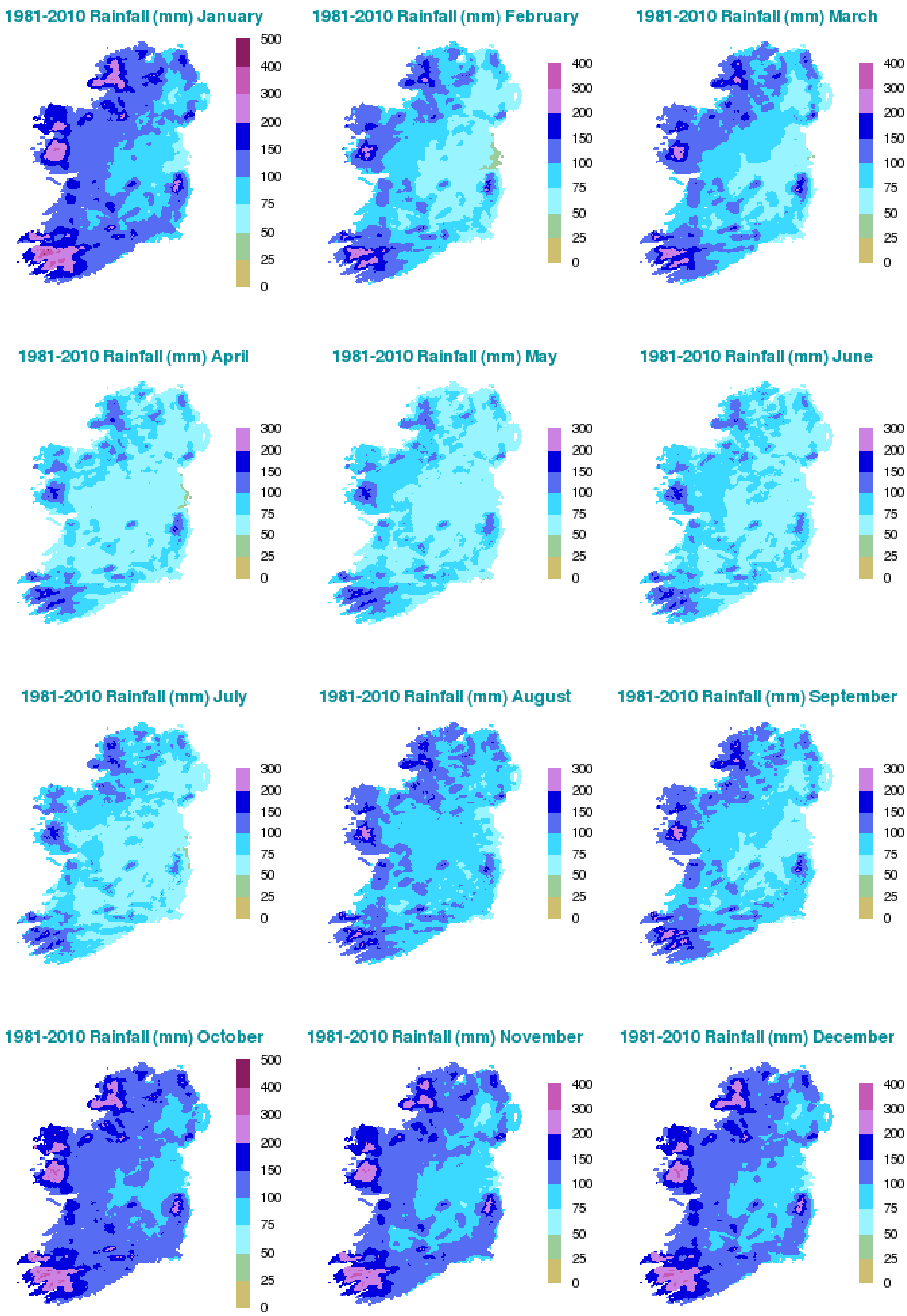


Figure 3.7: Average monthly rainfall (mm) data from 1981 to 2010 for Ireland (Source: Met Eireann, 2019c).

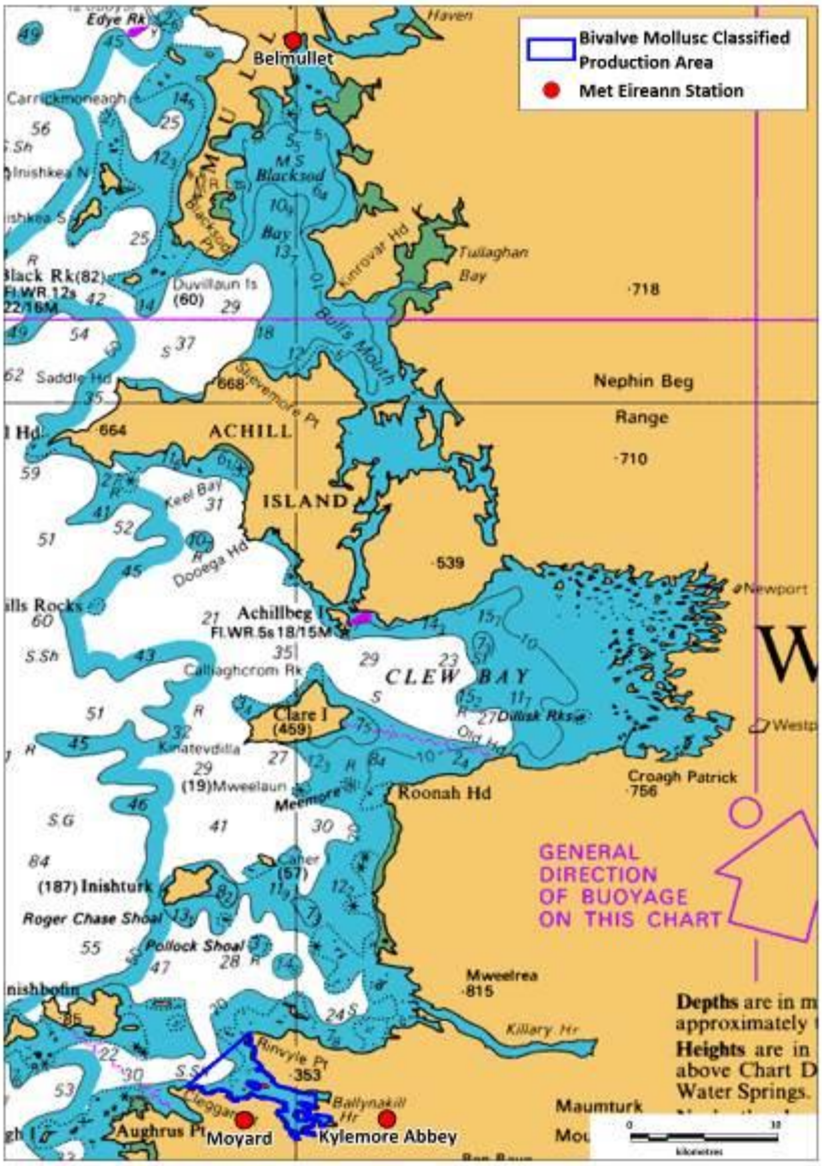


Figure 3.8 Location of Met Eireann weather stations in relation to Ballinakill Harbour.

Tables 3.5 and 3.6 show total monthly rainfall at two Met Eireann stations (Kylemore Abbey Gardens and Moyard, see Figure 3.8) located around the Ballinakill Harbour BMCPA from 2014 to 2018 (Met Eireann, 2019e; 2019f).

The Kylemore Abbey Gardens station is located 3.8km east of Ballinakill Harbour BMCPA. Maximum monthly rainfall was in December 2015 (420.8mm) and the lowest monthly rainfall was September 2014 (22.2mm). The 5-year average monthly rainfall ranged from a low of 106.6mm in April to a high of 285.2mm in January. Annual averages ranged from 171.7mm in 2016 to 200.7mm in 2015.

The Moyard station is located 2.3km west of Ballinakill Harbour BMCPA. Maximum monthly rainfall was in January 2014 (293.6mm) and the lowest monthly rainfall was September 2014 (20.3mm). The 5-year average monthly rainfall ranged from a low of 64mm in April to a high of 201.64mm in January. Annual averages ranged from 123mm in 2018 to 140.7mm in 2015. Over the 5-year period, Kylemore Abbey Gardens was almost 35% wetter than Moyard. Total rainfall at Kylemore Abbey Gardens was 10,286mm[2] compared to 7,536mm at Moyard.

Table 3.7 shows the total seasonal rainfall at Kylemore Abbey Gardens and Moyard from 2014-2018 (Met Eireann, 2019e; 2019f). The following seasonal fluctuations were observed from 2014-2017 (as a complete data set was not available for 2018, this year was excluded from the summary): In 2014, at both locations, summer was the driest season and winter was the wettest, in 2015 spring was the driest at both locations and winter was the wettest. In 2016, at both locations, spring was the driest and winter was the wettest and in 2017 spring was the driest at both locations and autumn was the wettest. On average over the 2 stations, summer was the driest season in 2014, with spring being the driest from 2015 to 2017 and winter was the wettest season from 2014 to 2016 with autumn being the wettest in 2017.

Table 3.5: Total monthly rainfall (mm) data at Kylemore Abbey Gardens Co. Galway, from 2014 to 2018

Year	2014	2015	2016	2017	2018	Monthly 5 yr Average
Jan	384.6	277.3	350.1	133.2	280.9	285.2
Feb	350.1	164.1	263.5	193.8	165.9	227.5
Mar	175.5	164.4	155	208.2	128.2	166.3
Apr	101.9	79.8	116.5	44.2	190.8	106.6
May	153.6	166.3	73	104.3	125.5	124.5
Jun	76.3	109.4	116.1	164.4	98.5	112.9
Jul	116.6	186.2	140.5	167	136.1	149.3
Aug	148.6	188.5	169.4	232	N/A	184.6
Sep	22.2	259	311.8	215.7	317.4	225.2
Oct	259.1	136.4	97.2	230.5	N/A	180.8
Nov	198.7	256.7	118.8	183.7	N/A	189.5
Dec	228.9	420.8	148	281.1	N/A	269.7
Annual Average	184.7	200.7	171.7	179.8	180.4	-

[2] With data from August, Oct-Dec 2018 missing

Table 3.6: Total monthly rainfall (mm) data at Moyard, Co. Mayo, from 2014 to 2018 (Source: Met Eireann, 2019f).

Year	2014	2015	2016	2017	2018	Monthly 5 yr Average
Jan	293.6	193.7	236.9	85.3	198.7	201.64
Feb	234.5	105.4	179.4	124.1	120.6	152.8
Mar	97.8	123.4	109	153.6	82.2	113.2
Apr	70.7	55	69.9	23.4	101	64
May	113.8	117.5	49.1	67.8	97.5	89.14
Jun	32.3	76	98	102.9	49.7	71.78
Jul	70.8	130.1	103.2	125.5	70.6	100.04
Aug	97.2	115.5	159.5	177	142.5	138.34
Sep	20.3	239.9	237.3	162.1	161.4	164.2
Oct	181.1	81.4	79	156.9	132	126.08
Nov	128.2	185.6	90.1	138.1	196.4	147.68
Dec	161	264.8	87.1	179.5	N/A	173.1
Annual Average	125.1	140.7	124.9	124.7	123.0	-

Table 3.7: Total seasonal rainfall (mm) at Kylemore Abbey Gardens and Moyard from 2014-2018 (Met Eireann)

Station	Season/Year	2014	2015	2016	2017	2018
Moyard	Spring	282.3	295.9	228	244.8	280.7
	Summer	200.3	321.6	360.7	405.4	262.8
	Autumn	329.6	506.9	406.4	457.1	489.8
	Winter	689.1	563.9	503.4	388.9	319.3#
Kylemore	Spring	431.0	410.5	344.5	356.7	444.5
	Summer	341.5	484.1	426.0	563.4	234.6**
	Autumn	480.0	652.1	527.8	629.9	317.4*
	Winter	963.6	862.2	761.6	608.1	446.8#
Averages	Spring	356.7	353.2	286.3	300.8	362.6
	Summer	270.9	402.9	393.4	484.4	248.7
	Autumn	404.8	579.5	467.1	543.5	403.6
	Winter	826.4	713.1	632.5	498.5	383.1

* No data for October & November
** No data for August
# No data for December

3.6.2. Frequency of Significant Rainfalls

Figure 3.9 shows the average monthly rainfall at Belmullet from 1981-2010 and Figure 3.10 shows the 5-year average and total monthly rainfall at Kylemore Abbey Gardens and Moyard. Over the 30-year period from 1981 to 2010, October was the wettest month followed closely by December and then November and January. Over this period, October followed by September had the greatest daily rainfall. Over the past 5 years, January has been the wettest month at both stations around the BMCPA. This was followed by December[3] and February at Kylemore and by December[3] and September at Moyard. Figure 3.10 also shows the monthly average rainfall averaged across the two locations (Kylemore and Moyard). Overall, January, December and September were the wettest months followed by February and November.

For the 5-year 2014-2018 period, average greatest daily rainfall at Kylemore Abbey Gardens was 32.2mm, with a maximum of 95.1mm and average greatest daily rainfall at Moyard was 26.2mm, with a maximum of 125.1mm. Across both sites, average greatest daily rainfall was 29.2mm, with an average maximum of 110.1mm. Over the same period, the number of wet days (rainfall >1mm) a month averaged at 18.6 with the maximum number averaging at 30.5 days/month.

Met Eireann has developed a depth duration frequency model for the estimation of point rainfall frequencies (Fitzgerald, 2007; Met Eireann, 2019g). For a 1 in 100 year return period, 32.9mm of rain would be expected over 1 hour and 126.5mm over 24 hours. Whiles these would be extreme uncommon events, the model predicts that once a year 10.9mm would fall in 1 hour and 42.3mm over a 24 hour period.

Increased faecal contamination of coastal waters is typically associated with high rainfall and storm events through surface water run-off from livestock or other animals present and through sewer and waste water treatment plant overflows (Mallin *et al.,* 2001; Lee & Morgan, 2003). It is therefore expected that run-off due to rainfall will be higher during the September to February period. However, as can be seen in the data below, extreme rainfall events leading to episodes of high run-off can occur in most months of the year and it is therefore not just the winter months that are at risk of increased contamination. When these occur during generally drier periods in spring and summer months, they are likely to carry higher loadings of faecal material which has accumulated on pastures where greater numbers of livestock are present.

[3] Despite there being no 2018 December data

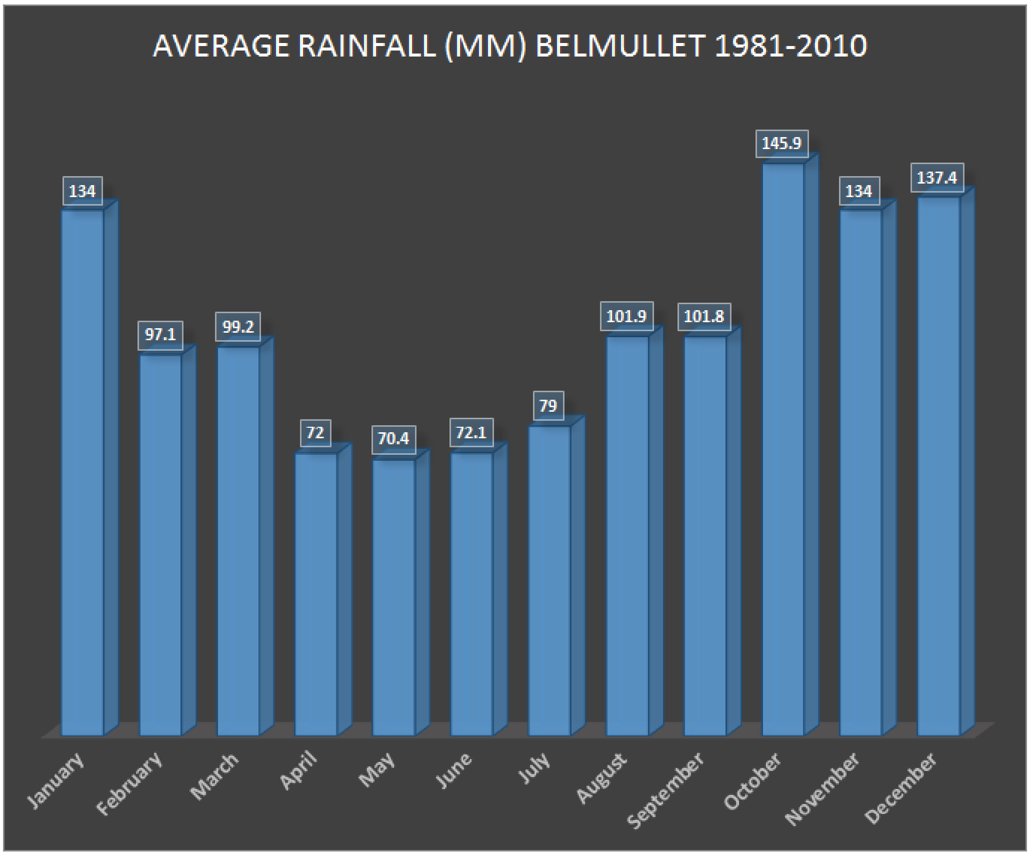


Figure 3.9: Average monthly rainfall (mm) at Belmullet from 1981-2010 (Source: Met Eireann, 2019d).

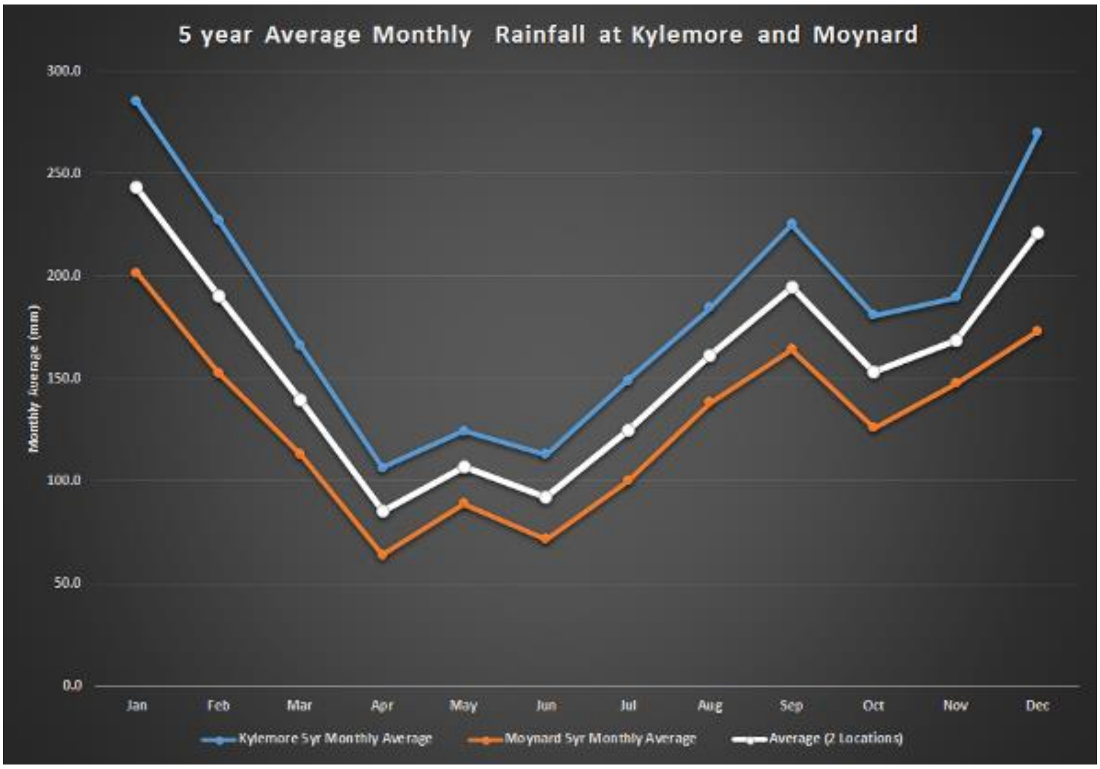


Figure 3.10: 5-year average monthly rainfall (mm) at Kylemore Abbey Gardens and Moyard (and average across 2 locations) from 2014-2018 (Source: Met Eireann, 2010e, 2010f).

3.7. Salinity

Surface salinities range from 32 to 34 PSU. Ballinakill Harbour is best described as a partially mixed estuary. The occasional occurrence of stratified conditions are mainly due to local conditions of evaporation, precipitation and wind particularly in the inner harbour and a halocline can be found during winter when wind speeds are low and rainfall is high (Southern, 1914). However, this halocline can be quickly dissipated in a few hours when strong winds occur.

Salinity monitoring indicates a good degree of mixing however, there is a tendency for salinities to be somewhat lower on the surface than for deeper waters with some quite low values following periods of high rainfall (AQUAFACT, 1991b). This pattern reflects the occasional influence of freshwater runoff into Ballinakill Harbour and is expected for this type of bay.

3.8. Turbidity

Marine Institute Shellfish Waters Directive monitoring indicate low levels of suspended sediments in Ballinakill harbor, ranging from <5mg/l (April, June and August) to 44mg/l in December.

3.9. Residence Times

The flushing time of Ballinakill Harbour is estimated using Edwards & Sharples (1986) formulae, to be *c.* 1.7 days (Marine Computation Services International, 1991).

3.10. Discussion

A low flushing time of 1.7 days indicates a high exchange rate of water within the bay which is advantageous as any contamination entering the area will be diluted and dispersed rapidly and the area can therefore not act as a sink for any contaminants. The main direction of water flow is to the west or south west during the mid-ebb period. Current flows during a flooding tide are mainly easterly or southeasterly in direction. Freshwater input can influence surface salinities at certain times and the occasional occurrence of stratified conditions can be found during winter when wind speeds are low and rainfall is high. However, this halocline will be quickly dissipated in a few hours when strong winds occur.

4. Identification of Pollution Sources

This section attempts to document all pollution sources within the Ballinakill Harbour catchment area.

4.1. Desktop Survey

Pollution sources were considered within the catchment area of Ballinakill Bay (see Figure 4.1). The Ballinakill catchment area covers 103.7km^2.The catchment extends *c.* 11.5km inland.

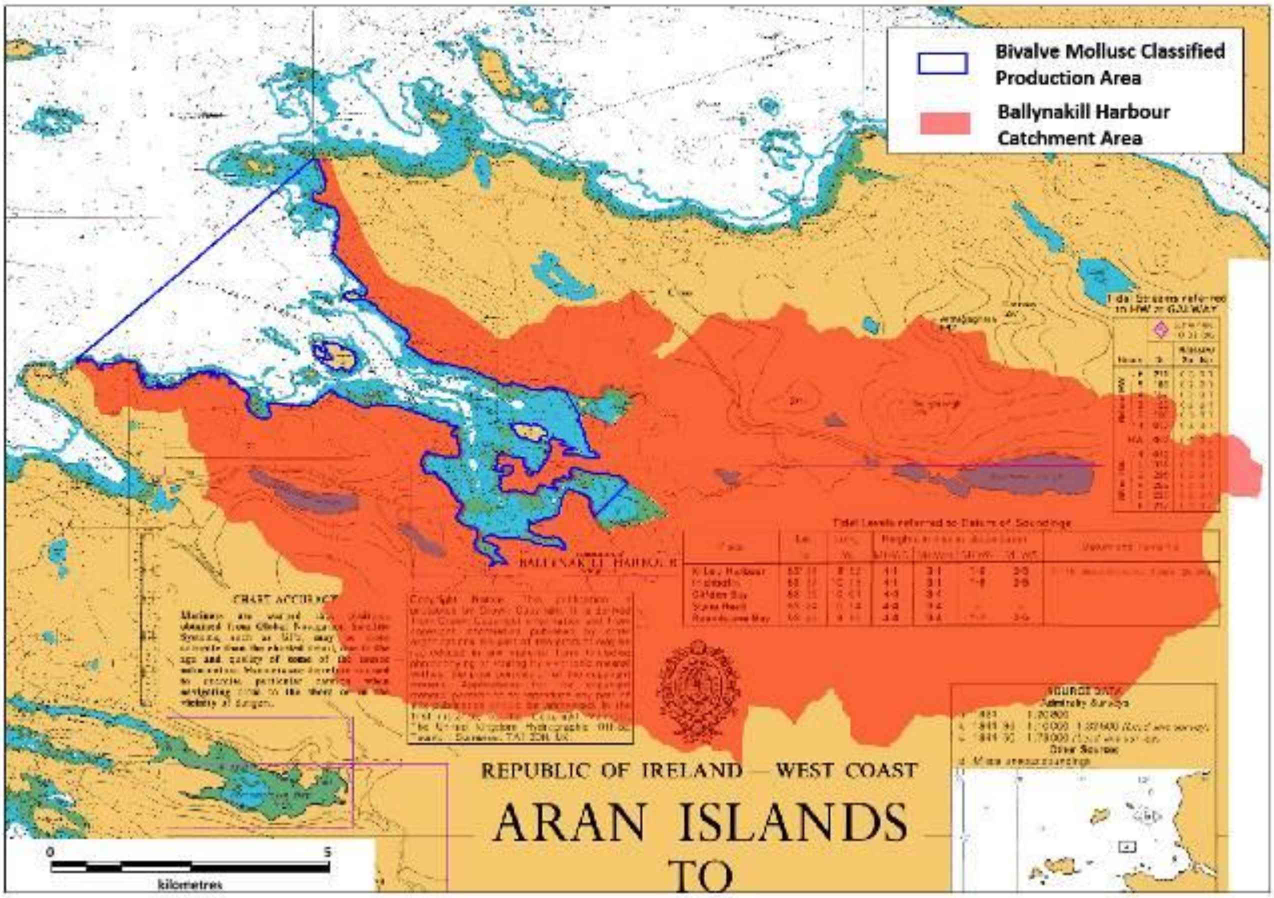


Figure 4.1: Ballinakill Harbour catchment area used for assessment of the pollution sources.

4.1.1. Human Population

Ballinakill Bay catchment is contained entirely within County Galway. Population census data used by the Central Statistics Office (CSO) is given in units of Electoral Divisions (ED). Figure 4.2 shows the EDs within the catchment area. The population data were obtained through the Central Statistics Office (CSO) online Small

Area Population Statistics (SAPS) (CSO, 2019a) for the year 2016. Figure 4.3 shows the human population within Ballinakill Bay catchment area and Table 4.1 shows these data in tabular form.

