Investigation of Australian Tubeworm, *Ficopomatus enigmaticus*, in the Tralee Ship Canal

Prepared by

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For

Tralee Rowing Club

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Executive Summary

- The Australian Tubeworm (*Ficopomatus enigmaticus*) was discovered living in the 2.5km long Tralee Ship Canal early in 2020 and was evidently resident there for some time. The canal water is brackish and has lagoon features which it seems make it particularly suited to the tubeworm.
- An investigation of the tubeworm was initiated by the Tralee Rowing Club with the support of the Community Waters Development Fund 2021.
- AQUAFACT International Services undertook the investigation of the canal to establish the extent of the infestation of the canal by the invasive alien tubeworm.
- The distribution and abundance of the tubeworm, its associated fauna and other fauna were surveyed to elucidate something of the general ecology of the canal as well as the canal as a location in which the tubeworm has proliferated.
- Some of the physical parameters of the canal were also investigated including water movements that would be relevant to the ecology of the canal and that of the tubeworm.
- The Australian Tubeworm was found to be very abundant and to be present in densities that seem to be exceptional when compared to any similar waterways in Ireland. The level of abundance seems to be similar to what may be more common in locations at much lower latitudes.
- The distribution of the tubeworm and other species along the length of the canal showed that the canal basin and the inner reaches of the canal were the most populated areas of the water body.
- The tubeworm which occupies hard surfaces along the length of the canal was seen to have a well-defined associated fauna that was also abundant and well adapted to the conditions of the canal.
- Canal sediments in the deeper areas were predominantly composed of unstable anoxic mud and were devoid or infauna. Shallower areas closer to the canal basin had more stable and structured sediments which were occupied by large numbers of two particularly well adapted species, one a polychaete and the other a bivalve mollusc.
- Some notes were made on the nekton in the canal but this aspect of the canal ecology had little relevance to the main focus of the investigation on the tubeworm.
- Some consideration was given to identifying strategies for the management and control of the tubeworm as it would appear that elimination of the tubeworm may be challenging in this water course.

1 Introduction

This report is an account of an investigation that was undertaken following the discovery of the Australian Tubeworm, *Ficopomatus enigmaticus (F. enigmaticus)*, in the Tralee Ship Canal (Canal) in early 2020. The investigation was undertaken by AQUAFACT International Services (Aquafact) on behalf of Tralee Rowing Club (TRC).

TRC was awarded funding by the Local Authority Waters Programme (LAWPRO) under its Community Waters Development Fund 2021 to undertake the investigation as an initiative aimed at supporting delivery of local projects and initiatives to address issues in water quality, biodiversity loss and climate change.

1.1 Local Authority Waters Programme

The European Union Water Framework Directive (WFD) places statutory obligations on Member States and their Local Authorities (LA) for the development and implementation of River Basin Management Plans (RBMP). The WFD was transposed into Irish law by the 2003 EU Water Policy Regulations as amended by the 2014 Regulations. WFD importantly mandates public participation in development and implementation of RBMPs.

This requirement for public participation led to the establishment of Local Authority Waters Programme (LAWPRO) in 2016. LAWPRO coordinates the response of 31 local authorities to these obligations under five themes as follows:

- Programme Coordination;
- Community Engagement;
- Catchment Science;
- Governance;
- Innovation.

LAWPRO is a Local Authorities Shared Service with 60 specialist staff from a broad range of backgrounds and expertise. These staff members are based within 13 different local authority centres nationwide, representing particular local authorities. One of the team of LAWPRO’s Community Water Officers is based at Kerry County Council (Kerry Co. Co.) in Tralee.

Under its Community Engagement remit, LAWPRO supports local community groups in their water related initiatives and projects. 2021 saw the fourth open call for projects under the Community Waters Development Fund and Tralee Rowing Club was successful in it application for funding to investigate the presence of *F. enigmaticus* in the Tralee Ship Canal where the rowing club is based.

1.2 Tralee Rowing Club

TRC was established in 2005 and currently has a membership of about 100 members and caters for people of all ages, both competitively and recreationally. The club has been using the canal over recent years and moved into its new clubhouse next to the canal basin slip in 2016.

The club takes a keen interest in the canal and has been active in efforts to keep the waterway clean not only for the benefit of club activities but as a way of enhancing this important local amenity used by the general public; locals and visitors alike.

The club is very much a community in how it operates and has long term interest in the environment and particularly the canal which is its home.

1.3 AQUAFACT International Services Ltd.

AQUAFACT is an environmental and hydrographic consultancy specialising in monitoring and managing resources in marine, freshwater and terrestrial environments. It provides a broad range of services as it collaborates with the wider Irish scientific community and its close association with Irish higher education research groups. It also has access to international networking and data transfer and retrieval facilities. In addition, AQUAFACT has direct liaison with a variety of consultants that complement its own inhouse expertise.

AQUAFACT offers a multi-disciplinary approach to the investigation of problems in marine, freshwater and terrestrial environments, including:

- Environmental Impact Statements (EIS)/Natura Impact Statements (NIS);
- Predictive modelling;
- Project design, environmental monitoring and management protocols;
- Resource management, habitat mapping and evaluation;
- Aquaculture and environmental management.

AQUAFACT was successful in its tender to undertake this investigation on behalf of TRC. The opportunity to collaborate with a local ecologist, Dr Noel Mulligan, provided a means of carrying out an effective investigation as it was possible to maintain a presence at the canal over the duration of the survey.

2 Background

There are two aspects that needed to be considered in looking at the background to this investigation. Firstly, the canal as a brackish water habitat impacted by marine and freshwater influences. Secondly, the presence of the *F. enigmaticus* in the canal that provokes questions and presents problems that were worth looking into.

2.1 History of Tralee Ship Canal

The history of the canal is recounted in 'Blennerville: Gateway to Tralee's Past' (Kelly, L. *et al*., 1989). Construction of the canal commenced in 1832 and continued on and off for 14 years. There were long periods during which construction was held up for different reasons but it was eventually completed and the canal was opened in 1846. It remained in use up to the middle of the 20th century after which it was abandoned as a working canal and remained unused for about 50 years up to the early 2000's. Fenit harbour, located to the west in deeper water, took over as it was better suited to the type of marine traffic which the canal could no longer accommodate.

Following its abandonment, the canal's lock gates fell into disrepair and the canal became tidal. The filling and ebbing of the tide over the years resulted in sea and estuary water from inner Tralee Bay deposited large amounts of silt along the full length of the canal. This reduced the depth of the waterway and the inner reaches of the canal became colonised by marsh and terrestrial vegetation. The canal basin itself was later completely infilled for safety reasons. The canal remained in a disused condition up until the 1990's.

2.2 Canal Restoration in the 1990's

The construction of the Jeannie Johnson, a replica of a sailing ship that took emigrants from Kerry to North America in the mid-1800's, took place in the late 1990's. Part of the Jeannie Johnson project envisaged the replica famine ship being moored in the canal basin as a tourist attraction. This would require the restoration of the canal as a waterway. While construction of the ship took place in Blennerville, work began on the restoration of the canal and its facilities.

The restoration involved the complete dredging of the canal, the reinstatement of the canal basis, the installation of a swing bridge midway along the canal, at Blennerville and the restoration of the lock gates at the western end of the canal. Since the restoration was completed, the waterway has been maintained in working condition for the past 20 years and, other than for short periods when the canal was tidal, due to work being undertaken on the lock gates, the waterway has remained filled with water with functioning lock gates that are used only occasionally as required.

The lock gates are designed to allow water to enter the canal during periods of spring tide. Tides in excess of 4.2m above chart datum see seawater spilling over the top of the lock gates on the flood and excess water leaving again on the ebb.

When initially designed, the canal was intended to be an 'impounded' waterway that was to be fed with freshwater from a nearby stream at Ballymullen. If it had been built as such it would have become a freshwater system with an entirely different ecology today. The plan for the impounded waterway was abandoned at an early stage in the construction and the canal was developed instead as a tidal fed system with a certain amount of freshwater filling the canal from springs and runoff from adjacent land to the north but also with the topping up of the canal with estuary and sea water from the inner bay during periods of spring tides. For this reason the canal has developed to become the brackish water habitat, with lagoon characteristics, that we have today.

2.3 Kerry County Council Management of Tralee Ship Canal

The Tralee Ship Canal is in the ownership of Kerry Co. Co. Since the dredging of the canal and the installation of new lock gates and the swing bridge in the late 1990's by the Office of Public Works, Kerry Co. Co. has been responsible for the upkeep of the waterway. Significant investment has been made in the development and maintenance of the canal towpath as an amenity for pedestrians and cyclists. The other elements of the canal infrastructure comprise the swing bridge at Blennerville, the canal and basin walls, the boat slip at the canal basin, and the canal basin pontoon.

The swing bridge and the pontoon in the canal basin are rarely used as there is virtually no traffic on the canal, other than the TRC activity, that would require their use. The lock gates are only occasionally operated and they have had to be serviced on a couple of occasions to maintain them in working order.

Maintenance work to repair some wear and tear to the rock armour of the canal walls is planned for 2021/22. This work will coincide with some other civil engineering works on repairs to the Canal Road that seems to be experiencing some subsidence.

2.4 Tralee Ship Canal Links to Natura 2000 Sites

It was intended to undertake an Appropriate Assessment Stage 1 Screening (AA Screening) of this project. It looked as if some minor project activities involving the planned removal of patches of tubeworm needed to be considered as this might have an impact on adjacent Natura 2000 sites.

It emerged that Kerry Co. Co. has proposed a major road works project that necessitates the draining of the canal for a period of c. 3 months. It was felt that the need to undertake an AA Screening for the project activities proposed here was moot. Kerry Co. Co. has presented an AA Screening Report (Anon,

2021) that more than adequately deals with any issues that might have arisen here with the tubeworm project.

In order to address any questions that might remain over the impact that the project could have on Natura 2000 sites, the information that would have been presented as part of an AA Screening Report is provided in Appendices 2, 3 & 4.

No further consideration is given to the potential impacts of this project's investigation of the Australian Tubeworm on Natura 2000 sites.

2.5 Recent Discovery of *Ficopomatus enigmaticus* in the Canal

The complete dredging of the canal during its restoration in the late 1990's and the fitting of lock gates, meant that the communities of animals and plant that came to occupy the waterway in recent years were the result of inward migration of species from the inner bay, the estuary and to some extent from the adjoining freshwater drains and ponds. It is probably safe to say that none of the communities of animals and plants living in the canal waters today are descendants from those of the earlier period when it functioned as a working canal more than 50 years prior to restoration. What is there today must have colonised the waterway in the last 20 years or so.

There does not appear to be any record of any ecological investigation of the canal. The ponds on its northern boundary have been the subject of final year degree projects by students of Wildlife Biology at the Institute of Technology Tralee (now Munster Technological University).

The estuary, marsh and ponds adjacent to the canal are visited by water birds especially during the winter period and these have been well studied. A group of Mute Swan is also resident and moves between the canal and the adjacent freshwater ponds. The presence of some fish species can also be easily observed including Three-Spined Stickleback and Grey Mullet. A shoal of Sprat also became trapped in the canal some years ago. In addition, large mats of filamentous green algal are obvious to those observing from the canal bank during the warmer periods. Nothing more seemed to be known of what lived in the water otherwise until this current investigation was initiated.

A local marine biologist/ecologist had noted the appearance of what turned out to be *F. enigmaticus* growing just below the surface on the walls and on pontoons and associated piles in the canal basin. The tubeworm was also evident to a significant extent on the sides of the canal proper immediately to the west of the basin but to a lesser extent further to the along the canal and especially its far western reaches.

It appears that the tubeworm had been present in the canal for some time as the extent to which the hard structures were encrusted with the organism indicated some years of growth. It was not possible to say how for how long but most likely in excess of 5 years, but it might easily be much longer. This was not investigated further as part of this work.

Identification of the tubeworm as *Ficopomatus enigmaticus* (Fauvel 1923) was confirmed by Dr Brendan O Connor (AQUAFACT), a leading benthic ecologist specialising in marine fauna including polychaete worms, a group which includes the Australian Tubeworm.

3 Aims and Objectives of the Investigation of *Ficopomatus enigmaticus*

The discovery of the Australian Tubeworm in the Tralee Ship Canal was brought to the attention of Kerry Co. Co. as the owner of the waterway. The presence of this invasive alien species was the catalyst for a broader investigation of the ecology of the canal.

The existence of the tubeworm was also brought to the attention of TRC as they are the principal users of the canal waters. It impacted directly on the club in that the growth of large aggregations on the pontoon used by the club to launch its rowing boats presented a problem. The tubeworm is abrasive and can damage the delicate gel coat finish of the racing boats but also could injure rowers who might accidentally come into contact with the tubeworm resulting in skin abrasions in unsanitary canal water.

Kerry Co. Co. supported the rowing club in its proposal to investigate the canal as described in an application submitted by the club to the Local Authorities Waters Programme, Community Water Development Fund 2021

TRC, as an eligible community group, was successful in its funding application and this lead to the project being undertaken that is being reported on here.

The Aim and Objectives of the project as described in the proposal submitted to LAWPRO were adjusted as detailed below and better articulate how the project was approached.

3.1 Aim of the Project:

The aim of the project was to investigate the presence of the Australian Tubeworm in the Tralee Ship Canal with a view to better understanding its ecology, its interrelationship with other canal fauna and to explore possible approaches to managing and controlling this invasive alien species.

3.2 Objectives of the Project:

1. Baseline Assessment of the Australian Tubeworm and associated fauna in the canal undertaken by a Consultant Ecologist;

2. Pilot scale trial to remove tubeworm from two sections in the canal basin, adjacent to the boat slip area and on another part of the canal basin wall adjacent to the marina pontoon. This was to facilitate the creation of a baseline for further monitoring of resettlement as well as exploring how to manage the tubeworm;
3. An AA Screening of the proposed pilot scale tubeworm removal exercise in accordance with National Parks & Wildlife Service (NPWS) requirements was envisaged.
   It is noted that this was not required as an AA Screening of the canal was undertaken by Kerry Co. Co. in connection with a civil engineering project. This effectively dealt with any issues that might arise from the minimal tubeworm removal operations associated with this project when compared to the possible impacts of the Kerry Co Co project.
4. Communicate findings of the project to create a greater awareness of the canal as a transition water body needing protection. Hopefully this will allow users of the canal amenity and the wider community to gain an appreciation of the canal in the context of the Tralee Bay area's excellent ecological resources and natural heritage.

4 Review of Literature on *Ficopomatus enigmaticus*

The following sections provide some relevant information in the form of notes on the Australian Tubeworm in the context of the current investigation.

The search of the literature in relation to *F. enigmaticus* was confined to review-type publications, as this was felt to be most appropriate to the nature of the investigation being undertaken which was not a basic research investigation of the biology or ecology of the tubeworm. The focus of the review of the literature was on ecology and the alien and invasive status of the tubeworm as a background to its investigation here and consideration of its management and control in the canal.

The following sources were reviewed:

- Centre for Agriculture and Biosciences International (CABI) - Invasive Species Compendium (https://www.cabi.org/isc/);
- World Register of Marine Species (WoRMS) (https://www.marinespecies.org);
- Biodiversity Ireland (BI) (https://www.biodiversityireland.ie);
- National Biodiversity Network (NBN) (https://nbnatlas.org);
- The Marine Life Information Network (MarLIN) (https://www.marlin.ac.uk)

The information published in the CABI Invasive Species Compendium has been used here to provide an appropriate overview of the species as it exists in the canal. This source was found to be most relevant and comprehensive.

4.1 Taxonomy

The following is the taxonomic tree for *Ficopomatus enigmaticus* (Fauvel 1923):

Domain: Eukaryota
Kingdom: Metazoa
Phylum: Annelida
Class: Polychaeta
Order: Sabellida
Family: Serpulidae
Genus: Ficopomatus
Species: *Ficopomatus enigmaticus*

4.2 Description

F. enigmaticus is a relatively small (up to c.50mm) sedentary polychaete worm with a symmetrical body. It secretes a calcareous tube within which it lives (see Figure 1.).

Figure 1. *F. enigmaticus* without tube

The tube is large enough to protect its entire body and it grows in length as the worm secretes new tube-forming material at the opening. *F. enigmaticus* has the typical segmented body form of true worms. A fan of tentacles at the anterior end of the body is found at the opening of the tube which it extends and uses to filter water for its food and it also serves in gas exchange. One of the tentacles is specialised to provide a plug like operculum which is used to seal the tube into which it withdraws for protection.

The surface of the worm’s calcareous tube has characteristics ring/flange features at intervals along its otherwise smooth length (See Figure 2.). The tube also has a coating of chitin that protects it from erosion.

Individuals have the habit of settling together to create large colonies. As an individual worm grows its tube is at first recumbent on the surface on which it settles but then rises from the surface as it grows in length. This growth behaviour has the effect of the colony creating a structure that provides a lot of open spaces that other species can take refuge within. A colony can form a mat of many

Figure 2. *F. enigmaticus* tubes

centimetres in thickness on a flat surface and it can also grow to produce a more spherical shaped mass when it has no further room to spread horizontally.

The colony produced by the mass of tubeworms growing together, increases in size as new individuals settle on its outer margins steadily increasing the size of the colony. The worms deepest in the colony die off in time so that large colonies only have living tubeworms on the outermost layers. The surface of the colony as well as its inner reaches may be home to associated fauna.

Large colonies can form reefs and a diameter of 7m has been recorded.

