Supplementary Environmental Impact Statement (EIS) for a proposed salmon farm site at Shot Head, Bantry Bay, County Cork, Ireland.

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Executive summary.

The Minister for Agriculture, Food and the Marine granted Aquaculture and Foreshore Licences to the applicant, Marine Harvest Ireland (MHI), for a proposed salmon farm site at Shot Head, Bantry Bay, in September 2015, Site Reference Number T05/555. Following its granting, the licence was appealed to the Aquaculture Licences Appeals Board (ALAB). Following written appeals, and two sessions of oral hearing, granted to appellants, ALAB has now requires, under Section 47 of the Fisheries (Amendment) Act 1997, a Supplementary EIS to be compiled, to respond to two issues:-

Issue 1.

The risk (*i.e. posed by the proposed salmon farm installation*) of sea-lice infestation of wild salmonids migrating from/to the Dromogowlane and Trafrask rivers and any resulting implications for local freshwater pearl mussel (FPM) populations.

Issue 2.

The impact of salmon farm waste on water quality in Bantry Bay, having regard to the maintenance of 'good water status' as required under the Water Framework Directive.

Response to Issue 1.

Sea lice parasitise marine fish. Two species, *Caligus elongatus* and *Lepeophtheirus salmonis*, parasitise salmonids in marine conditions in European waters. The salmon louse, *L. salmonis*, is widely regarded as the more problematic of the two on salmon farms and the more prevalent on wild salmonids, even in areas without salmon farms.

Ovigerous (egg-bearing) female *L. salmonis* are carried into estuarine areas on wild salmonid hosts, returning to their native rivers to breed, where the louse eggs hatch into Nauplius larvae. These metamorphose after 4 days into infestive Copepodid larvae, in the same estuarine waters through which the next generation of wild salmonid smolts swim at their maximum density at the beginning of their seaward migration. This natural coincidence of maximum numbers of infestive larvae and wild smolts in both time and space, maximises the chances of efficient lice infestation, in order that *L. salmonis* can continue to complete its life cycle.

The advent of salmon farming in the last 50 years or so has changed the dynamics of this infestation process, because the many Copepodids which fail to find hosts in their natural infestation zones may have the potential to drift into open waters and, if they encounter a farm site, may establish an on-farm breeding population. The question them arises; can farm-origin Copepodids discharged from on-farm breeding populations find their way back to natural infestation zones to infest subsequent migrations of wild fish? Bearing in mind that Copepodids are extremely small, only have a 10-day lifespan, are planktonic and have no swimming host to assist then in this journey, this represents a considerable task. However, a range of critical variables apply, which may assist or impede such a journey:-

1. Lack of adequate, timely on-farm lice treatments, resulting in on-farm epizootics of infestation, which is against the interests of the salmon famer but does increases Copepodid discharge and dispersal.

2. Impact of farm fish stock size / numbers on total ovigerous female lice numbers and the consequent potential for high Copepodid production and dispersal.

3. Local hydrography relative to site locations, e.g. “the hydrographic distance” between infested farm sites and salmonid rivers.

4. The role of additional forcing factors such as freshwater, stratification and wind in the farm-origin Copepodid dispersal.

There is a population of Freshwater Pearl Mussel (FPM) in the Trafrask River, the mouth of which is some 2.5 km by sea from the proposed Shot Head salmon farm site. As a result of environmental threats against them, both Atlantic salmon in their freshwater phase and FPM are protected as Habitats Directive Annex II species. FPM is particularly threatened throughout its geographic range; 90% of European stocks were wiped out in the 20th Century and Irish stocks fell by 8% in the period between 2006 and 2012 alone. It is widely recognised that threats are terrestrial, arising from increased sediment loads and/or eutrophication in the freshwater environment

FPM have a specialised life cycle, where a Glochidia larval stage is released from the adult female mussel into its freshwater habitat and must attach to the gills of a juvenile salmonid vector host in order to complete its development and to disperse. Once fully developed, the Glochidia falls to the river bed and, if settling on a suitable substrate, will bury itself and develop to adulthood. However, the majority of Glochidia perish naturally without finding a host and those that do and find a suitable substrate are even more sensitive to adverse water conditions than adult mussels. This has resulted in a situation throughout Ireland, where juvenile recruitment is either absent or extremely low and FPM populations now generally comprise ageing adults that would appear to be on a path to extinction unless their environmental conditions can be improved.