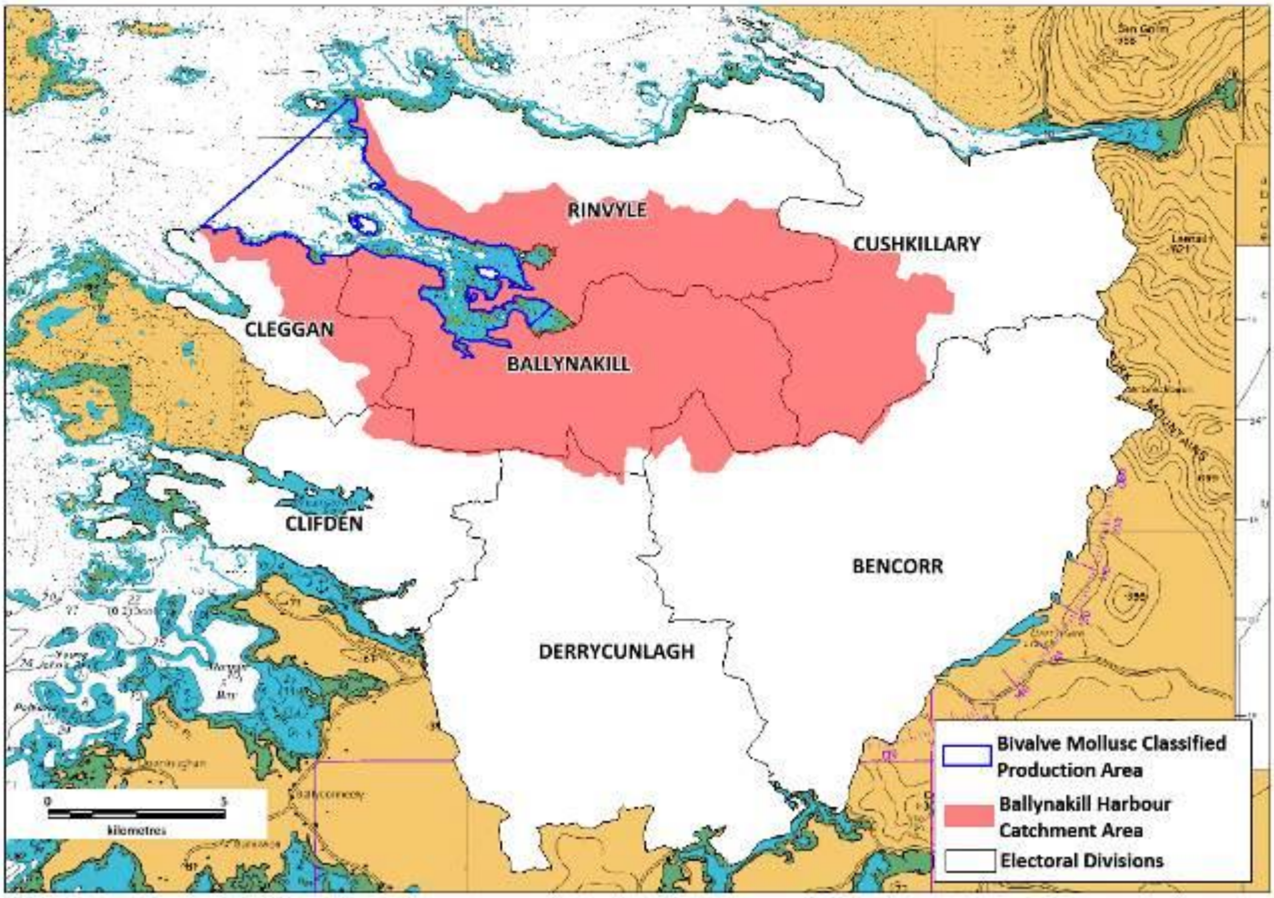


Figure 4.2: Electoral Divisions within the Ballinakill Harbour Catchment Area.

The Ballinakill Harbour Catchment Area overlaps 7 ED's (all partially): Ballinakill, Bencorr, Cleggan, Clifden, Cushkillary, Derrycunlagh and Rinvyle. Clifden contains by far the largest population (2,159) followed by Rinvyle (1,226) and Ballinakill (439).

These 7 ED's accommodate a total population of 4,960. As most of these ED's only partially overlap the catchment area, an attempt was made to estimate the actual population within the catchment. The percentage of the ED lying within the catchment was calculated in GIS and from this value the population size was calculated e.g. if 50% of ED lies within catchment area then 50% of the total population was taken to be the population size of the area within the catchment. Using this method, the population of the catchment areas is estimated at 1,320 people. Table 4.1 shows this estimation.

There are three main villages/urban centres within the catchment area: Letterfrack, Tully Cross and Moyard. Letterfrack population was recorded as 192 in the 2011 census (Galway County Council, 2011). Population data for Tully Cross and Moyard are not available.

There are 2,928 households within the 7 ED's within the catchment areas. Of this, 12.5% are vacant (365) and a further 24% are holiday homes (704). Of 796 houses actually within the catchment (based on the % of the ED within the catchment), 10.7% are vacant and 22.6% are holiday homes. Table 4.2 shows the number of households in each ED and the proportion actually within the catchment areas.

Human population in given areas is obtainable from census data; however, relating this information to the level of microbial contamination in coastal waters is difficult and is constrained by the geographic boundaries used. Nonetheless, it is clear that areas with a higher population will have higher levels of sewage and wastewater entering the Ballinakill system. Therefore, the highest levels of sewage and waste would be expected to enter from the north and northeastern shoreline in the ED of Rinvyle. Given the number of holiday homes in the catchment, it is also reasonable therefore to expect the population in the area to increase by almost a quarter during the summer holiday period.

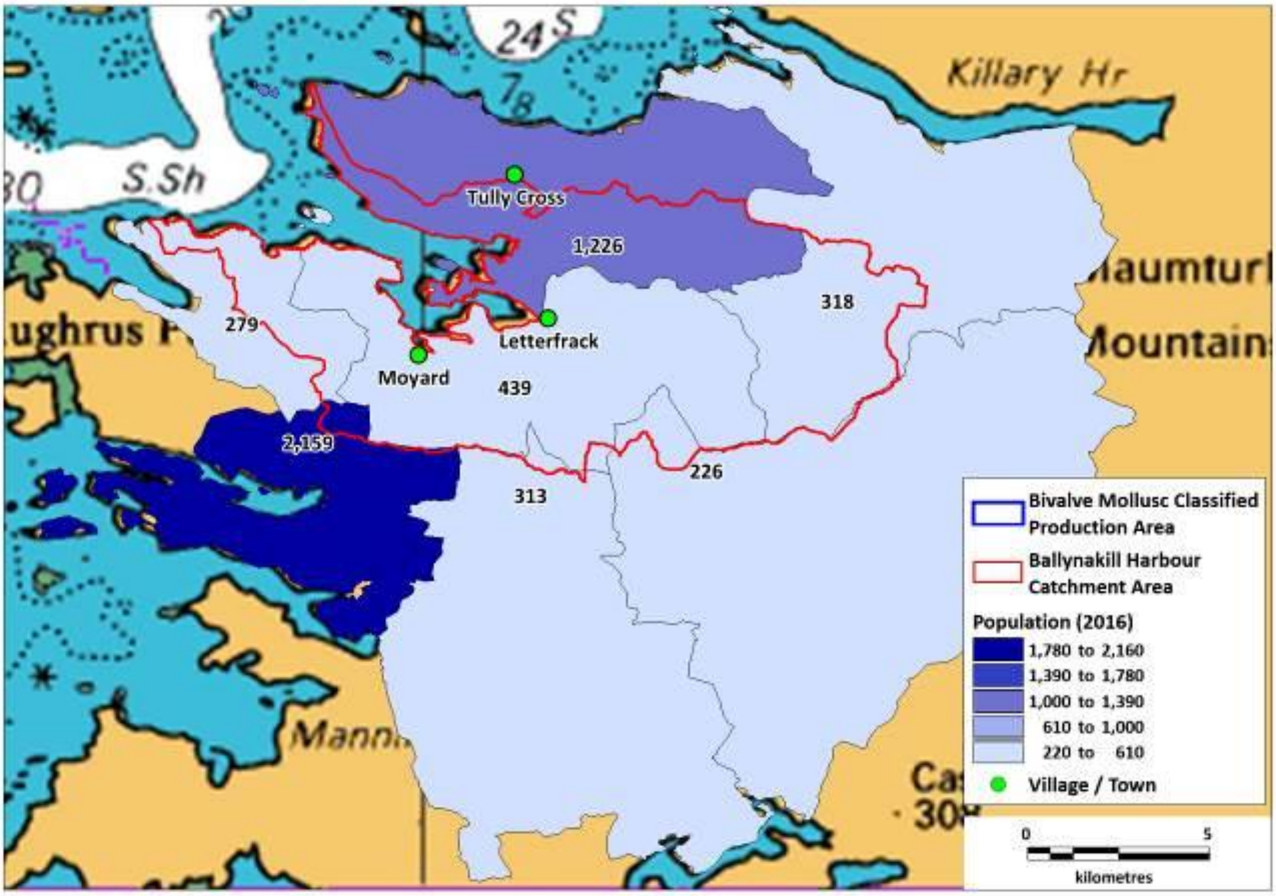


Figure 4.3: Human population within the Ballinakill Catchment Area (Source: CSO, 2019a).

Table 4.1: Human population within the Ballinakill Bay Catchment Area (Source: CSO, 2019a).

Electoral Division	Population (2016)	% ED in Catchment	Estimated Population
Ballinakill	439	98.21	431
Bencorr	226	2.57	6
Cleggan	279	47.62	133
Clifden	2159	3.69	80
Cushkillary	318	29.06	92
Derrycunlagh	313	1.03	3
Rinvyle	1226	46.88	575

Table 4.2: Households within the EDs in the Ballinakill Bay Catchment Area (Source: CSO, 2019a).

Electoral Division	Total Households	No. Occupied*	Unoccupied holiday homes	Vacant houses	Total Households in Catchment	No. Occupied in Catchment	Unoccupied holiday homes in Catchment	Vacant houses in Catchment
Ballinakill	301	215	54	32	296	211	53	31
Bencorr	120	59	43	18	3	2	1	0
Cleggan	170	110	42	18	81	52	20	9
Clifden	1245	827	221	197	46	31	8	7
Cushkillary	106	74	22	10	31	22	6	3
Derrycunlagh	268	121	130	17	3	1	1	0
Rinvyle	718	453	192	73	337	212	90	34
Total	2928	1859	704	365	796	531	180	85

4.1.2. Tourism

In 2017, 3.6 million tourists visited the West Region of Ireland (Failte Ireland, 2018a). This figure was made up of 1,911,000 overseas tourists, 1,622,000 domestic tourists and 109,000 Northern Irish tourists. Of the overseas tourists, 1,673,000 visited Co. Galway (Failte Ireland, 2018b). Kylemore Abbey is located in the eastern extent Ballinakill Bay catchment area and this is the top fee-paying tourist attraction in the area (and 8th overall in the country). 558,000 tourists visited this centre in 2017 (Fáilte Ireland, 2018a). Connemara National Park is the top non-fee paying attraction in the area (and 16th overall in the country), attracting 221,713 visitors in 2017. This attraction is located within the Ballinakill Harbour catchment area and the park's visitor centre is located in Letterfrack. There is also an Ocean's Alive Visitor Centre in Derryinver on the north shore of Ballinakill Harbour. Other tourist attractions in the area include the island of Inishbofin and Ballinakill Lake.

While most of these attractions are located outside the catchment area, the tourists may also visit Ballinakill Harbour while in the area. For Ireland as a whole, in 2017 most tourists visited between July and September (31%), followed by April to June (27%), October to December (23%) and January to March (18%). There is no reason to expect this trend to be any different in the west.

There are no blue flag beaches, shore angling sites, deep sea charters or caravan/camping sites in the Ballinakill Harbour area. There are a number of beaches in the harbour area: Tonadooravaun on the northern coast and Ardkyle and Bundouglas Beaches on the southern shore and a small number of quays and slips which provide sea access.

Increases in population in the local area due to tourism may result in an increase in the quantity of sewage discharged within the Ballinakill Harbour catchment areas. In addition, Papadakis *et al.* (1997) found significant correlations between the number of swimmers present on beaches and the presence of pathogenic bacteria. In 2007, Elmir *et al.* (2007) showed the role of human skin as an intermediate mechanism of pathogen transmission to the water column. The main swimming areas in the BMCPA are on the southern shore at Ardkyle and Bundouglas beaches and on the northern shore at Tonadooravaun. No information on water quality is available for these beaches but nearby beaches are indicative of excellent water quality (Webster, 2018; 2017; Webster & Lehane, 2016; 2015). In addition, waste can enter the area from recreational vessels.

4.1.3. Sewage Discharges

Sewage effluent can vary in nature depending on the degree to which the sewage has been treated. Discharges of sewage effluent can arise from a number of different sources and be continuous or intermittent in nature:

- treated effluent from urban sewage treatment plants (continuous);
- storm discharges from urban sewage treatment plants (intermittent);
- effluent from 'package' sewage treatment plants serving small populations (continuous);
- combined sewer and emergency overflows from sewerage systems (intermittent);
- septic tanks (intermittent);
- crude sewage discharges at some estuarine and coastal locations (continuous).

Treatment of sewage ranges from:

- none at all (crude sewage);
- preliminary (screening and/or maceration to remove/disguise solid matter);
- primary (settling to remove suspended solids as sewage sludge). Typically removes 40% of BOD (Biochemical Oxygen Demand), 60% of suspended solids; 17% of nitrogen and 20% of phosphorus from the untreated sewage;
- secondary (settling and biological treatment to reduce the organic matter content). Typically removes 95% of BOD, 95% of suspended solids, 29% of nitrogen and 35% of phosphorus from the untreated sewage. Nutrient removal steps can be incorporated into secondary treatment which can reduce ammonia - N down to 5 mg/l and phosphorus to 2mg/l.
- tertiary (settling, biological treatment and an effluent polishing step which may involve a reed bed (unlikely for a coastal works) or a treatment to reduce the load of micro-organisms in the effluent)., typically removes 100% of BOD, 100% of suspended solids, 33% of nitrogen and 38% of phosphorus from the untreated sewage.

4.1.3.1. Waste Water Treatment Works

The Letterfrack UWWTP (Urban Waste Water Treatment Plant) is the only one within the Ballinakill Harbour catchment. The location of these works can be seen in Figure 4.4 and Table 4.3 provides details of the works. The plant is designed for a PE (Population Equivalent) of 800 and the current PE loading is 221. The projected 2023 PE for the Letterfrack agglomeration is 232 PE.

The WWTP was constructed in early 2009. Prior to this there was no public sewage collection system in Letterfrack and individual septic tanks or private treatment plants located at the rear of properties had served residential and commercial properties. Typically, the effluent from the septic tanks discharged to percolation areas. The plant provides primary and secondary treatment. The plant consists of the following process elements: collection manhole, inlet forward feed pumping works, preliminary works including mechanical screening and grit removal, primary settlement tanks, secondary biological waste water treatment system based on activated sludge technology, final lamella clarifier, sludge drying reed beds and influent and discharge flow monitoring. The influent design Dry Weather Flow (DWF) for an 800PE is 100m^3/day. Average recorded influent flows from October 2011 to April 2014 is 105m^3/day.

4.1.3.2. Continuous Discharges

There is a continuous discharge associated with the Letterfrack WWTP. The high quality final effluent from the treatment process flows directly into the Sruffanboy Stream via a concrete headwall and a 225mm diameter outfall pipe with non-return flap valve. The Sruffanboy Stream flows through Letterfrack and discharges into the adjacent Barnaderg Bay via a waterfall approximately 3m high. Barnaderg Bay then opens into Ballinakill Harbour, some 400m away. The location of the discharge can also be seen in Figure 4.4 and Table 4.4 provides details of the discharge.

There is no geo-referenced database for septic tanks and on-site domestic waste water treatment systems. In order to estimate the numbers of these domestic sewage facilities within the catchment, information on the number of permanent private households and their sewage facilities was sourced from the 2016 census (CSO, 2019a). Of the 1,732 permanent private households in the 7 EDs, 29.7% (515) were connected to a public sewer/treatment system and 63.5% (1,100) had septic tanks or other individual treatment systems. The estimate for the total number of private permanent households actually within the catchment (based on % within the catchment) is 470 and of this 8.1% (38) are on the public system while 86% (404) households have their own septic tanks or other individual treatment systems. Table 4.5 shows this information at the ED level and an estimation (based on % within the catchment) of the numbers actually within the catchment.

Table 4.3: Sewage Treatment Works within the Ballinakill Harbour Catchment Areas (Source: EPA, 2019a).

Name	Easting	Northing	Longitude	Latitude	p.e.
Letterfrack Sewage Treatment Works	70,885	257,511	-9.94793	53.55169	221

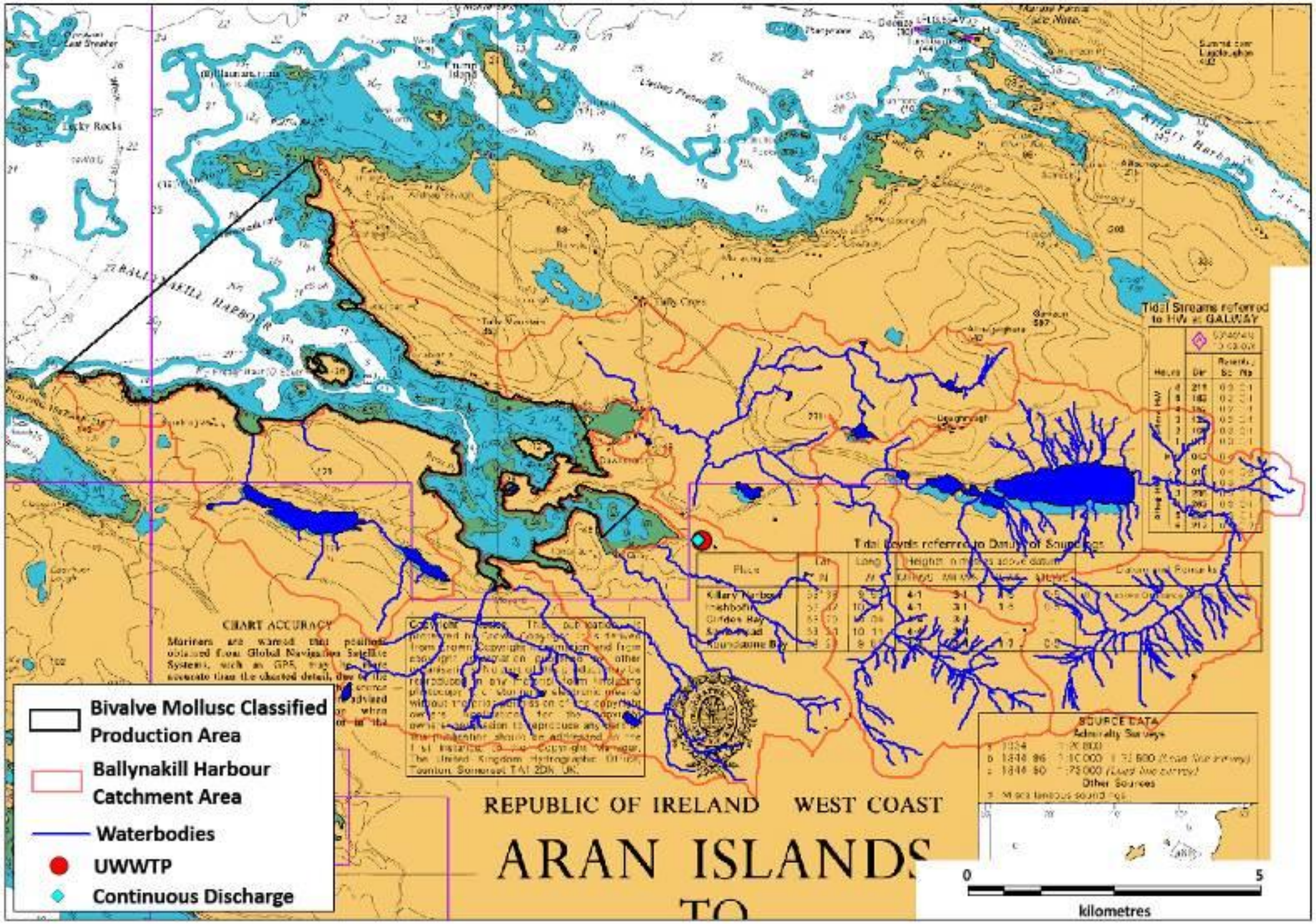


Figure 4.4: Sewage Treatment Works and Continuous Discharges within the Ballinakill Harbour Catchment Areas (Source: The EPA, 2019a).

Table 4.4: Continuous Discharges within the Ballinakill Harbour Catchment Areas (Source: EPA, 2019a).

Name	Treatment	Easting	Northing	Longitude	Latitude	Receiving Body	Max Discharge/ day (m^3)	Discharge / Annum (m^3)	DWF/ day (m^3)
Letterfrack WWTP	Secondary Treatment	70,876	257,496	-9.949103	53.55165	Sruffanboy Stream	156.6	18,510	52m^3/day*

Table 4.5: Sewage facilities at permanent households in the Catchment Area (CSO, 2019a).

Electoral Division	Entire ED						Catchment %					
	Permanent Private Household	Public Sewage Scheme	Individual Septic Tank	Other individual treatment	Other /Not Stated	No sewage facility	Permanent Private Households	Public Sewage Scheme	Individual Septic Tank	Other individual treatment	Other /Not Stated	No sewage facility
Ballinakill	178	15	142	10	11	0	175	15	139	10	11	0
Bencorr	56	0	46	8	2	0	1	0	1	0	0	0
Cleggan	103	3	86	9	2	3	49	1	41	4	1	1
Clifden	800	485	227	37	49	2	30	18	8	1	2	0
Cushkillary	66	0	50	10	5	1	19	0	15	3	1	0
Derrycunlagh	114	4	78	14	18	0	1	0	1	0	0	0
Rinvyle	415	8	344	39	24	0	195	4	161	18	11	0
Total	1732	515	973	127	111	6	470	38	367	37	27	2

4.1.3.3. Rainfall Dependent / Emergency Sewage Discharges

There are no storm water overflows associated with the Letterfrack network or WWTP.

4.1.4. Industrial Discharges

There are no licenced waste facilities or IE (Industrial Emissions) / IPC[4] (Integrated Pollution Control) facilities in the Ballinakill Harbour catchment areas. There are 5 Section 4 licences (see Figure 4.5) for the discharge of trade effluent. Table 4.6 shows details of these Section 4 licences. Specifics of the discharges are unknown. Where available, details on the discharges can be seen in Table 4.6.

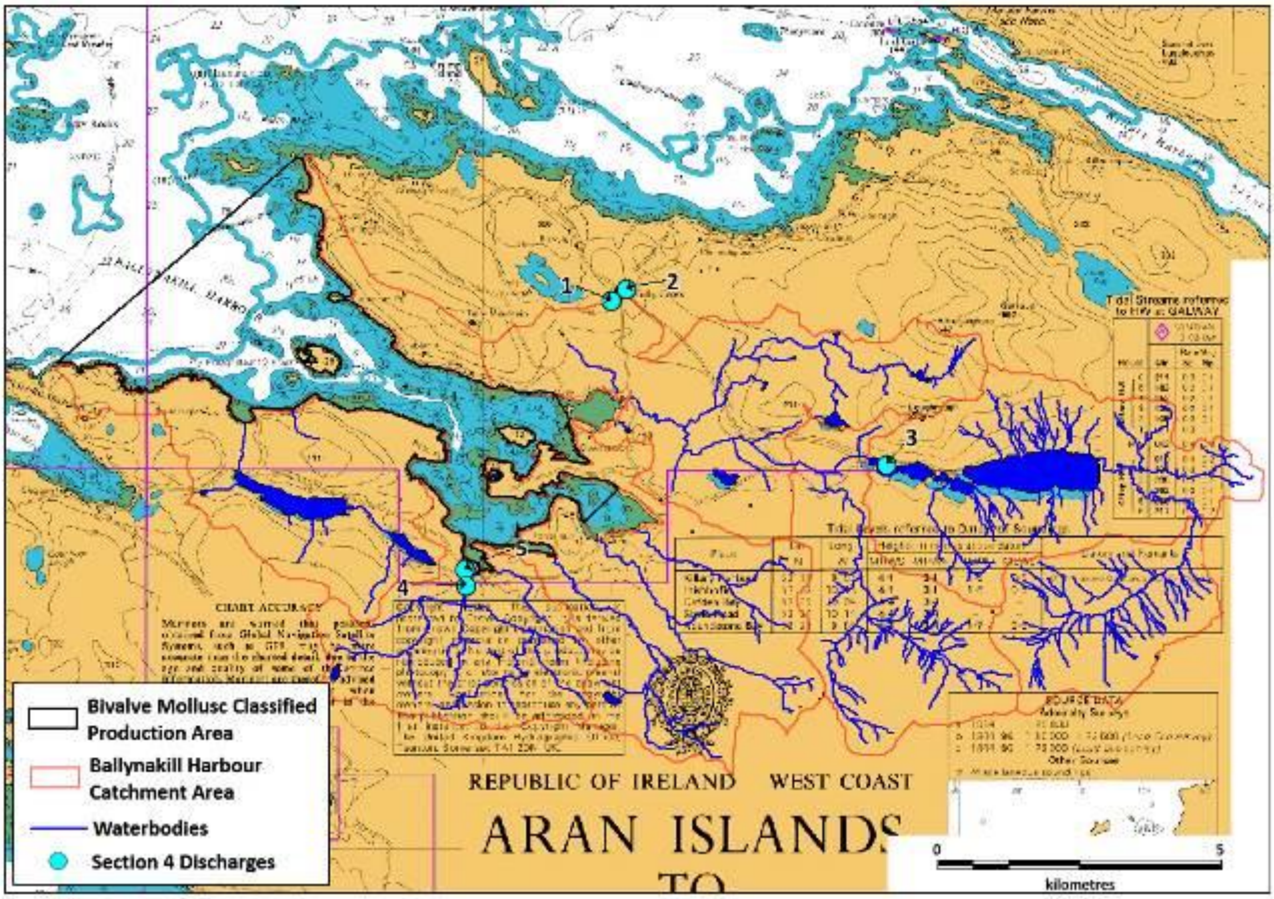


Figure 4.5: All industrial discharges within the Ballinakill Harbour Catchment Areas (Source: EPA, 2019c).

[4] The categories of industry coming within the scope of IPC licensing are Minerals and Other Materials, Metals, Mineral Fibres and Glass, Chemicals, Food and Drink, Textiles and Leather, Fossil Fuels, Cement, Waste (class 11.1), Surface Coatings, Other Activities (includes testing of engines, manufacture of integrated circuits and printed circuit boards, production of lime and manufacture of ceramics)

Table 4.6: Details on Section 4 discharges with the Ballinakill Harbour Catchment Areas (Source: EPA, 2019c).

Map ID	File Reference	Licence holder	Facility address	Longitude	Latitude	Easting	Northing
1	W351/02	Maol Reidh Lodge	Renvyle (hotel)	-9.9663	53.58722	69838.3	261483.5
2	W111/78	Connemara West ltd	Tully cross, Galway	-9.96243	53.5891	70100.3	261685.5
3	W294/94	Lady Abbess	Kylemore Abbey, Galway	-9.89291	53.56126	74621.34	258462.5
4	W068/78	J.D. Murray	Crocnaraw, Moyard, Galway	-10.0053	53.54223	67117.28	256548.5
5	W291/94	Mc Murray Carpets Ltd	Moyard, Galway	-10.0055	53.54468	67112.28	256821.5

4.1.5. Land use Discharges

Figure 4.6 shows the Corine land use within the Ballinakill Harbour catchment area. Figure 3.5 (page 27) shows all rivers/streams within the catchment area. Within the catchment area, land use is dominated by peat bogs (65.07km^2; 62.8%), followed by land principally occupied by agriculture but with significant areas of natural vegetation (15.39km^2; 14.8%) and coniferous forest (6.03km^2; 5.8%) (see Figure 4.7). Forestry (coniferous and broad-leafed) makes up 7.9% of the land use in the area (8.17km^2).