4.3 Life Cycle

The following are some of the most pertinent facts regarding the reproductive biology and life cycle of *F. enigmaticus*

- *F. enigmaticus* is dioecious meaning that the sexes are separate but there is evidence of protandric hermaphroditism where individuals start off as male and change to being female later in the life cycle;
- Small eggs (c.60µ) are released and are fertilised by sperm in the water body;
- Eggs develop to produce the free swimming trochophore larvae which settle on hard structures at a size of c.160µ after about 3 weeks where they secrete their tubes and can grow at between 0.4 and 1.5mm per day;
- Sexual maturity is reached after about 4 months and in specimens of as little as 5mm;
- Females can release from 1,000 to 10,000 eggs;
- Temperature is one of the most important factors affecting reproduction with reports of spawning occurring in different sites at temperatures from 10 - 18ºC;
- Spawning can occur up to three times per year but takes place generally twice per year, in spring/summer and autumn;
- *F. enigmaticus* typically lives for at least 2 years but can be up to 4 years and older in age.

4.4 Distribution

F. enigmaticus is a brackish water species distributed in subtropical-temperate areas worldwide in both hemispheres. It is thought to have originated in the Indian Ocean or perhaps on the Australian coastline where the genus, Ficopomatus, is best represented. It appears to have been introduced to other regions in the southern and northern hemisphere due to marine traffic (as marine fouling on the hulls of ships or as larvae carried in a ship's ballast water). It seems to have appeared in Europe less than 100 years ago. With global warming it is expected that it will spread further north and may reach as far north as Norway at some stage in the future.

Like most first reports of its presence in a particular geography, it is probably the case that it had been present previous to when first reported but had not come to attention.

It was first recorded as *Mercierella enigmatica* (Fauvel) in Ireland at Blackrock, Cork Harbour in 1973 (Kilty and Guiry, 1973). It has since been found in some other brackish water locations (Minchin (2007) records it from Arklow, Co. Wicklow and Poolbeg, Co. Dublin). Dr. D. McGrath sent material to AQUAFACT he collected in Kilrush marina which proved to be *F. enigmaticus.*

Its transfers from region to region may be facilitated by shipping as referred to above but possibly also by the movement of aquaculture livestock as is the case with some other alien species.

It is now found in Africa, Asia, Europe, N&S America and Oceania.

4.5 Habitats & Environmental Requirements

F. enigmaticus is mainly a brackish water species that tolerates highly variable salinity (optimum 10 - 30 psu (practical salinity units). It lives in water with dissolved oxygen at optimum levels of 6 - 8 mg/ml and optimum temperatures of 10 - 20 C. Full salinity water may be tolerated but growth is stunted. The typical habitats invaded by this species include estuaries, coastal lagoons, harbours, and inland brackish waters, always in areas protected from wave action. This species seems to be able to survive equally well in either polluted or non-polluted habitats.

F. enigmaticus requires a hard surface on which to settle once its other environmental preferences have been met.

F. enigmaticus is commonly found in shallow waters with optimum depth between 0.5 and 2 m where this species has the opportunity to build reefs. It has also been found in deeper water.

F. enigmaticus will settle on a hard surface ranging from harbour infrastructure, ships' hulls to floating and sunken debris. It appears to be more resistant to pollution than salinity changes outside of its tolerance range for a particular region.

F. enigmaticus exposed to seawater had lower biomass and growth in comparison with those living in brackish water. Temperature and phytoplankton also seem to be two important variables affecting the reproduction of *F. enigmaticus* Temperature needs to be higher than 15-18ºC to enhance reproductive success.

F. enigmaticus is a filter feeding species and consumes phytoplankton and other suspended material. It released faeces which along with indigestible detritus filtered from the water falls to the bottom and accumulates, creating anoxic sediments in still water.

F. enigmaticus reefs have associated fauna. Some of this is due to the open space within the reef forming colony that can accommodate a variety of small organisms that use it for shelter and to find food. Barnacles, crabs, amphipods, isopods and other polychaetes have been reported to be associated with *F. enigmaticus* colonies.

4.6 Enemies

F. enigmaticus has few natural enemies. Nonetheless, four species are reported as predators including the shore crab, the common eel and a species of goby.

In one region a species of mullet is known to cause collateral damage to the tubes by grazing on algae growing on the tubeworms.

4.7 Invasiveness & Impacts

Natural dispersal of *F. enigmaticus* is limited to the dispersal of larvae within the habitat occupied. Artificial dispersal sees *F. enigmaticus* spread primarily by shipping as hull fouling and ballast water. It can also be potentially dispersed in association with movement of mollusc species used for aquaculture. This explains how the species moved from distant regions to where it is currently found. It should also be noted that even small leisure crafts can cause dispersal from one area to another. Close monitoring and strict protocols around the movement of craft and structures as well as aquaculture livestock is important in managing unwanted transfer.

F. enigmaticus is listed as one of the 100 worst invasive species for Europe due to the impacts on biodiversity and the socio-economic effects

Impact can be due to nuisance as fouling of marina infrastructure and boat hulls. It can clog intake pipes and moving parts such as on lock gate systems with some economic impact. Its presence in areas used for recreational boating activities can have adverse effects.

F. enigmaticus can have beneficial effects in improving water quality by its filtering action removing suspended solids but it may result in impact on other species by competing for phytoplankton.

F. enigmaticus can be considered to be an ecosystem engineer, an organism able to create new habitats for other species; the spaces among the reef tubes are occupied by epibenthic species, and the spaces generated below the reefs are also occupied by other benthic species. This has both positive and negative impacts and can significantly alter the species balance in a habitat.

While not all alien species are invasive, it is the case that *F. enigmaticus* is considered invasive because of its negative impacts.

F. enigmaticus has no economic value. Its tubes are primarily made from calcium carbonate and there is a light coating of chitin covering the outside of the tubes. These materials would not represent any significant value if harvested.

4.8 Eradication and Control

Prevention of *F. enigmaticus* introduction and dispersal is suggested as the most appropriate management strategy. Failing effective preventative measures consideration has to be given to control options.

No planned eradication measures have been reported.

Pesticides treatments (*e.g.* anti-fouling) are generally not considered an option for control/eradication of *F. enigmaticus* in most habitats due in part to regulations but also to efficacy. Such treatments are now generally considered unacceptable.

Habitat restoration has led to the disappearance of *F. enigmaticus* in certain areas and generally this has been associated with increased seawater input. The elimination of the tubeworm in cases reported have been a benefit due to works carried out for other environmental enhancement purposes and not for the eradication of the tubeworm *per se*.

Physical removal of tubeworm fouling from a power plant cooling water intake is the only method of control reported. This approach may make sense if required on a limited scale but could not be used against an extensive problem with *F. enigmaticus* across a large area. While physical removal might eliminate fouling for a period, it is more than likely that prevailing favourable environmental conditions would see it return as a problem.

Depletion of oxygen levels in ballast water did not seem to be effective in killing what would be considered sensitive larval stages. Similarly, antifoulants designed to prevent boring shipworms were also found to be ineffective.

5 Methodology

The following subsections describe the methodologies applied in the execution of the project aimed at achieving the four stated objectives.

The investigation focused on a scientific study of the ecology of the canal with particular reference to *F. enigmaticus.* Great care was taken to ensure that scientific rigour was applied in every aspect of the work. The scale of the investigation did not allow the pursuit of some interesting features of the waterway ecology that would have been a distraction from the core aim and objectives.

5.1 Field Survey of Canal

The project as proposed had two main parts. One was the investigation of the canal to better understand the ecology of the Australian Tubeworm. The other was to investigate and suggest possible approaches to managing and controlling the tubeworm as a fouling organism.

5.1.1 Sampling of Fauna of the canal

A preliminary examination of the canal was undertaken to see how to approach the proposed ecological investigation so as to better understand how the Australian Tubeworm occupied the watercourse in terms of its distribution, abundance and proliferation. As the tubeworm is just one part of the canal fauna, the investigation was also structured to better understand something of the distribution and abundance of other fauna and the ecology of the canal in general. Some other observations were made and are included as notes on canal flora.

The canal water is occupied by a community of organisms that require hard surfaces such as the side walls, submerged debris and floating structures on which to settle and grow. It is also occupied by completely different macro-invertebrates that take refuge by burrowing in the soft sediments on the bottom of the canal and in sediment found in the spaces between the stone block armour of the canal sidewalls.

Some consideration had also to be given to the those organisms swimming or floating in the canal and to something of the water exchange that takes place over the lunar cycle which sees estuary and inner bay water entering the canal at high water during periods of spring tides and the loss of canal water during the subsequent ebb tides. This tidal water exchange would likely be an important variable that deserved consideration, contributing as it would be expected to the physical and biological parameters affecting canal inhabitants.

The presence of floating macroalgae was noted. Some consideration was given to attached macroalgae in particular in how it might have affected the growth and performance of *F. enigmaticus* where there was competition for hard surfaces.

The flora at the water’s edge on the canal bank was also noted at is said something of the brackish water influence on the terrestrial fringe.

5.1.1.1 Soft sediment sampling

Some trials were undertaken to identify the most appropriate equipment for sampling canal sediments.

A 10cmx15cm Van Veen grab sampler (sample area - 150cm ^{2}) was tested initially and was found to work properly but to have a limited penetration of the canal sediments even when supplemented with some weights. The canal sediments were found to be very soft and deep with fauna remaining well out of reach of the grab sampler which was designed for, and would have suited, sampling in more typical marine bottom sediments.

Figure 3. Core sampler with inset of 15 cm cross section.

Even with maximum penetration achieved, the grab was found inadequate to sample the upper reaches of the canal where it was determined that the infauna, principally Sand Gaper (*Mya arenaria)* and Ragworm (*Hediste diversicolor)* were found to be burrowing to a depth of c 20+ cm.

A purpose-built self-inverting core sampler (diameter - 15cm; sample Area - 175cm^{2} and penetration – 30+ cm) was developed, tested and was found to be suited to the conditions along the full length of the canal for soft sediment sampling (See Figure 2. Note insert indicating burrows of *H. diversicolor* at 15+ cm). This was operated from a boat by means of an extendable pole allowing sampling in water depth of up to 6m which was adequate for the depth range encountered and especially in the deepest section close to the lock gates. Trials showed that the sampler produced approximately double the amount of infauna that the grab sampler produced in areas where the fauna was moderately deeply buried and the discrepancy was even greater where fauna was more deeply buried. In the latter areas the grab sampler would have failed to retrieve representative samples of the infauna.

The sampling protocol involved taking a single sample at each of the canal sampling locations. Samples were grouped. At a particular location, one sample was taken from the centre line and two were taken from the north side of the centre line close by and one from the south side. This allowed for a semi-quantitative assessment of the presence and abundance of the infauna.

All sediment sampled for fauna and sediment granulometry were taken by means of the purpose-built core sampler. Figures 4 & 5 show the locations at which core samples were taken.

Samples were taken for granulometry from 5 locations; four sampling points were located along the center-line of the canal (C1, C4, C7, and C10) and one was taken from a pocket of sediment created in a damaged section of the canal wall on the north side *c.* 750m from the canal basin (B). This latter sample was taken as this and similar pockets of sediment in areas of damage to the canal wall were seen to be occupied by burrowing fauna.

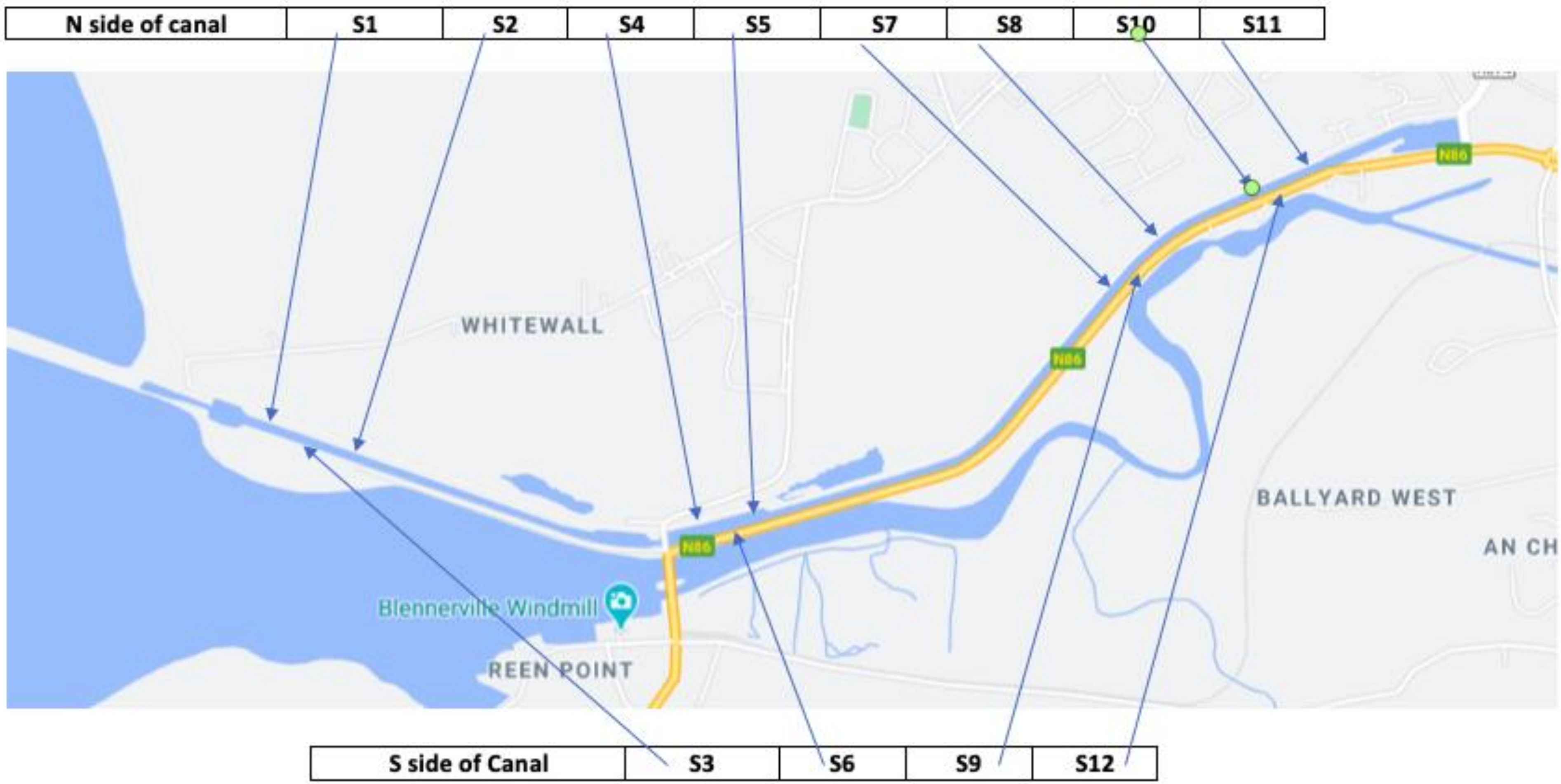
The presence of infauna in the gaps between the rock armour along the canal wall close to the canal basin was noted but it was not possible to quantitatively sample this material as it would have necessitated interference with the fabric of the canal wall itself. This was noted and a photographic record was made of this feature and this is presented in the Results section of the report.

Samples for infauna/epifauna analysis were passed over a 1mm mesh to separate out the fauna and larger items of debris from the fine sediments.

Samples were preserved in 4% Formalin and were sorted and identified later using 'Handbook of the Marine Fauna of North-West Europe' (Hayward & Ryland, 1995). All identification was confirmed with reference to Aquafact experts.

Figure 4. Location of samples from centre line of canal (C1-12) and from pocket of sediment in damaged N wall close to surface (A,B,C)

Figure 5. Location of samples from either side of canal central channel (S1-12).



5.1.1.2 Hard Substrate Sampling

The side walls of the canal and basin were inspected to estimate the level of tubeworm coverage. This was carried out during two periods when the canal had been drained giving access to these surfaces which are otherwise permanently submerged.

Semi-quantitative samples of tubeworm colonies were taken using a quadrat made from the same material and with the same dimensions (diameter - 15 cm) as the core sampler and penetrating to a depth of 20+cm or to the hard surface. This allowed samples with a relatively large surface area (175 cm^2) to be taken which were useful for quantitative estimation of some of the less abundant fauna associated with the tubeworm. A smaller diameter core sampler (diameter - 7.8cm) with a surface area of 48m^2 penetrating to a depth of 10cm had to be used to facilitate counts of very abundant and typically small species associated with *F. enigmaticus*

Photographs were taken of 4 cm diameter surface areas sections of *F. enigmaticus* on which counts were made of the numbers of individuals to calculate densities per square meter.

Quantitative sampling of the tubeworm was confined to an area which was considered to be representative of the canal basin where this species is most abundant and where sampling could be performed with a sufficient degree of control and accuracy using the canal basin pontoon as a sampling platform.

A variety of other *ad hoc* samples were taken to supplement the sampling described above. This involved a large number of samples being taken from a variety of locations including those where the colonies of *F.e* had become clogged with mud and had associated infauna. These latter sites were also qualitatively sampled for comparison purposes for the associated infauna which was very different to the associated fauna of *F. enigmaticus* where it was attached to hard surfaces free from the influence of sedimentation.

5.1.1.3 Nekton/Plankton observations

The canal was occupied by numbers of Grey Mullet that appeared in small shoals from time to time. Some of these were adults of *c*. 30cm. Shoals of numerous smaller Grey Mullet were also encountered. No effort was made to estimate their abundance as they were a transitory feature of the canal fauna. It is understood that these enter and leave the canal and are not permanently resident and were therefore not considered to be particularly relevant to the investigation.