Under these circumstances ALAB’s first question to be addressed in this Supplementary EIS requires that two related potential risks are addressed:-

1. What is the direct risk that farm-origin lice originating from the operation of a salmon farm site at Shot Head could impact on local seagoing wild salmon populations, which are an Annex II protected species in their freshwater phase, and for that matter wild sea trout populations, which are not similarly protected?

2. What is the indirect risk that impacts arising as a result of Bullet 1 will reduce the number of seagoing salmonids and thereby reduce the numbers of their offspring in their freshwater phase such that the availability of vector hosts for FPM glochidia larvae is reduced?

RPS International Consulting Engineers and Watermark aqua-environmental were commissioned by the applicant, Marine Harvest Ireland (MHI) to carry out dispersional modelling studies on all waste streams discharged from the proposed Shot Head site, including the discharge and dispersal of lice. This required that RPS generate a Hydrodynamic (HD) model to drive the individual dispersion models. RPS have recently completed the development of the RPS Irish Seas Tidal Surge Model using MIKE 21/3 Coupled FM modelling software, a global standard developed by the Danish Hydraulics Institute. The RPS model is built using the most up to date and highest resolution digital information available to guarantee its accuracy. RPS used a section of their Tidal Surge model to create an HD model for Bantry Bay, which was then calibrated against multiple empirical hydrographic datasets collected from stations both close to salmon farm sites and elsewhere throughout the bay, to further guarantee accuracy.

The HD model was then used to investigate the dispersion of lice larvae, from all sites in Bantry Bay. MIKE software has many separate, coupleable modules, including the Hydrodynamic, Transport, Particle Tracking and Spectral Wave modules. In this case the coupling used was between the HD module and the Particle Tracking Module.

The numbers of lice larvae discharged from each site was calculated on a worst-case basis, from the infestation of the maximum numbers of fish present and a range of discharge parameters, based on historical lice levels on Bantry Bay sites, which have been monitored 14 times per annum for many years under the Statutory National Sea Lice Monitoring Program. The lice larval growth and survival parameters employed were as used by others working in this field, in Scottish and Norwegian government research groups. Models were generated to show lice dispersal in still weather tidal currents only and also in sustained Force 5 SW wind forcing conditions.

The graphical outputs from the lice dispersion model show dispersed *L. salmonis* Copepodid densities down to a lowest density contour level of zero to 0.0001 Copepodids /m^3 water. Even under the worst-case conditions modelled, the highest Copepodid densities, found close to the site, were in the range of zero to 1.0 Copepodids/m^3, with dissipation from this level well within 1km of the site centre. Density values typically fall to the lowest contour level, of zero to 0.0001 Copepodids/m^3, within 2km of the site centre and invariably fall to this level beyond 2km from the site centre, both in still weather and beyond the immediate influence of the typical density plume in wind-forced conditions.

The model showed that zero Copepodids could penetrate Trafrask Harbour or the Trafrask river under the conditions modelled.

At the Copepodid density levels generated by the model, an analysis of risk showed that the highest risk of attachment of a single Copepodid was to a salmonid passing very close to the site centre. This risk was between zero and one chance in 1,250. One kilometre beyond the site, in the direction of the Copepodid plume under wind forcing, this chance reduced to between zero and one chance in 31,250. In all areas beyond the plume and in the outer Bay generally the risk falls to between zero and one chance in 1,250,000. In areas at greatest hydrographic distance from the site, including Trafrask Harbour, the chance of attachment by a single Copepodid falls to zero.

Infestation risks calculated one the basis of infestation by a single louse ignore the central purpose of infestation, which is for settled lice stages to mature and mate. Thus, the minimum successful infestation would be for at least two Copepodids of opposite sex to settle. For this to occur pushes all chances of success ever closer towards zero, even close to the site centre.

Discussion offered in the document examines the dynamics of the two-way interrelationship between wild origin and farm origin *L. salmonis*. It sets out the stark differences between the highly efficient, natural wild infestation process, following millions of years of evolution, to be specifically targeted to river estuarine areas, where evolved strategies can assist in generating and maintaining high Copepodid densities to maximise infestation, as against the serendipity of Copepodid dispersions across open seas, resulting from chance encounters with salmon farm sites. *L. salmonis* has no evolved strategies to enable them to target river estuaries in adequate numbers from salmon fam locations unless specific spatial and hydrographic conditions apply.