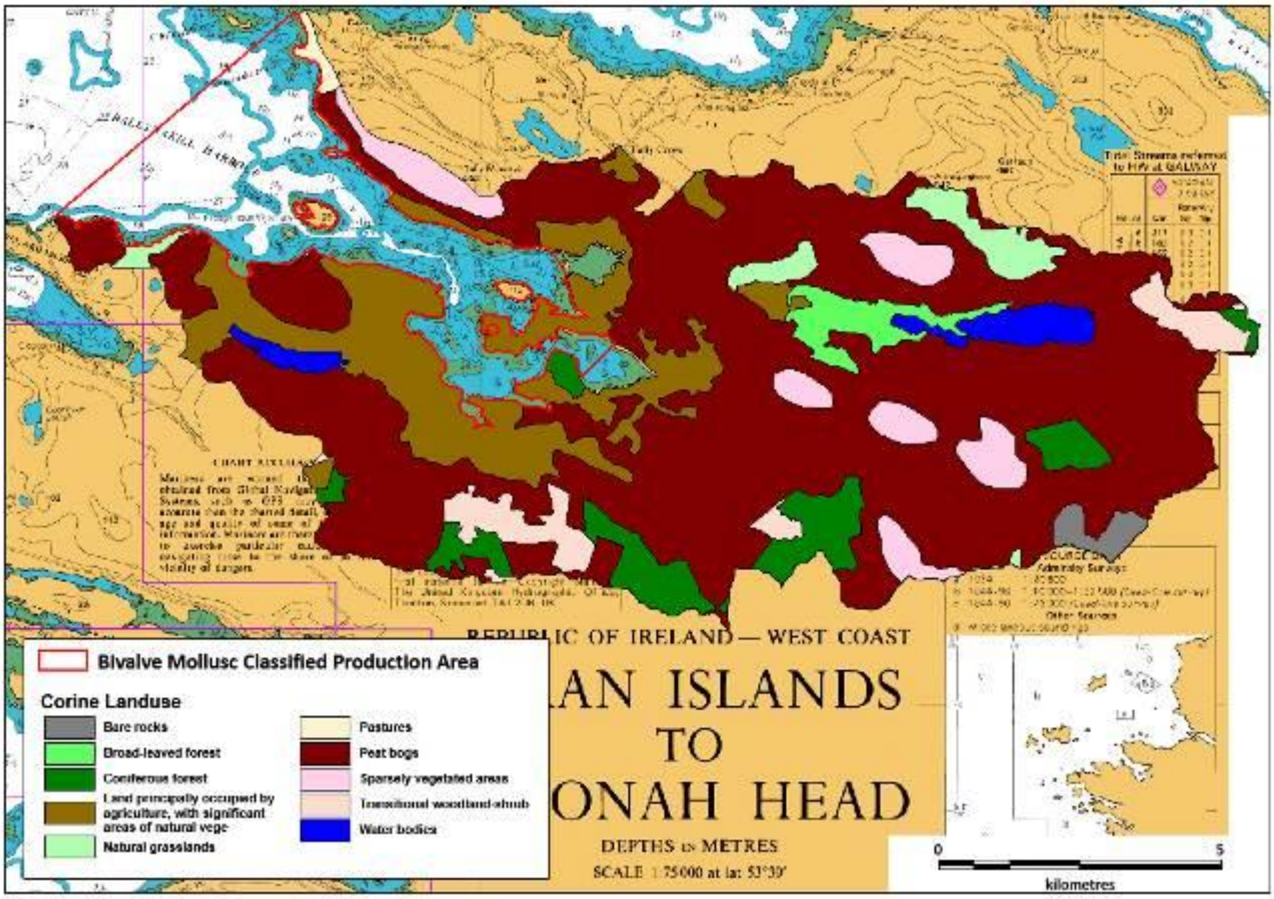


Figure 4.6: Land use within the Ballinakill Harbour Catchment Area (Source: EPA).

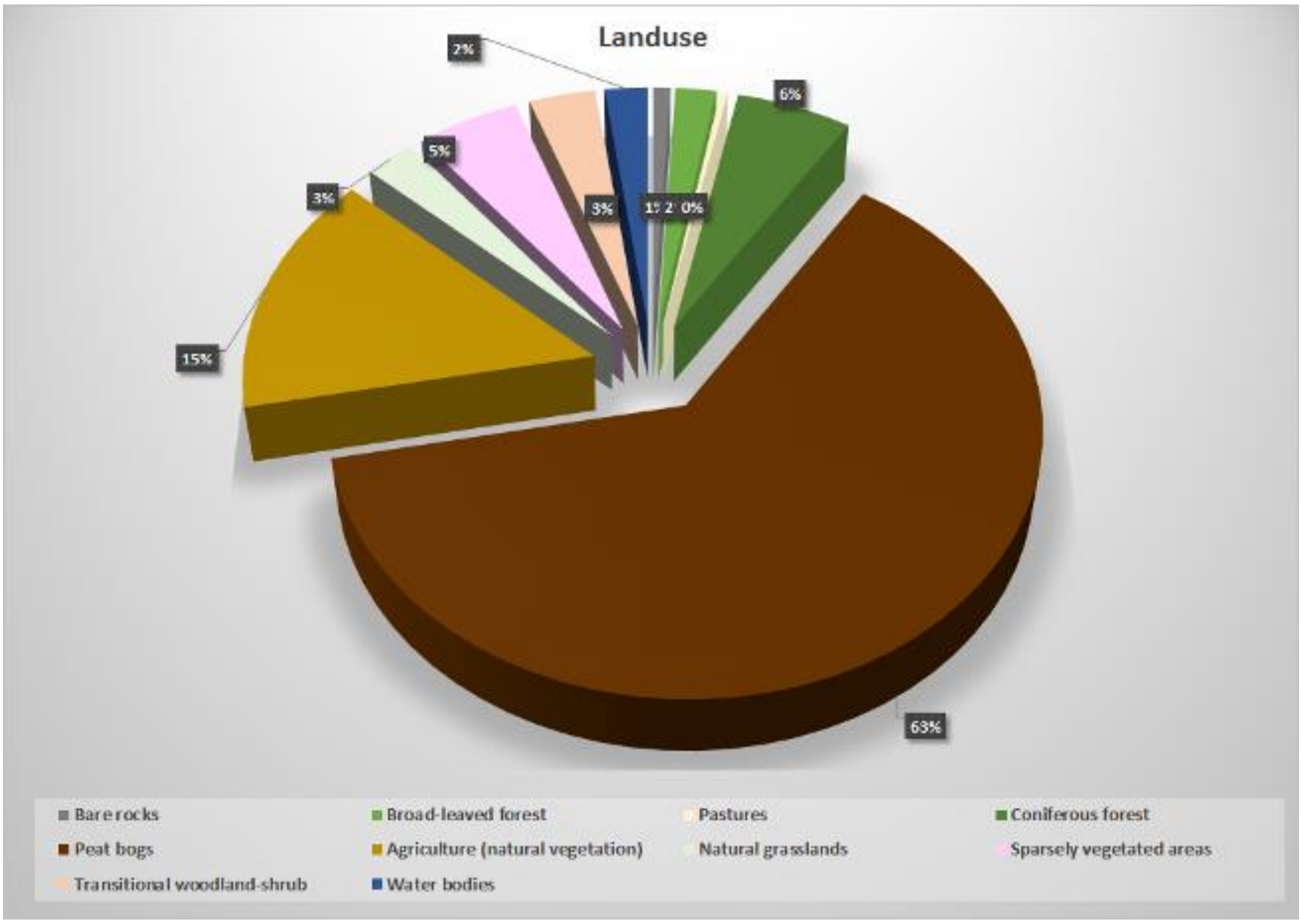


Figure 4.7: Breakdown of land use within the Ballinakill Harbour Catchment Area.

Data from the Census of Agriculture 2010 (CSO, 2019b) can be seen in Table 4.7 below. Figures 4.8 to 4.14 show thematic maps for each category in Table 4.11. There are no farms or agricultural activity in the Derrycunlagh area which partially boarders the southern extent of the Ballinakill Harbour catchment.

Numbers of farms within the catchment range from 37 in Buncorr and Cleggan to 115 in Rinvyle. The total area farmed within the catchment varies from 879 ha in Cleggan to 3,000 ha in Cushkillary. The average farm size ranges from 15.5 ha in Rinvyle to 68.2 ha in Cushkillary.

Total grass and rough grazing (combination of total pasture, total silage, total hay and rough grazing) accounted for almost all of the area farmed, ranging from 879 ha in Cleggan to 3,001 ha in Cushkillary. There is no record of crops being grown in the catchment in the 2010 survey.

The total number of cattle within the catchment range from 98 in Cushkillary to 776 in Rinvyle. The total number of sheep within the catchment range from 1694 in Cleggan to 9,829 in Cushkillary. The total number of horses within the catchment range from 25 in Cleggan to 90 in Clifden.

The total area farmed in the entire ED's shown in Figures 4.8 to 4.14 amounts to 11,507 ha. However, as most of these ED's only partially overlap the catchment area, an attempt was made to estimate the actual area farmed within the catchment. The percentage of the ED lying within the catchment was calculated in GIS and from this value the area farmed was calculated *e.g*. if 50% of ED lies within catchment area then 50% of the area farmed was taken to be the area farmed within the catchment. Using this method, the area farmed within the catchment is estimated at 3,976 ha. This represents 34.5% of the area.

Table 4.7: Farm census data for all EDs within the Killary Approaches and Killary Harbour Catchment Areas (Source: CSO, 2019b).

ED Name	No. Farms	Area Farmed (ha)	Avg. Farm Size (ha)	Total Crops (ha)	Total Grass & Rough Grazing (ha)*	Cattle	Sheep	Horses
Ballinakill	53	1738	32.8	0	1737	347	2659	43
Buncorr	37	2230	60.3	0	2230	126	5944	31
Cleggan	37	879	23.8	0	879	295	1694	25
Clifden	74	1838	24.8	0	1839	765	3271	90
Cushkillary	44	3000	68.2	0	3001	98	9829	26
Derrycunlagh	0	0	0	0	0	0	0	0
Rinvyle	115	1822	15.8	0	1821	776	5757	62

Total Grass and Rough Grazing was taken to be the sum of Total Pasture, Total Silage, Total Hay and Rough Grazing.

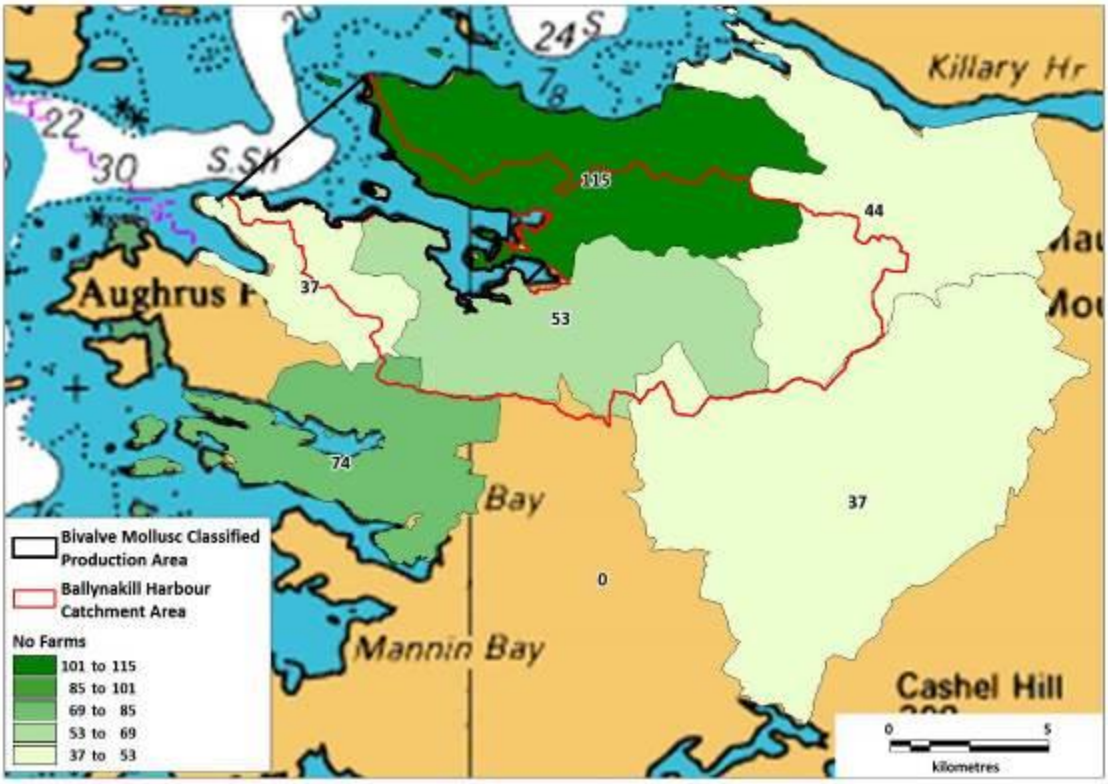


Figure 4.8: Number of farms within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

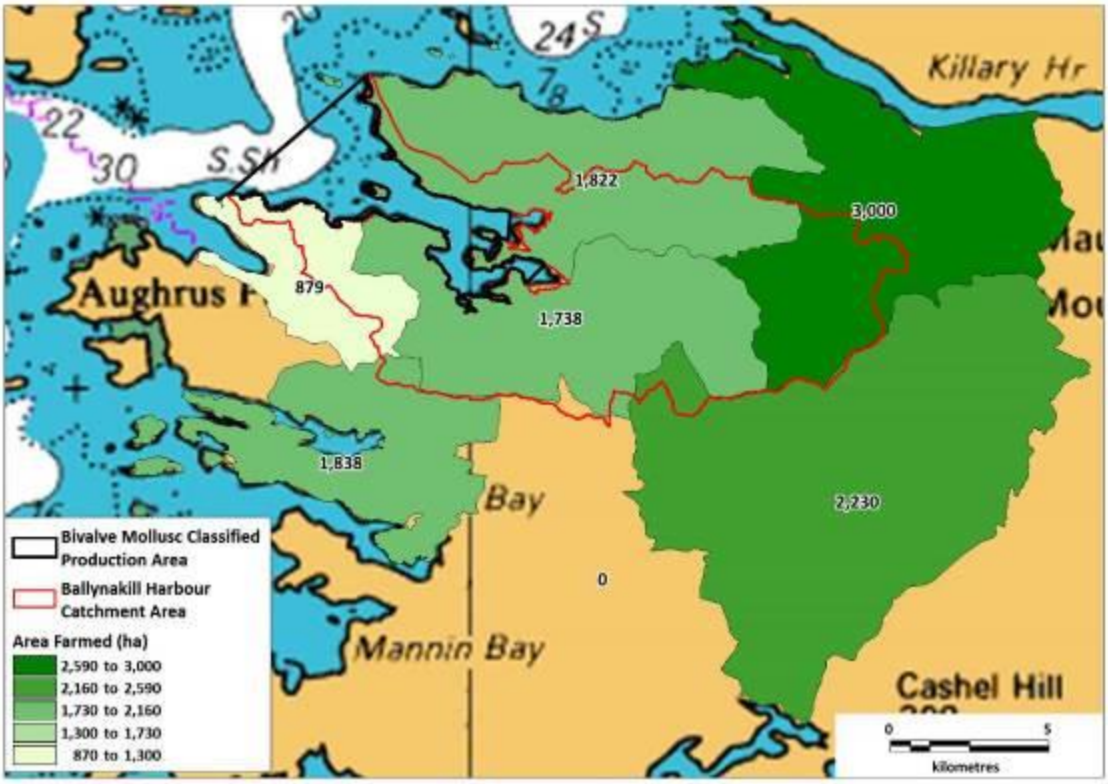


Figure 4.9: Area farmed (ha) within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

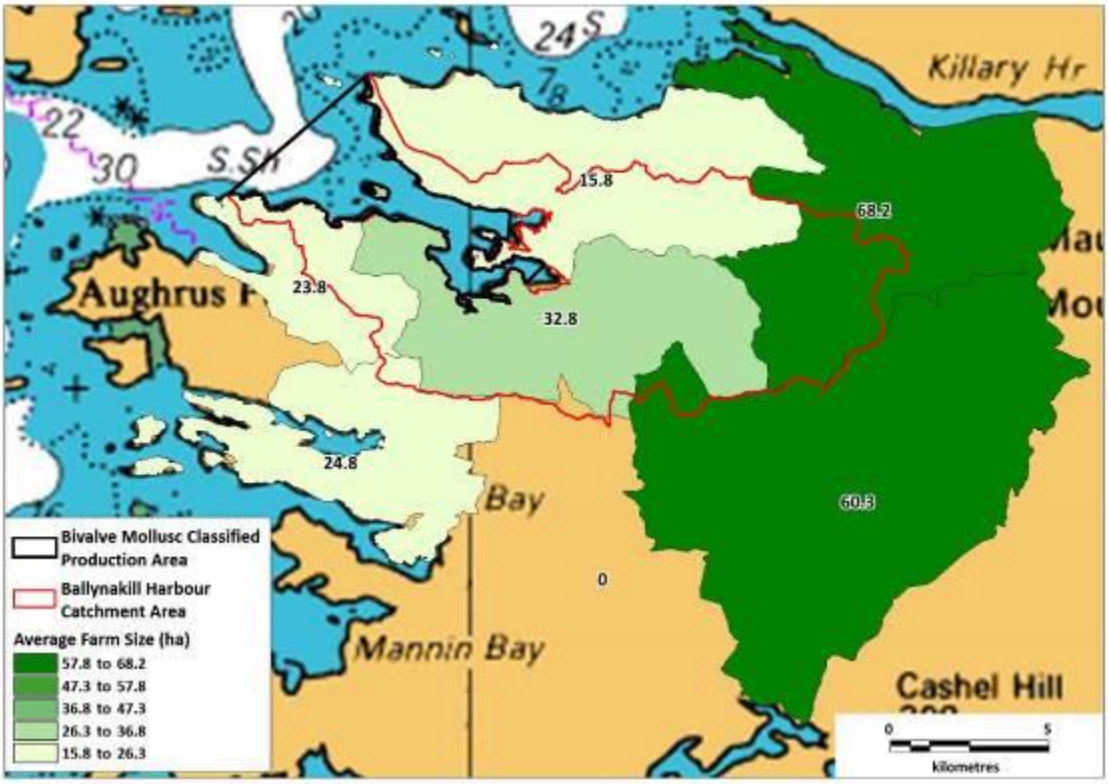


Figure 4.10: Average farm size (ha) within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

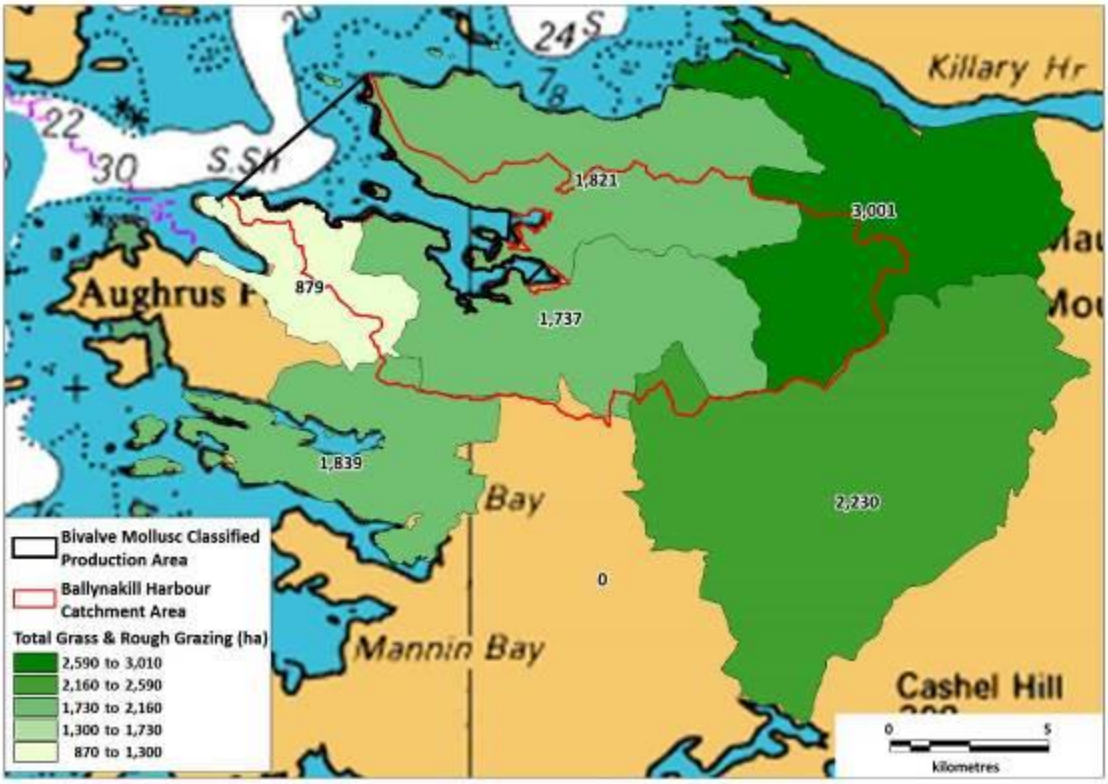


Figure 4.11: Total grass and rough grazing within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

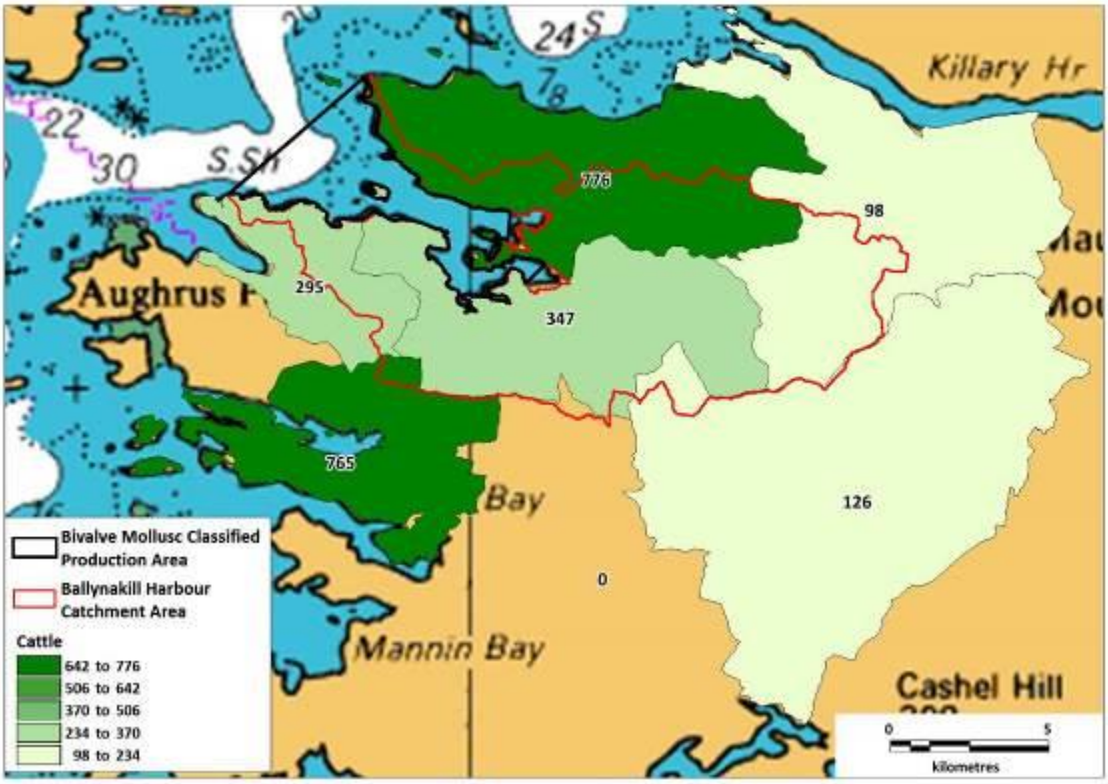


Figure 4.12: Cattle within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

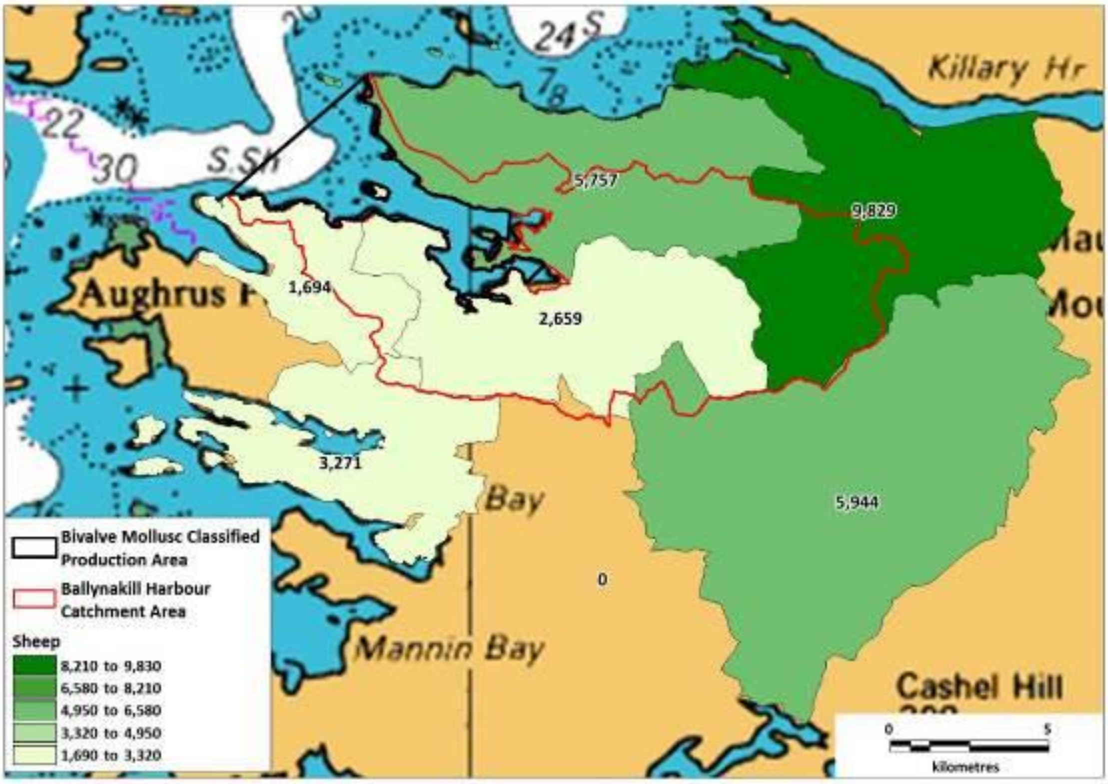


Figure 4.13: Sheep within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

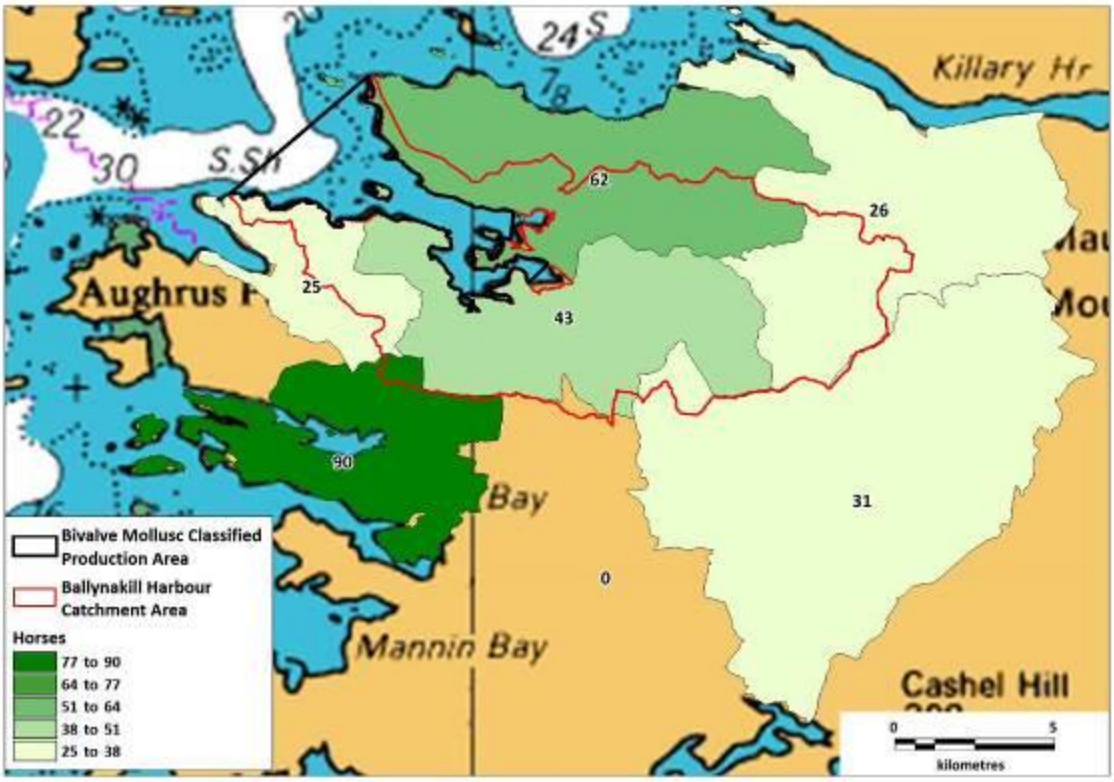


Figure 4.14: Horses within the Ballinakill Harbour Catchment Areas (Source: CSO, 2019b).