Some demersal fish species and free swimming invertebrates were also encountered. These move about freely on the soft sediments and side walls of the canal. No attempt was made to quantitatively sample these but their presence, distribution and relative abundance was noted.

A plankton net suitable for larval zooplankton was used on one occasion at a number of locations on the canal (16th June, 2021) to see if there was any zooplankton present but this did not yield any specimens. It was not considered to be important to the aim of the project to attempt any further sampling of plankton.

As an alternative to the hit and miss approach to plankton sampling for the presence of planktonic larvae of *F. enigmaticus* in the canal water, a set of spat collectors (a string of three tiles of different materials) was suspended in the canal water at the end of March 2021. This was examined ever two weeks and the first sign of settlement was seen in mid April 2021. The spat collectors were expected to provide some evidence of spawning and settlement of those species of interest over the course of the following months when larval settlement would be anticipated. Settlement of *F. enigmaticus* was particularly being looked for.

5.2 Pilot Scale Treatments to Manage *Ficopomatus enigmaticus*

A number of approaches were being considered from the outset of the investigation on how it might be possible to investigate the management of *F. enigmaticus* in the canal. This included looking at biotic and abiotic factors that might be manipulated to effect control. These ranged from physical removal to control over salinity of canal water by flooding with freshwater to possible exposure of *F. enigmaticus* to air by draining the canal for an extended period.

It was realised that the short time frame of this investigation might compromise the execution of effective trials that would provide sufficient time to allow conclusive findings to be made. There was also the matter of how the proposed interventions, such as draining or flooding with freshwater, could be carried out in a waterway that is in regular use by the rowing club.

It was noted that individual *F. enigmaticus* specimens had the capacity to withdraw into their tubes and to seal the opening by means of special structure (operculum) that prevented desiccation and yet afforded sufficient access to gas exchange for respiration. Given the capacity of *F. enigmaticus* to withstand drying out and its adaptation to brackish water conditions, it was decided to investigate strategies that might be relevant if they could be rolled out across the 2.5km length of the canal from lock gates to basin. This would involve two approaches included conducting trials on the effect of prolonged immersion in freshwater and prolonged exposure to air. These two approaches along with the physical removal of tubeworm from specific areas were tested.

Appropriate trials were nonetheless proceeded with so that something might be learned that could be useful in proposing management strategies for this invasive alien species.

5.2.1 Physical Removal of Tubeworm from Canal Walls

The simplest approach to control involved the physical removal of *F. enigmaticus.* The difficulty with this approach is that the surface area affected amounts to thousands of square meters, much of which is awkward to access. In addition unless all the tubeworm was removed, it is likely that the remaining *F. enigmaticus* would spawn and provide the larvae to recolonise cleared areas. For this reason it was expected that this simple approach even if confined to areas with the heaviest fouling and creating the greatest nuisance would likely only be a temporary solution.

A modified trial was proceeded with that involved removal of tubeworm from two areas in the canal basin. One of these cleaned areas was on the canal wall to the north of the boat slip and the other was a stretch between two of the piles holding the basin pontoon in place (See Figure 6). In both cases the *F. enigmaticus* was removed from the water surface level to a depth of 1+m.

Figure 6. Section of *F. enigmaticus* removed from canal basin wall

The removal step alone would allow some estimate of the effort involved in removal by scraping off the tubeworm. It had been hoped to employ a heated power washer or steam generator to complete the task and ensure that any remaining tubeworm was killed; unfortunately, resources did not allow for this.

These cleared areas would principally provide a baseline for any follow up investigation or management approaches to controlling *F. enigmaticus.* The removal step is only part of what will be needed to see if this approach has relevance; later monitoring of the cleared surfaces will be required extending completion of this investigation.

This approach will be considered in combination with observations on the settlement of *F. enigmaticus* on spat collectors as described above.

It was also hoped to consider the findings from these trials alongside the likely more significant impact on *F. enigmaticus* that the Kerry Co. Co. draining of the canal for 3 months during the summer or 2021 would have provided.

Unfortunately this will not proceed as the planned draining of the canal in Summer 2021 did not proceed but instead is now planned for early 2022.

5.2.2 Exposure of *Ficopomatus enigmaticus* to Air

Samples of *F. enigmaticus* were removed from the canal during a period of cool weather in the winter/ spring 2020/2021. Air temperature over the course of the trial was generally between 6 & 9 C (min 5 C & max 11 C). These samples were stored in a large container and air circulation that might cause excessive desiccation was prevented by means of a loose fitting cover that allowed oxygen levels in the container air space and high relative humidity to be maintained.

Specimens were removed from the storage unit and placed for a couple on minutes in canal water of salinity of 7 – 9 psu (normal for canal water at the time of year) after set intervals of exposure to air. The response of *F. enigmaticus* to being re-immersed was monitored to confirm if the specimen had survived out of water over the interval of exposure to air. This process was repeated for different lengths of exposure to see what period of exposure to air was needed to provide effective killing off the specimens.

5.2.3 Exposure of *Ficopomatus enigmaticus* to Freshwater

Further samples of *F. enigmaticus* were removed from the canal during the period of cool weather in the winter/spring 2020/2021 when the canal water was of a salinity of 7 – 9 psu. All samples were placed in a large container of aerated freshwater sourced from a local stream; this source ensured that there was no trace of salt in the water.

Specimens were removed from the freshwater storage container after fixed intervals and returned to normal canal water to confirm if the specimens had survived. This process was repeated over a period to see at what duration of immersion in freshwater that the specimens would be fully killed off.

6 Results

Results are presented here for the different elements of the investigation as described in the methodology section above.

6.1 Physical Environment

Some consideration was given to the physical environment of the canal in the context of the investigation. The resources available however did not provide the opportunity to undertake any in-depth study of the physical and chemical aspects of the canal system. The aim of the investigation would not have justified the expenditure of significant time and resources on this despite the extent of changes in the physical environment that arises from time to time due to tidal conditions and the management of the canal system. The following provides an overview of the physical parameters of the canal environment that were measured as well as some *ad hoc* observations.

Figures 4 above provides an overview of the general layout of the canal. The canal (from lock gates to basin) is *c.* 2,500m in length. It is about 17m wide along its course at water surface level, except for wider lay-by areas at the swing bridge and at the lock gates. The dimensions of the rectangular canal basin are c. 100m (east/west) x c. 50m (north/south).

Depths measured, taken when the canal was filled, along the bottom of the canal ranges from c. 2.1m in the canal basin with a gradual fall to a depth of 4.2m at the lock gates. The depth in the vicinity of the Blennerville swing bridge was 2.9m. It was noted that there were some depressions along the length of the canal where depth might be up *c.* 0.3m greater and particularly so close to the lock gates due to the scouring effect of water currents when the lock gates are open. When emptied, a distinct narrow channel meanders the length of the canal that is created by water flow and the bottom sediments on either side slopes towards this channel.

Table 1 provides approximate estimates of some parameters of interest as they relate to the available space for canal fauna. This also explains how water conditions in the canal can vary as the volume of water is relatively small.

Table 1. Canal physical parameters (approx.)	
Volume or water in canal	125,000 m^3
Sub-Surface area of canal channel and basin walls	20,000 m^2
Surface area of mud on bottom of canal channel and basin	40,000 m^2

Fresh water enters the canal as run off from land to the north though a number of land drainage channels, two of these are linked to ponds. It is understood that there may be some freshwater entering the canal from springs also, apparently within the canal basin, but none could not be located or otherwise confirmed. Estuary and inner bay water also enters the canal over the lock gates at spring tides for a number of days every two weeks. This occurs when tides are in excess of 4.2m above chart datum as this is the level of the top of the lock gates. Storm surge conditions also add to this tidal effect on canal filling. The water in the canal is relatively clean and there was no evidence of any significant diffuse or single point pollution sources.

There can be a litter problem from time to time and floating debris tends to accumulate along with floating algae that is washed into the canal over the lock gates. Together these are driven by prevailing winds to gather in the eastern end of the canal basin. The algae fraction eventually rots and/or sinks and presumably adds nutrients to the canal water. The remainder, being predominantly plastic material, is removed from time to time. A small amount of dense items of rubbish is found here and there along the length of the canal and in the canal basin. This material provides a surface on which *F. enigmaticus* could settle and was particularly evident in the canal basin.

Water temperature at the surface in the canal basin varies over the course of the year from occasional readings recorded in 2021 (See Table 2). Temperature variation at the bottom follows the surface records but with less extremes in terms of max. and min. temperatures. Salinity was measured on a number of occasions over the course of the investigation by means of a refractometer (V2 Refractometer). Salinity ranges reflected the influence of periods or wet weather where the inner bay surface water was at a level of *c*. 19 psu and occasionally spilled into the canal.

Table 2. Temperature and salinity of canal basin water.

	Temp (C)		Salinity (psu)
	Surface	Bottom	
Winter	0	4	4-6
Summer	21	18	19-22

A salinity of 22 psu was recorded recently (September 2021) ahead of the opening of the lock gates following a period of very settled and dry weather; at this time the inner bay salinity was at c. 30psu. Following the emptying and refilling of the canal in early August and again in September 2021 the canal salinity was raised to *c*. 27-29 psu.

Table 3. Salinity at 9.00 on 4th December 2020 at depth of 0.5 m.

Canal Basin	*c.* 6 psu
Swing bridge at Blennerville	*c.* 6 psu
Inside Lock Gates	*c.* 7 psu
On shoreline c. 500m from lock gates	*c.* 19 psu

Salinity was also measured for a number of samples of water taken at different locations on 4th December 2020. This represented the situation after the canal had been emptied and refilled 5 weeks previously with inner bay water of *c.* 19-20 psu (see Table 3). It appeared as if the drop in water level resulted in much more than 50% of the canal water draining and being replenished with inner bay water, yet the salinity was reduced significantly most probably by run-off from land entering the canal over the 5 week period between the closing of the lock gates and sampling.

The salinity was measured again on the 18th December very shortly after the canal was drained and refilled following a week-long period of exposure to tidal exchanges (see Table 4). The low salinity in the basin of <5 psu on 18th December, within 6 hours after the canal was refilled confirms that there was stratification as much more than 50% of the water in the canal on that day had entered from the bay which had a salinity of *c*. 17 psu. If complete mixing had taken place with the residual water in the canal, a much higher salinity that 5 psu would have been observed.

Table 4. Salinity at 12.00 on 18th December 2020 at depth of 0.5 m.

Canal Basin	<5 psu
Inside Lock Gates	17 psu
On shoreline 500m from lock gates	*c.*17 psu

It is likely that the flooding of the canal with inner bay water while there was a residue of lower salinity water lying in the central channel may have resulted in the usual estuarine surface 'wedge' of freshwater coming to lie close to the surface along the length of the inner canal and being held there by an incoming deeper seawater 'wedge'. This condition was mostly likely partly maintained by the prevailing WSW wind that was blowing on the day of sampling and is generally the prevailing wind effect on canal water.

It was also found by observation that when more saline and relatively cooler inner bay water enters the canal over the lock gates it tends to sink, as it is slightly more dense than the water in the canal that is generally warmer, less saline and consequently less dense. The local wastewater treatment system for Tralee discharges into the inner bay close to the entrance to the canal. The nutrient levels of the inner bay were not measured but are likely to be comparatively high due to the influence of the wastewater discharge and the freshwater from the river Lee that drains agricultural land in the area. During spring tides in the summer, the water exiting the canal as the tide ebbs is canal surface water. This suggests that there is a partial 'overturning' of water on a tidal cycle during spring tides and perhaps a replenishment of nutrients in the canal. Tests using water samples taken from the canal and the inner bay stained with a food dye confirmed the density differences referred to here.

Measurements of water turbidity were made on a number of occasions at the Blennerville Swing Bridge. Turbidity seemed to be seasonal and also reflected the degree to which inner bay water had been disturbed by wind and wave action before entering the canal. Turbidity was therefore partly determined by suspended silt from this source. During calm conditions and when water exchange with the inner bay had not taken place, the turbidity due to suspended silt declined. A residual turbidity remained and was most probably due to the presence of phytoplankton. This observation was not confirmed as it was outside the scope of the investigation.

Table 5. Canal water turbidity range.	
Max.	1.5m Secchi
Min.	2.3m Secchi

No measurement of oxygen levels was made but there was no evidence of oxygen depletion in the behaviour of any of the fauna at any point over the course of the investigation. This observation relates to the attached and free swimming fauna found close to the surface and not those species living in or close to the bottom which may be particularly well adapted to low oxygen tension conditions.

There may be issues with low oxygen on the bottom where there is close contact with unstable anoxic muddy sediments and when outgassing of Hydrogen Sulphide has been noted at certain times. Outgassing coincided with periods when the canal water level was dropped resulting in a reduction in the hydrostatic pressure at the mud/water interface allowing gas bubbles in the mud to expand and to escape. This outgassing was noted particularly in the basin.

Given the known ability of some of the infauna to withstand low oxygen conditions and the presence of very old specimens living in the muddy bottom, it appears that there had not been any chronic or acute oxygen shortage in recent years. It is noted later that there was evidence of stress caused to some infauna due to the canal being drained but this was not a response to low oxygen levels in the water *per se*.

Samples taken for granulometry were processed at AQUAFACT's laboratory and the results confirm what was evident from the handling of core samples. The results are shown in Appendix 1. The sediments are of a fine texture and comprise a mixture of organic material dispersed throughout a predominantly inorganic silt/mud fraction. The sediments tended to be very fluid, uncompacted, without any structure and were consequently unstable. There was little evidence that the accumulated sediments were derived from the drains coming from the land to the north of the canal and were most probably the result of 20+ years of silt-laden water entering the canal for a number of days on each spring tide cycle. No dredging of the canal had taken place since the lock gates were reinstated c 20 years ago. The organic fraction may be from a number of sources but included amongst them must be a significant contribution of faeces and pseudo-faeces generated by the canal fauna and in particular the three most abundance species described below.

6.2 Distribution and Abundance of Fauna

The focus of this investigation was primarily on *F. enigmaticus.* Results are presented here from the sampling programme of hard surfaces targeted at this species and also its associated fauna. Some notes are also presented on the results of a generalised search of hard surfaces for other species not associated with *F. enigmaticus.* This includes species which likely compete with the tubeworm and are less abundant today due to this competition.

Results are also presented for all the fauna encountered as part of the core sampling programme of the soft sediments along the length of the canal.

Notes are presented on other species found as part of a more generalised *ad hoc* sampling of the water close to the bottom and side walls of the canal, in particular nekton which was not being targeted by other sampling methods. Brief notes on algae and terrestrial plants are also included.

A list of all species found during the investigation is presented in Appendix 1.

6.2.1 Distribution and Abundance of *F. enigmaticus*

The results presented here relate to the examination of the hard surfaces along the length of the canal including the vertical cut stone infrastructure around the lock gates, the swing bridge and the north wall of the canal basin. It also included the sloped stone armour of the canal side walls along the entire length of the rest of the canal.

The canal was surveyed when it had been drained allowing inspection of the surfaces from normal canal high water level to where the walls meets the muddy bottom. The surfaces on the two pontoons were also examined.

Figure 7. *F. enigmaticus* dislodged from TRC pontoon

This inspection was undertaken on a number of occasions and more systematically on two occasions in the spring and later summer of 2021.

Submerged surfaces of both pontoons were found to be completely covered with *F. enigmaticus* at the commencement of the survey. Following the drying out of the canal when the pontoons had come to rest of the bottom, much of the heavy tubeworm fouling was dislodged (see Figure 7), but there was evidence shortly afterwards of resettlement on the bare surfaces exposed by the dislodged tubeworm masses.

Because of the significant difference in the level of incidence of *F. enigmaticus* encountered along the length of the canal, the results are considered for two sections of the canal as follows:

- Canal proper extending from the lock gates to a point *c*. 600m - 700m west of the entrance to the canal basin;
- Canal basin and the canal extending *c*. 600m - 700m westward from the entrance to the basin.

It is estimated that the linear length of the space between the stone armour available to *F. enigmaticus* along the length of the canal was between 10m - 30m/m^2 depending on the size of stone armour used. This metric (average of *c.* 20m^2 by an average gap width of 2.5cm) was used to generate an estimate of the abundance of tubeworm when comparing areas where the tubeworm was confined to the gaps between the stone armour with the more densely populated areas. Where the tubeworm completely filled the gap it was calculated that there was a coverage of 0.05m^2 of *F. enigmaticus* / m^2 (*i.e. c.* 5% coverage) of the wall surface. Estimates of coverage were also interpolated from this where *F. enigmaticus* was less abundant and only partly filled the gaps.

The incidence of tubeworm abundance increased slowly but progressively from the lock gates as far as the Blennerville swing bridge. Along this length of the canal the tubeworm was confined to the gaps between the stone armour and was not very abundant (see 0m - 700m in Figure 8).

The level of incidence increased from small clusters of individuals occupying some of the space in the gaps between the stone armour to more completely filling these spaces (see 700m - 1500m in Figure 8).

From 1500m eastwards, the incidence increased with the tubeworm coming to fill most of the space between many of the stone armour blocks and creeping onto the surface of the stone armour and forming a mat (see 1600m to 1900m in Figure 8).