The models created for this application process apply only to Bantry Bay and show that, largely as a result of its highly ocean- and wind-influenced, destratified characteristics, Nauplius and Copepodid larvae can do no more than disperse throughout the water column at ever-dwindling densities, within the plankton, during their short lives. It is observed that Bantry Bay conditions do not apply to larval lice dispersal in the Norwegian salmon farming industry, for a number of reasons. This requires an entirely different approach, both to salmon farm and lice management and to hydrographic and to dispersional modelling.

The RPS Bantry Bay model shows that the chances of Copepodid attachment to isolated salmonids in the open waters of the bay, and more particularly to wild smolt emerging from rivers into river estuaries, are so low that no farm-origin augmentation of wild salmon lice infestation levels is anticipated, either in Trafrask Harbour or in any other river estuary in the bay.

For these reasons it is concluded that, in particular in view of the historical maintenance of low lice levels on farm sites and the naturally low lice infestation potential of Bantry Bay open waters as a whole, there is effectively no lice risk projected from the proposed Shot Head site, to wild salmonids at any location, either in the open waters of Bantry Bay or in the Trafrask or any other river estuary in the bay.

It is further submitted that there is also zero risk that anadromous salmonids will be reduced in numbers in their freshwater phase, as a result of the presence of the Shot Head site, to impact on the availability of vector hosts for FPM Glochidia larvae.

However, a cautionary note is added. Those FPM stocks in the Trafrask system, and elsewhere around Bantry Bay and indeed further afield in Ireland that are not currently listed in SI 296 2009 are under huge risk of extinction, largely through neglect of their freshwater habitat. It is strongly recommended that a concerted effort be made by the local community, through and local and national authorities and pressure groups to rectify this situation, if they wish this protected species to endure.

Response to Issue 2.

Under the terms of SI 272 2009, all water bodies in Ireland, be they rivers, lakes, groundwater bodies, coastal or transitional (estuarine) waters, or artificial water bodies, require assessment in terms of their *Ecological Status*. SI 272 sets out all the required standards for such assessments, which are under the remit of the Environmental Protection Agency (EPA). Water body Ecological Status is classified by the assessment of a required range of Quality Elements, selected for each water body type.

Bantry Bay as a whole comprises three Transitional and two Coastal Water Bodies. The largest water body in the bay, Outer Bantry Bay, qualifies as a Coastal Waterbody. On the basis of the assessment of a range of Quality Elements, Outer Bantry Bay has maintained “High” Ecological Status, ever since the introduction of SI 272, in 2009. Salmon farming has been carried out in Bantry Bay for 40 years and is the location of all salmon grow-out sites in the bay, including the proposed Shot Head site. It also accommodates a considerable shellfish farming sector.

The question to be answered in this section is therefore whether High Ecological Status will be maintained in Outer Bantry Bay, once the Shot Head site is fully operational, if the licence is upheld.

This question is answered by the use of water quality (WQ) modelling, as set out in the RPS WQ Report for all Bantry Bay salmon farm sites, which is available on the ALAB website, and by the long-term monitoring of water conditions, associated with the operation of the salmon farm sites in the bay. It should be noted that the Irish aquaculture industry is the custodian of perhaps the largest monitoring database for the waters in which it operates, in the country.

In this case the Bantry Bay HD module developed by RPS was used to drive both a solute dispersion module for soluble discharges from the site and also a sediment module, to drive the dispersion of settleable solids. As in the case of the lice dispersion model, WQ models were run on a multi-layer, worst-case scenario, in order to provide safety and confidence in the modelled outcomes.

Under the terms of the 2008 105 EC, EQS Directive, and SI 272 2009, mixing zones from point sources of pollution can be allowed for under specified terms in Quality Element assessments and the EPA, who are responsible for setting the Ecological Status of all water bodies in the county also take this into account when assessing the relevant water body Quality Elements.

The coastal water body Quality Elements that are available from the applicant in this case arise as a result of the monitoring carried out by all aquaculture operations under the terms of the DAFM protocols for water column and benthic monitoring of aquaculture sites. These include Dissolved Inorganic Nitrogen (DIN), Dissolved Oxygen Saturation (DO) and Benthic Infauna. All available water column control site data collected by salmon farm operators in Bantry Bay since the introduction of SI 272 in 2009 is tabulated in the main text. Median values, upon which Quality Element Assessments are made, are highlighted in the table.