A number of studies have reported a strong association between intensive livestock farming areas and faecal indicator concentrations of microorganisms in streams and coastal waters due to run-off from manure, especially during high flow conditions, both from point and non-point sources of contamination (*e.g.* Crowther *et al.,* 2002). Studies have shown that *E. coli* can survive in faeces for extended periods of 70–100 days at temperatures in the region of 10°C (Wang *et al.*, 1996; Kudva *et al.,* 1998; Bolton *et al.,* 1999). Table 4.8 shows the potential daily loading of *E. coli* from livestock (compared to humans and birds). It can be seen that sheep rank the worst, followed by pigs, cows, birds, humans and poultry.

Table 4.8: Potential daily loading of *E. coli* (Jones & White, 1984).

Source	Faecal Production (g/day)	Average Number (*E. coli*/g)	Daily Load (*E. coli*)	Rank
Man	150	13×10^6	1.9×10^9	5
Cow	23600	0.23×10^6	5.4×10^9	3
Sheep	1130	16×10^6	18.1×10^9	1
Chicken	182	1.3×10^6	0.24×10^9	6
Pig	2700	3.3×10^6	8.9×10^9	2
Gull	15.3	131.2×10^6	2×10^9	4

The large majority of livestock in the area are sheep. Cattle are also present but in lower numbers. All of the agricultural land use in the area is total grass and rough grazing. Sheep are present in relatively large numbers throughout although higher numbers are found along the northern shoreline compared to the southern shore line of Ballinakill Harbour. Highest numbers of cattle are also found along the northern coastline with lower numbers along the southern coastline. Sheep numbers would be expected to increase in spring following the birth of lambs and decrease in the autumn as they are sent to market. Therefore, larger quantities of livestock droppings will be deposited during this period, though it may not impact the fishery until washed into the sea during and/or after periods of rainfall unless deposited directly on the shoreline.

In addition to the deposition of faeces from livestock, slurry is also spread on agricultural lands which not only adds to *E. coli* loadings, but also increases nitrogen and phosphorus run-off to waterbodies. The Nitrates Directive for the purposes of agriculture is implemented through the Nitrates Action Programme (NAP) which is contained in the Good Agricultural Practice for Protection of Waters Regulations 2017. These regulation set out the maximum nitrate and phosphorus levels which can be applied to land through a combination of manure deposited directly by livestock and spreading of organic and chemical fertilizer. The total quantity of livestock manure per calendar year is not to exceed 170 kg of nitrogen per hectare (or must not exceed 250 kg in derogation). The total quantity of organic and chemical fertilizer must not exceed what is needed by the crops grown. The spreading of fertilizer is prohibited within the wetter months of the year, the exact period varies by location as the country has been divided into three zones. Fertilizer is not to be spread if the land is waterlogged, frozen, covered with snow, heavy rain forecast within 48 hours or land is unsuitable due to a slope greater than 10%. Further restrictions provide buffers around water bodies, which range from 5 – 250 metres depending on the water body or usage (*e.g.* water abstraction for human consumption).

4.1.6. Other Pollution Sources

4.1.6.1. Shipping

Operational waste from vessels, if not properly managed, can end up in the sea where the potential for contamination or pollution occurs. Wastes generated or landed in ports and harbours can be broadly divided into a) operational and domestic waste from ships and boats, b) waste from commercial cargo activities and c) wastes generated from maintenance activities and associated maritime industry activities.

Marpol Annex IV defines sewage as “drainage from medical premises, toilets, urinals, spaces containing live animals and other waste waters when mixed with sewage waste streams”. Although adopted in 1973, the

Annex did not come into effect until September 2003, with subsequent amendments entered into force in August 2005. Annex IV requires ships to be equipped with either a sewage treatment plant, a sewage commuting and disinfecting system or a sewage holding tank. Within 3 miles of shore, Annex IV requires that sewage discharges be treated by a certified Marine Sanitation Device (MSD) prior to discharge into the ocean. Sewage discharges made between 3 and 12 miles of shore must be treated by no less than maceration and chlorination and sewage discharged greater than 12 miles from shore are unrestricted. Annex IV also established certain sewage reception facility standards and responsibilities for ports and contracting parties.

Ship sewage originates from water-borne human waste, wastewaters generated in preparing food, washing dishes, laundries, showers, toilets and medical facilities. However, as waste enters the Lough environment from many sources, it makes the identification of specific impacts from ship/boat waste very difficult. It is widely recognised that the majority of pollution entering the marine environment comes from land based sources and atmospheric inputs from land based industrial activities, with only an estimated 12% originating from shipping activities (GESAMP [Joint Group of Experts on the Scientific Aspects of Marine environmental Pollution], 1990).

Figure 4.15 shows all shipping and boating facilities and activities in Ballinakill Harbour. Table 4.9 details these facilities. There are no commercial or fishing ports in the area.

The 2 quays in the area are limited to Derryinver Quay on the north shore and Keelkyle Quay in Barnaderg Bay on the south shore. There are several slipways and jetties located along the shoreline of the inner harbour area. Letterfrack Sea Safari boat tours offer daily 1 hour sightseeing boat tours of Ballinakill Harbour from Derryinver Quay and 2 hour evening angling trips are also available.

The fishing vessels operating from Derryinver Pier fish for shrimp, lobster and crab (brown and spider with only 1 vessel fishing for scallop and this is only on a very intermittent basis (no scallops fished since 2017). It is mostly potting in the area with one small trawler that fishes outside Ballinakill only mooring the vessel in the bay.

All quays are used frequently by a number of groups most notably the wild fisheries, aquaculture and aqua-tourism sectors.

While data on sewage discharge levels from boating activities in the area are not available, it is highly unlikely that any discharges from the relatively small number of vessels in the area would have any negative impacts on water quality.

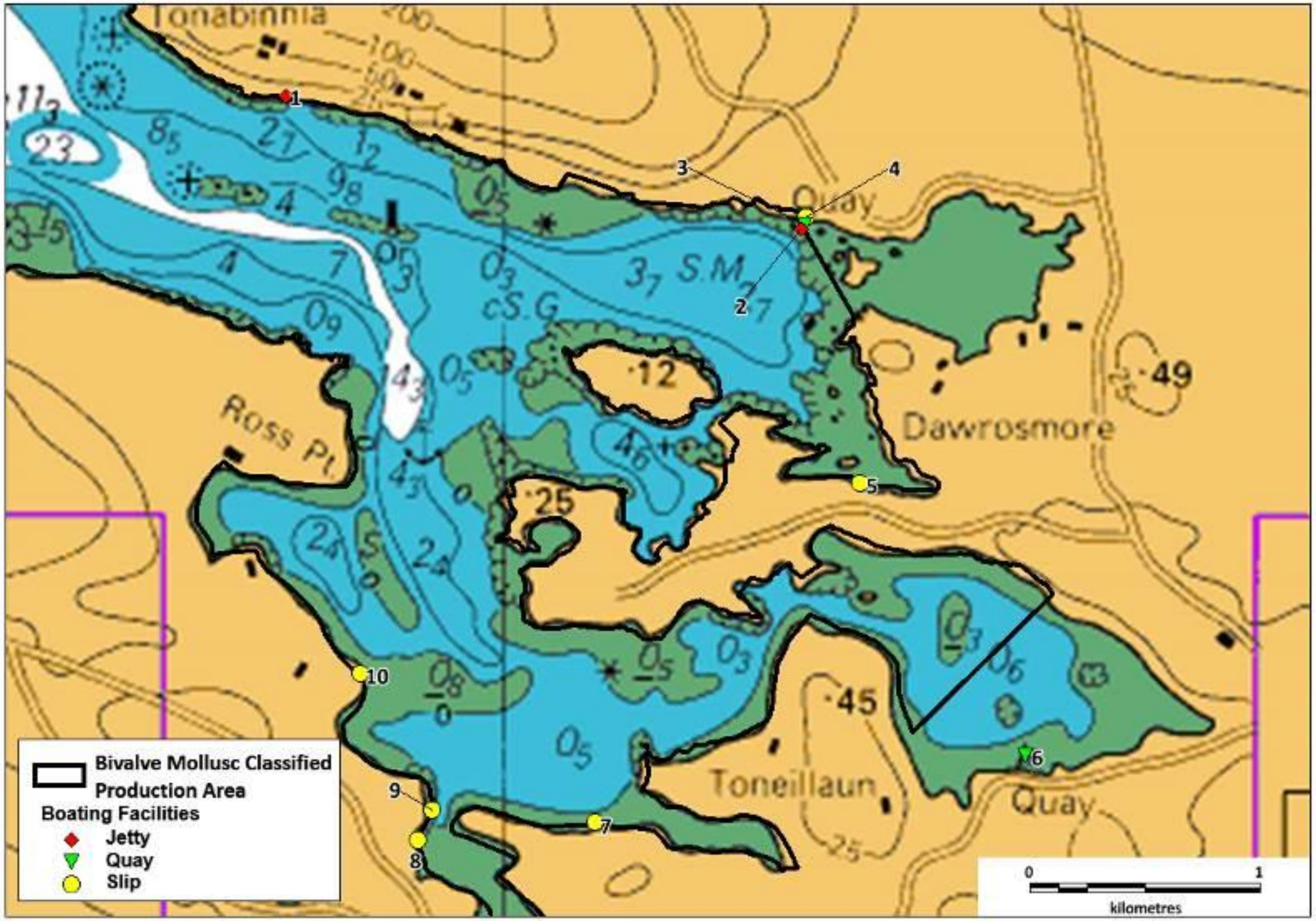


Figure 4.15: Boating facilities in Ballinakill Harbour

Table 4.9: Boating facilities Ballinakill Harbour.

Map ID	Description	Name
1	Jetty	
2	Jetty	
3	Quay	Derryinver Quay
4	Slip	
5	Slip	
6	Quay	Keelkyle Quay
7	Slip	
8	Slip	
9	Slip	
10	Slip	

4.1.6.2. Birds

It is important to document the bird populations in the Ballinakill BMPA area as bird faeces are rich in faecal bacteria (Oshira & Fujioka, 1995) and have been shown to be a source of faecal contamination in the marine environment (Jones *et al.,* 1978; Standridge *et al.,* 1979; Levesque *et al.,* 1993, Alderisio & DeLuca 1999, Levesque *et al.,* 2000, Ishii *et al.,* 2007).

The Ballinakill Harbour BMCPA also overlaps a Special Protection Area (SPA): Illaunnanoon SPA (IE004221) which covers the island of Illaunnanoon (also known as Lamb's Island) and the surrounding marine waters and intertidal rocks (see Figure 2.4). It is situated at the mouth of Barnaderg Bay on the east side of Ballinakill Harbour. The site is designated for the Sandwich Tern and the site supports a nationally important population (80 pairs in 1984, 35 pairs in 1995 and 90 pairs in 2001). Other species recorded on the island in 2001 include Common Tern (20 pairs), Black-headed Gull (70 pairs) and Common Gull (12 pairs).

There was an I-WeBS (Irish Wetland Bird Survey) survey site in Ballinakill Harbour which was surveyed by Birdwatch Ireland in 2007/2008. The total peak counts for each season can be seen in Table 4.10.

Table 4.10: Total peak counts of waterbirds at the Ballinakill Harbour I-WeBS survey site in 2007/08 (Source: BWI, 2019).

Species	1% National	1% International	2007/08
Teal	340	5000	26
Red-breasted Merganser	20	1700	6
Grey Heron	25	2700	3
Oystercatcher	690	8200	3
Greenshank	20	2300	1
Redshank	300	3900	1
Common Gull		16400	20
Great Black-backed Gull		4200	1
Total			61

Population levels of birds throughout the site is fairly stable throughout the year, with slight increases in summer when the terns arrive. However, it is highly likely that these levels are low when compared with land-based discharges.

4.1.6.3. Aquatic mammals

The islands of Freaghillaun, Glassillaun and Roeillaun (which means Seal Island in Irish) are all potential haul out sites for both Common (*Phoca vitulina)* and Grey seals (*Haliochoerus grypus*). Other aquatic mammals that occur in Ballinakill include Otter (*Lutra lutra),* Bottlenose Dolphin (*Tursiops truncatus)* and Harbour Porpoise (*Phocoena phocoena*).

No estimates of the volumes of seal faeces are available although it is reasonable to assume that what is ingested and not assimilated in the gut must pass. Assuming 6% of a median body weight for grey seals of 185kg, that would equate to 11.1kg consumed per day and probably very nearly that defecated. The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21 x 104 CFU *E. coli* per gram dry weight of faeces (Lisle *et al.,* 2004). *Salmonella* and *Campylobacter* spp. have also been found in wild seals (Stoddard *et al.,* 2005).

Aquatic mammals due to the low numbers, oceanic nature of the bay and the dilution factors at work are unlikely to impact contamination levels to any significant degree.

4.2. Shoreline Survey Report

A shoreline survey was carried out by the Sea Fisheries Protection Authority over 3 days between October 2018 and January 2019. Figure 4.16 shows the GPS (Global Positioning System) and photography sites accounted for during the 3 survey days.

The aim of this survey was to identify/confirm and mark all discharges, pollution sources, waterways and marinas along the shoreline. GPS coordinates were recorded for all features and marked on a map. In addition, all features were photographed digitally (where possible). Notes were made on the numbers and types of farm animals obvious from the shoreline and on wild fowl/populations of wild animals with an estimation of their numbers.

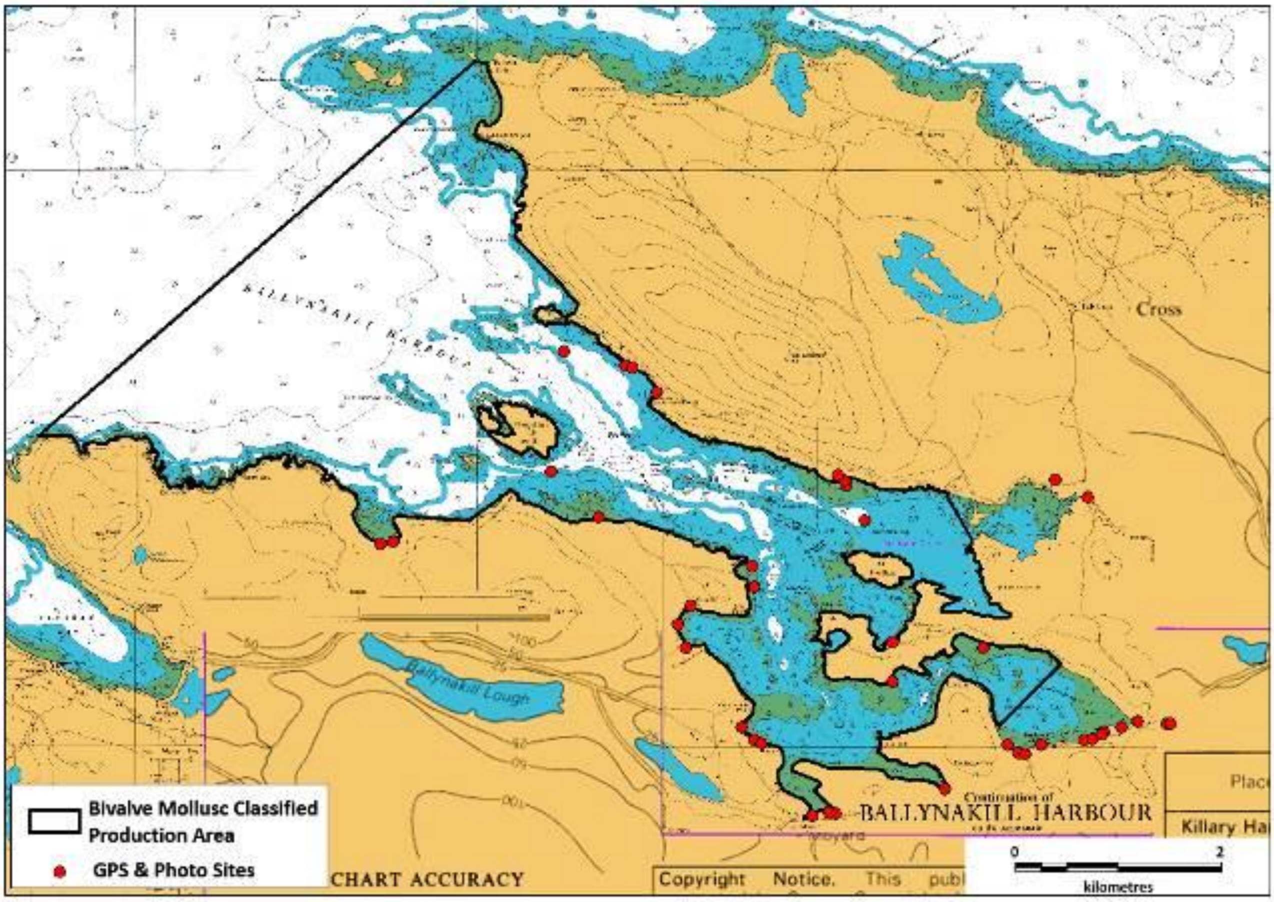


Figure 4.16: Locations of GPS and Photograph Sites.

Figure 4.17 shows the locations of all features observed during the shoreline survey. In total 40 features were identified. In total, 14 rivers/streams were identified, 14 drains, 1 WWTP, 1 discharge from WWTP and 1 discharge pipe. Figures 4.18 to 4.29 show aerial imagery of the location of the features and Figures 4.30 to 4.32 shows images of most of these features. Table 4.11 details all features identified and the numbering used is cross-referenced to Figures 4.17 to 4.32.

Table 4.11: Features identified during the shoreline survey. Refer to Figures 4.18 – 4.29 for locations and Figures 4.30 to 4.32 for photographs.

No	Observation	Latitude	Longitude	Easting	Northing
1	Letterfrack waste water treatment plant	53.55211	-9.94863	70901.46	257544.2
2	Letterfrack waste water treatment plant discharge pipes	53.55211	-9.94916	70866.34	257545.2
3	Sruffanboy Stream, WWTP Letterfrack discharges upstream	53.55235	-9.95342	70584.77	257579.6
4	Small stream, some enrichment	53.55183	-9.95582	70424.13	257526.1
5	Field drain, some enrichment	53.5514	-9.95834	70255.81	257482.9
6	Field drain, some enrichment	53.55123	-9.95869	70231.58	257465
7	Owengarve River, some enrichment	53.55083	-9.96008	70138.95	257417.7
8	Field drain, some enrichment	53.55076	-9.96113	70068.96	257416.7
9	Pipe, some enrichment	53.55037	-9.96754	69642.96	257385
10	Owennabaunoge River	53.54951	-9.96983	69488.6	257293.8
11	Field drain	53.54959	-9.97097	69413.25	257304.5
12	Field drain	53.55033	-9.9724	69320.76	257389.5
13	Traheen River	53.54652	-9.98173	68690.43	256982.4
14	Tullyboy River	53.54439	-9.99769	67626.2	256775.2
15	Drain	53.54445	-9.99876	67555.47	256783.9
16	Moyard River	53.54411	-10.0012	67392.68	256750.6
17	Field drain	53.55045	-10.0087	66918.79	257470
18	Field drain	53.55069	-10.0096	66854.6	257498.6
19	Field drain, some enrichment	53.55182	-10.0115	66733.56	257627.8
20	Stream	53.5587	-10.0196	66217.17	258408.7
21	Drain, some enrichment	53.56072	-10.0209	66139.41	258635.9
22	Stream	53.56236	-10.019	66273.78	258814.7
23	Salmon cages	53.56398	-10.0097	66892.84	258977.9
24	Ballinakill razor bed	53.56583	-10.01	66879.63	259184
25	Stream	53.57007	-10.0325	65401.22	259698.2
26	Salmon cages	53.57407	-10.0395	64949.63	260156.3
27	Stream	53.5679	-10.0627	63393.11	259514.3
28	Stream	53.56778	-10.0646	63266.87	259504.9
29	Mussel longlines	53.58442	-10.0377	65104	261304.5

No	Observation	Latitude	Longitude	Easting	Northing
30	Ballinakill razor bed	53.58321	-10.0286	65701.23	261153.1
31	Stream	53.58303	-10.0276	65764.8	261130.6
32	Stream, running off mountain adjacent mussel longlines	53.58087	-10.0239	66003.26	260883.5
33	Stream	53.57324	-9.99632	67807.03	259983.1
34	Oyster trestles	53.57278	-9.99615	67816.87	259932
35	Random water sample point	53.56978	-9.99347	67985.02	259592.8
36	Small river	53.57327	-9.96553	69846.32	259929.4
37	Dawros River	53.57182	-9.96073	70160.01	259759.6
38	Oyster trestles	53.55928	-9.98928	68229.73	258416.9
39	Oyster trestles	53.55577	-9.9894	68211.04	258025.9
40	Oyster trestles	53.55877	-9.9761	69101.61	258335.2
41	Sheep 40+	53.57376	-9.997284	67744.74	260042.8

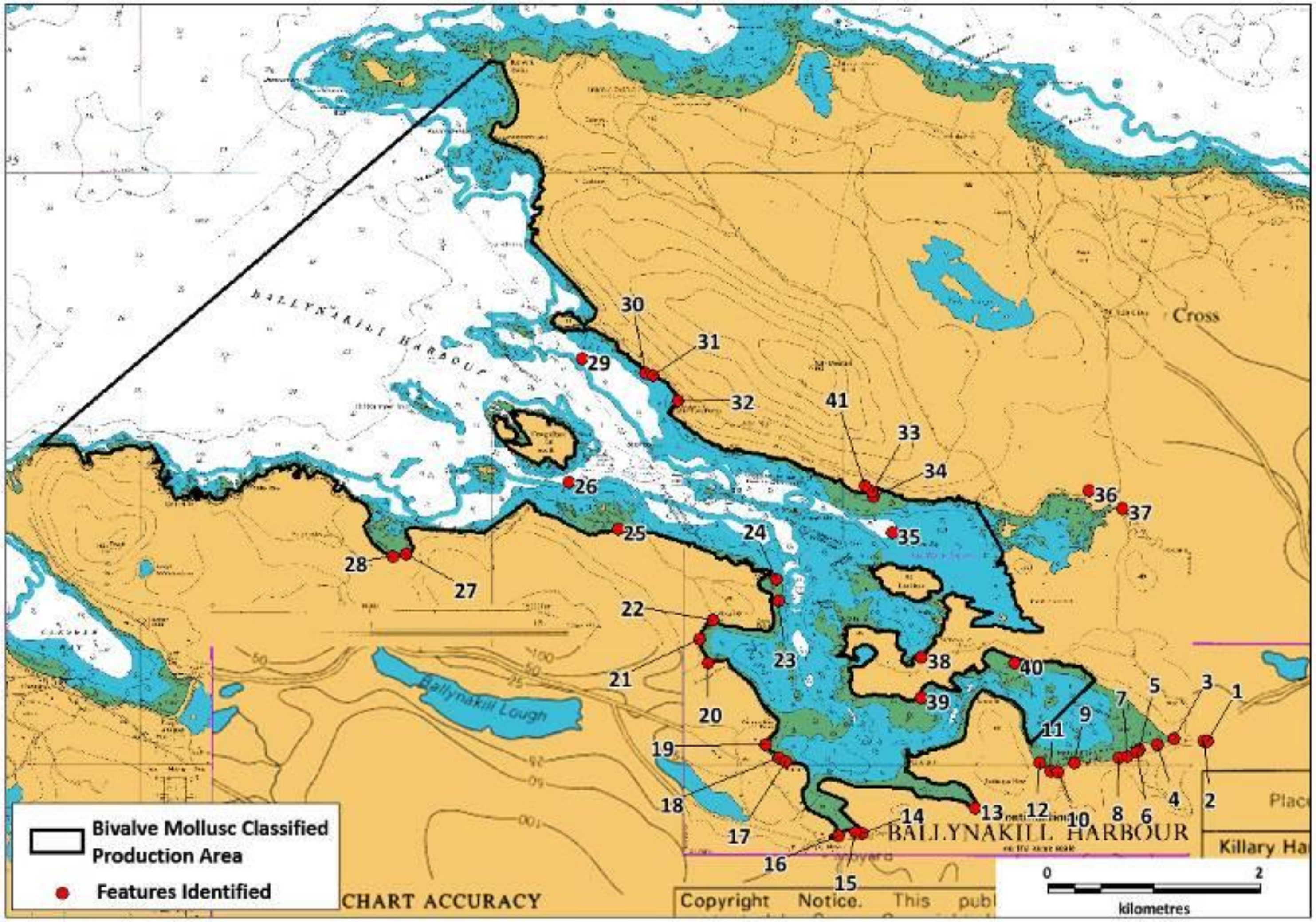


Figure 4.17: All features (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.18: Features 1-8 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.19: Features 9-12 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

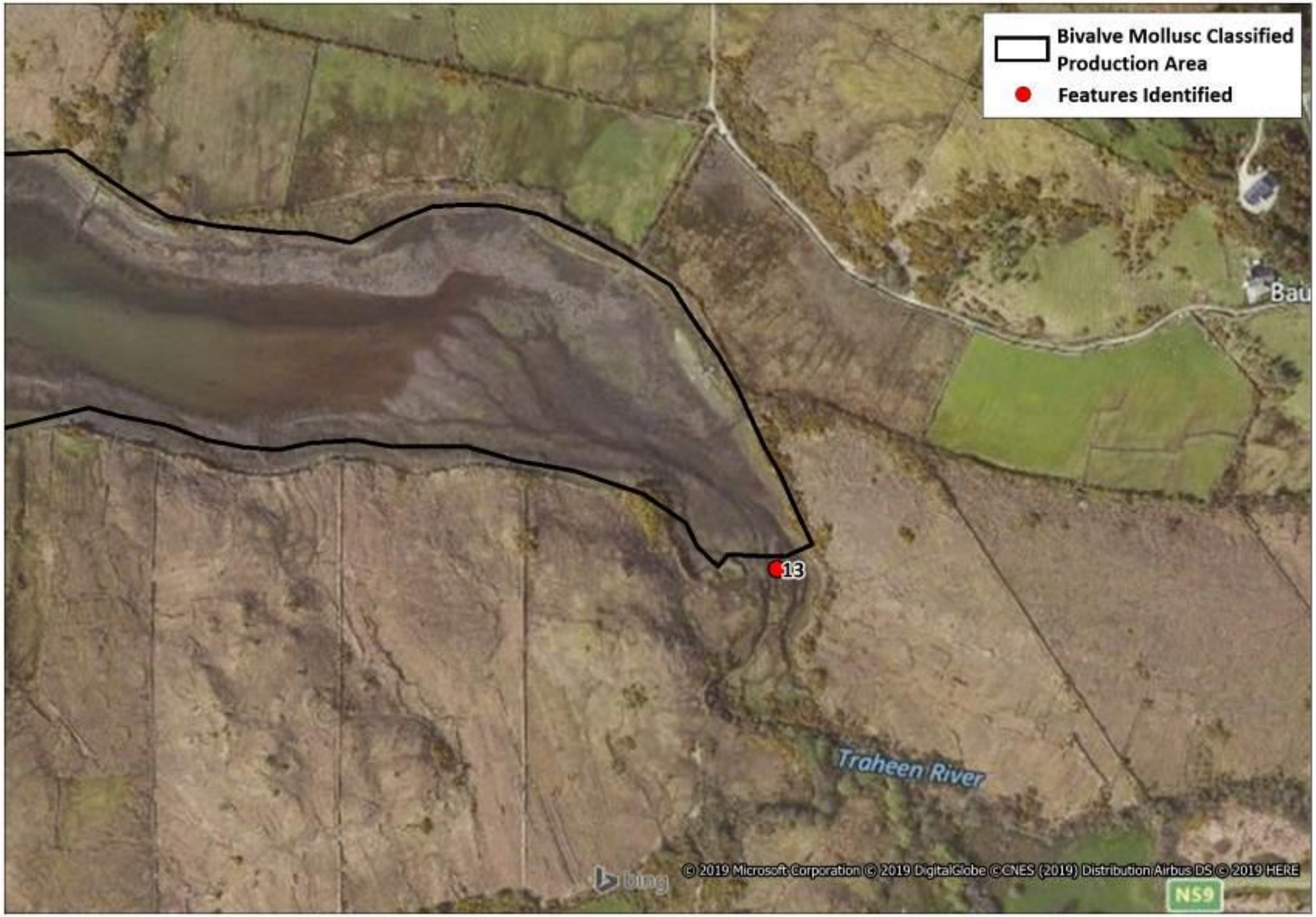


Figure 4.20: Feature 13 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.21: Features 14-16 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.22: Features 17-19 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.23: Features 20-22 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.24: Features 23-24 (numbering cross-reference to Table 4.11) identified during the shoreline survey.