The incidence of *F. enigmaticus* from this point eastwards to the entrance to the canal basin (at 2300m from the lock gates) increased steadily to the point that the entire surface of much of the stone armour was completely covered. The coverage changed from being simply a mat of *F. enigmaticus* on the surface to the formation of clumps which increased in thickness by rising from the surface to create three dimensional structures with the outer layer of actively growing tubeworms covering a maze of water-filled open space within that provides niches for the associated infauna that is described below.

The occurrence of *F. enigmaticus* within the canal basin itself sees the prevalence of large clumps growing along the canal wall from the surface to a depth of 1.5+ m where it meets the muddy bottom. This was typically a growth of *c*. 0.2 m in thickness along much of the 250+m length of the canal basin wall. Spherical lumps was found growing on the hard surface of debris scattered along the bottom of the canal basin, some of which are up to 0.7m - 0.8 m in diameter (See Figure 9).

The piles supporting the marina pontoon provided the substrate for the largest aggregations which were up to 2 m in diameter. These were partly sheared off by the pontoon linkage brackets as the pontoon structure dropped and settled on the bottom as the canal was emptied.

F. enigmaticus found in areas close to the entrance to, and within the canal basin itself, was characterised by larger clumps of tubeworm completely covering the hard surfaces to the virtual exclusion of everything else.

F. enigmaticus clumps that broke free from the hard surface on which they had been growing generally fell into the mud directly below. In these instances those individuals lying clear of the anoxic mud continued to grow and the colony increased in size as normal. Those parts of these detached colonies that were submerged in the mud and the additional mud that came to occupy the space in the colony above the mud line of the bottom, came to be occupied by mud-dwelling species as described below.

It is noted that the description provided above relates to the situation that applied prior to the onset of winter of 2020/2021. At that time the canal was emptied for a number of weeks and this coincided with a particularly cold spell of weather. This resulted in some die-off of large areas and especially the surface dwelling individuals on the larger mats and clumps of *F. enigmaticus.* The combined effect of frost and exposure to cold air was responsible for this die-off (see Figure 10).

The mortality of large amounts of *F. enigmaticus* resulted in the surface area provided by the dead tubeworms skeletons being used as a substrate for the settlement of green algae with the onset of spring/summer 2021 (see Figure 10).

The situation changed again with the onset of summer 2021 and many of the patches of *F. enigmaticus* which had been covered with an embryonic coating of green algae seemed to recover and the tubeworm re-emerged as the dominant organism covering the canal basin walls while sharing the space with the green algae that seemed to persist alongside the tubeworm. There had clearly be a fresh settlement of tubeworms. This is supported by the evidence presented below where a heavy settlement of *F. enigmaticus* was recorded. While the green algae remained in place along much of the inner reaches of the canal and basin, *F. enigmaticus* seemed to successfully re-establish itself below the algae that tended to float free and extend into the water providing space for the tubeworm to continue to grow. It appears that this algal covering dies back in winter each year.

Figure 8. % Coverage by *F. enigmaticus* of canal wall from the lock gates (0m) to entrance to basin (2300m)

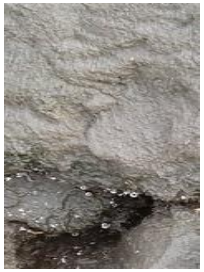
0m - <5% 	100m - <5% 	200m - <5% 	300m - <5% 	400m - <5% 	500m - <5% 	600m - c. 5% 	700m - c. 5% 
800m - c. 5% 	900m - c. 5% 	1000m - 5-10% 	1100m - 5-10% 	1200m - c10% 	1300m - 10-15% 	1400m - 10-15% 	1500m -10-20% 
1600m - 10-20% 	1700m - c.20% 	1800m - 20-25% 	1900m - 20-25% 	2000m - c. 25% 	2100m - 25-50% 	2200m -c.50% 	2300m - c.50% 

Figure 9. % Coverage by *F. enigmaticus* of walls and structures within the canal basin

North Wall - 90-95% 	South Wall - 80-90% 	East Wall - 80-90% 	West Wall - 90-95% 
Marina Pontoon - 90-95% 	Marina Pontoon Pile - 100% 	TRC Pontoon - 90-100% 	Base of Ladder - 100% 

Figure 10. Examples of die-back of *F. enigmaticus* due to drying out and frost followed by settlement and growth of algae on dead *F enigmaticus.*

Normal *F.e.*	Frost on *F.e.*	Early Stage Algae Growth on Dead *F.e.*
		 

Dead Clumps of *F.e.*	Algal Settlement after *F.e.* dieback
	

6.2.2 Fauna Associated with *F. enigmaticus* Colonies

Where attached colonies of *F. enigmaticus* formed large clumps these had open spaces within. This space remained relatively open and water-filled where the tubeworm was growing on surfaces free from the influence of bottom sediments. It would appear that the accumulation of mud along the bottom close to the canal walls may have been partly the result of faecal material produced by the tubeworm. This build-up of mud is most pronounced in the vicinity of the pontoons which carried the heaviest colonies of tubeworm in the canal system. This faecal material did not seem to collect in the open space within these colonies attached to hard surfaces well clear of bottom sediments This may be partly the result of the activities of the associated fauna that occupied this space.

Where the colonies became detached and came to lie on the bottom, an amount of faecal material and mud from other sources accumulated within what would otherwise have been open space within the colonies.

The open water-filled matrix of attached *F. enigmaticus* and the mud-filled matrix of the *F. enigmaticus* clumps lying on the bottom of the canal were found to have different associated fauna.

The sampling of attached *F. enigmaticus* for associated fauna involved the use of two sampling processes. One was designed to estimate the presence of larger less abundant species while the other approach was more suited to smaller more abundant small species. A large core sampler (175cm^2 by 20+cm deep) was employed for the former and a smaller core sampler (48cm^2 by 5cm deep) was used for the latter.

Table 6. Main species associated with *F. enigmaticus* (Attached or on the Bottom)

Species	Number/m^2	Att/Bott
Ficopomatus enigmaticus	150,000	Attached
Gammarus zaddachi	5,000	Attached
Potamopyrgus antipodarum	3,500	Attached
Lekaneshaera rugicauda	3,000	Attached
Anguilla anguilla	145	Attached
Mya arenaria	5,000-10,000	Bottom
Hediste diversicolor	3,000 - 5,000	Bottom

A summary of the results of the sampling of the fauna associated with attached tubeworm colonies is presented in Table 6. Detail results of the sampling are presented in Appendix 1. The table opposite lists the incidence of each of the species found. This included invertebrate fauna but surprisingly also a number of juvenile Common Eel (*Anguilla anguilla*) and one specimen of Flounder (*Platichthys flesus)* was also found.

When the dislodged colonies which had come to lie on the muddy bottom were examined, the species present included some more typical of what was found in the core samples of the canal sediments as described below. Species found included those associated with attached *F. enigmaticus* but also included Rag Worm (*H. diversicolor*) and Sand Gaper (*M. arenaria).* All specimens of Sand Gaper. found were juvenile and did not include any of the larger specimens found in the core samples as described below. This suggested that these were recently settled (estimated age of <2 years). These results were not quantified as it was not possible to find a way of sampling that could be regarded as representative. Estimates are given in Table 6.

6.2.3 Species found in Muddy Bottom Core Samples

Appendix 1 shows the results for all the core samples taken from muddy sediments along the length of the canal and in the sediments trapped in the damaged areas of the canal side wall. The core sampler penetrated to more than 20 cm (unless a hard bottom was encountered) and so was effective in retrieving any infauna. The samples from the western end of the canal yielded very sparse evidence of any infauna. Samples from the centreline of the waterway were particularly poor. This was expected based on preliminary examination of the canal sediments which appeared to be very unsuited to harbouring burrowing fauna that would typically be associated with more stable and structured fine muddy sediments.

On approaching the eastern end of the canal and before entering the canal basin there was a steady increase in the quantity of specimens recovered and in this case the two species demonstrating the greatest abundance were Ragworm (*H. diversicolor)* or Sand Gaper (*M. areanaria).* The sediments in the case of these samples were found to be slightly more compacted, more stable and structured.

Two species of Mysid shrimp turned up in the samples and clearly these were captured by the core sampler as these specimens were sitting on or swimming just above the bottom. One of these, Chameleon Shrimp (*Praunus flexuosus*), was taken in samples C8, C9 & C10. The rest of the specimens found in the sediments were either Rag Worm or Sand Gaper, both of which are well adapted to living in muddy conditions.

The photographs depicted in Figure 11 and 12 clearly demonstrate how the richness of the infauna steadily increased from being very poor in the western end of the canal. The ‘C1-12’ and ‘S1-12’ refer to the sample locations along the centreline (C) and the sides (S) of the canal as presented in Figures 4 & 5 earlier in this report.

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Figure 11 Specimens recovered from core samples taken from the centre of canal

Specimens recovered from core samples taken from the centre of canal (C1-C12)

Specimens recovered from core samples taken from sides of canal (North Side S1,2,4,5,7,8,10,11 & South Side S3,6,9,12)

6.2.4 Notes on Some Fauna

Bird species were noted during the investigation but were not counted as they were not relevant to the project aim and objectives. A group of Mute Swan (*Cygnus olor) is* resident in the canal and adjacent ponds and breeds successfully each year. Cormorant (*Phalacrocorax carbo)* regularly fish in the canal from time to time. Redshank (*Tringa totanus*), Black-Headed Gull (*Croicocephalus ridibundus*), Rook (*Corvus frugilegus*) and Hooded Crow (*Corvus cornix*) foraged in the canal when it was drained.

Otters (*Lutra lutra*) was encountered and was particularly noted during the period when the canal had been drained.

Plankton sampling was only attempted on two occasions and no plankton was recorded. Planktonic stages of benthic fauna were clearly present even if not picked up by the plankton net as was evident from results presented for settlement of tubeworm on spat collectors deployed from April to September 2021. The incidence of plankton more generally was outside the scope of this investigation.

Figure 12. Specimens of *Potamopyrgus antipodarum* amongst *tubeworms.*

Nekton was not targeted particularly in the sampling programme but some selective hand-netting along the upper reaches of the canal yielded a variety of species. In addition to the occasional appearance of shoals of Grey Mullet (*Chelon labrosus*) these was significant quantities of Three-Spined Stickleback (*Gasterosteus aculeatus*) along the inner reaches in particular and these tended to be swimming close to the sidewalls and feeding in these locations. Flounder (*Platichthys flesus*) was observed settled on the surface of some pockets of mud in areas where the canal side wall was damaged and mud had accumulated and was populated by burrowing infauna. Some specimens were recovered from the surface of mud and the side walls and were identified. Grey Shrimp (*Crangon crangon*) and Sand Goby (*Pomatoschistus microps*) were also found in similar situations and were more abundant than flounder. Shoals of mysid shrimps (*Neomysis integer and Pandalus flexuosus)* and a true shrimp (*Palaemonetes varians)* were found to be common in the warmer weather from June to August 2021.

Figure 13. Sand Gapers emerging from gaps between canal wall stone armour

While New Zealand Mudsnail *(Potamopyrgus antipodarum)* was found in the sampling of attached *F. enigmaticus*, its abundance was not uniform. In some places its incidence was very high while in others much lower. This variability in density could not be looked at as part of the investigation. While the sampling of *F. enigmaticus* at the marina pontoon reported above showed an average level of 3,500 *P.a.* /m^2, some samples revealed levels of *c.* 10 times this where the mudsnail was densely packed in the spaces between the tubes (see Figure 12). It is noted that *P. antipodarum* is an alien, is regarded as invasive and has been in Ireland for more than one hundred years.

The presence of the Sand Gaper (*M. arenaria)* living in the gaps between the stone armour on the walls in the upper reaches of the canal was not obvious on cursory inspection. The gaps in most instances were either filled with *F. enigmaticus* or were deep and narrow making inspection difficult.

Figure 14. Emerged Sand Gapers lying exposed at base of canal wall

When the canal was drained during the early Spring 2021 and remained empty for a number of weeks, medium to large specimens of *M. arenaria* (c. 50 - 100 cm) living deeply buried in the gaps (see Figure 13) emerged fully from their burrows and came to rest on the surface of the side wall or tumbled down the sloped sides coming to rest further down the wall or on the edge of the mud (see Figure 14).

There was evidence of *c*. 75 - 100 specimens per square meter from what emerged but densities much greater than this are very likely living in the spaces between the stone armour . Along the length of the canal where *M. arenaria* was present there were many thousands seen to be affected. Some of these were preyed on and their empty shells were found around the area. Others survived the long exposure and seemed to revive when water returned, ever after prolonged exposure. No estimate of the level of mortality was made but many of those that emerged and survived did not manage to return to the mud as the ability to burrow from the surface seems to be lacking in large adult specimens. These specimens continued to live, for a time at least, exposed on the surface of the side wall or on the mud.

It was not possible to estimate what % of the specimens living in the gaps that managed to survive. On closer examination, it was noted that the presence of the Sand Gaper in the gaps between the stone armour created space that would otherwise have been fully filled with compact silt. This may have an effect on the stability of sections of the canal wall where there is a high incidence of Sand Gapers. The emergence of a large number of these may have to be considered in terms of possible impact on the integrity of the rock armour if as is expected all of these will die if the canal is emptied for 3 months.

6.2.5 Notes of Some Species of Marsh Flora

It is worth noting that the terrestrial vegetation along the canal reveals something of the influence of the canal's brackish character. The vegetated margin on both sides of the canal extends down to the top of the stone armour of the canal side walls as far as the normal water's edge. This area is very occasionally inundated under extreme high water conditions and when a storm surge coincides with spring times. Salt tolerant species, Sea Plantain (*Plantago maritima*), Lax-flowered Sea-lavender (*Limonium humile)* and Sea Aster (*Aster tripolium*), are found all along the canal close to the water line. It is most likely that the soil above the waterline is heavily influenced by the salt in the brackish water creating an environment suited to these marsh dwelling species. More typical terrestrial vegetation is found away from the water's edge further up on the canal bank.

Over the course of the winter and early spring 2020/2021 it was evident that there was very little algae in the canal, either attached or floating. No evidence of green algae was observed when the canal was emptied during this period. As the spring progressed and on the arrival of summer with its rising temperatures, there was a proliferation of green algae including both attached and floating. These were not identified to species level as the focus of the investigation did not allow for this. It would appear that the species present included *Cladophora spp*. that formed floating mats as well as attached growths. *Ulva/Enteromorpha spp*. was found covering hard surfaces on the walls and pontoons and also was seen to detach and formed floating mats of algae.

Bladderwrack (*Fucus vesiculosus*) and Egg Wrack (*Ascophyllum nodosum)* were found floating in the canal at different times and dispersed along the length of the waterway. These entered the canal over the lock gates during periods of spring times having been carried from the shoreline outside the canal. This floating algae was progressively moved up the canal as far as the canal basin by prevailing winds.

Early in the year and before the green algae became more obvious, a dusting of green algae covered all areas of dead *F. enigmaticus* This later developed as described earlier and a substantial amount of green algae was present in the canal by early summer. This persisted up to the end of the investigation. It is expected that this growth will die back once the winter sets in, and probably was the case in early 2020, leaving the canal free from green algae over the winter period.

6.3 Pilot Scale Removal of *Ficopomatus enigmaticus*

The investigation of how it might be possible to manage *F. enigmaticus* in the canal was predicated on establishing its abundance, its distribution and something of the ecology of the canal as a baseline. The sampling programme described above assisted in providing some important insight into the scale and nature of the infestation by this invasive alien species.

The trials planned involved three different approaches. These were as follows:

- Physical removal of *F. enigmaticus*;
- Exposure to freshwater;
- Exposure to air.

In an effort to understand how surfaces of the canal might be recolonised by fresh settlement of tubeworm, an investigation into larval settlement was also undertaken.

6.3.1 Settlement of *Ficopomatus enigmaticus*

The biology of the species in terms of life cycle from spawning through to settlement and growth was an important consideration in the investigation. To this end a set of three spat collectors was deployed in mid-March when it was anticipated that there would be a settlement of *F. enigmaticus* larvae following a spring spawning event. The string of three tiles employed were suspended from the marina pontoon and occupied the water column from 20cm below the surface to 1.0m below and were held clear of the muddy bottom (See Figure 15). On one occasion when the canal was emptied in early September 2021 the tiles were removed and suspended in aerated canal water for 3 days before being returned. This was to ensure that further monitoring could be continued following completion of the investigation.

The information these spat collectors would provide along with the information on tubeworm distribution and abundance will be used to make recommendations on what might be possible in terms of a strategy to manage the species if this is to be considered.

Figure 15 shows the growth of algae that settled on the spat collector tiles in the period from mid-April when algae was first noticed to mid-June. *F. enigmaticus* was slow to appear alongside a small number of a barnacle, *Balanus crenatus,* in amongst the algal which has covering most of the surface of the tiles by this time. The period from mid-June to mid-July saw the entire surface area of the three tiles being covered with a recumbent mat of *F. enigmaticus* and the effective displacement of the algae and the *B. crenatus*. Growth continued and resulted in all the settled specimens growing to adult

Figure 15. Growth of *F.e* over period from 21st June to 24th August on Spat Collector Tiles

Top Middle Bottom 21/6/2021	Top Middle Bottom 24/8/2021

size in less than two months. By the end of August the specimens displayed additional growth and what was initially a recumbent mat of tubeworms progressed to become clusters of individuals rising from the surface of the tiles to produce the typical clump of individuals. This was especially pronounced on the lowest tile in the set and particularly on the bottom part of this tile.

6.3.2 Physical Removal of Tubeworm

A trial was initiated at the end of August 2021 where two areas of the canal basin wall were cleared completely of tubeworm covering from the surface to a depth of 1+ m. This involved the use of a garden space and a stiff-bristle brush to remove as much as possible of the growth (See Figure 16).