Figure 4.25: Features 25-26 (numbering cross-reference to Table 4.11) identified during the shoreline survey

Figure 4.26: Features 27-28 (numbering cross-reference to Table 4.11) identified during the shoreline survey

Figure 4.27: Features 29-32 (numbering cross-reference to Table 4.11) identified during the shoreline survey

Figure 4.28: Features 33-35 & 41 (numbering cross-reference to Table 4.11) identified during the shoreline survey

Figure 4.29: Features 38-40 (numbering cross-reference to Table 4.11) identified during the shoreline survey

Figure 4.30: Features 2-15 located during the shoreline survey. Refer to Figures 4.17-4.21 for site locations.

Figure 4.31: Features 16 -28 located during the shoreline survey. Refer to Figures 4.21-4.26 for site locations.

Figure 4.32: Features 32 -38 located during the shoreline survey. Refer to Figures 4.27-4.29 for site locations.

Figure 4.33 shows the locations of the piers/jetties/berths/slipways/pontoons/shore access points located during the shoreline survey. In total, 2 were identified and these are Derryinver Pier and Barnaderg Pier.

Figure 4.33: Piers located during the shoreline survey.

4.3. Locations of Sources

Figure 4.34 shows all watercourses discharging into Ballinakill Bay and Table 4.12 provides cross-referenced details for this map. Figure 4.35 shows all discharges in the Ballinakill Bay catchment area and Tables 4.13 to 4.15 provides cross-referenced details for the WWTP, drain and pipe discharges and Section 4 discharges respectively.

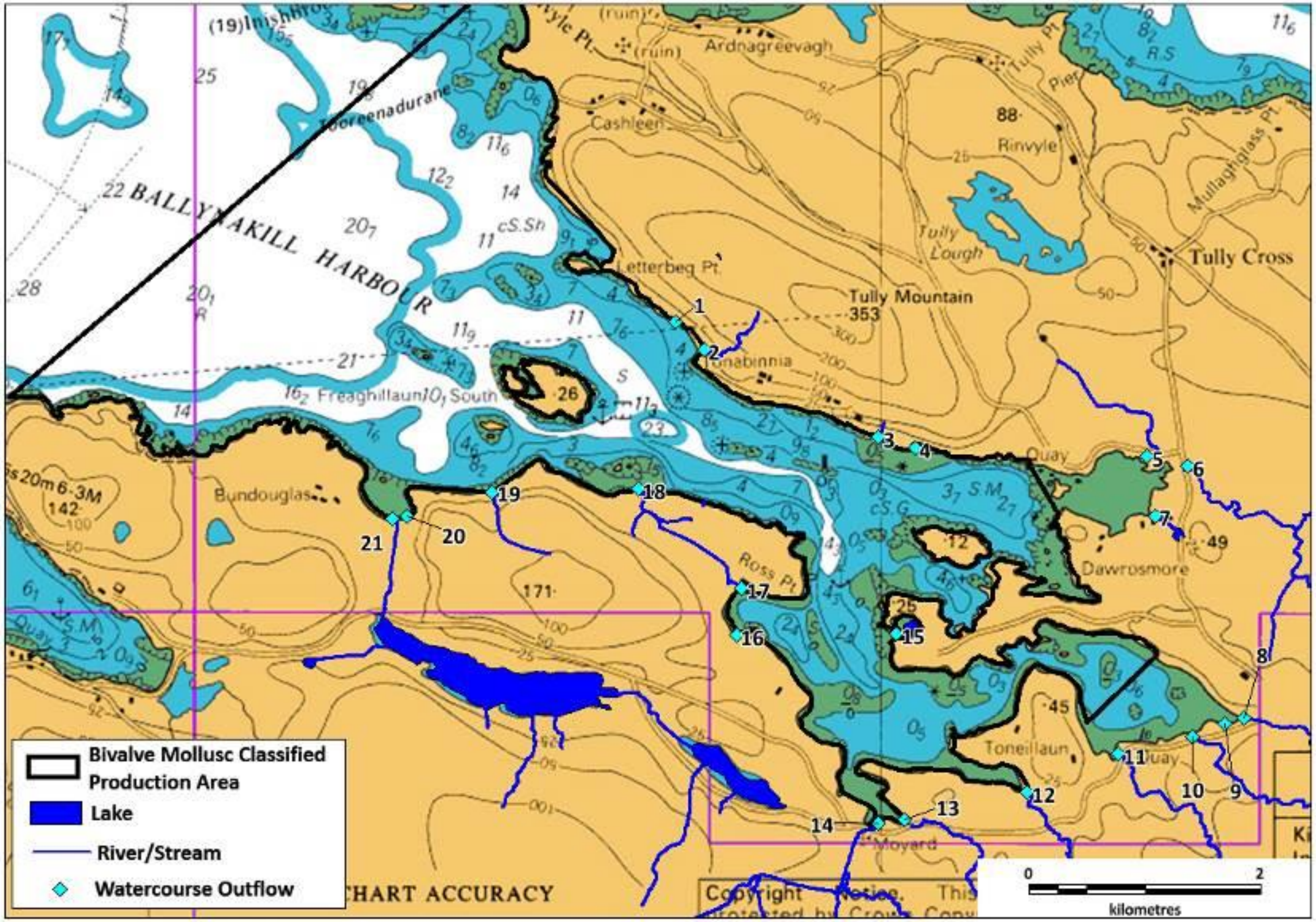


Figure 4.34: Location of all watercourses discharging into Ballinakill Harbour.

Table 4.12: Cross-referenced table for Figure 4.34 watercourses.

Map ID	Feature	Longitude	Latitude	Easting	Northing
1	Stream	-10.027621	53.583025	65764.81045	261130.6434
2	Stream	-10.023917	53.580867	66003.262	260883.5156
3	Stream	-10.001128	53.574039	67491.06637	260081.0052
4	Stream	-9.99632	53.57324	67807.02766	259983.1442
5	Small river	-9.966084	53.572557	69807.6402	259851.3994
6	Dawros River	-9.96073	53.57182	70160.00971	259759.599
7	Stream	-9.965017	53.567965	69864.20738	259338.4416
8	Sruffanboy Stream	-9.95342	53.55235	70584.76673	257579.6136
9	Small stream	-9.95582	53.55183	70424.13012	257526.1175
10	Owengarve River	-9.960075	53.550786	70138.95167	257417.6953
11	Owennabaunoge River	-9.969829	53.549512	69488.61876	257293.7614
12	Traheen River	-9.981733	53.546517	68690.43419	256982.3563
13	Small river	-9.99769	53.54439	67626.19908	256775.213
14	Moyard River	-10.0012	53.54411	67392.68005	256750.5902
15	Outflow from lake	-9.998761	53.558787	67600.19204	258379.3336
16	Stream	-10.01963	53.5587	66217.1747	258408.6669
17	Stream	-10.01895	53.56236	66273.78313	258814.6826
18	Stream	-10.03249	53.57007	65401.22318	259698.1821
19	Stream	-10.051534	53.569826	64138.96169	259707.2231
20	Stream	-10.0627	53.5679	63393.1129	259514.2714
21	Stream	-10.0646	53.567783	63266.8719	259504.9003

Regarding the features noted in the walk over survey of the area, 28 were water courses of varying sizes *e.g.* field drain, streams, rivers (including the Sruffanboy Stream to which the Letterfrack waste water treatment pipe discharges, 4 were oyster trestles, 2 were area where salmon cages occurred, 2 were razor shells sites and 1 was a mussel farm (long lines).

Even though some enrichment was recorded at a number of the drains, it is considered that the greatest potential threats to water quality in Ballinakill Harbour are at the Sruffanboy Stream and the Dawros and Owengarve Rivers.

5. Shellfish and Water Sampling

5.1. Historical Data

5.1.1. Shellfish Water Quality

The Marine Institute carry out quarterly water quality monitoring as part of the Shellfish Waters Directive in Ballinakill Harbour. All sampling is confined to the oyster aquaculture area. The EPA carry out monitoring under the Water Framework Directive However, *E. coli* is not routinely measured under these programmes.

5.1.2. Shellfish Flesh Quality

In accordance with EU regulation 2017/625 and subsequent implementing regulation EU 2019/627, the SFPA are required to establish the location and fix the boundaries of shellfish harvesting areas. The process involves regular sampling of shellfish from each area to be classified in order to establish levels of microbiological contamination which subsequently determines which classification should be awarded for that particular area. The SFPA currently sample shellfish flesh at three locations in Ballinakill Bay production areas for classification purposes. Figure 5.1 shows the locations of these sampling points and Table 5.1 shows the coordinates of the sampling sites and the species sampled. The locations sampled for Pacific oysters was relocated to its current location in 2018 because of an absence of oysters due to mortality issues. The original location can also be seen in Figure 5.1 and Table 5.1.

Table 5.1: Coordinates of sampling sites within the Ballinakill Production Area.

Sample Code	Species	Latitude	Longitude
GY-BL-BL-PO	Pacific Oysters	53.573105	-9.995408
GY-BL-BL-MU	Mussels	53.58350	-10.03420
GY-BL-BL-RAZ	Razors	53.565833	-10.008333

The Regulations stipulate that the competent authority must monitor the levels of E.*coli* within the harvesting area and that according to the sample results, must classify the area as being one of three categories - A, B or C.

An A classification allows for the product to be placed directly on the market, whereas a B or C classification requires the product to go through a process of depuration, heat treatment or relaying before it can be placed on the market. Table 5.2 summarises this system. Table 5.3 shows the current and historical (back to 2014) classifications within Ballinakill Bay. For the 2019-2020 period, Ballinakill is classified as A seasonal for mussels, A for razors (this is a preliminary classification) and A for oysters.

Table 5.2: Classification system for shellfish harvesting areas.

Classification			Permitted Levels	Outcome
	A	<230	Less than 230 *E. coli*100g flesh	May go direct for human consumption if end product standard met.
	B	<4600	Less than 4,600 *E. coli*100g flesh	Must be subject to purification, relaying in Class A area (to meet Category A requirements) or cooked by an approved method.
	C	<46000	Less than 46,000 *E.coli*100g flesh	Must be subject to relaying for a period of at least 2 months or cooked by an approved method.
	Above 46,000 *E.coli*/100g flesh			Prohibited. Harvesting not permitted

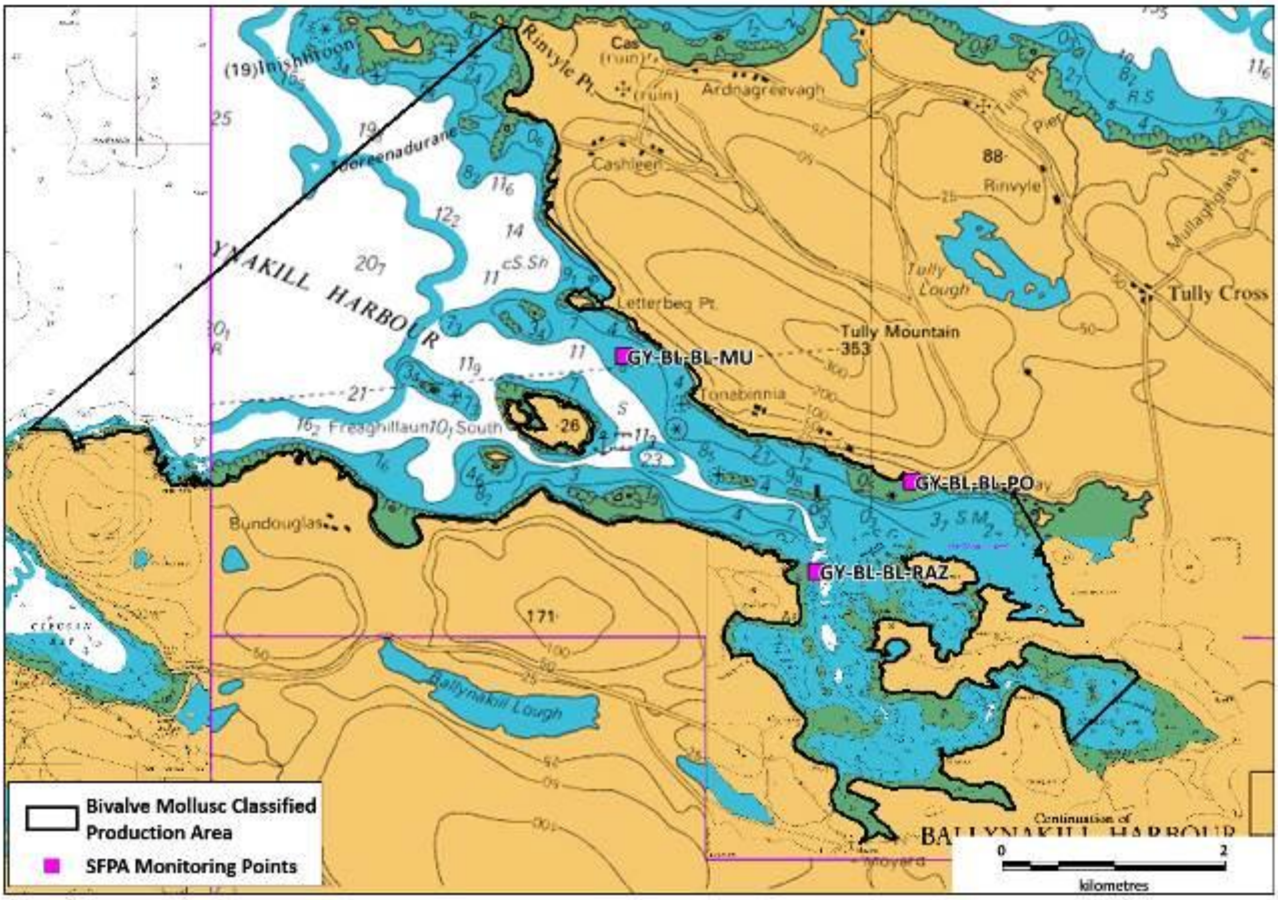


Figure 5.1: Locations of SFPA shellfish monitoring points for classification purposes.

Table 5.3: Current and historical classification of shellfish beds in Ballinakill Bay (2014 – 2019).

Boundaries	Bed Name	Species	Classification					
			2014	2015	2016	2017	2018	2019
Rinvyle Point to Cleggan Point	All Beds	Mussels	A*	A**	A	A	A	A***
		Oysters	B	A**	A#	A#	B	A
		Razors				A##	A##	A##

* Seasonal Classification 01 October to 01 May reverts to Class B at other times

** Seasonal Classification 01 December to 01 June reverts to Class B at other times

*** Seasonal Classification 01 October to 01 July reverts to Class B at other times

Seasonal Classification 01 December to 01 April reverts to Class B at other times

Seasonal classifications apply where the data shows a clear seasonal trend over a number of seasons, different classification categories apply for different seasons.

Preliminary Classification – Classifications are described as preliminary when an area is being classified for the first time or after a period in suspension. The term may also be used where an incomplete dataset of results was to hand

Tables 5.4 to 5.6 list the *E. coli* results for mussels, oysters and razor clams from Ballinakill from 2014 to January 2019 (where available). Figures 5.2 to 5.4 show these data in graphical form.

As shown in Table 5.3 above, Ballinakill has had an **A** classification for mussels since 2016. Prior to this, it had a seasonal **A** classification between October 1st and May 1st in 2014 and between December 1st and June 1st in 2015, with classification going back to **B** outside of these time periods. Since 2016, there was only one instance of a **B** result for the Ballinakill mussels (see Table 5.4). The *E. coli* count on that occasion was 2,400 MPN/100g. Since 2016, the Ballinakill mussels had an **A** result 97% of the time and a **B** result 3% of the time (See Figure 5.2). The most recent data from Ballinakill mussels (January 2019) gave an A result. Currently Ballinakill mussels are classified as a seasonal A, the period from the 1st October to the 1st of July is an A classification. Outside of this period mussels in Ballinakill revert to a B status.

As shown in Table 5.3 above, Ballinakill has had a seasonal **A** classification for oysters from 2015 to 2017 between 01 December to 01 June in 2015 and between 01 December to 01 April In 2016 and 2017, with classification falling back to **B** outside of these time periods. Prior to this, it had a **B** classification for oysters in 2014 (see Table 5.5). Ballinakill oysters are currently classified **B** for the 2018/2019 period[5]. Since 2016, there were only 2 instances of a **B** result for the Ballinakill oysters. *E. coli* counts ranged from 330 to 490 MPN/100g during these B result periods. Since 2016, the Ballinakill mussels had an **A** result 95% of the time and a **B** result 5% of the time (See Figure 5.3). The results from pacific oysters from Ballinakill have showed an improving trend line since 2016 and are currently classified as an A status.

As shown in Table 5.3 above, Ballinakill has had a preliminary **A** classification for razors since 2017 and they are currently classified preliminary **A** for the 2018/2019 period[5]. Since 2017, all monitoring values were an **A** result (See Figure 5.4 and Table 5.6). Currently the razors in Ballinakill are awarded an A status.

Table 5.4: ***E. coli*** **results from Ballinakill Harbour mussels from 2014 to January 2019 (source: SFPA).**

Date	MPN *E. coli* /100g	Category	Date	MPN *E. coli* /100g	Category
30-Jan-14	20	A	27-Jul-16	18	A
6-Feb-14	20	A	31-Aug-16	45	A
28-Feb-14	20	A	29-Sep-16	230	A
31-Mar-14	20	A	25-Oct-16	18	A
30-Apr-14	20	A	7-Nov-16	18	A
29-May-14	20	A	12-Dec-16	20	A
13-Jun-14	20	A	10-Jan-17	18	A
21-Jul-14	20	A	14-Feb-17	18	A
5-Aug-14	20	A	28-Mar-17	18	A
15-Sep-14	20	A	24-Apr-17	18	A
7-Oct-14	18	A	25-May-17	18	A
18-Nov-14	330	B	29-Jun-17	18	A
5-Dec-14	18	A	4-Jul-17	20	A
5-Jan-15	18	A	9-Aug-17	18	A
26-Mar-15	230	A	24-Oct-17	78	A
16-Jun-15	18	A	28-Nov-17	18	A
14-Jul-15	490	B	18-Dec-17	18	A
6-Aug-15	230	A	27-Feb-18	18	A
30-Sep-15	18	A	21-Mar-18	18	A
20-Oct-15	18	A	30-Apr-18	18	A
14-Jan-16	230	A	21-May-18	78	A
24-Feb-16	18	A	5-Jul-18	18	A
16-Mar-16	18	A	22-Aug-18	2400	B
29-Apr-16	18	A	30-Sep-18	18	A
12-May-16	45	A	31-Oct-18	18	A
28-Jun-16	18	A	10-Jan-19	18	A

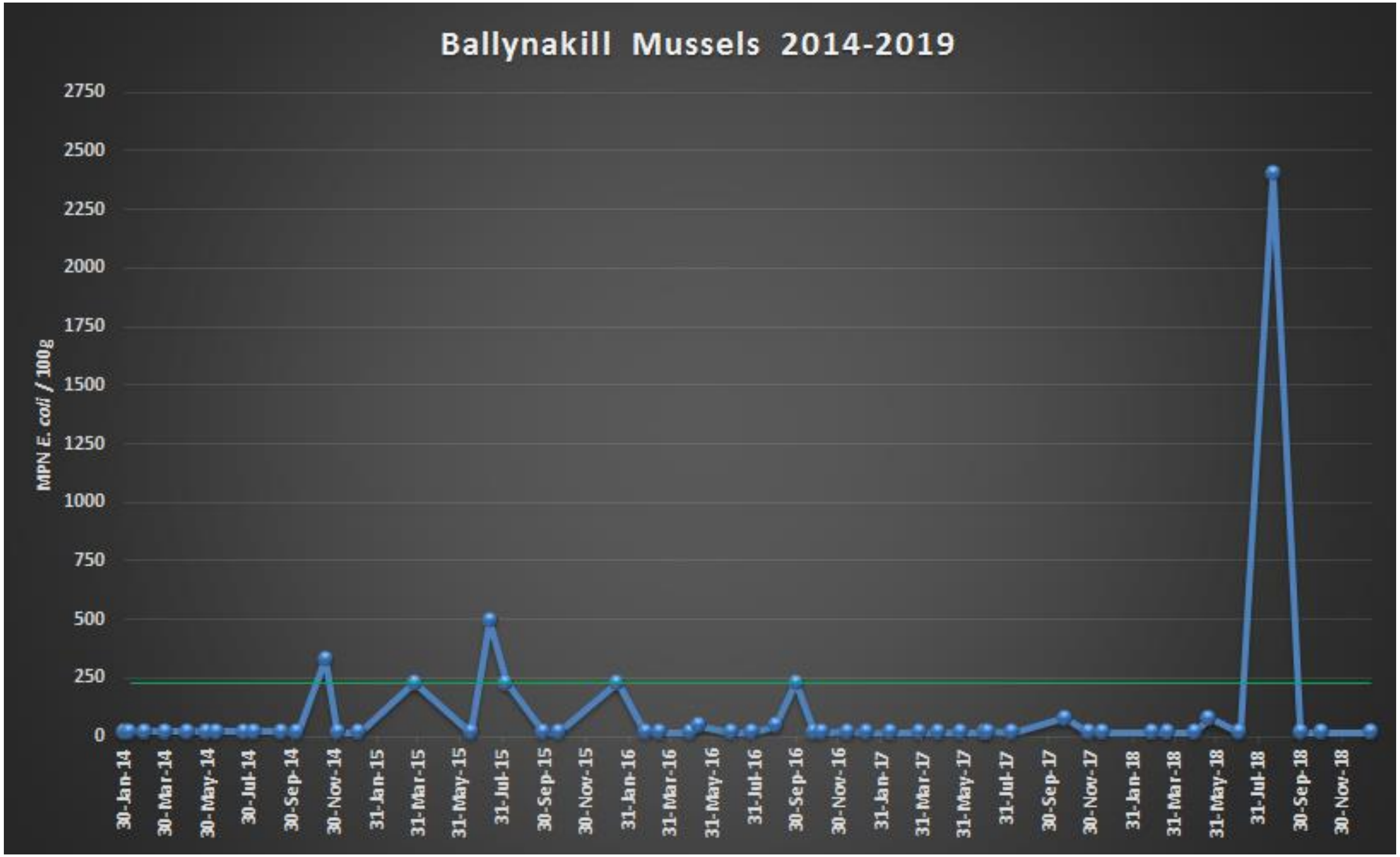


Figure 5.2: *E*. coli results from mussels at Ballinakill from 2014 to 2019 (source: SFPA).

Table 5.5: ***E. coli*** **results from Ballinakill Harbour oysters from 2014 to January 2019 (source: SFPA).**

Date	MPN *E. coli* /100g	Category	Date	MPN *E. coli* /100g	Category
30-Jan-14	80	A	29-Aug-16	18	A
3-Feb-14	50	A	14-Sep-16	230	A
3-Mar-14	20	A	25-Oct-16	18	A
1-Apr-14	20	A	15-Nov-16	18	A
28-May-14	20	A	5-Dec-16	18	A
10-Jun-14	20	A	16-Jan-17	18	A
16-Jul-14	230	A	1-Feb-17	20	A
6-Aug-14	20	A	1-Mar-17	18	A
10-Sep-14	230	A	10-Apr-17	18	A
6-Oct-14	1700	B	11-May-17	330	B
24-Nov-14	45	A	6-Jun-17	230	A
8-Dec-14	20	A	4-Jul-17	230	A
21-Jan-15	18	A	14-Aug-17	78	A
16-Feb-15	18	A	4-Sep-17	130	A
24-Mar-15	18	A	24-Oct-17	45	A
8-Apr-15	18	A	6-Nov-17	18	A
18-May-15	490	B	19-Dec-17	490	B
15-Jun-15	78	A	22-Jan-18	18	A
21-Jul-15	330	B	27-Feb-18	18	A
4-Aug-15	130	A	7-Mar-18	18	A
15-Sep-15	790	B	24-Apr-18	18	A
19-Oct-15	18	A	1-May-18	18	A
11-Nov-15	18	A	26-Jun-18	18	A
7-Dec-15	18	A	18-Jul-18	20	A
11-Jan-16	18	A	14-Aug-18	18	A
22-Feb-16	18	A	10-Sep-18	45	A
22-Mar-16	18	A	15-Oct-18	18	A
12-Apr-16	230	A	6-Nov-18	18	A
18-May-16	18	A	11-Dec-18	18	A
7-Jun-16	18	A	22-Jan-19	18	A
20-Jul-16	45	A			

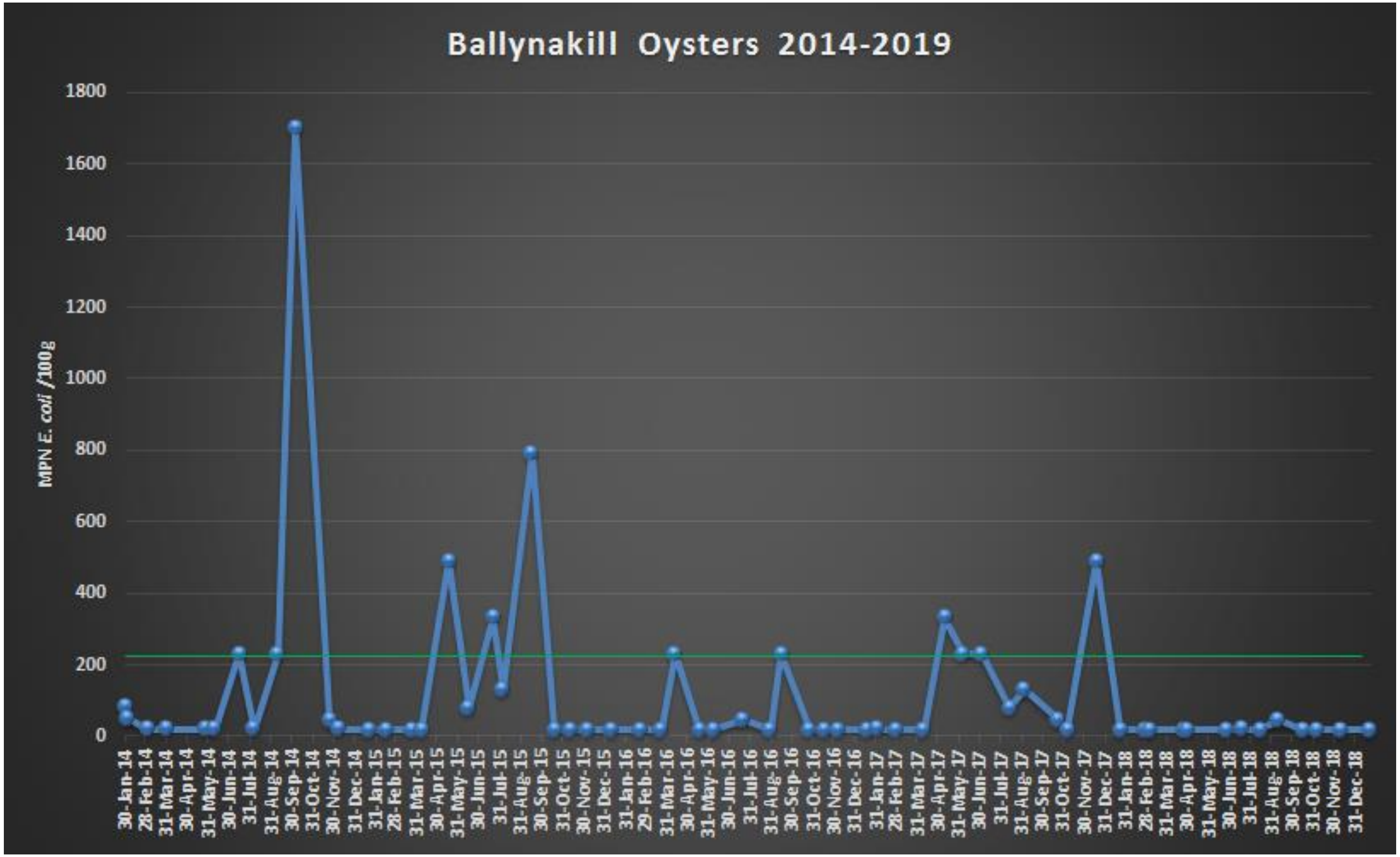


Figure 5.3: *E. coli* levels from oysters at Ballinakill from 2014 to 2019 (source: SFPA).

Table 5.6: *E. coli* results from Ballinakill Harbour razors from March 2017 to January 2019 (source: SFPA).

Date	MPN *E. coli* /100g	Category
27-Mar-17	18	A
10-Apr-17	18	A
24-Apr-17	18	A
8-May-17	18	A
22-May-17	18	A
6-Jun-17	18	A
19-Jun-17	18	A
4-Jul-17	18	A
29-Aug-17	20	A
19-Sep-17	20	A
9-Oct-17	18	A
1-Nov-17	20	A
21-Mar-18	18	A
14-May-18	18	A
26-Jun-18	18	A
11-Jul-18	18	A
11-Jul-18	18	A
31-Jul-18	78	A
20-Aug-18	18	A
20-Aug-18	18	A
4-Sep-18	20	A
1-Oct-18	18	A
7-Nov-18	18	A
7-Nov-18	18	A
15-Jan-19	18	A

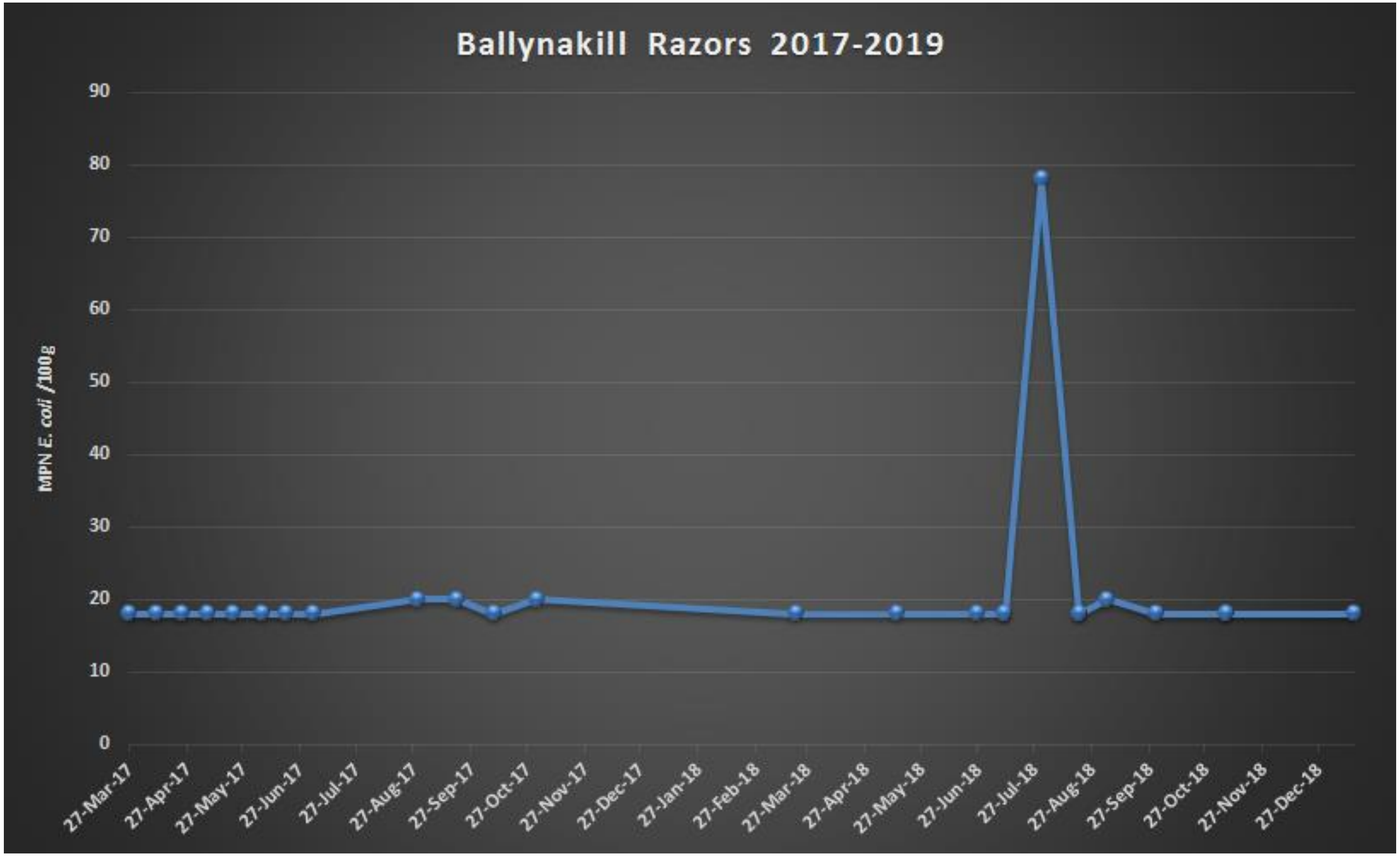


Figure 5.4: ***E. coli*** **levels from razors at Ballinakill from 2014 to 2019 (source: SFPA).**

Table 5.7 shows the summary statistics for the *E. coli* historical data from the 3 shellfish monitoring sites from 2014 to January 2019. The geometric mean of *E. coli* levels was highest for oysters (2014-2019), followed by mussels (2014-2019) and razor clams (2017-2019). Table 5.8 shows the variations of the annual geometric means of *E. coli* for the shellfish beds that had at least 5 samples per year from the year 2014. Figure 5.5 shows the trend in geometric mean from 2014 to 2018 for all 3 species in Ballinakill Harbour. The geometric mean for mussels ranged from 20.8 MPN/100ml in 2017 to 59.8 MPN/100ml in 2015. The geometric mean for oysters ranged from 19.6 MPN/100ml in 2018 to 67 MPN/100ml in 2017. The geometric mean for razors ranged from 18.5 MPN/100ml in 2017 to 20.5 MPN/100ml in 2018.

There was no significant differences in *E. coli* levels based on season for both oysters and mussels (one-way ANOVA, p = 0.181897 and p = 0.486637 respectively, Appendix 1) and there was also no significant difference in *E. coli* levels between species (one-way ANOVA, p = 0.188197, Appendix 1).

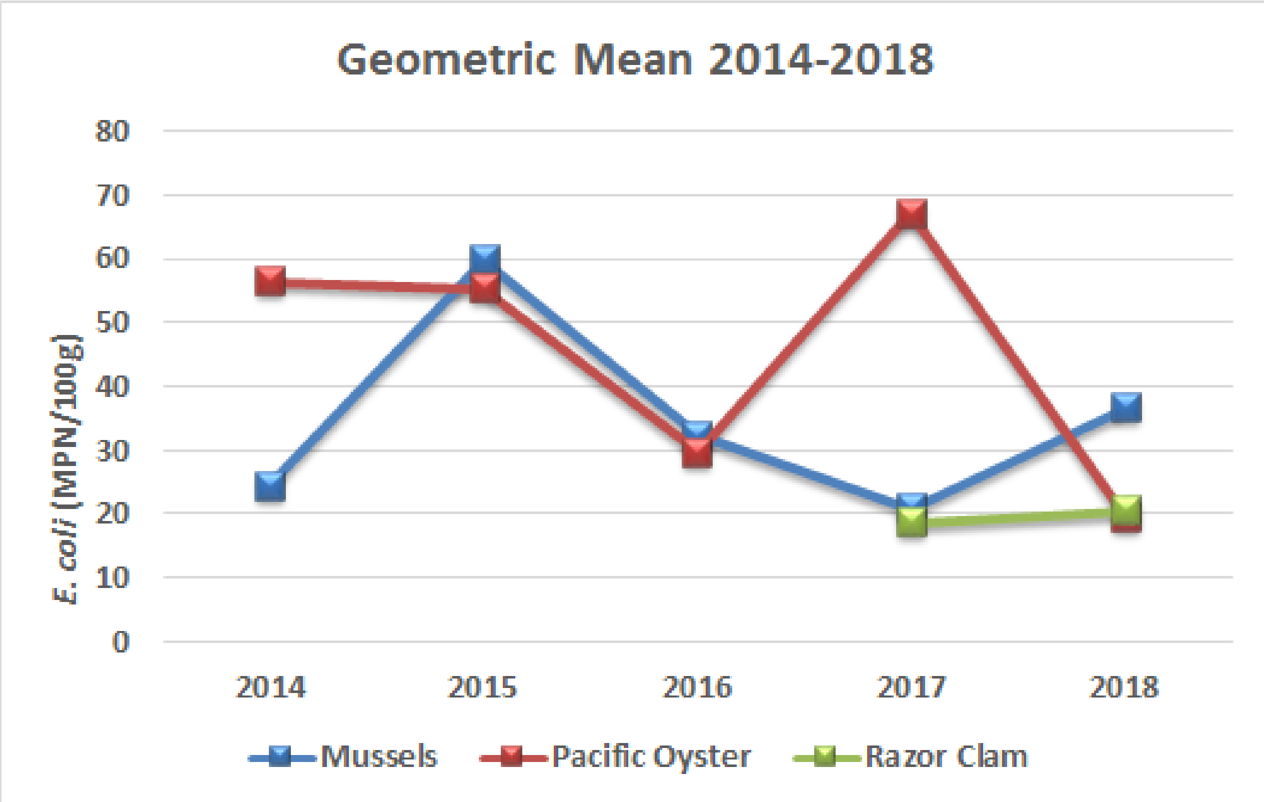


Figure 5.5: Trend in geometric mean of *E. coli* levels from 2014 to 2018 for all 3 species in Ballinakill Harbour.

Table 5.7: Summary statistics of historical *E. coli* data monitored from shellfish beds in Ballinakill Harbour.

Code	Species	Date of 1st Sample	Date last Sample	Minimum *E. coli* (MPN/100g)	Maximum *E. coli* (MPN/100g)	Median *E. coli* (MPN/100g)	Geometric Mean *E. coli* (MPN/100g)
GY-BL-BL-MU	**Mussels**	30/01/2014	10/01/2019	18	2400	18	30.4
GY-BL-BL-PO	**Pacific Oyster**	30/01/2014	22/01/2019	18	1700	18	40.8
GY-BL-BL-RAZ	**Razor Clam**	27/03/2017	15/01/2019	18	78	18	19.4

Table 5.8: Variation of annual geometric means of *E. coli* (MPN/100g) from shellfish beds monitored in Ballinakill Harbour.

Code	Species	2014	2015	2016	2017	2018
GY-BL-BL-MU	**Mussels**	24.4	59.8	32.3	20.8	36.5
GY-BL-BL-PO	**Pacific Oyster**	56.4	55.2	29.7	67	19.6
GY-BL-BL-RAZ	**Razor Clam**				18.5	20.5

In addition to *E. coli* monitoring carried out by SFPA, the Marine Institute (MI) conducts monthly monitoring for the presence of toxin producing phytoplankton in shellfish waters, including *Alexandrium* spp. and *Dinophysis* spp. and for marine biotoxins (including DSP, PSP and ASP) in shellfish flesh. The MI also monitors shellfish flesh for chemical contaminants *e.g.* heavy metals, organochlorides, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), pentachlorophenol (PCP) and Tributyl Tin Oxide (TBTO).

Over the period 2014 to 2018, there have been 25 biotoxin related closures and 26 biotoxin related harvest restrictions. The most recent closure was in October 2018 for razor clams. In 2018, Ballinakill was also closed for razors clams in September, June and April, oysters in June and February and there was a harvest restriction on scallops in March and April.

5.1.3. Norovirus (NoV)

Norovirus (formerly Norwalk agent) is a small (27-30 nm), genetically diverse single stranded RNA virus (Doré, 2009) (taxonomic family Caliciviridae) that causes approximately 90% of epidemic non-bacterial outbreaks of gastroenteritis around the world (Lindesmith *et al.,* 2003). People infected with a NoV typically experience relatively mild gastroenteritis with typical symptoms being stomach cramps, diarrhoea, vomiting and slight fever. The virus is life threatening to those with post-operative stress, the very young and very old (EPA, 2011). NoV often occurs in outbreaks and is the most common cause of Infectious Intestinal Disease (IID) in the community (Doré, 2009). It has a strong seasonal occurrence is known as the 'winter vomiting disease'. Transmission is via the faecal-oral route and the virus is highly infectious requiring only low numbers to be present to cause infection (Doré, 2009). Direct person to person spread is most common, especially in closed communities and outbreaks are often associated with highly publicised closures of hospital wards and other care settings. Because of the high rate of infection in the community, it is no surprise that NoVs are present in large numbers in municipal waste water (Doré, 2009), an infected person may excrete 0.15 billion NoV particles per day to the sewer system (EPA, 2011). The true extent of NoV removal during waste water treatment is unclear; however, it is clear that significant numbers of NoV remain in treated waste water discharges into the aquatic environment even where traditional bacterial indicators have been reduced to comply with current environmental standards (Doré, 2009). The inappropriate discharge of waste water into the environment may contaminate shellfisheries and drinking water supplies and represent a significant public health risk.

Ballinakill Bay was part of the 2-year Norovirus monitoring programme. Table 5.9 shows the Norovirus results from samples tested for Norovirus from November 2016 to October 2018.

Table 5.9: Norovirus results from Ballinakill from November v2016 to October 2018.

Date sampled	Species	NoV GI copies/g	NoV GII copies/g
15-Nov-16	*C. gigas*	<LOQ	Not detected
06-Dec-16	*C. gigas*	Not detected	Not detected
16-Jan-17	*C. gigas*	Not detected	Not detected
01-Feb-17	*C. gigas*	<LOQ	Not detected
01-Mar-17	*C. gigas*	Not detected	Not detected
12-Apr-17	*C. gigas*	Not detected	Not detected
11-May-17	*C. gigas*	Not detected	Not detected
06-Jun-17	*C. gigas*	Not detected	Not detected
04-Jul-17	*C. gigas*	Not detected	Not detected
14-Aug-17	*C. gigas*	Not detected	Not detected
04-Sep-17	*C. gigas*	<LOQ	Not detected
24-Oct-17	*C. gigas*	Not detected	Not detected
06-Nov-17	*C. gigas*	<LOQ	Not detected
19-Dec-17	*C. gigas*	Not detected	<LOQ
22-Jan-18	*C. gigas*	126	Not detected
07-Mar-18	*C. gigas*	Not detected	Not detected
24-Apr-18	*C. gigas*	Not detected	Not detected
01-May-18	*C. gigas*	Not detected	Not detected
18-Jul-18	*C. gigas*	Not detected	Not detected
14-Aug-18	*C. gigas*	Not detected	Not detected
10-Sep-18	*C. gigas*	Not detected	Not detected
Oct-18	*C. gigas*	Not detected	Not detected

5.2. Recent Data

5.2.1. Sampling Sites & Methodology

Eight water sampling sites were sampled within the Ballinakill Harbour BMCPA between October 2018 and January 2019. The locations of these sites can be seen in Figure 5.7 and Table 5.10 shows the station coordinates. Three stations were sampled on the 23rd October 2018 (Stations 1, 3 and 8), there was no rain on the day of sampling and in the 2 days prior to sampling and total rainfall for the 2 weeks prior to sampling was

44.6mm. Three stations were sampled on the 25th October 2018 (Stations 5-7). There was 2.7mm of rain on the day of sampling and 42.2mm of rainfall in the 2 weeks prior to sampling. Two stations were sampled on the 21st January 2019 (Stations 2 and 4). There was 13mm of rain on the day of sampling and 39.8mm of rainfall in the 2 weeks prior to sampling.

Of the 8 water samples collected, 5 were taken from river/stream outflows (stations 2, 4-7), 1 was from the Derryinver Bay waterbody (station 3) and 2 were taken over the razor beds (stations 1 and 8).

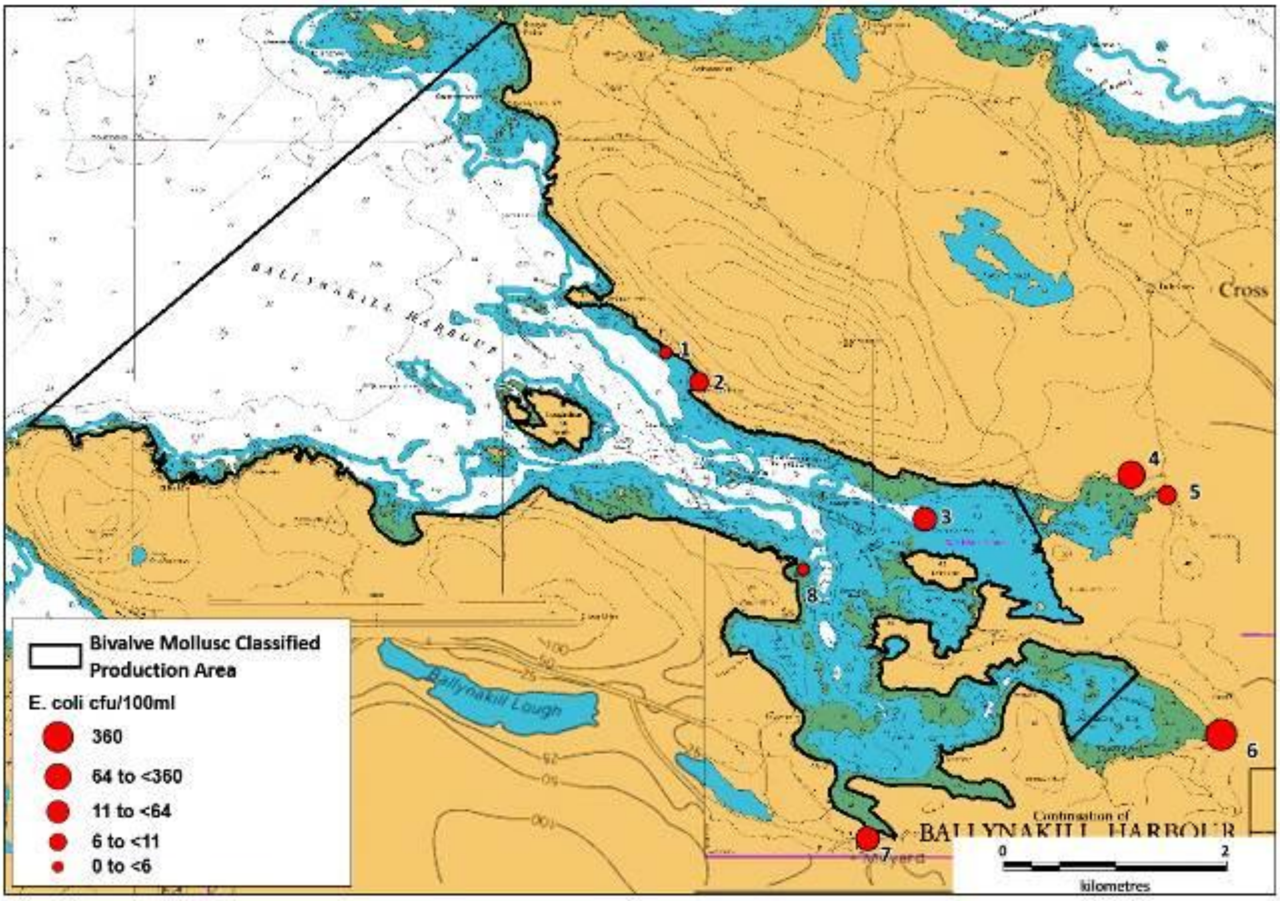


Figure 5.6: Water sampling sites

Table 5.10: Water sample coordinates with date of sampling.

Station Number	Feature	Latitude	Longitude	Easting	Northing	Sampling Date
1	Ballinakill razor bed	53.58321	-10.0286	65701.23	261153.1	23/10/2018
2	Stream (Running off mountain adjacent mussel longlines)	53.58087	-10.0239	66003.26	260883.5	21/01/2019
3	Derryinver Bay	53.56978	-9.99347	67985.02	259592.8	23/10/2018
4	Small river	53.57327	-9.96553	69846.32	259929.4	21/01/2019
5	Dawros River	53.57182	-9.96073	70160.01	259759.6	25/10/2018
6	Sruffanboy Stream (WWTP Letterfrack discharges upstream)	53.55235	-9.95342	70584.77	257579.6	25/10/2018
7	Moyard River	53.54411	-10.0012	67392.68	256750.6	25/10/2018
8	Ballinakill razor bed	53.56583	-10.01	66879.63	259184	23/10/2018

All water samples were collected in sterile plastic water bottles. These samples were stored in a cool box until delivery to either Aqualab in Killybegs, Co. Donegal or CLS in Ros Muc, Co. Galway (within 24hrs of collection). Both labs are INAB accredited and the *E. coli* analysis was carried out on the water samples by membrane filtration. Appendix 2 contains the result certificates from the lab.

5.2.2. Microbial Analysis Results

Table 5.11 shows the water sample analysis results (Refer to Appendix 2 for result certificates). Highest *E. coli* levels came from the Sruffanboy Stream which flows into Barnaderg Bay (Station 6; 360 cfu/100ml); this is to be expected as the Letterfrack waste water plant discharges effluent to this water course. The second highest *E.coli* count came from an unnamed river in the northeastern corner of the site which flows into Derryinver Bay (Station 4; 64 cfu/100ml). The Moyard River which flows into Fahy Bay on the southern shore had a value of 14 cfu/100ml (station 7) followed by a value of 11 cfu/100ml in the waters of Derryinver Bay (Station 3). The stream discharging close to the razor bed on the north shore had a value of 8 cfu/100ml (Station 2). The Dawros River had a value of 6 cfu/100ml (Station 5). Both sites 1 and 8, which were located over the razor beds, had a value of 0 cfu/100ml.

Table 5.11: Water *E. coli* results for Ballinakill Harbour.

Station No.	*E. coli* (cfu/ 100ml)
1	0
2	8
3	11
4	64
5	6
6	360
7	14
8	0

6. Overall Assessment of the Effect of Contamination on Shellfish

6.1. Human sewage/Human population

Only one WwTP discharges close to the production area that being the Letterfrack plant which discharges into the Sruffanboy Stream. The level of treatment is secondary and there is no stormwater overflow associated with the plant. The current plant population equivalent loading is 221 with a projected rise to 232 in 2023. Whilst the population equivalent is modest and the treatment level is secondary, there will be some contamination from this plant into Barnaderg Bay through the discharging stream and, in light of the predicted movements of contaminants, this may impact the fishery in the west of the bay and where it discharges seaward.

Using the CSO (2019) figures, it is estimated that approximately 404 households within the catchment have their own septic tanks or treatment systems. These discharges are expected to contribute to faecal loadings on the main watercourses discharging into the area. In this area of Co. Galway, population concentrations are low overall with only two villages present at Letterfrack and the much smaller Moyard. Other than these areas, houses are spread out throughout the lower lying areas of land. Much of the area, particularly around Tully Mountain, is upland and is not suitable for dwelling houses. However, the area is a popular tourist destination in the summer and areas such as Letterfrack and the Connemara National Park are popular locations for visitors. None of the islands in the area are inhabited and the level of industrial activity is very low.

No other obvious sewage related discharges were noted during the shoreline survey. Whilst correlation between *E. coli* and norovirus levels is troublesome, it is worth noting the almost non-existent levels of norovirus detected in pacific oyster samples from Ballinakill during the recent 2016 – 2018 study by the Marine Institute and the SFPA.