The two areas chosen were as follows:

- 12 m stretch adjacent to the main pontoon between two of the piles which were also cleaned;
- 12 m stretch on the north side wall adjacent to the TRC pontoon and boat slip in the canal basin.

The conditions of the two areas cleaned were significantly different. In the case of the main pontoon, the area cleared comprising close fitting cut stone masonry and mass concrete and there was little difficulty clearing all fragments. In the case of the area cleared adjacent to the boat slip, the wall there is constructed of more loosely fitting stone blocks with lots of gaps in which the tubeworm had taken hold. It was not possible to remove all of the material as this would have interfered with the structural integrity of the wall.

The fact that the two surfaces cleaned are different in structure will provide an opportunity to look at the process of tubeworm resettlement on the two main types of canal surface. Settlement is likely to start shortly after the cleaning process with the anticipated autumn spawning. If there is no autumn spawning and settlement there will be an opportunity to observe recolonisation of the bare walls in 2022. This trial could not be progressed any further before the end of the investigation period in mid-September.

What has been provided is a baseline that will be available for further monitoring of settlement in late 2021 and throughout 2022 and beyond.

Figure 16. Areas of canal wall cleaned for later recording of resettlement

Wall adjacent to marina pontoon	Wall adjacent to TRC slip and pontoon
	

6.4 Exposure to Air

Trials on the effect of exposure of *F. enigmaticus* to air were conducted during the winter of 2020/2021. A table illustrating the periods of exposure that the tubeworm were subjected to is presented in Appendix 1. This shows how the specimens responded to being returned to canal water after exposure to air. This was done to determine if the specimens had survived exposure and to see if there was any evidence of reduced vitality if they were still alive.

As the trial was initiated with a limited number of specimens it was necessary to reuse the same specimens to allow longer periods of exposure to be tested when it became apparent that *F. enigmaticus* was not dying off as was expected. This was not ideal as these re-used specimens had been returned to canal water for about 2 minutes to check vitality before being exposed to air again. This may have had a resuscitative effect. The results nonetheless are interesting.

The results record the index of vitality as it was hoped from the outset that there would be a gradual reduction in vitality before specimens died. This did not turn out to be a reliable metric as specimens either showed a response and were clearly alive or didn't respond and simply confirmed that they had not survived. The trial continued for a period of 480 hours (20 days) and at this level of exposure to air under the conditions of the trial, specimens of *F. enigmaticus* still survived the continuous exposure to air. While it was noted that the reuse of some specimens may have partly resuscitated them, allowing them to survive for the 20 day period of the trial, some specimens were continuously exposed to air for a total of 312 hours (13 days) and had not been returned to water at any stage and were still alive and responded well to re-immersion in canal water after that period of exposure.

6.5 Exposure to Freshwater

Trials on the effect of exposure to freshwater were initiated shortly after the exposure to air trials had commenced. The table presented in Appendix 1 records the effect of immersion in fresh water (salinity of 0 psu).

The results of these trials indicate that *F. enigmaticus* starts to show the ill-effects of exposure to full freshwater (despite surviving very well in canal water of salinity of 5-6 psu). A preliminary test showed that all specimens in a sample placed in freshwater had died after *c.* 5 days. This prompted the follow-on trial where samples were exposed to periods of 6, 18, 36, 72, 168 and 216 hours.

Specimens showed a degree of lethargy after a short period and some specimens had started to die after 72 hours. There was still evidence of significant survival at that point but the subsequent sample taken after 168 hours showed that some specimens were still alive but were not coping well. When these were returned to canal water the survivors resuscitated and it is thought that a significant percentage of these would probably survive.

The final sample taken after 216 hours (9 days) revealed that very few specimens were seen to show any signs of life with the vast majority (>90% having died earlier). The survivors appeared to be heavily compromised.

7 Dissemination of Findings

While the investigation has intrinsic value and contributes to our knowledge of the Australian Tubeworm as an invasive alien species living under Irish conditions, it is important to consider how best to disseminate the findings of the study. Dissemination is managed in different ways depending on the target audience and the purpose.

7.1 Tralee Rowing Club

Tralee Rowing Club (TRC) sponsored this investigation which was funded by LAWPRO. Members assisted with some of the investigation activities undertaken by the local ecologist on behalf of AQUAFACT. Assistance was provided in contributing to an event as part of Heritage Week 2021. This included an audio-visual presentation and an outdoor display of the investigation in terms of the species found living in the canal that the public would not have been aware of. The presentation and the display were titled 'What Lies Beneath' - An Ecological Investigation of the Tralee Ship Canal.

The full report (this document) will be provided to TRC who will submit it to LAWPRO to show completion of the investigation that was funded under the LAWPRO Community Water Development Fund 2021.

The ecologist will make a presentation on the investigation to the general membership of the club later in 2021. The membership also have access to the audio-visual presentation on the TRC website and Facebook page.

7.2 Kerry County Council

Kerry Co. Co. as owner of the waterway were supportive of the Investigation and it is planned that TRC will provide a copy of the report to the Kerry Co. Co. Executive Engineer - Area Engineering Manager responsible for the canal and to the Kerry Co. Co. Biodiversity Officer. The report may be of assistance to the Kerry Co. Co. in its plans for the canal in terms of general management but also in terms of any plans that it might want to consider if a decision is to be taken on managing the tubeworm as an invasive alien species. Some of the findings will provide insights into the ecology of the canal and how it impacts on the management of the engineering aspects of the waterway and vice versa. The findings may inform how best to deal with the general management of the canal into the future.

7.3 National Parks and Wildlife Service

Kerry Co. Co. has plans to undertake road maintenance activities that will necessitate the draining of the canal for an extended period in early 2022. It is also understood that repairs to damage to the stone sidewalls of the canal and the bank are also to be undertaken at this time. As part of this plan under the planning regulations, Kerry Co. Co. submitted an AA Screening Report which was considered by the NPWS as part of the normal consultation process. Because of this, it was considered that the work associated with this investigation did not necessitate the preparation of another AA Screening Report. However, it is proposed to issue a copy of the report of this investigation to NPWS on completion of the investigation as it may be useful in its approach to managing this invasive alien species as the findings may contribute to the knowledge of the species in Ireland.

7.4 LAWPRO

A copy of the full investigation report will be submitted by TRC now that the investigation has been completed once the report has been finalised and approved.

7.5 Community and Environmental Groups

A presentation of the investigation was published on the Heritage Week Website and remains widely available to those interested locally and nationally in natural heritage. In addition, TRC and the investigation ecologist mounted a display of the findings of the investigation at the canal basin at the start and end of Heritage Week. There was clearly a level of interest in this amenity and its ecology. It may be possible to find other fora at which to present the findings of the investigation later.

7.6 Other Users of Tralee Bay Amenities and General Public

Consideration is being given to mounting a small notice on the canal with a QR code that would allow users of the canal to find out more about ‘what lies below the surface or the waterway’ that they might not be aware of.

7.7 Research Community and Publication

There are findings made as part of this investigation that will be worthy of note and it is proposed to submit a relevant scientific paper or note for publication. This will be a matter for AQUAFACT and could involve some collaboration with other researchers looking at invasive alien species and *F. enigmaticus* in particular. This is under consideration

8 Discussion and Conclusions

The investigation as proposed was largely completed as planned. The aim has been achieved and the objectives as set out have each been addressed in the investigation and are reported in the Methodology, the Results and in the Discussion and Conclusions below. One of the objectives was to undertake an AA Screening of the proposed project. While an AA Screening was originally envisaged, this was not required as Kerry Co. Co. had already completed an AA Screening Report that more than dealt with all the relevant issues in regard to potential impacts on Natura 2000 sites. It was decided to include the content that would have been submitted in the proposed AA Screening so that any reader of the report interested in this could find that the investigation did not have any significant impact on Natura 2000 sites. This material is presented in Appendices 2, 3 & 4.

8.1 Discussion

The discussion that follows addresses the two main elements of this report namely the presence of the Australian Tubeworm, associate fauna and sediment in-fauna in the canal and also consideration of how it might be possible to manage the tubeworm as an invasive alien species.

A number of areas for further investigation are highlighted in bold.

8.1.1 Presence of *Ficopomatus enigmaticus* and Other Fauna in Tralee Ship Canal

The investigation confirmed the presence of *F. enigmaticus* in the canal and went further to explore the distribution of the tubeworm and to quantify its abundance. In addition, other aspects of the canal ecology were studied. This include more detailed investigation of the fauna associated with the tubeworm but also the distribution and abundance of soft sediment infauna along the length of the canal. Some other matters were also noted.

F. enigmaticus was found in abundance in the canal basin and was found to dominate the hard surfaces on which it settled and grew. Its abundance appears to exceed anything reported elsewhere in Ireland where it has been discovered but with nothing approaching the abundance found here. Its growth pattern seems to be more like what is found in sites further south in areas such as those in parts of the Iberian Peninsula. **Some comparative study of the abundance of the tubeworm in Ireland would be worthwhile.**

The gradual increase in prevalence of *F. enigmaticus* from the lock gates in the west, along the 2.5km length of the canal is remarkable and it seems it must reflect the hydrography of the canal in terms of the prevailing wind effect on the enclosed water body, canal water circulation and its temperature and salinity stratification in periods of settled and warm weather. The impact of the regular replenishment of the canal's brackish water by more saline water from inner Tralee Bay and the inflow of freshwater from the land along the length of the canal, all combine to create an environment where clearly *F. enigmaticus* thrives. The replenishment of the canal water from the inner bay must also reflect the annual cycle of inner bay salinity and turbidity due to the influence of the river Lee and the extensive area of mudflats close by. It is further noted that this regime is influenced by settled dry weather conditions on the one hand and stormy and wet conditions of the other. **A systematic**

monitoring of the abundance of the tubeworm along the length of the canal could be considered as a longitudinal study to establish if the current status is stable or is transitory.

Inspection of the hard surfaces on the shore outside the canal and indeed more widely of inner Tralee Bay yielded no evidence of any *F. enigmaticus* outside of that resident in the canal. This is discussed further in the section below. It was not possible to say how the canal became infested with the tubeworm and it may never be known but this deserves some investigation as it would be useful to know in terms of managing the spread of the tubeworm to other waters. **If possible the source of the infestation of the Tralee Ship Canal should be looked into sooner rather than later**.

The investigation looked in some detail at the fauna associated with the tubeworm and quantified this for the area where the tubeworm is most prolific, in the canal basin. It found particular species that clearly are well adapted to the niches that the large tubeworm colonies provide in terms of shelter and food within the open water-filled spaces in the large aggregations on the basin walls and pontoons. The diversity of associated fauna was limited but the abundance of the small number of species recorded was significant in terms of biomass. **Clearly further investigation of the ecology of associated fauna would be possible and would likely be fruitful.**

The presence and abundance of *L. rugicauda* and *G. zaddachi* was not surprising but the presence of Common Eel (*A. anguilla)* and in particular its relatively high abundance was noted as unusual. The New Zealand Mudsnail (*P. antipodarum)* was found in quite large numbers in some areas within the basin and seemed to have appeared and increased in abundance very quickly in mid-summer 2021 as it had not been noted in some earlier sampling. Close inspection of many samples from early on did not reveal the presence of any of this gastropod and it unlikely that it was overlooked. There also appeared to be a significant variability in the abundance of *P. antipodarum* within the basin, with some patches of *F. enigmaticus* being very heavily populated and others much less so. Given the relatively sudden appearance of the species it may be that the patchiness in temporary and it may become more evenly distributed over the course of the year. It was interesting to note that a proportion of these snails had *F. enigmaticus* attached to their shells; no available surface for settlement is missed. **Further research might be worthwhile into the Common Eel and its fate as a resident of the canal. Similarly the population dynamics of the New Zealand Mudsnail could prove very interesting.**

The marked increase in the abundance of *F. enigmaticus* in moving from the lock gates to the canal basin was dramatic. It may be that what was found is merely a stage in the progression or the decline in the abundance of the tubeworm. **The status of *F. enigmaticus'* abundance and whether it will increase or decrease would be important to know and for this reason the future monitoring of *F. enigmaticus* should be considered.**

The progression in the abundance of *F. enigmaticus* in moving eastwards along the canal was also reflected in the abundance of the infauna of the canal sediments. The centre of the canal has a deep layer of anoxic, unstable and unstructured mud that seems to be devoid of life. At the edges of the channel and particularly so in the area close to the basin, the presence of two species increased dramatically and dominates the soft sediment that seem to be more stable and structured, probably due in part to the presence of these two dominant species, the Sand Gaper and the Ragworm. These species create deep burrows/tubes in the mud to 30+cm and add substantial structure to the substrate.
The presence of these two species in the bottom sediments was of interest in terms of the general ecology of the canal but the large numbers of the Ragworm anywhere there was suitably deep sediment is testament to the tendency for this species to occupy every available suitable space in the waterway. It turned up in large numbers in areas of the canal wall damaged due to erosion where sediment had accumulated within centimetres of the water surface and dry out regularly. They also occupied the gaps between the stone armour where there was sufficient sediment present to provide shelter. They appeared in large numbers in the mud that came to fill the open spaces in clumps of *F. enigmaticus* that broke from their attachment and came to rest of the muddy bottom. Juvenile Sand Gapers were also found in large numbers in this setting also.

The revelation that the gaps between the stone armour was home to large numbers of large adult Sand Gapers was unexpected. This was discovered following the emptying of the canal for an extended period which resulted in the bivalve emerging from its deep burrows and coming to lie on the side wall or the bottom of the canal. As well as those that managed to emerge, there were clearly many more much larger specimens that tried to escape from the sediments in the gaps but were prevented from doing so because of their much larger size. This phenomenon has a particular relevance to the management of the canal and is discussed below. **The abundance of the Sand Gapers occupying the spaces between the stone armour deserves some further investigation and is probably relevant to understanding how to protect the side walls from erosion**.

The focus of the investigation was primarily on the tubeworm, its ecology and to a large extent also the infauna as described above. The presence of plankton and nekton was considered but there were no findings of particular importance to this investigation. A number of fish species and swimming and crawling crustaceans were found including large numbers of Three-Spined Stickleback, Sand Goby, Brown Shrimp, Shore Crab, mysid Shrimp and a prawn, *P. varians*.

Algae were looked at and were important in some respects. Some algae that enter over the lock gates at high water during spring tides add nutrients once they die and sink. Green algae proliferate in warm sunny weather and provide a source of food for resident swans in particular. These algae also produces a covering of hard surfaces that appears to compete for space with *F. enigmaticus* but it does not presents much by way of competition for space with *F. enigmaticus* which seems to win the battle particularly as the green algae die back each winter.

Cold weather sees the canal covered in ice for a period in some winters and when the water level is dropped at these times it results in the exposed *F. enigmaticus* being subjected to freezing conditions and mortality. This was noted during the investigation. While a substantial proportion of the tubeworm died it appears that a fresh settlement of a new year class was able to take the place by settling on the dead tubeworm and restoring the situation to normal. The tubeworm displayed resilience in its ability to withstand the vagaries of the canal environment and its management. It will be interesting to see how it, and the rest of the canal fauna, manage to cope with the planned 3 month of drying out planned for early 2022. **This planned draining of the canal certainly deserves to be monitored as it will not only tell a lot about the ecology of the canal and the individual species but it may be very important in understanding how best to manage the invasive alien Australian Tubeworm. It is recommended that such monitoring of be undertaken.**

8.1.2 Management and Control of *Ficopomatus enigmaticus*

When first discovered, it was clear that the abundance of *F. enigmaticus* in the canal was such that it had the potential to be a nuisance and to impact on the canal. It quickly became clear that the investigation of the tubeworm needed to include some consideration to its management, control or possible elimination. A review of the literature indicated that control would be challenging and that elimination might not be possible without drastic measures, whatever these should be in this particular case. It was clear also that there were some interesting aspect to the ecology of the tubeworm that were not all bad, if value judgements are to be considered. The species filters the water and removes silt, effectively cleaning the water. It also provides shelter and food for other species.

It must be remembered that the Australian Tubeworm is an invasive alien species and some consideration needs to be given to how its presence in Ireland is to be managed if the level of infestation in the Tralee Ship Canal was to be replicated elsewhere. This will be a matter for national and local authorities and agencies tasked with environmental and wildlife protection. There are wider issues to be considered including further proliferation in the Tralee Ship Canal itself. Could the canal be overrun with the species or is there a natural limit to the biomass that the canal can support? These and other questions are worth consideration. The possible future impact on other waterways needs to be looked, should there be a risk of the tubeworm being transported or transmitted accidentally outside the area. There is a definite need for research into how to manage *F. enigmaticus* now and not to wait until it becomes a bigger problem as is likely at some future date. **A comparative study of *F enigmaticus* Tralee Ship Canal and other areas around the coast of our island should be looked at**.

The position taken here as part of this investigation was that some trials would be undertaken to look into strategies for the management of the tubeworm. There were limitations on what was feasible. Trials were carried out on how exposure to extended period to air and to freshwater might be used. If the canal was drained, then a period of exposure to air would be possible. The trials suggest that this could be as long as 20+ days in winter time but could be less in the warmer less humid summer time.

If seawater entering the canal could be prevented for a period and the freshwater from the land allowed to wash out the brackish water then it might be possible to use freshwater to control the tubeworm. The trials suggest that the degree of exposure to full freshwater might not need to be as long as for exposure to air but it would require that the canal water become fully fresh if this was to be an approach. This might take a long time especially as salinity stratification might see a refuge being provided for *F. enigmaticus* in the deepest most saline parts of the canal.