Five section 4 discharge licences are located within the catchment but at the time of the survey, data was not available on the specifics of the discharges. Only two though discharge in proximity to the fishery and when the receiving Moyard River was sampled during the shoreline surveyed, it displayed very low levels of contamination.

Whilst a number of piers were identified during the shoreline survey, actual vessel numbers and traffic were low and it is unlikely that boats or related discharges will have anything other than a minimal impact.

6.2. Agriculture

CSO data on farmed areas for the Ballinakill catchment when extrapolated out of the electoral division areas data set give an estimate of 3,976 hectares of farmland within the catchment. The same data indicated that sheep were the predominant animal farmed with the electoral divisions of Rinvyle and Ballinakill supporting a total of 8,416. Numbers of sheep were also noted during the shoreline survey on lands adjacent the northern shore of the bay. Numbers of studies have reported a strong association of livestock farming areas and faecal indicator concentrations of microorganisms in streams and coastal waters due to run-off from manure, especially during high flow conditions, both from point and non-point sources of contamination (*e.g.* Crowther et al., 2002).

Impacts are most probable to the Dawros River, Owengarve Stream and to a lesser extent the Owennabaunoge River. It is likely that the smaller streams and drains will also carry some contamination.

6.3. Rivers and Streams

In total, twenty eight water courses of varying size were identified during the shoreline survey with the majority being field drains; however, a number of small rivers were also identified. The most significant inputs of freshwater to Ballinakill Bay are from the Owengarve and Dawros Rivers. The catchments of these rivers include upland areas of the Twelve Bens and a mountain range to the north of Kylemore Lough which are used for grazing sheep. The other water course that is relevant is the small Sruffanboy Stream in to which the effluent of the Letterfrack WwTP is disposed – this stream enters the eastern end of Barnaderg Bay and when sampled showed the highest faecal contamination of the whole survey at 360 cfus per 100 ml. Aside from this result all other water samples taken from water courses showed low levels of contamination.

It is likely though that contamination from septic tanks and diffuse agricultural input may input to these smaller water courses and may impact the fishery where ever they discharge immediately upon it. The small streams at Knocknahaw and Ardagh would be case in point due to both discharging near to oyster licensed areas.

The small streams away from the actual fishery may be too small and carry very low levels of contamination as observed during sampling to impact anything other than background levels.

6.4. Movement of Contaminants

The output of a 2 dimensional hydrodynamic model carried out by Marine Computational Services Ltd (MCS) in 1991 that was carried out as part of an Environmental Impact Statement (EIS) prepared by AQUAFACT on behalf of Tully Mountain Salmon Farm as part of a salmon farm licence that that Company applied to the Government for was used to examine the current speeds and directions within Ballinakill Bay. The model domain extended from the open sea west of Ballinakill into the eastern parts of the bay. The model output was calibrated and validated using current velocity and direction data recorded by surface mid water and off bottom drogues and a tidal gauge.

It is expected that any contamination originating from the Struffanboy Stream and Owengarve River entering Barnaderg Bay will be transported seaward and over the oyster growing licence at Dawros Beg due to the westerly ebbing tide at the narrows here. In addition, when these freshwater loads enter the sea, their plumes deflect northwards in the bay due to:

1. A clockwise moving lower salinity current around Ireland
2. The Coriolis effect and
3. The northward flowing longshore drift direction in this area.

Therefore, whatever the level of faecal pollution is present in the inflowing freshwater, it is the marine waters along the north sections of the inner bays (Derryinver to the north and Barnaderg to the south) that might experience negative impacts from whatever pollution is present in the freshwater. This may well be exacerbated by the predominant south westerly winds pushing water back into the bay in a north easterly direction. In addition, inputs from the Dawros River and whatever diffuse contamination originates from agriculture is expected to move west on the ebbing tide; this will likely include waters moving across the oyster site at Ardagh and later in the ebb that of the mussel site at Letter Beg.

However, the oceanographic characteristics of marine waters in this bay are typified by high salinity levels, low suspended solids loadings, a short residence time (1.7 days) and current velocities that allow for good dilution/dispersion.

6.5. Wildlife

There is one sea bird colony in Ballinakill Bay and it is designated as a Special Protection Area (SPA). Illaunnanoon SPA is a small island that is situated at the mouth of Barnaderg Bay on the east side of Ballinakill Harbour. The site is designated for the Sandwich Tern and the site supports a nationally important population (80 pairs in 1984, 35 pairs in 1995 and 90 pairs in 2001). Other species recorded on the island in 2001 include Common Tern (20 pairs), Black-headed Gull (70 pairs) and Common Gull (12 pairs). The colony at Illaunnanoon lies immediately adjacent to a licensed oyster area and may have some contaminating affect but this is likely to be limited due to the dilution effect of the surrounding water, the short period of the year it is occupied and the low levels of birds. No other wildlife was noted during the shoreline survey.

6.6. Seasonality

While there is little tourism infrastructure in the immediate vicinity of Ballinakill Harbour, the area will see a rise in people during the summer months. The nearby Connemara National Park and the village of Letterfrack are focal points and both are within the catchment area of the bay. A figure of 180 unoccupied holiday homes was calculated based on the CSO figures for 2019 and it can be surmised that at least some of these will be occupied on a seasonal basis.

In terms of agriculture, numbers of sheep would be expected to be higher in Spring/Summer when lambs would be present but at this time of the year, there will also be more extensive grazing on the hills and thus impacts would be more widely spread.

There will be a distinct seasonal flux of seabirds with the arrival of terns in the late Spring and early Summer. Impacts from these seabirds will be most concentrated in the immediate vicinity of the nesting site which is adjacent to the oyster licence but recorded bird numbers are relatively low. As such, some diffuse impacts may arise.

To be expected, the analysis of the rainfall data shows a clear seasonal trend between the drier summer months and the wetter autumn/winter; however, as can be seen from the data, extreme rainfall events leading to episodes of high run-off can occur in most months of the year. Analysis of the historical microbiological sampling data for mussels and oysters showed no clear seasonal trend between higher results, there was no clear differentiation between the summer/autumn/winter or spring periods. A pattern of results though has been identified by the Sea Fisheries Protection Authority in respect of the mussel fishery. Analysis of the historical dataset, for the most recent three year period in particular, showed a trend for higher results outside of the 1st October to the 1st of July period. Consequently mussels are awarded an A classification within this period, reverting to a B at all other times.

7. Recommendations

7.1. BMPA Boundaries

The licenced area for Oysters in Ballinakill Bay extended outside of the existing BMPA area (Figure 7:1). Therefore, the BMPA area was extend to include the entire licence area (Figure 7:2). The BMPA area has increased from 19.36km^2 to 19.75km^2.

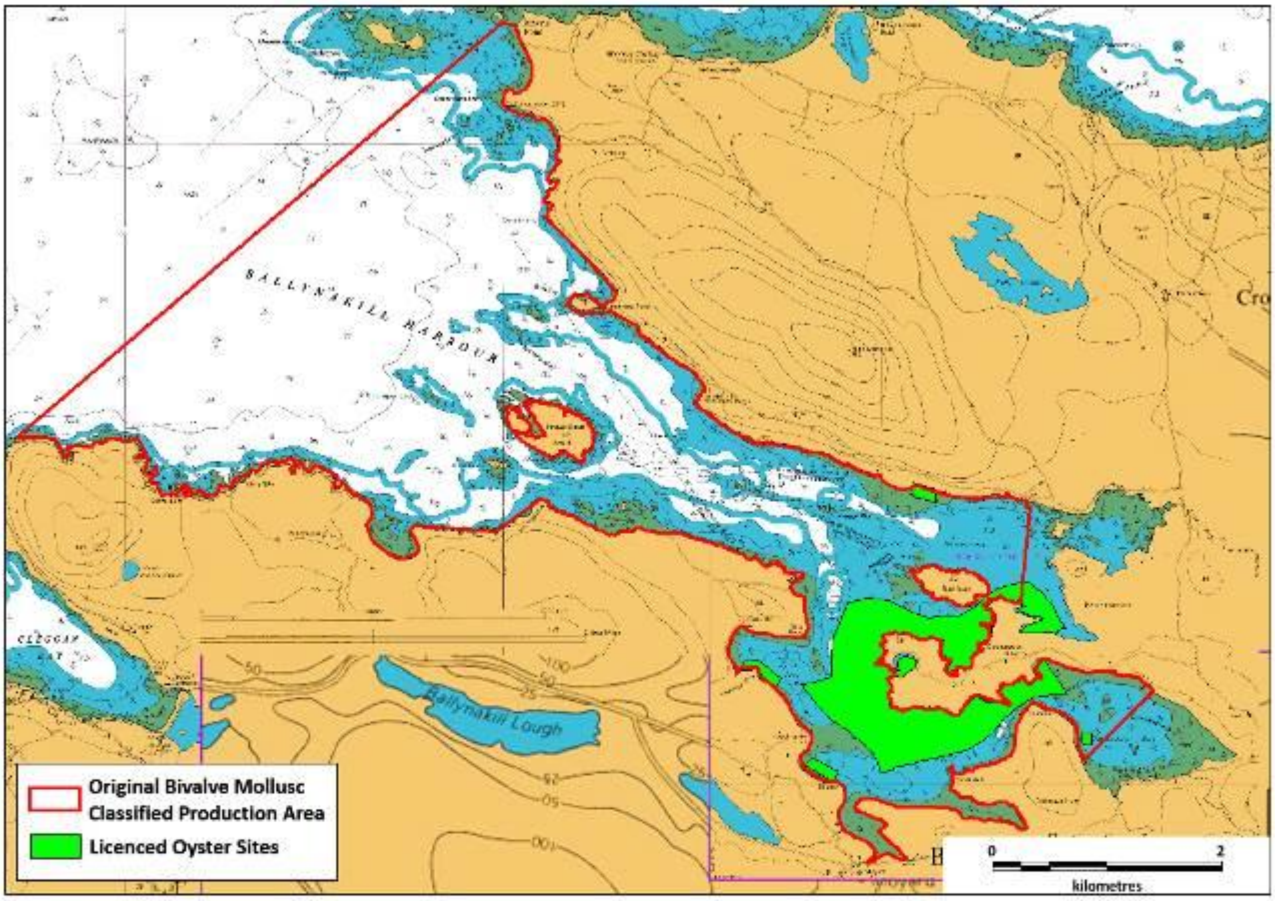


Figure 7.1: Original BMPA area.

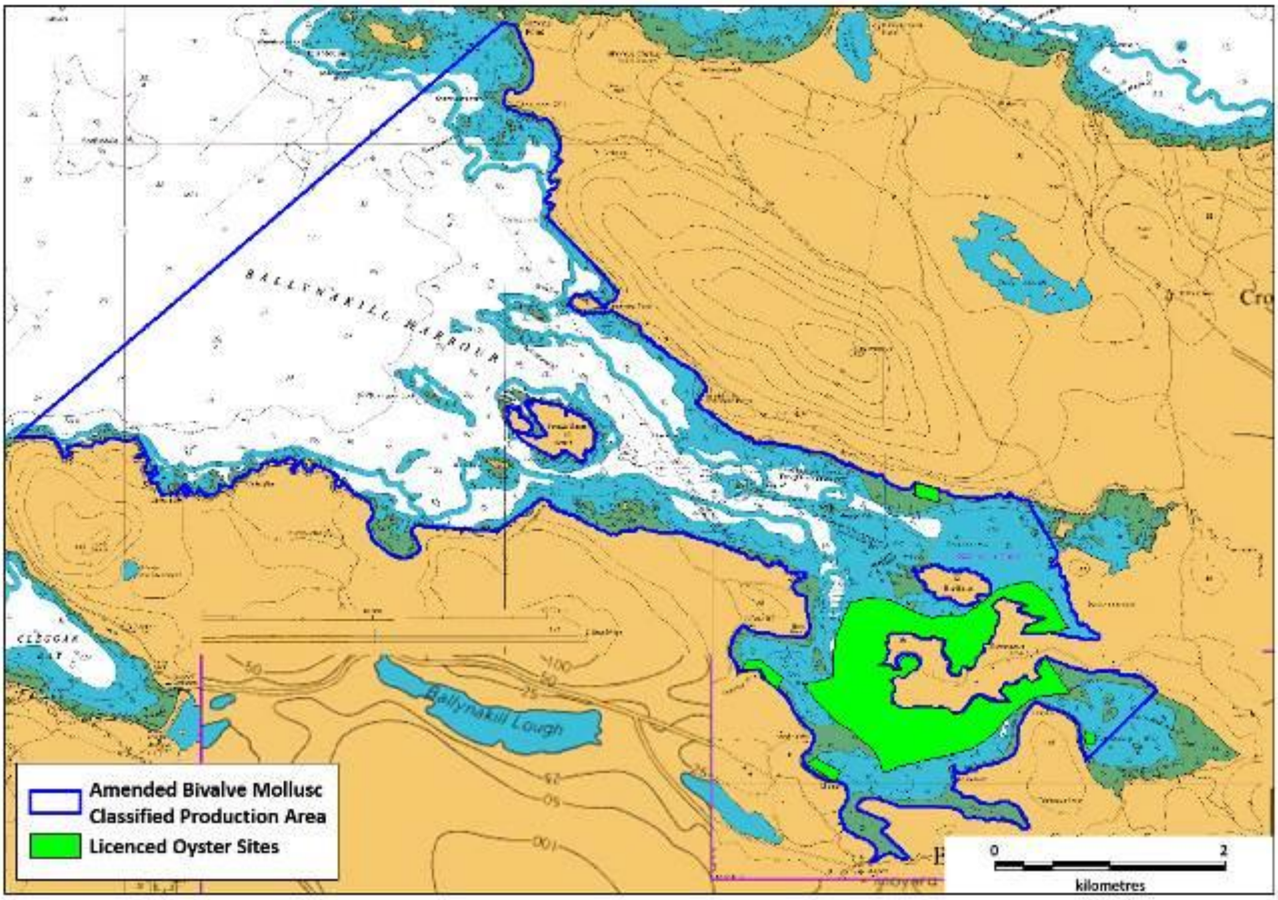


Figure 7.2: Amended BMPA area.

The table below outlines the co-ordinates for the BMPA area in its entirety.

Table 7.1: Coordinates of the Production Area.

Corner	Latitude	Longitude	Easting	Northing
NW	-10.0491	53.60947	64427.09	264114.5
NW	-10.0507	53.60956	64318.85	264127.7
SW	-10.1148	53.57718	59974.39	260648.3
SE	-9.97384	53.55194	69230.34	257571.3
SE	-9.96462	53.55728	69857.81	258148.3
NE	-9.98222	53.56434	68713.55	258966.1
NE	-9.9809	53.57174	68823.86	259787.3

8. RMPs and Sampling Plan

8.1. Mussels *(Mytilis edulis)*

There is only one licensed area for mussels in Ballinakill Harbour that is located to south of Leitir Mor on the northern shore of the harbour. Mussels are grown here on standard longline droppers and it is natural therefore that the mussel RMP should be located at this licensed site. Whilst the site is located to the open seaward mouth of the harbour, it will be influenced by the two ebbing tidal streams that empty the harbour. Any potential contamination is likely to arrive on these two streams and further potential contamination from sheep farming on the adjacent northern shore may also impact the site particularly during the Spring/Summer period when more livestock might be expected to be on the land.

Whilst it is expected that the area of the site most likely to suffer any contamination would be at that eastern landward end where the ebbing tidal streams are encountered first, it was noted in analysis of the historical microbiological dataset that levels of contamination are generally very low.

Sample depth will be set at 1 metre as it is expected that any contamination will carried on surface waters due to freshwater influences. It was found that haloclines do form quite frequently in Ballinakill during the winter months or after periods of heavy rain with salinity levels in the upper layers displaying lower values than deeper waters. Due to commercial harvesting taking place at various stages throughout the year the sampling frequency should be monthly.

The location of the RMP for mussels is 53.58350N and 10.0342W (65,330.7E 261,195.9N) and is shown on Figure 8.1. Samples should be taken from this point or no more than 100 metres maximum from it.

8.2. Razor Clams *(Ensis spp)*

Razor clams are fished at four general locations within Ballinakill Harbour but it is the bed at Ross Point that lays furthest to the east in the production area and thus more likely to be influenced by any potential freshwater inputs. Due to the ebbing tidal streams from Fahy Bay, Barnaderg Bay and to a lesser extent Roeillaun Bay all passing this point, it is regarded as the most likely point where any potential contamination might occur.

As this is a subtidal site, sampling should take place as per normal commercial harvesting methods. Commercial harvesting takes place infrequently within the harbour and this will be reflected in the sampling frequency.

The location of the RMP for razor clams is 53.565833N and 10.008333W (66,988.3E 259,181.3N) and is shown on Figure 8.1 below (see attached Annexes for sampling plan summary). Samples should be taken from this point or no more than 250 metres maximum from it.

8.3. Oysters *(Crassostrea gigas & Ostrea edulis)*

Pacific oyster licences are located all within the inner bays including Barnaderg, Derryinver, Fahy and Roeillaun. The largest oyster licence is centred around Dawros Beg and will be the location of the RMP for pacific oysters. All waters emptying from Barnaderg Bay pass through the channel neck here adjacent and across the oyster licence. The eastern part of Barnaderg Bay is also the location where the Sruffanboy Stream to which the Letterfrack waste water treatment plant discharges. The Owengarve River also discharges into the nearby Barnaderg Bay and any diffuse contamination from the Moyard, Tullyboy and Traheen watercourses will also be directed eastwards here on the flood tide. As current velocities are relatively low in Barnaderg Bay, if coliform bacteria do persist from the waste water treatment plant, they could be present in this area. Furthermore, the site chosen is also close to the bird colony at Illaunnanoon Island.

The original RMP for pacific oysters which was located on the northern shore of Ballinakill Bay within the licensed site is no longer practical due to a lack of stock on the site (pers. comm. from Rossaveal SFPA staff).

Samples should be taken from trestles at the sampling location and sampling will be on a monthly basis. The location of the RMP for oysters is 53.554887N and 9.989499W (68,219E 257,926N) and is shown on Figure 8.1 below Samples should be taken from these points or no more than 100 metres maximum from them.

Native oyster stock is limited to the licensed area at Dawros and in particular to the very small localised area close to the existing pacific oyster sampling location where they are grown on a small section of the bag and trestle farm. For that reason the RMP location will also be located here. In addition the location will also be subject to the same potential contaminant flows as the pacific oyster site. Samples should be taken from trestles at the sampling location and sampling will be on a monthly basis.

8.4. Pulled Carpet Shell Clams *(Venerupis corrugata)*

In this instance and based on samples submitted for analysis, it has been decided that an indicator species approach, as outlined in the 'Microbiological Monitoring of Bivalve Mollusc Harvesting Areas – Guide to Good Practice' will be taken with the pulled carpet shell clam species. The indicator species in this instance will be the razor clam as both species when sampled all returned class A results less than 230 *E. coli* per 100 gram of flesh. Thus the RMP and sampling plan as outlined for the razor clams will preclude the need for an RMP and separate sampling regime for the carpet shell clams.

8.5. King Scallops *(Pecten maximus)*

Classification monitoring data obtained from the official monitoring of other bivalve molluscs within an existing classified production area are used to determine the classification of scallops fished from within an existing classified production area. Therefore, a specific scallop RMP and associated scallop monitoring is not required.

All scallops harvested within classified production areas are classified as B unless harvested within classified production areas where all other mollusc shellfish are classified as being of class A, in such cases scallops may be classified as A.

The coordinates of all the RMPs and the relevant species can be seen in Table 8.1.

Table 8.1: Coordinates of each RMP and its relevant species.

RMP	Code	Species	Latitude	Longitude	Easting	Northing
RMP 1	GY-BL-BL	Mussels	53.581017	-10.029309	65,646.7	260,910.4
RMP 2	GY-BL-BL	Razors	53.565833	-10.008333	66,988.3	259,181.3
RMP 3	GY-BL-BL	P. Oysters	53.554887	-9.989499	68,219	257,926
RMP 4	GY-BL-BL	N. Oysters	53.554887	-9.989499	68,219	257,926

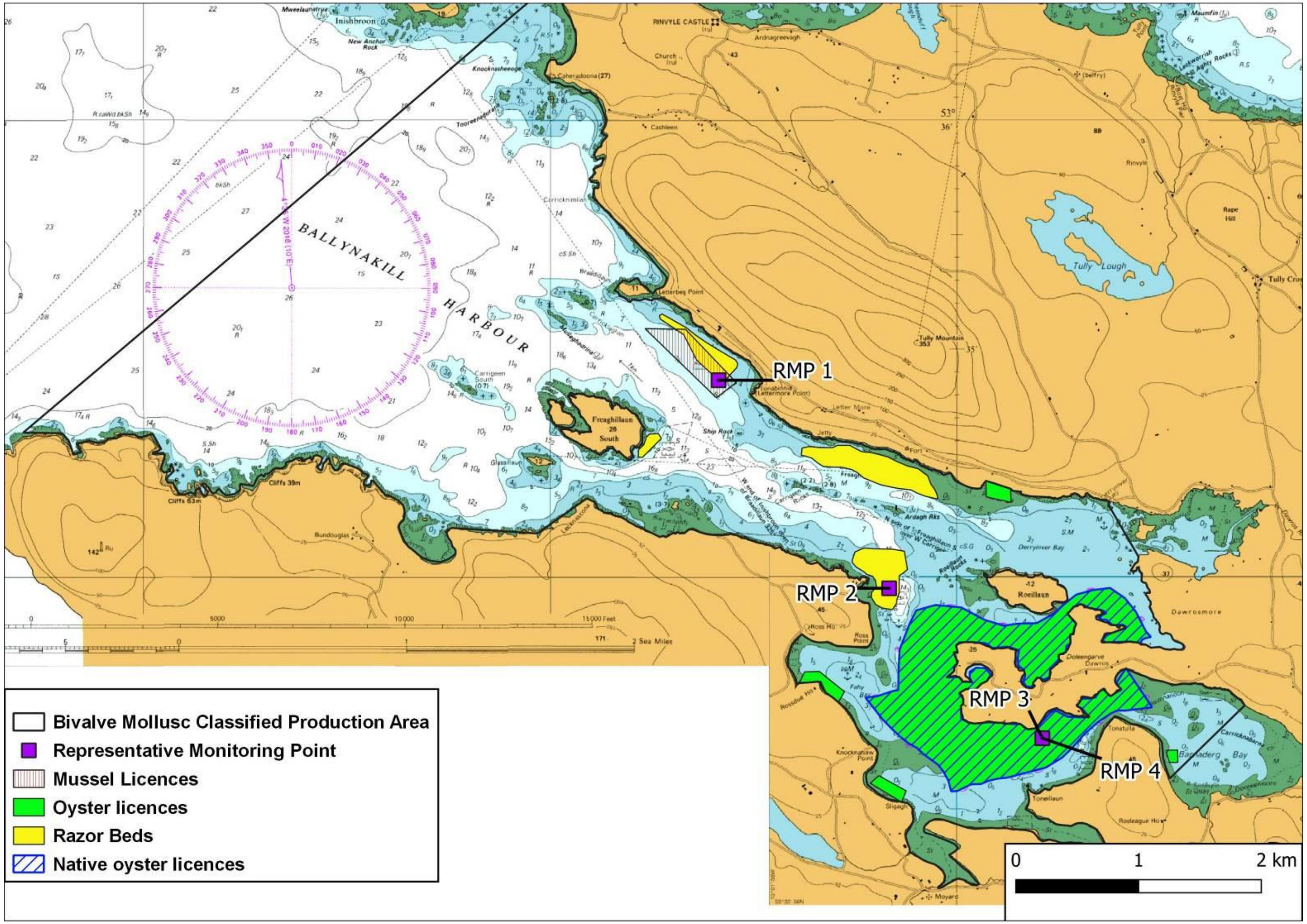


Figure 8.1: 4 RMPs within the Ballinakill Bay Production Area and their relevant species.

8.6. Species Specific RMP Maps

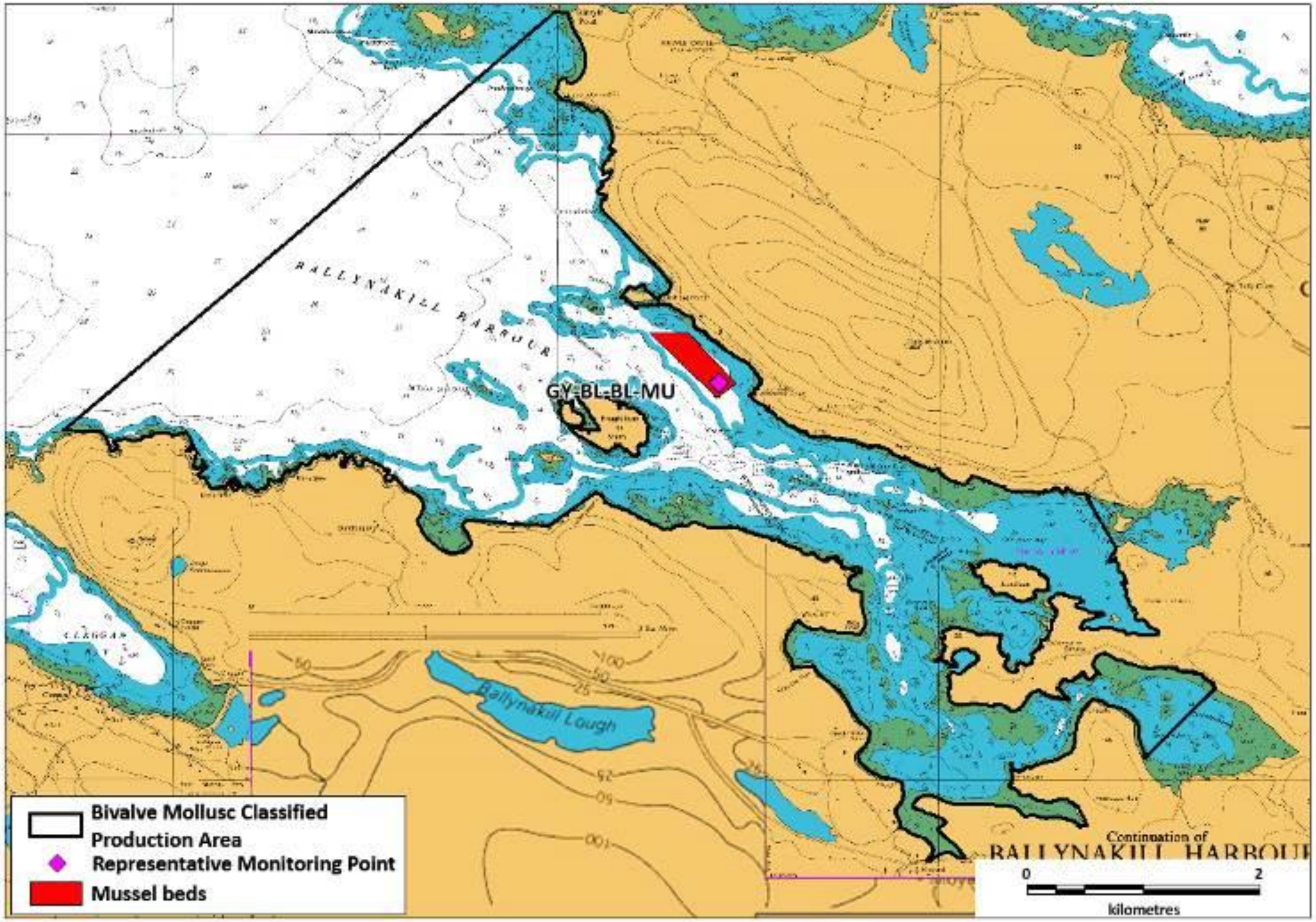


Figure 8.2: Location of the Mussel RMP within Ballinakill Bay.