Of the two strategies, Kerry Co. Co. will have the opportunity to test one shortly as part of its road maintenance and canal wall repair work. The option of managing the canal water to allow it to become completely fresh could be looked at and would definitely be of more interest to the rowing club as it could continue with its activities which will not be the case when the canal is drained for 3 months in 2022.

Whatever approach is taken it is to be expected that unless total eradication is achieved, *F. enigmaticus* will re-colonise the waterway from any reservoir of specimens that manage to survive any eradication attempt. Based on the experience of this study, the Australian Tubeworm appears to be very resilient and will not be easily controlled or eradicated.

It would appear that control rather than eradication or elimination is probably the only viable option.

The clearance of two areas of canal basin wall will provide an ideal platform to assess the resettlement of these areas over the coming months and years and may be of assistance in understanding something of the rate of growth of *F. enigmaticus* in the canal. As mentioned already, the opportunity to study the recolonisation of these cleared areas and to study the impact of the draining of the canal for 3 months should not be missed.

The unusual character of the canal as a waterway built for boat traffic but not having any such traffic should be considered as it may be relevant in terms of the presence of marine fouling generally and in particular the level of tubeworm fouling in the canal. It is know that only one vessel sat in the canal for any time over the past 20 years. This means that the water in the canal has not be subjected to the impact of marine antifouling paints which would be expected in any similar marina or harbour location where all vessels would be treated with very effective and potent antifouling paints. Such antifoulants must produce a diffuse antifouling impact and perhaps this can be enhanced where boats are washed and recoated and where the washings ends up in the water and continues to release the toxins that affect fouling organism. **No investigation of how *F. enigmaticus* is affected by antifoulants was considered here but it would be worth a review.**

An inspection of another marina recently where there has been evidence of *F. enigmaticus* for some years revealed that the tubeworm has not proliferated to the extent that it has in the Tralee Ship Canal. There may be some reason other than the impact of antifouling paints that could explain this much slower spread than that experienced in the Tralee Ship Canal. Given the relatively small volume of water in the canal, if it was the case that there was a large number of vessels moored in the basin that had been treated with antifoulants, it may be that the level of *F. enigmaticus* would be less that it is today.

8.2 Conclusions

The proposed investigation addressed the questions posed in the aim and the objectives set at the outset. The report provides a comprehensive account of the Australian Tubeworm in the Tralee Ship Canal and delivers more by way of results and findings that could have been anticipated for what was expected from a very modestly funded investigation.

The tubeworm is clearly well adapted to the prevailing conditions in the canal which are determined by the physical structure of the canal; its exposure to inflow from inner Tralee Bay and the management regime which sees the canal gates only very occasionally opened. The absence of any vessels treated with antifoulants may also be a factor. The tubeworm's needs in terms of abiotic and biotic requirements appear to be well satisfied. It is clearly a very effective competitor in its occupation of available space in this brackish water canal. Not only is it an alien species by definition but it also displays it invasiveness in the canal setting in it virtual domination of the attached fauna. It would appear to be approaching a peak level of invasiveness in the canal basin. It remains to be seen if it has yet to become more prevalent along the full length of the canal where it is as yet not very abundant.

It is not possible to say what the canal fauna would be like if the tubeworm had not been present and so dominant. It may be possible to see what this would be like once the canal in refilled after the 3 month period when it will lie empty in 2022. If the tubeworm does not make an immediate comeback it may be possible to see other species colonise the hard surfaces even if this is only for a period before the re-emergence of the dominance of the tubeworm that is likely to make a reappearance.

The status of the invasion by the tubeworm deserves to be monitored in the medium to long term. Kerry Co. Co. has an ideal opportunity to take the findings of this report, the initiation of trails on settlement as part of the work already done and the further opportunity to study developments once the canal is emptied for 3 months and afterwards. This provides an ideal setting in which the ecology of the canal can be monitored following its refilling.

The tubeworm has an associated fauna that also suggests that it is well adapted to the canal conditions and the shelter provided by the structure that the tubeworm provides.

The tubeworm and its associated fauna as well as the infauna found in the canal sediments and to an extent in the spaces provided by the gaps in the stone armour of the canal walls, seem to be well able to cope with the current management regime for the canal. Exposure to tidal conditions and low temperatures in winter and high temperatures and desiccation in the summer period, when the lock gates are left open for an extended period, do not seem to threaten the survival of the faunal communities of the canal. While heavy mortalities are sustained due to disruption to the normal environmental conditions that the species are adapted to, populations of all the species encountered seem to be able to recover relatively quickly from such challenges.

The canal provides those interested in the biology and population dynamics of an invasive alien species like the Australian Tubeworm with a very good location for further study. This probably applies equally to a number of the other species found associated with the tubeworm and to some of those living in the sediments.

The local authority, Kerry Co. Co. which owns and operates the canal, may consider the findings in this report in how it might want to manage the Australian Tubeworm. There would appear to be a limited number of options available and it will be a case of undertaking a cost benefit analysis on these. Any attempt at complete elimination of the tubeworm which would require significant effort and resources, would also require a clear understanding of the population dynamics of the tubeworm. The alternative might be a strategy of partial control or selective removal of tubeworm from areas where it is causing a nuisance and otherwise leaving it alone.

Further study of the tubeworm is probably required to get a more in-depth understanding of the biology and ecology of the species under Irish conditions and the particular condition of the Tralee Ship Canal where it seems to be at its peak. It is hoped this investigation would be of some assistance in any such study.

The funding provided by LAWPRO hopefully has been well expended in exploring some interesting aspect of the ecology of this Irish brackish water body. The findings are available and can be put to good use in assisting with understanding the dynamics of a number of species in this brackish water habitat. This will be of interest to some researchers in the field of invasive species and in lagoon ecology. It will also be valuable in the dissemination of useful insights into aquatic ecology to the general public and those with particular interest in brackish waters. It hopefully will provide those that use the Tralee Ship Canal amenity with some understanding of 'What lies beneath the surface of the water' that they travel in rowing boats on or that they walk, run or cycle alongside.

9 References

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10 Appendices

Appendix 1 Results of Sampling of Tralee Ship Canal

1.1 Results of Samples of F. enigmaticus and Associated Fauna

The following outlines the sampling protocol and results from sampling the canal basin population of *F. enigmaticus* adjacent to the marina pontoon.

1.1.1 Abundance of F. enigmaticus

Photograph were taken of 4cm diameter surfaces for counts (sample area 1/800 m²) and repeat 4 times. The images were overlaid with an acetate and each living specimen was marked and counted. See Table 7.

Table 7. Abundance of *Ficopomatus enigmaticus*
Ficopomatus enigmaticus • Number of occupied *F. enigmaticus* tube in 4 samples was as follows: 190/187/170/208 • Average per 1/800m² surface area = 188 • Number per m² = *c.* 150,000

1.1.2 Core Samples for Abundance of Gammarus zaddachi, Lekaneshaera rugicauda, Pomatopyrgus antipodarum & Anguilla anguilla.

A 7.8cm wide x 10cm deep circular cores was used to sample and estimate the abundance of small species (Sample area = 1/200m²)

Table 8. Abundance of *Gammarus zaddachi*, *Lekaneshaera rugicauda* & *Pomatopyrgus antipodarum*.
Gammarus zaddachi • Number of *G. zaddachi* in 7 samples was as follows: 29/24/28/28/22/19/26 • Average per sample = 25.1 • Approximate number per m² = *c.* 5,000
Lekaneshaera rugicauda • Number of *Lekaneshaera rugicauda* in 7 samples was as follows: 26/3/2/20/2/34/23 • Average per sample = 15.4 • Approximate number per m² = *c.* 3,000

Table 8. Abundance of *Gammarus zaddachi*, *Lekaneshaera rugicauda* & *Pomatopyrgus antipodarum*.
Pomatopyrgus antipodarum • Number of *P. antipodarum* in 7 samples was as follows: • 20/2/5/27/1/43/29 • Average per sample = 18.1 • Approximate number per m^2 = *c.* 3,500

A 15cm wide x 20cm deep circular cores was used to sample and estimate the abundance of small species (Sample area = 1/60M^2)

Table 9. Abundance of *Anguilla anguilla*
Anguilla anguilla • Number of eels in each of the 7 samples was as follows: 2/4/3/2/0/3/3 • Average per sample = 2.4 • Average per m^2= *c.* 145

It is noted that one specimen of European flounder *(Platichthys flesus*) was taken in the sampling for Common Eel (*A. anguilla).*

1.1.3 Results of Core Sampling of Canal Sediments

Results are presented here on the species found in core samples taken along the centre-line of the canal (see Table 10), on the north and south side of the centre-line close to the canal wall (see Table 11) and in samples taken from pockets of mud in damaged areas of the side wall (see Table 12).

Table 10. Samples from centre line of canal (16th June 2021).
Number per sample (estimate of number per m^2)

Location	***H. diversicolor*** **(S - <40mm/ M - 40-60mm / L - >60mm)**	***P. flexuosus***
C 1	-	-
C 2	-	-
C 3	-	-
C 4	-	-

Table 10. Samples from centre line of canal (16th June 2021). Number per sample (estimate of number per m²)		
C 5	-	-
C 6	-	-
C 7	-	1 (c. 50/m^2)
C 8	-	2 (c. 100/m^2)
C 9	-	6 (c. 300/m^2)
C 10	-	1 (c. 50/m^2)
C 11	S - 3 / M - 10 / L - 0 (c. 650/m^2)	-
C 12	S – 0 / M – 2 / L – 1 (c. 150/m^2)	-

Note: 1. Refer to map for locations. 2. Sediment Samples taken from C1, C4, C7, C10

Table 11. Samples taken to N&S side of center-line of canal (16th June, 2021). Number per sample (estimate of number per m²)		
Location (Side)	***H. diversicolor*** **(S - <40mm/ M - 40-60mm / L - >60mm)**	***M. arenaria*** **(S - <20mm/ M – 20-50mm / L - >50mm)**
S 1 (N)	**-**	**0 (S – / M – / L –)**
S 2 (N)	**-**	**0 (S – / M – / L –)**
S 3 (S)	**-**	**0 (S – / M – / L –)**
S 4 (N)	**-**	**0 (S – / M – / L –)**
S 5 (N)	**-**	**0 (S – / M – / L –)**
S 6 (S)	**-**	**0 (S – / M – / L –)**
S 7 (N)	24 (S – 14 / M – 10 / L – 0) (c. 1,300/m^2)	3 (S – 0 / M – 3 / L – 0) (c. 150/m^2)
S 8 (N)	2 (S – 1 / M – 1 / L – 0) (c. 100/m^2)	5 (S – 1 / M – 4 / L – 0) (c. 250/m^2)
S 9 (S)	18 (S – 12 / M – 6 / L – 0)	0 (S – 0 / M – 0 / L – 0)

Table 11. Samples taken to N&S side of center-line of canal (16th June, 2021). Number per sample (estimate of number per m²)		
Location (Side)	***H. diversicolor*** **(S - <40mm/ M - 40-60mm / L - >60mm)**	***M. arenaria*** **(S - <20mm/ M – 20-50mm / L - >50mm)**
	(c. 1,000/m^2)	(c. 0/ m^2)
S 10 (N)	26 (S – 24 / M – 2 / L – 0) (c. 1,500/m^2)	32 (S – 12 / M – 20 / L – 0) (c. 1,800/m^2)
S 11 (N)	40 (S – 31 / M – 9 / L – 0) (c. 2,000/m^2)	55 (S – 30 / M – 14 / L – 1) (c. 3,000/m^2)
S 12 (S)	**14 (S – 11 / M – 2 / L – 1) (c. 800/m2)**	**9 (S – 3 / M – 6 / L – 0) (c. 500/m2)**

Table 12. Samples from sediment pocket in damaged canal wall (21st June 2021). Number per sample (estimate of number per m^2)		
Location	***H. diversicolor*** **(S - <40mm/ M - 40-60mm / L - >60mm)**	***M. arenaria*** **(S - <20mm/ M – 20-50mm / L - >50mm)**
A	72 (S – 41 / M – 25 / L – 6) (c. 4,000/m^2)	1 (S – 1 / M - / L – 0) (c. 50/m^2)
B	123 (S – 43 / M – 65 / L – 15) (c. 7,000/m^2)	1 (S – 0 / M - 1 / L – 1) (c. 50/m^2)
C	59 (S – 16 / M – 34 / L – 9) (c. 3,500/m^2)	3 (S – 1 / M - 1 / L – 1) (c. 150/m^2)

Note: 1. Refer to map for locations. 2. Sediment Sample taken from location

1.1.4 List of Species Found During the Investigation

The following is a list of all fauna living at or below the surface in the Tralee Ship Canal. Included also are algae and those angiosperm plants living close to the water's edge.

Table 13. List of species identified as part of the investigation	
Vertebrates	**Invertebrates**
Otter **(***Lutra lutra)*	Australian Tubeworm (*Ficopomatus enigmaticus*)
Mute Swan (*Cygnus olor*)	Sand Gaper (Mya arenaria)
Cormorant (*Phalacrocorax carbo*)	Ragworm (*Hediste diversicolor*)
Curlew (*Numenius arquata*)	An Isopod (*Lekaneshaera rugicauda*)
Redshank (*Tringa totanus*)	An Amphipod (*Gammarus zaddachi*)
Thicklip Grey Mullet, (*Chelon labrosus)*	Chameleon Prawn *(Praunus flexuosus)*
Three-spined stickleback (*Gasterosteus aculeatus*)	An Opossum Shrimp (*Neomysis integer)*
Sand goby (Pomatoschistus minutus)	New Zealand Mudsnail (*Potamopyrgus antipodarum*)
Flounder (Platichthys flesus)	Shore Crab (*Carcinus maenas*)
Common Eel (*Anguila anguilla*)	A Shrimp (*Palaemonetes varians*)
Plants	Grey Shrimp (*Crangon crangon*)*;*
Sea Aster **(***Aster tripolium)*	
Lax-flowered Sea-lavender (*Limonium humile)*	
Sea Plantain (*Plantago maritima)*	
Algae	
Gut Weed *(Ulva/Enteromorpha spp.)*	
Green Algae *(Cladophora spp.)*	
Bladder Wrack *(Fucus vesiculosus)*	

1.1.5 Granulometry of Sediments in Tralee Ship Canal

Table 14 illustrates the results of the granulometry of 5 samples taken along the length of the canal. The sample stations C 1, C4, C 7, C 10 and B are indicated on Figure 4

Table 14. Granulometry of sediments in Tralee Ship Canal

Station	>8mm	Gravel (4-8)	Gravel (2-4)	Very Coarse Sand (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Very Fine Sand (%)	Silt-Clay		Gravel	Sand	Mud	Sand:Mud	Sand % (of Sand + Mud)
C1	0	1.2	5.4	13.4	17.1	13.7	2.4	18.2	28.5	99.9	6.6	64.8	28.5	2.3	69.5
C4	0	1.6	11	14.4	17.1	13	1.4	17.1	24.3	99.9	12.6	63.0	24.3	2.6	72.2
C7	0	3.2	10.7	14.5	18.3	14.5	0.8	17.2	20.8	100	13.9	65.3	20.8	3.1	75.8
C10	0	0.9	7.8	16.4	18.7	13.5	0.8	19.1	22.8	100	8.7	68.5	22.8	3.0	75.0
B	0	7.1	4.2	8.1	10.2	10	5.3	25.8	29.2	99.9	11.3	59.4	29.2	2.0	67.0

1.2 Exposure to Air Trials (December 2020)

Table 15 shows the results of trials on the exposure of *F. enigmaticus* specimens to air