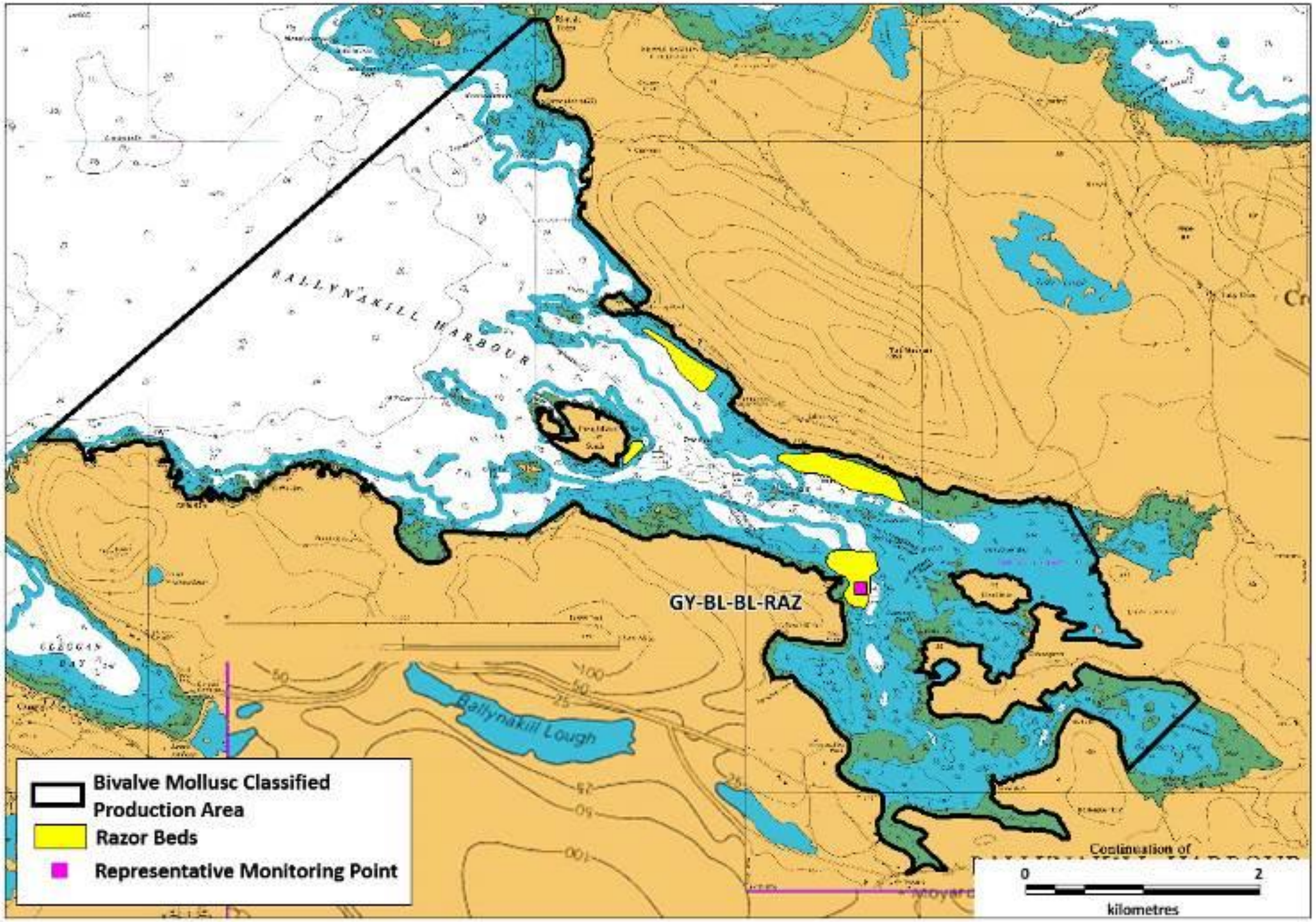


Figure 8.3: Location of the Razor Clam RMP within Ballinakill Bay.

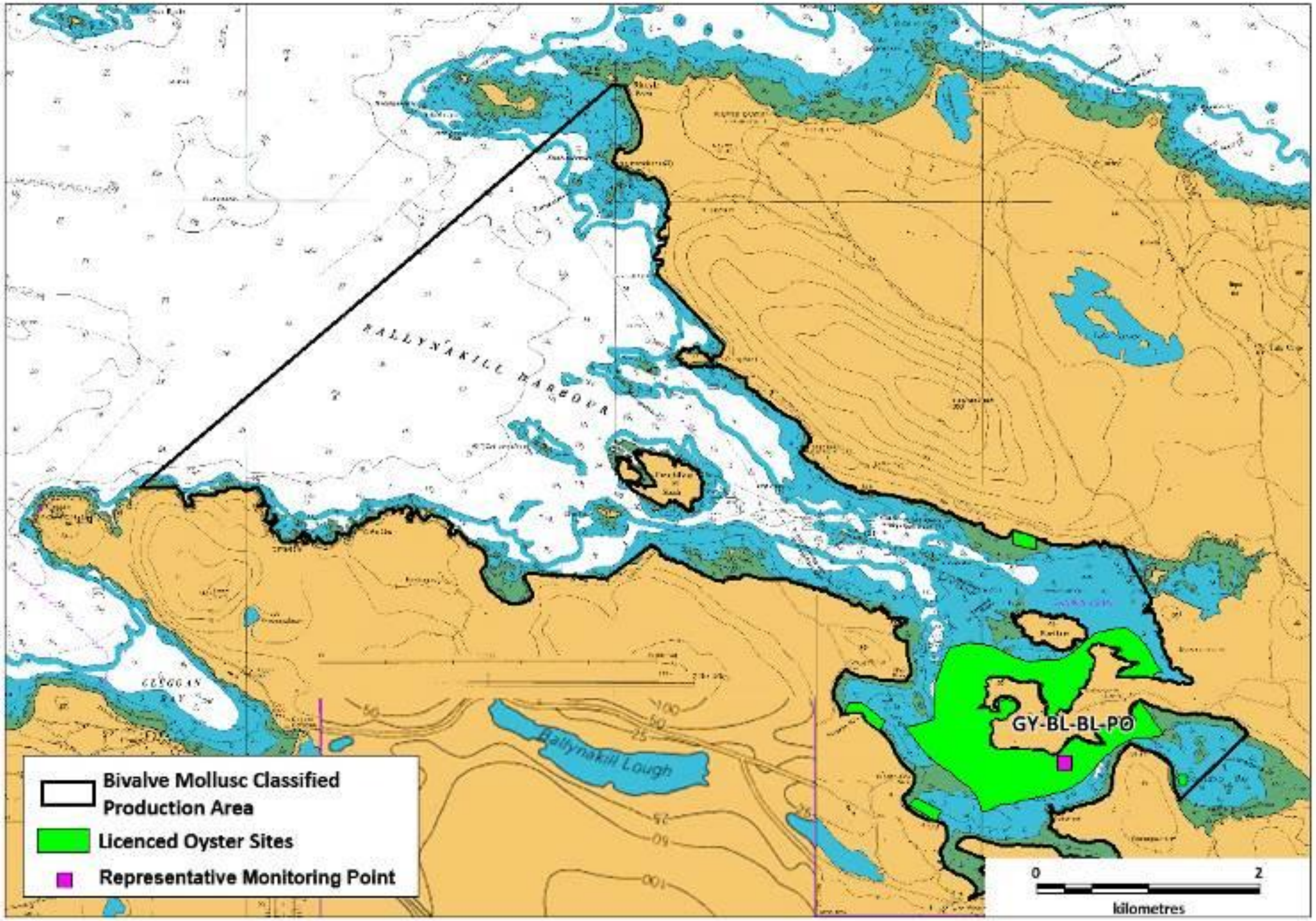


Figure 8.4: Location of the Pacific Oyster RMP within Ballinakill Bay.

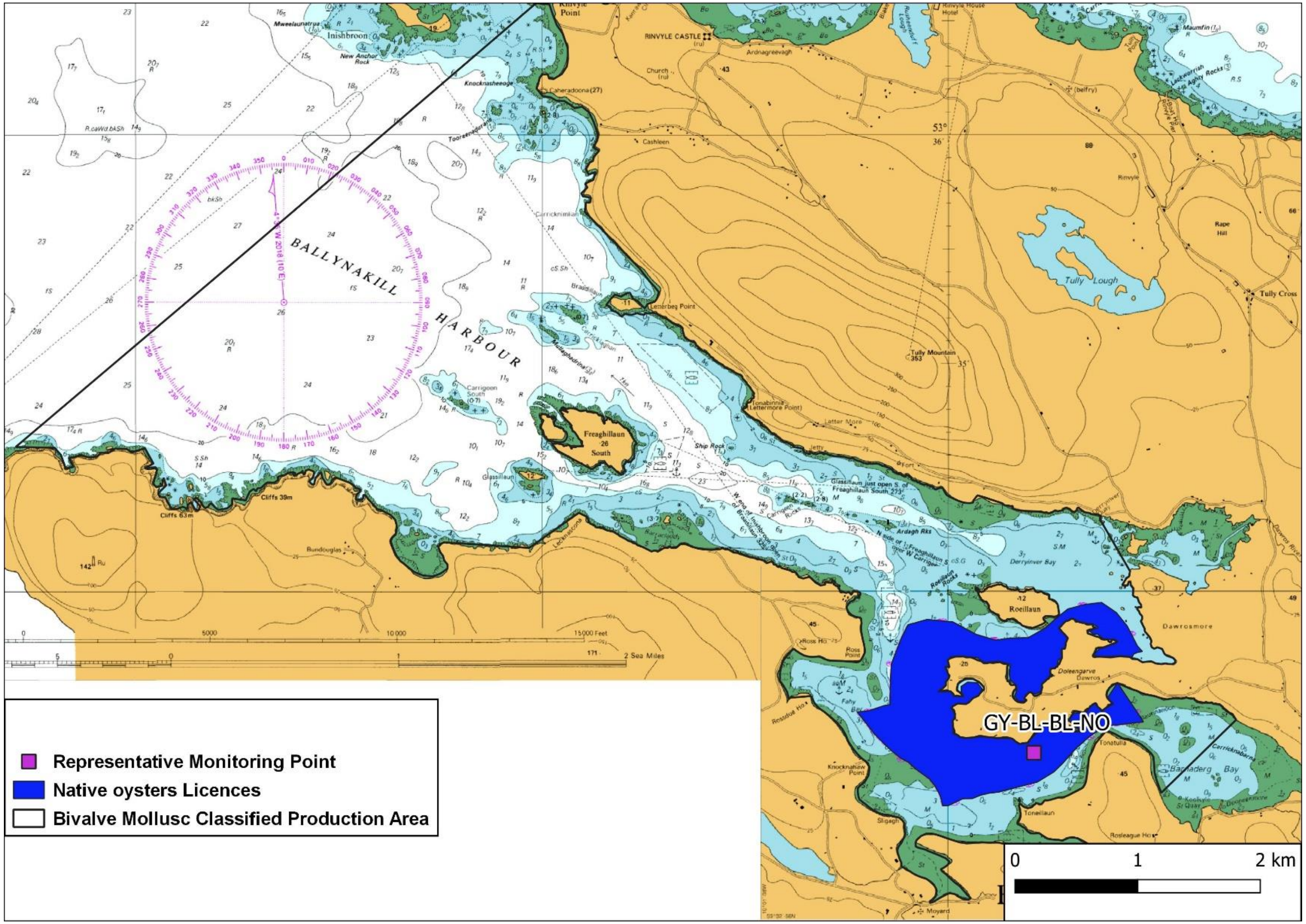


Figure 8.5: Location of the Native Oyster RMP within Ballinakill Bay.

8.7. *General sampling methods*

All collection and transport of shellfish samples for *E.coli* testing under the Sampling Plan identified as part of the Ballinakill Sanitary Survey should follow the Sea Fisheries Protection Authority's own Code of Practice for the Microbiological Monitoring of Bivalve Mollusc Production Areas (SFPA, 2017). The guidance notes are found at Appendix 9.2 of that document.

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Appendix 1

Statistical Analysis

One way ANOVA: Log *E. coli* vs Season (Oyster Flesh results 2014-2019)

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Spring	15	23.04996	1.536664	0.265697
Summer	15	26.26762	1.751175	0.238967
Autumn	15	26.91292	1.794195	0.424769
Winter	16	23.01786	1.438617	0.144666

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.340824	3	0.446941	1.678011	0.181897	2.766438
Within Groups	15.18206	57	0.266352			
Total	16.52289	60				

One way ANOVA: Log *E. coli* vs Season (Mussel Flesh results 2014-2019)

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Spring	13	18.84193	1.449379	0.111215
Summer	14	23.05924	1.647089	0.449546
Autumn	12	18.33332	1.527776	0.214357
Winter	13	17.88252	1.375578	0.08855

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.546448	3	0.182149	0.824889	0.486637	2.798061
Within Groups	10.59921	48	0.220817			
Total	11.14565	51				

One way ANOVA: Log *E. coli* vs Species (Flesh Results 2014-2019)

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Mussels	52	78.11701	1.50225	0.218542
Oysters	61	99.24837	1.627022	0.275381

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.43701	1	0.43701	1.753187	0.188197	3.926607
Within Groups	27.66854	111	0.249266			
Total	28.10555	112				

Appendix 2

Species Specific Sampling Plans

Ballinakill

Bivalve Mollusc Classified Production Area

Mussel Sampling Plan Information

Site Name: Ballinakill

Site Identifier: GY-BL-BL

Monitoring Point Coordinates

Latitude: 53.581017 **Longitude:** -10.029309

Species: *Mytilus edulis*

Sample Depth: 1 metre **Sample Frequency:** Monthly

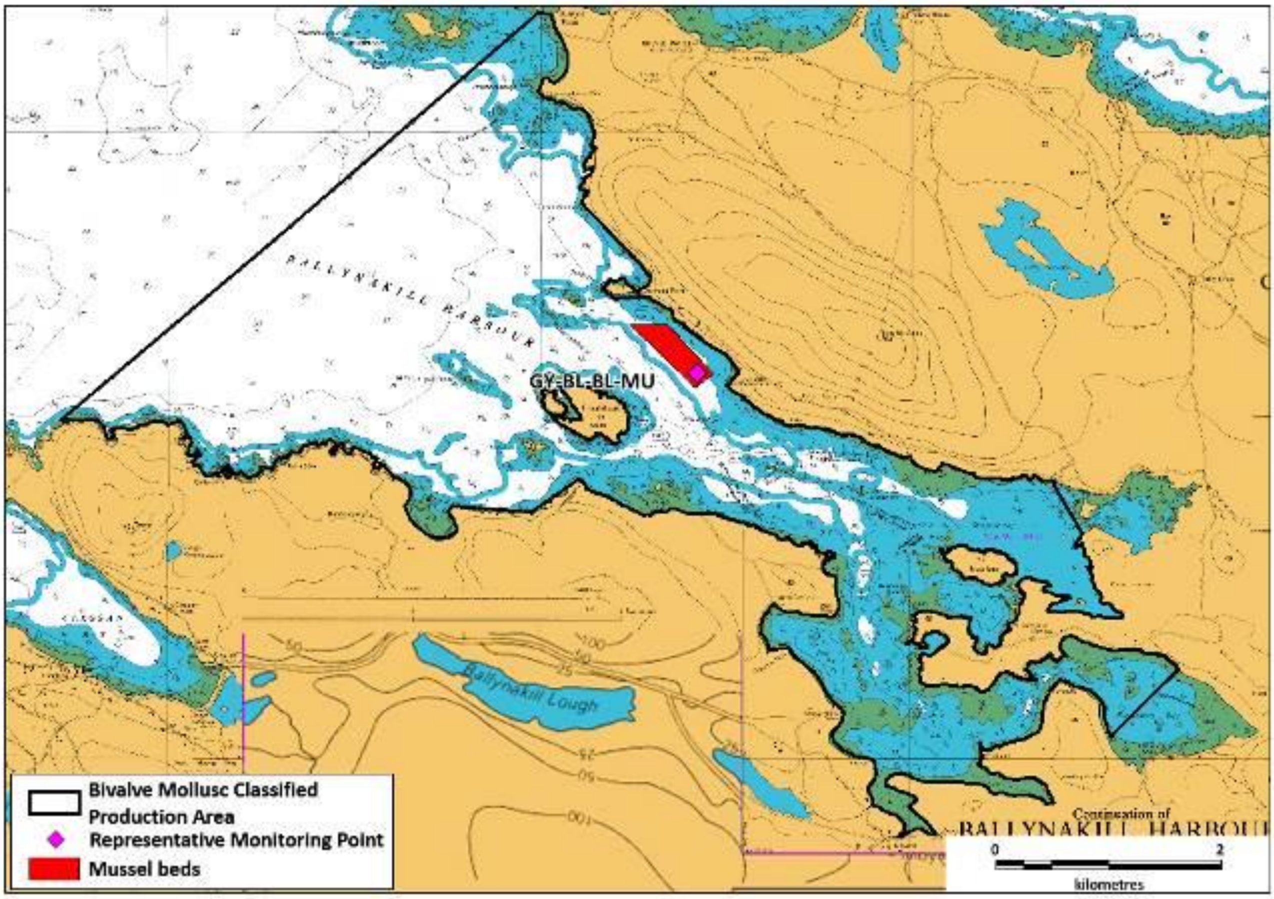
Responsible Authority: Sea Fisheries Protection Authority

Authorised Samplers: SFPA Port office Rossaveal

Maximum Allowed Distance from Sampling Point: The sample must be taken from within 100 metres of the sampling point.

Sampling Size: Minimum 15 market sized animals

Sampling Method: Taken from Long-line at point



Ballinakill

Bivalve Mollusc Classified Production Area

Razor Clam Sampling Plan Information

Site Name: Ballinakill

Site Identifier: GY-BL-BL

Monitoring Point Coordinates

Latitude: 53.565833 **Longitude:** -10.008333

Species: *Ensis spp.*

Sample Depth: N/A **Sample Frequency:** Monthly (May-October)

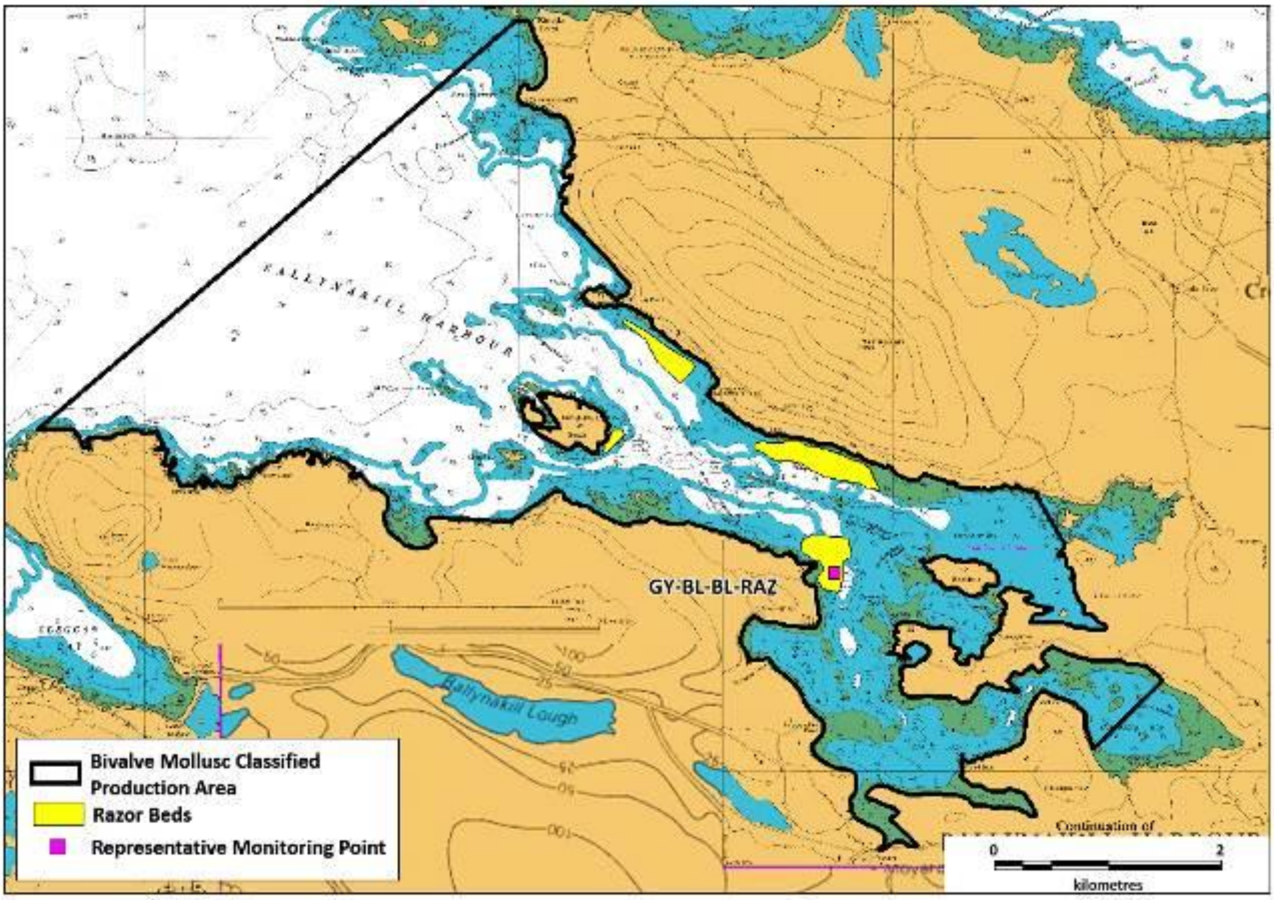
Responsible Authority: Sea Fisheries Protection Authority

Authorised Samplers: SFPA Port office Rossaveal

Maximum Allowed Distance from Sampling Point: The sample must be taken from within 250 metres of the sampling point.

Sampling Size: Minimum 10 market sized animals

Sampling Method: Taken from Dredge at point



Ballinakill

Bivalve Mollusc Classified Production Area

Pacific Oyster Sampling Plan Information

Site Name: Ballinakill

Site Identifier: GY-BL-BL

Monitoring Point Coordinates

Latitude: 53.554887 **Longitude:** -9.989499

Species: *Crassostrea gigas.*

Sample Depth: N/A **Sample Frequency:** Monthly

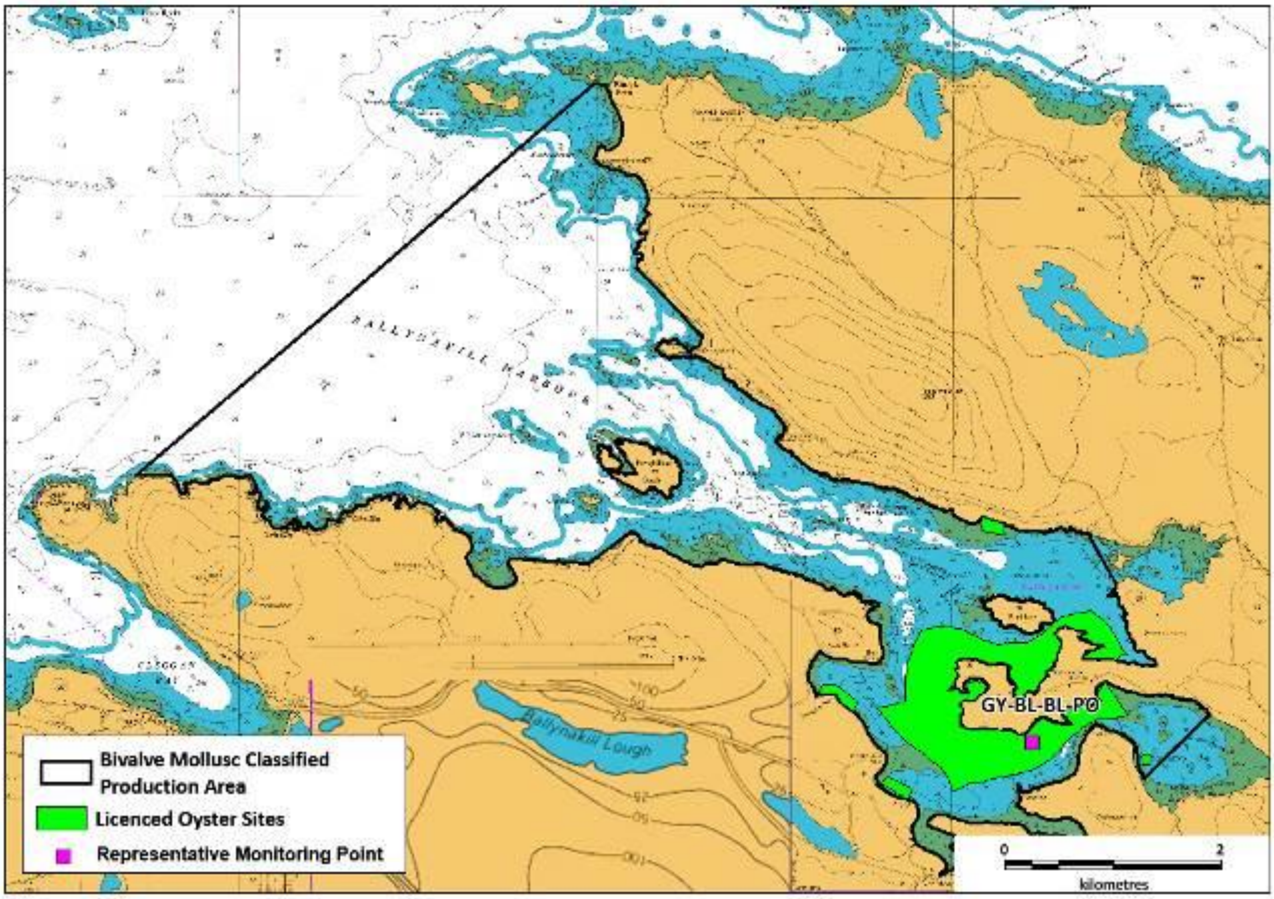
Responsible Authority: Sea Fisheries Protection Authority

Authorised Samplers: SFPA Port office Rossaveal

Maximum Allowed Distance from Sampling Point: The sample must be taken from within 100 metres of the sampling point.

Sampling Size: Minimum 10 market sized animals

Sampling Method: Taken from oyster trestles at point



Ballinakill

Bivalve Mollusc Classified Production Area

Native Oyster Sampling Plan Information

Site Name: Ballinakill

Site Identifier: GY-BL-BL

Monitoring Point Coordinates

Latitude: 53.554887 **Longitude:** 009.989499

Species: *Ostrea edulis*

Sample Depth: N/A **Sample Frequency:** Monthly

Responsible Authority: Sea Fisheries Protection Authority

Authorised Samplers: SFPA Port office Rossaveal

Maximum Allowed Distance from Sampling Point: The sample must be taken from within 100 metres of the sampling point.

Sampling Size: Minimum 10 market sized animals

Sampling Method: Taken from oyster trestles at point