Table 15. Exposure to air trial

F. enigmaticus **Exposure Trials**

Date	Time	Since Start Hours	Days	Sample	Exposure	Temp (C)	Vitality
30-Nov	18:00	0	0	0	**0**	10C	1
01-Dec	00:00	6	0.25	6	**6**	9-10C	>1/2 & <1
	06:00	12	0.5	12	**12**	10C	>1/2 & <1
	12:00	18	0.75	18	**18**	10C	>1/2 & <1
	18:00	24	1	24	**24**	10C	>1/2 & <1
02-Dec	00:00	30	1.25	30	**30**	10C	>1/2 & <1
	06:00	36	1.5	36	**36**	9-10C	>1/2 & <1
	12:00	42	1.75	42	**42**	9-10C	1/2
	18:00	48	2	48	**48**	8-11C	>1/2 & <1
03-Dec	00:00	54	2.25				
	06:00	60	2.5	60	**60**	8-10C	>1/2 & <1
	12:00	66	2.75				
	18:00	72	3	72	**72**	7-9C	>1/2 & <1
04-Dec	00:00	78	3.25				
	06:00	84	3.5	6	**72**	7-9C	>1/2 & <1
	12:00	90	3.75				
	18:00	96	4	12	**78**	7-8C	>1/2 & <1
05-Dec	00:00	102	4.25				
	06:00	108	4.5	18	**84**	7C	>1/2 & <1
	12:00	114	4.75				
	18:00	120	5	24	**90**	7C	>1/2 & <1
06-Dec	00:00	126	5.25				
	06:00	132	5.5	30	**96**	6-7C	>1/2 & <1
	12:00	138	5.75				
	18:00	144	6	36	**102**	6-7C	>1/2 & <1
07-Dec	00:00	150	6.25				
	06:00	156	6.5	42	**108**	6-7C	>1/2 & <1
	12:00	162	6.75				
	18:00	168	7	48	**114**	6C	>0 & <1/2
08-Dec	00:00	174	7.25				
	06:00	180	7.5				
	12:00	186	7.75				
	18:00	192	8	60	**120**	5-6C	>1/2 & <1
09-Dec	00:00	198	8.25				
	06:00	204	8.5				
	12:00	210	8.75				
	18:00	216	9	72	**132**	6-7C	>1/2 & <1
10-Dec	00:00	222	9.25				
	06:00	228	9.5				
	12:00	234	9.75				
	18:00	240	10	6	**144**	6-8C	>1/2 & <1
11-Dec	00:00	246	10.25				
	06:00	252	10.5				
	12:00	258	10.75				
	18:00	264	11	12	**156**	7-8C	>1/2 & <1
12-Dec	00:00	270	11.25				
	06:00	276	11.5				
	12:00	282	11.75				
	18:00	288	12	18	**168**	7-8C	>1/2 & <1
13-Dec	00:00	294	12.25				
	06:00	300	12.5				
	12:00	306	12.75				
	18:00	312	13				
14-Dec	00:00	318	13.25				
	06:00	324	13.5				
	12:00	330	13.75				
	18:00	336	14	24	**204**	7-8C	>1/2 & <1
15-Dec	00:00	342	14.25				
	06:00	348	14.5				
	12:00	354	14.75				
	18:00	360	15				
16-Dec	00:00	366	15.25				
	06:00	372	15.5				
	12:00	378	15.75				
	18:00	384	16	30	**240**	8-9C	>1/2 & <1
17-Dec	00:00	390	16.25				
	06:00	396	16.5				
	12:00	402	16.75				
	18:00	408	17				
18-Dec	00:00	414	17.25				
	06:00	420	17.5				
	12:00	426	17.75				
	18:00	432	18	36	**276**	8-9C	>0 & <1/2
19-Dec	00:00	438	18.25				
	06:00	444	18.5				
	12:00	450	18.75				
	18:00	456	19				
20-Dec	00:00	462	19.25				
	06:00	468	19.5				
	12:00	474	19.75				
	18:00	480	20	42	**312**	9C	>0 & <1/2
							Trial ends

1.3 Exposure to Freshwater Trails (December 2020)

Table 16 shows the results of trials on the exposure of *F. enigmaticus* specimens to freshwater

Table 16. Exposure to freshwater trial

		***F. enigmaticus* Exposure Trials**				
		Since Start				
Date	Time	Hours	Days	Sample	Exposure	Response
10-Dec	18:00	0	0	0	**0**	Alive
11-Dec	00:00	6	0.25	6	**6**	Lethargic
	06:00	12	0.5			
	12:00	18	0.75	18	**18**	Lethargic
	18:00	24	1			
12-Dec	00:00	30	1.25			
	06:00	36	1.5	36	**36**	Lethargic
	12:00	42	1.75			
	18:00	48	2			
13-Dec	00:00	54	2.25			
	06:00	60	2.5			
	12:00	66	2.75			
	18:00	72	3	72	**72**	Lethargic
14-Dec	00:00	78	3.25			
	06:00	84	3.5			
	12:00	90	3.75			
	18:00	96	4			
15-Dec	00:00	102	4.25			
	06:00	108	4.5			
	12:00	114	4.75			
	18:00	120	5			
16-Dec	00:00	126	5.25			
	06:00	132	5.5			
	12:00	138	5.75			
	18:00	144	6			Dying
17-Dec	00:00	150	6.25			
	06:00	156	6.5			
	12:00	162	6.75			
	18:00	168	7	168	**168**	Dying
18-Dec	00:00	174	7.25			
	06:00	180	7.5			
	12:00	186	7.75			
	18:00	192	8			>50% Dead
19-Dec	00:00	198	8.25			
	06:00	204	8.5			
	12:00	210	8.75			
	18:00	216	9	216	**216**	.90% Dead
20-Dec	00:00	222	9.25			Trial Ends
	06:00	228	9.5			
	12:00	234	9.75			
	18:00	240	10			

Appendix 2 Appropriate Assessment Screening of Project 'Investigation of *Ficopomatus enigmaticus* in Tralee Ship Canal

2.1 Natura 2000 sites within 15Km of Tralee Ship Canal

Figure 17 below shows the Natura 2000 sites within a 15Km radius of the Tralee Ship Canal. Table 17 lists the 11 sites and only two of these have a hydrological/ecological connection with the canal. For this reason the other nine sites are excluded from further consideration in terms of potential for significant impact on the conservation interests from the proposed project.

Tralee Bay and Magharees Peninsula, West to Cloghane SAC (002070) and the Tralee Bay Complex SPA (004188) are the only two sites relevant in the context of this project.

Figure 17 . Natura 2000 sites (SAC- brown, SPA- green) located within a 15km radius of the Tralee Ship Canal.

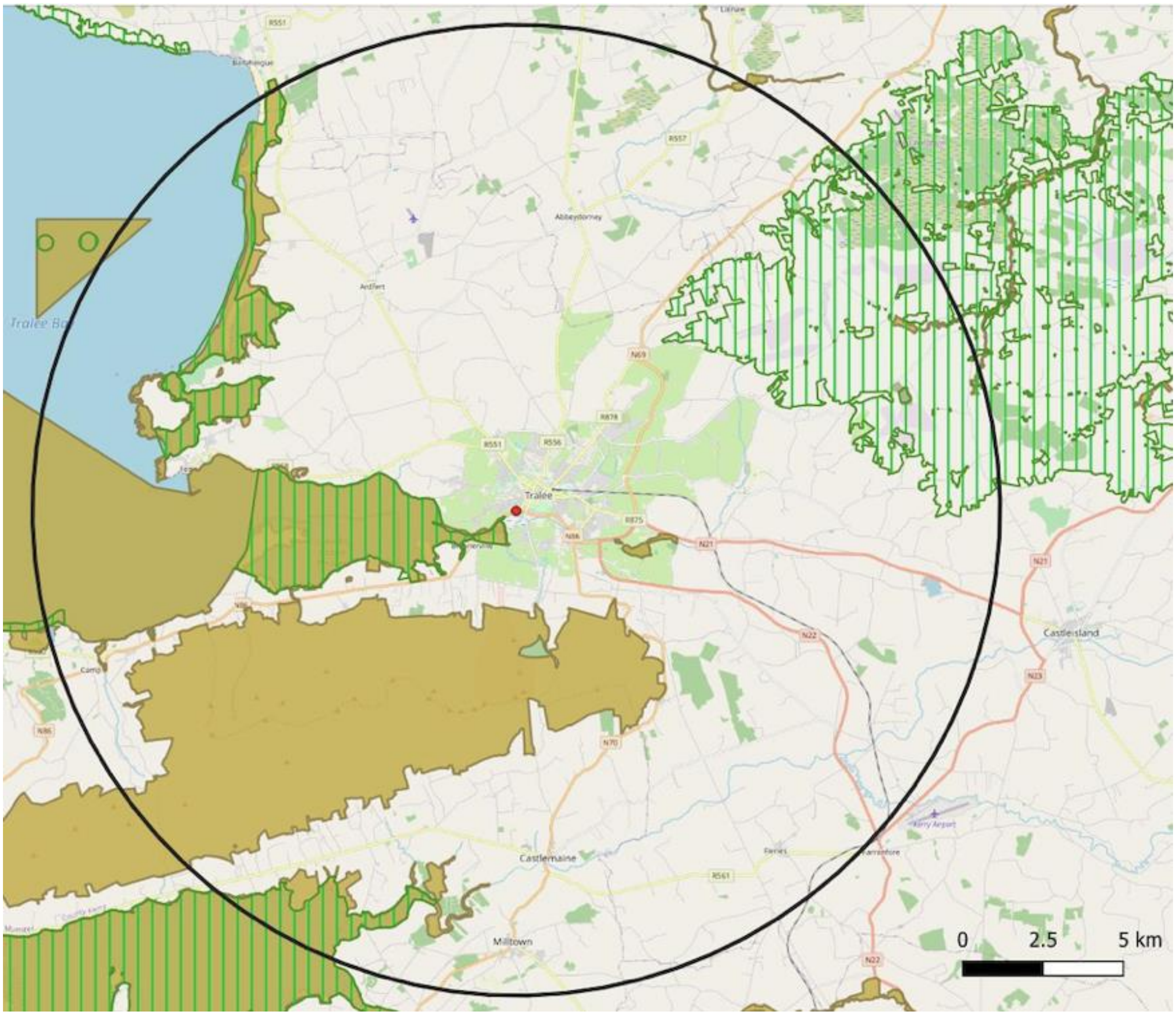

Table 17. List of Designated Natura 2000 Sites lying within 15Km of the Tralee Ship Canal and reason for inclusion/exclusion for consideration

Designated Site	Approximate Distance from Site	Reason for Inclusion/Exclusion
Tralee Bay and Magharees Peninsula, West to Cloghane SAC (002070)	0km	Inclusion as project site lies partly within SAC
Tralee Bay Complex SPA (004188)	<0.1km	Inclusion as project has direct hydrological connection with SPA
Ballyseedy Wood SAC (002112)	< 4.5km	Exclusion as no hydrological/ecological connection with SAC
Stack's to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle SPA (004161)	< 8.5km	Exclusion as no hydrological/ecological connection with SAC
Slieve Mish Mountains SAC (002185)	2km	Exclusion as no hydrological/ecological connection with SAC
Akeragh, Banna and Barrow Harbour SAC (000332)	< 8m	Exclusion as no hydrological/ecological connection with SAC
Lower River Shannon SAC (002165)	< 15km	Exclusion as no hydrological/ecological connection with SAC
Castlemaine Harbour SAC (000343)	< 10km	Exclusion as no hydrological/ecological connection with SAC
Castlemaine Harbour SPA (004029)	< 11km	Exclusion as no hydrological/ecological connection with SAC
Magharee Islands SAC (002261)	< 15km	Exclusion as no hydrological/ecological connection with SAC
Magharee Islands SPA (004125)	< 15km	Exclusion as no hydrological/ecological connection with SAC

Appendix 3 – Assessment of Significance of Impacts on Natura 2000 Sites

Table 18 lists the qualifying interests and special conservation interests of the two sites as appropriate. The following two tables (Table 19 & 20) detail how the small scale of the activities associated with the two was considered to be insignificant in terms of impact and have been ruled out.

Table 18. Qualifying Interests (SAC) and Special Conservation Interests (SPA) of Relevant Designated Sites

Designated Site	Qualifying Interests SAC or Special Conservation Interests SPA
Tralee Bay and Magharees Peninsula, West to Cloghane SAC (002070)	**Habitats** [1130] Estuaries [1140] Tidal Mudflats and Sandflats [1150] Coastal Lagoons* [1160] Large Shallow Inlets and Bays [1170] Reefs [1210] Annual Vegetation of Drift Lines [1220] Perennial Vegetation of Stony Banks [1310] Salicornia Mud [1330] Atlantic Salt Meadows [1410] Mediterranean Salt Meadows [2120] Marram Dunes (White Dunes) [2130] Fixed Dunes (Grey Dunes)* [2170] Dunes with Creeping Willow [2190] Humid Dune Slacks [6410] *Molinia* Meadows [91E0] Alluvial Forests* **Species** [1355] Otter (*Lutra lutra*) [1395] Petalwort (*Petalophyllum ralfsii*)
Tralee Bay Complex SPA (004188)	**Species** **[A038] Whooper swan (*Cygnus cygnus*)** **[A046] Light-bellied brent goose (*Branta bernicla hrota*)** **[A048] Shelduck (*Tadorna tadorna*)** **[A050] Wigeon (*Anas penelope*)** **[A052] Teal (*Anas crecca*)** **[A053] Mallard (*Anas platyrhynchos*)** **[A054] Pintail (*Anas acuta*)** **[A062] Scaup (*Aythya marila*)** **[A130] Oystercatcher (*Haematopus ostralegus*)** **[A137] Ringed plover (*Charadrius hiaticula*)** **[A140] Golden plover (*Pluvialis apricaria*)** **[A141] Grey plover (*Pluvialis squatarola*)** **[A142] Lapwing (*Vanellus vanellus*)** **[A144] Sanderling (*Calidris alba*)**

Table 18. Qualifying Interests (SAC) and Special Conservation Interests (SPA) of Relevant Designated Sites	
Designated Site	**Qualifying Interests SAC or Special Conservation Interests SPA**
	[A149] Dunlin (*Calidris alpina*) **[A156] Black-tailed godwit (*Limosa limosa*)** **[A157] Bar-tailed godwit (*Limosa lapponica*)** **[A160] Curlew (*Numenius arquata*)** **[A162] Redshank (*Tringa totanus*)** **[A169] Turnstone (*Arenaria interpres*)** **[A179] Black-headed gull (*Larus ridibundus*)** **[A182] Common gull (*Larus canus*)** **[A999] Wetland and Waterbirds**

Table 19. Possible significant impacts of project on Special Conservation Interests of the Tralee Bay Complex SPA (004188)	
Special Conservation Interests	**Possible Impact of Project on Special Conservation Interest**
[A038] Whooper swan (*Cygnus cygnus*)	None
[A046] Light-bellied brent goose (*Branta bernicla*)	None
[A048] Shelduck (*Tadorna tadorna*)	None
[A050] Wigeon (*Anas Penelope*)	None
[A052] Teal (*Anas crecca*)	None
[A053] Mallard (*Anas platyrhynchos*)	None
[A054] Pintail (*Anas acuta*)	None
[A062] Scaup (*Aythya marila*)	None
[A130] Oystercatcher (*Haematopus ostralegus*)	None
[A137] Ringed plover (*Charadrius hiaticula*)	None
[A140] Golden plover (*Pluvialis apricaria*)	None
[A141] Grey plover (*Pluvialis squatarola*)	None
[A142] Lapwing (*Vanellus vanellus*)	None
[A144] Sanderling (*Calidris alba*)	None

Table 19. Possible significant impacts of project on Special Conservation Interests of the Tralee Bay Complex SPA (004188)	
Special Conservation Interests	**Possible Impact of Project on Special Conservation Interest**
[A149] Dunlin (*Calidris alpina*)	None
[A156] Black-tailed godwit (*Limosa limosa*)	None
[A157] Bar-tailed godwit (*Limosa lapponica*)	None
[A160] Curlew (*Numenius arquata*)	None
A162] Redshank (*Tringa totanus*)	None

Table 20 Possible significant impacts of project on the Qualifying Interests of the Tralee Bay and Magharees Peninsula, West to Cloghane SAC (002070)	
Qualifying Interests	**Possible Impact of Project on Qualifying Interest**
Habitats	
[1130] Estuaries	None
[1140] Tidal Mudflats and Sandflats	None
[1150] Coastal Lagoons*	None
[1160] Large Shallow Inlets and Bays	None
[1170] Reefs	None
[1210] Annual Vegetation of Drift Lines	None
[1220] Perennial Vegetation of Stony Banks	None
[1310] Salicornia Mud	None
[1330] Atlantic Salt Meadows	None
[1410] Mediterranean Salt Meadows	None
[2120] Marram Dunes (White Dunes)	None
[2130] Fixed Dunes (Grey Dunes)*	None
[2170] Dunes with Creeping Willow	None

Table 20 Possible significant impacts of project on the Qualifying Interests of the Tralee Bay and Magharees Peninsula, West to Cloghane SAC (002070)	
Qualifying Interests	**Possible Impact of Project on Qualifying Interest**
[2190] Humid Dune Slacks	None
[6410] *Molinia* Meadows	None
[91E0] Alluvial Forests*	None
Species	
[1355] Otter (*Lutra lutra*)	None
[1395] Petalwort (*Petalophyllum ralfsii*)	None

Appendix 4 Natura 2000 Site Synopses

4.1 Site Synopsis - Tralee Bay and Magharees Peninsula, West to Cloghane SAC

Table 21 is the Site Synopsis for the Tralee Bay and Magharees Peninsula, West to Cloghane SAC

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
This large site in Co. Kerry stretches from Tralee town westwards to Fenit Harbour and Cloghane, encompassing Tralee Bay, Brandon Bay and the Magharees Peninsula. It includes extensive mudflats at the eastern end, the beaches of Derrymore Island, the sand dunes and lagoons of the Magharees Peninsula, as well as the rocky headlands at its end. The site includes two Statutory Nature Reserves, Tralee Bay and Derrymore Island, and much of the estuarine part of the site has been designated a Special Protection Area (SPA) for birds and their habitats. The site is mostly underlain by limestone, but significant parts of this are covered with glacial drift or windblown sand. The main exposures occur at Fenit port, Oyster Hall, Blennerville and at Rough Point and Fahamore, but there are some other low outcrops on the beaches west to Castlegregory. Elsewhere the sandstones and slates of the Dingle Beds appear. The site is a Special Area of Conservation (SAC) selected for the following habitats and/or species listed on Annex I / II of the E.U. Habitats Directive (* = priority; numbers in brackets are Natura 2000 codes): [1130] Estuaries [1140] Tidal Mudflats and Sandflats [1150] Coastal Lagoons* [1160] Large Shallow Inlets and Bays [1170] Reefs [1210] Annual Vegetation of Drift Lines [1220] Perennial Vegetation of Stony Banks [1310] *Salicornia* Mud [1330] Atlantic Salt Meadows

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
[1410] Mediterranean Salt Meadows [2120] Marram Dunes (White Dunes) [2130] Fixed Dunes (Grey Dunes)* [2170] Dunes with Creeping Willow [2190] Humid Dune Slacks [6410] *Molinia* Meadows [91E0] Alluvial Forests* [1355] Otter (*Lutra lutra*) [1395] Petalwort (*Petalophyllum ralfsii*) Both the Tralee and Brandon (Owenmore) estuaries feature wide expanses of sheltered intertidal flats, often fringed with saltmarsh vegetation. Plant species are typically scarce on the flats, although there are some eelgrass (*Zostera* spp.) beds and patches of green algae (e.g. *Ulva* spp. and *Enteromorpha* spp.). The eelgrass beds at Derrymore Island include *Zostera noltii*, a species which has a limited distribution in Ireland. A variety of polychaetes (worms) and bivalve molluscs are also present in the intertidal sections. The majority of Tralee Bay is shallow and composed of sublittoral sediments. In the more sheltered areas of the bay, there is a variety of important sublittoral sediment communities in which a number of rare species occur. Seagrass beds in sandy substrates are characterized by oysters and the rare anemone *Calliactis parasitica* which lives on shells inhabited by the hermit crab *Pagurus bernhardus*. The little known hydroid, *Laomedia angulata*, is also found on the fronds of the seagrass. The native oyster, *Ostrea edulis,* occurs in sediment communities throughout the bay. Maerl beds, composed of the free-living coralline algae *Lithothamnion corallioides* and *Phymatolithon calcareum*, and characterized by anemones (*Anthopleura balli*) and oysters, occur in the middle of the bay. The rare anemone *Halcampa chrysanthellum* has been recorded here. The intertidal reefs of Tralee Bay and the Magharees peninsula range from being exposed to sheltered from wave action, and the communities present are good examples of the communities typically found on these types of shores. The barnacle/limpet community with the lichen *Lichina pygmaea* is an uncommon community and is found in the upper-mid shore at Rough Point. The low shore at Rough Point, which is moderately exposed to wave action, and the shore at Coosanea, which is sheltered from wave action, are both very species-rich. Rocky outcrops on the shore half way round the bay near Camp are known to support a community of the uncommon honeycomb worm *Sabellaria alveolata*. The sublittoral reefs support communities characterised by a variety of red foliose algae, as well as the brown algae *Dictyota dichotoma,* and are typical of communities that are subjected to sand scour as indicated by the presence of the red algae *Furcellaria lumbricalis* and *Polyides rotundus*. In the transition zone between the intertidal flats and saltmarsh, specialised colonisers of mud predominate - swards of Common Cord-grass (*Spartina anglica*) are extensive on the leeward side of Derrymore Island, while swards of Glasswort (*Salicornia europaea* agg.) also occur in parts of the site. Saltmarsh vegetation frequently fringes the mudflats, with the most extensive areas being found at Blennerville, Derrymore Island and Formoyle in Brandon Bay. The dominant type of saltmarsh present is Atlantic salt meadow. Characteristic species occurring include Common Saltmarsh-grass

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
(*Puccinellia maritima*), Sea Aster (*Aster tripolium*), Thrift (*Armeria maritima*), Sea-milkwort (*Glaux maritima*), Sea Plantain (*Plantago maritima*), Red Fescue (*Festuca rubra*), Creeping Bent (*Agrostis stolonifera*), Saltmarsh Rush (*Juncus gerardi*), Long-bracted Sedge (*Carex extensa*), Lesser Sea-spurrey (*Spergularia marina*) and Sea Arrowgrass (*Triglochin maritima*). Areas of Mediterranean salt meadows, characterised by clumps of Sea Rush (*Juncus maritimus*), occur occasionally. Sandy beaches backed by strips of 'white' dunes are common along the southern shore of the site. The vegetation of these 'white' dunes is dominated by Marram (*Ammophila arenaria*). However, the main dune area on this southern shore occurs on the Magherees Peninsula - a tombolo which joins a number of the Magharees Islands with the mainland. Here there are extensive areas of fixed 'grey' dunes, which feature a number of damp hollows or dune slacks. The fixed dunes are species-rich, with characteristic species such as White Clover (*Trifolium repens*), Lesser Hawkbit (*Leontodon taraxacoides*), Common Centaury (*Centaurium erythraea*), Lady's Bedstraw (*Galium verum*) and grasses (e.g. *Festuca rubra, Poa trivialis* and *Avenula pubescens*). Relatively scarce plants found on the dunes include the following: Fringed Rock- cress (*Arabis brownii*), Fragrant Orchid (*Gymnadenia conopsea*), Squinancywort (*Asperula cynanchica*), Autumn Lady's-tresses (*Spiranthes spiralis*) and Dodder (*Cuscuta epithymum*). Dune slack species include Strawberry Clover (*Trifolium fragiferum*), Chaffweed (*Anagallis minima*) and the fungus *Inocybe halophila*. Lough Gill, a natural sedimentary lagoon, is located at the base of the Magherees Peninsula. The lagoon is only slightly brackish and therefore contains freshwater species along with lagoon specialists. Submerged flora present includes Beaked Tasselweed (*Ruppia maritima*) and Horned Pondweed (*Zannichellia palustris*), while species fringing the lagoon include Common Reed (*Phragmites australis*), Sea Club- rush (*Scirpus maritimus*) and Grey Club-rush (*S. lacustris* subsp. *tabernaemontani*). Other coastal habitats that occur within the site include shingle beaches, rocky shores and vegetated sea-cliffs. The site also contains fragments of terrestrial habitats such as deciduous woodland, scrub, heath, dry limestone grassland, wet grassland and freshwater marshes. There is some good limestone flora on the hill at Oyster Hall, with Burnet Rose (*Rosa pimpinellifolia*), Southern Polypody (*Polypodium australe*) and Hairy Rock-cress (*Arabis hirsuta*) occurring. There is an old record for the Red Data Book species, Sea-kale (*Crambe maritima*). At Fahamore and Rough Point it is the intertidal communities that are particularly rich, benefiting from a multitude of microhabitats in the eroded limestone. Red algae are frequent, including the agar seaweeds *Gelidium* and *Pterocladia*. A small area of *Molinia* meadow is found in the site, with species such as Purple Moor-grass (*Molinia caerulea*), Devil's-bit Scabious (*Succisa pratensis*), Sharp-flowered Rush (*Juncus acutiflorus*) being common, and species such as Greater Tussock-sedge (*Carex paniculata*), Tormentil (*Potentilla erecta*), Marsh Cinquefoil (*Potentilla palustris*), Wild Angelica (*Angelica sylvestris*) and Common Valerian (*Valeriana officinalis*) also frequent.

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
Beach features dominate the northern coast of the Dingle Peninsula with an excellent series of shingle ridges forming Derrymore Island and the tombolo which links former Magheree Islands (Rough Point, etc.) to the mainland. Here there is a large area of well developed sand dunes with an exceptionally rich flora and great topographic variation. The flora includes Fringed Rock-cress, Squinancywort, Dodder, Autumn Lady's-tresses and Chaffweed - all plants with a restricted distribution in the west of Ireland. These occur in a vegetation with abundant Red Fescue, scattered Marram, and herbs such as Lady's Bedstraw, Wild Thyme (*Thymus praecox*), Common Bird's-foot-trefoil (*Lotus corniculatus*) and Kidney Vetch (*Anthyllis vulneraria*). Yellow-rattle (*Rhinanthus minor*), eyebrights (*Euphrasia* spp.), Pyramidal Orchid (*Anacamptis pyramidalis*) and Heath Spotted-orchid (*Dactylorhiza maculata*) are four sensitive species which also occur here. At the seaward edge drift line vegetation is often present. The more stable areas of shingle support Sea Beet (*Beta vulgaris* subsp. *maritima*), Sea Mayweed (*Matricaria maritima*), Sea Campion (*Silene vulgaris* subsp. *maritima*), Curled Dock (*Rumex crispus*), oraches (*Atriplex* spp.), Sea Sandwort (*Honkenya peploides*) and Silverweed (*Potentilla anserina*). Between the dunes where erosion has removed the sand down to the water table there are temporary ponds or dune slacks with many additional species. Marsh Pennywort (*Hydrocotyle vulgaris*), Silverweed, various sedges (*Carex panicea* and *C. nigra*) and, in places, Strawberry Clover, Adder's-tongue (*Ophioglossum vulgatum*), Knotted Pearlwort (*Sagina nodosa*) and the orchids *Dactylorhiza majalis* and *D. incarnata* all occur. Some parts of the dune slacks feature a vegetation community characterised by the presence of Creeping Willow (*Salix repens*). Woodland is rare on the Dingle Peninsula so the three stands included in this site are locally important. A deserted river valley at Killelton, the steep valley of the Finglas River at Camp and the west-facing slopes of Drom Hill opposite Cloghane all have features of significant interest. The last site has many species of lower plant (liverworts and lichens) that form distinctive elements of the westernmost natural woods in Ireland. At Garrahies Wood, adjacent to the Finglas River, there is an example of wet woodland on base-rich soils subject to flooding. The woodland type falls into the ash-alder alluvial forest category. The most common tree species are Alder (*Alnus glutinosa*), Downy Birch (*Betula pubescens*) and willows (*Salix* spp.). Bluebell (*Hyacinthoides non-scripta*), grasses and Bramble (*Rubus fruticosus* agg.) are the most common species in the ground layer. The dune complex on the Magharees Peninsula supports the largest Irish breeding population of Natterjack Toads. Indeed, the population may be the largest breeding population in Britain and Ireland. The Natterjack Toad is listed as vulnerable in the Red Data Book and is protected under both European and national legislation. The toads require shallow warm water to spawn in and sandy habitats for over- wintering. Their tadpoles are vulnerable to predation in permanent lakes but despite this they have some success in Lough Gill which is a shallow lake with flat shores of sand, wet grassland or marsh. Natterjack Toads also breed within the site at Fermoyle, to the west. Also recorded from Fermoyle is the rare whorl snail *Vertigo angustior*, a species listed on Annex II of the E.U. Habitats Directive. Two species of hover fly - *Platycheris perpilladus* and *Sphaerophoria loewi* - have their only Irish records from the Magharees Peninsula dune system and a water beetle, *Cercyon sternalis,* was first recorded in Ireland in 1997 in Lough Gill. The site supports populations of several rare plant species which have not been mentioned already. The bryophyte Petalwort (*Petalophyllum ralfsii*), which is listed on Annex II of the E.U.

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
Habitats Directive, is known from the dune slacks on the Magharees Peninsula and Smooth Brome (*Bromus racemosus*), a Red Data Book grass, has been recorded from two wet meadows within the site. Several aquatic plants of interest grow in Lough Gill, the rarest being the Red Data Book stonewort *Chara canescens*. The Slender-leaved Pondweed (*Potamogeton filiformis*) occurs far to the south of its distribution elsewhere in Ireland and Britain, while there are also old records for Spiral Tasselweed (*Ruppia spiralis*). The marshes along the southern shore in the past support a rich variety of vegetation including several species rare in Kerry such as Water Dock (*Rumex hydrolapathum*) and Greater Spearwort (*Ranunculus lingua*), as well as sedges (*Carex dioica, C. limosa* and *C. diandra*) on patches of peat. Despite local reclamation it is likely that most of these still survive. Otters regularly feed within this extensive site though it is not known if they breed. Otter is listed on Annex II of the E.U. Habitats Directive. Tralee Bay, including Lough Gill, is an internationally important wetland for wintering waders and wildfowl. Species present which are listed on Annex I of the E.U. Birds Directive include Whooper Swans (24, mid-1980s), Golden Plover (3,053, 1994-95) and Bar-tailed Godwit (903, 1995-96). The dunes also provide an important feeding ground for Chough, a resident Annex I species. Other wintering waders and wildfowl present include: Pale-bellied Brent Goose (944, mid-1980s), Shelduck (218, 1995-96), Gadwall (14, 1994-95), Teal (860, 1994-95), Pintail (56, 1995-96), Shoveler (144, mid-1980s), Scaup (1560, 1994-95), Scoter (620, 1994-95), Red-breasted Merganser (46, 1994-95), Ringed Plover (332, 1994-95), Grey Plover (674, 1995-96), Lapwing (5700, 1994-95), Knot (320, 1994-95), Sanderling (270, 1994-95), Purple Sandpiper (103, mid-1980s), Dunlin (4122, 1995-96), Black-tailed Godwit (508, 1994-95), Curlew (826, 1994-95), Redshank (352, 1995-96), Greenshank (21, 1994-95) and Turnstone (477, mid-1980s). Most of these species are present in nationally important numbers. The dunes at this site face pressures from intensive farming practises and recreational use by visitors. The most threatening activities include fertilisation of the species-rich dune grasslands, over-grazing, and trampling of areas of dunes adjacent to tourist facilities (e.g. caravan parks). These activities may lead to severe erosion and eutrophication of the dune grasslands and dune slacks. Parts of the dune system are also vulnerable to invasion by Sea Buckthorn (*Hippophae rhamnoides*). Agricultural run-off from areas of fertilised dune grasslands in the vicinity of Lough Gill pose a continued threat to the nutrient status of the lagoon; algal blooms and fish kills have occurred in the past. Removal of sand has also occurred and poses a threat to the integrity of the system. Generally, the intertidal areas are relatively robust, although certain communities are vulnerable. For example, *Spartina* has spread widely, and may oust less vigorous colonisers of mud and may also reduce the area of mudflat available to feeding birds. Other activities, such as land reclamation and aquaculture, pose potential threats in terms of damage to habitats and potential disturbance to wintering birds. Domestic and industrial wastes are discharged into inner Tralee Bay, but water quality is generally satisfactory - except in the inner bay, reflecting the sewage load from Tralee Town. Further

Table 21. Site Name: Tralee Bay and Magharees Peninsula, West to Cloghane SAC. Site Code: 002070
industrial development along the bay in the vicinity of Tralee Town and Fenit and water polluting operations are potential threats. This site is of considerable ecological and conservation significance for the excellent diversity of habitats it contains, many of which are listed on Annex I of the E.U. Habitats Directive. The occurrence of a species listed on Annex II of the E.U. Habitats Directive adds further importance to the site. The presence of a number of Red Data Book species, including the largest population of Natterjack Toads in Ireland, is also notable, as is the occurrence of several species listed on Annex I of the E.U. Birds Directive.

4.2 Site Synopsis Tralee Bay Complex SPA

Table 22 is the Site Synopsis for the Tralee Bay Complex SPA

Table 22. SITE NAME: TRALEE BAY COMPLEX SPA. SITE CODE: 004188
The Tralee Bay Complex SPA is located along the coast of north Co. Kerry between Ballyheige in the north, Tralee in the east and Stradbally in the west. The site includes the inner part of Tralee Bay, including Derrymore Island, the inlets of Barrow Harbour and Carrahane Strand, Akeragh Lough, Lough Gill, and much of the intertidal habitat from Scraggane Point at the northern end of the Magharees Peninsula around the coast to *c*. 2 km south of Ballyheige. Inner Tralee Bay is well sheltered by the Derrymore Island peninsula. The intertidal sediments vary from muddy sands on the upper shore to firm rippled sands on the lower, more exposed shore. The sediments have a diverse macro-invertebrate fauna, with such species as Cockle (*Cerastoderma edule*), Lugworm (*Arenicola marina*), Ragworm (*Hediste diversicolor*), Baltic Tellin (*Macoma baltica*) and Shrimp (*Crangon crangon*) occurring. The intertidal flats have extensive beds of Eelgrass (*Zostera* spp.). The site is a Special Protection Area (SPA) under the E.U. Birds Directive, of special conservation interest for the following species: Whooper Swan, Light-bellied Brent Goose, Shelduck, Wigeon, Teal, Mallard, Pintail, Scaup, Oystercatcher, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Sanderling, Dunlin, Black-tailed Godwit, Bar-tailed Godwit, Curlew, Redshank, Turnstone, Black-headed Gull and Common Gull. It is also of special conservation interest for holding an assemblage of over 20,000 wintering waterbirds. The E.U. Birds Directive pays particular attention to wetlands and, as these form part of this SPA, the site and its associated waterbirds are of special conservation interest for Wetland & Waterbirds. Tralee Bay Complex SPA is an internationally important wetland for wintering waders and wildfowl. It supports an internationally important population of Light- bellied Brent Goose (1,412) and nationally important populations of a further 21 species, i.e. Whooper Swan (101), Shelduck (220), Wigeon (1,634), Teal (623), Mallard (571), Pintail (54), Scaup (892), Oystercatcher (1,011), Ringed Plover (344), Golden Plover (6,393), Grey Plover (195), Lapwing (6,106), Sanderling (228), Dunlin (2,444), Black-tailed Godwit (139), Bar-tailed Godwit (608), Curlew (1,170), Redshank (635), Turnstone (229), Black-headed Gull (1,320) and Common Gull (599) – all figures are five year

Table 22. SITE NAME: TRALEE BAY COMPLEX SPA. SITE CODE: 004188
mean peak counts for the period 1995/96 to 1999/2000, except the gulls which are four year mean peak counts for the period 1996/97 to 1999/2000. Tralee Bay Complex SPA is of high ornithological importance as it annually supports over 20,000 wintering waterbirds, including an international important population of Light-bellied Brent Goose and nationally important populations of 21 other species. It is of note that three of the species that regularly occur, Whooper Swan, Golden Plover and Bar-tailed Godwit, are listed on Annex I of the E.U. Birds Directive. Tralee Bay is a Ramsar Convention site and parts of the Tralee Bay Complex SPA are designated as Nature Reserves. Lough Gill is a Wildfowl Sanctuary.