In the case of DIN, the median value for the period is 0.1152mg DIN/l, whilst the median salinity value for the bay is 34.3‰. The dispersion model projects that the peak DIN values occur just clear of the proposed Shot Head site centre, at 0.04mg/l DIN. This diminishes gradually to <0.0002 mg/l DIN within a maximum distance of 3km from the site centre in all directions.
Taking the highest value of 0.04mg DIN/l and adding the median ambient of 0.1152 DIN/l for the bay, a peak elevated ambient of 0.1552 mg/l DIN (0.04 + 0.1152) is found for a limited area, flowing east for up to 3km from the site on the flood tide and similarly, to the west, on the ebb. This gradually reduces to <0.1154 mg/l DIN, (= 0.1152 + <0.0002) within a maximum of 3km from the site centre.

The Quality Element standard for High Ecological Status waters is a winter DIN concentration of 0.17mg DIN/l, at a median salinity of 34.5‰. Thus, the elevation of ambient DIN to 0.1552 DIN/l close to the site and <0.1154 DIN/l in the open waters of the bay are both well within the set QE standard for High Ecological Status, on a worst-case basis, with the proposed Shot Head site fully operational. More than anything else, this demonstrates that DIN dispersing from the Shot Head site at worst case will not elevate ambient DIN to the extent that any enviromental disturbance, such as elevated primary production will result, and High Ecological Status will be maintained.

For Dissolved Oxygen (DO) saturation, with no elevated primary production, no elevation of summer DO levels will be expected as a result of the operation of the site. It is however possible that ambient DO could be impacted by Biological Oxydation Demand (BOD) dispersing from the site, mainly in organic carbon and nitrogen-based molecules in the discharges, which consume oxygen as they break down. Reference to the RPS WQ Model document and the original EIS demonstrates that the DO saturation in the bay and the quantity discharged and rate of dispersal of BOD from the site cause only a minor reduction of DO in the bay, leaving the post-Shot Head DO saturation well within the High Ecological Status Quality Element standard for coastal water bodies of a 95%ile of >80% DO saturation at a median salinity of 35‰.

In the case of Benthic Infauna, these are regularly sampled, at all MHI sites, in respect of the requirements of the DAFM Protocol No.1 for Offshore Finfish Farms – Benthic Monitoring and as well as under the requirements of The Aquaculture Stewardship Council (ASC) Audit process, to which MHI subscribes for all its sites. Both existing MHI sites in Bantry Bay, at Roancarrig and Ahabeg, pass the annual DAFM audit and both have achieved the ASC Standard. Modelling of solids settlement at the proposed Shot Head site is fully covered both in the Shot Head EIS and in the RPS Bantry Bay WQ Document. This projects low levels of settlement at the Shot Head site, due mainly to the use of large pens with low, organic standard, stocking densities, high feed digestibility and due to the wind-wave assisted deep water current regime in the bay. As a result, benthic infaunal composition is only impacted within the Acceptable Zones of Effects established for salmon farming operations. Beyond these limits, benthic infaunal composition is projected to be normal throughout the Outer Bantry Bay Water Body. Thus, the benthic infauna Quality Element is satisfied under the standards which apply to salmon farm installations, as agreed by the Scottish Environmental Protection Agency (SEPA), DAFM and the ASC.

In conclusion, in answer to the question raised, the High Ecological Status of Outer Bantry Bay will remain well within its QE value limits after the Shot Head site is fully operational should ALAB decide to uphold its licence. Further with retention of High Ecological Status, the wild salmonid stocks of Bantry Bay will suffer no additional impacts, over and above those caused by existing freshwater impacts, marine mortality, angling and commercial draft netting. Freshwater Pearl Mussel in the Trafrask River will be exposed to no further risks, over and above those present within their freshwater habitat, as a result of degradation of the terrestrial catchment of the river.

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Supplementary Environmental Impact Statement (EIS) for a proposed salmon farm site at Shot Head, Bantry Bay, County Cork, Ireland.

Section 1.
Introduction.

The Minister for Agriculture, Food and the Marine granted Aquaculture and Foreshore Licences to the applicant, Marine Harvest Ireland (MHI), for a proposed salmon farm site at Shot Head, Bantry Bay, in September 2015, Site Reference Number T05/555. Once granted, the licence was appealed by numerous appellants to the Aquaculture Licences Appeals Board (ALAB). Following written appeals, three appellants were granted an Oral Hearing by ALAB. Two sessions of the Oral Hearing ensued, for two days in March 2017 and a further two days in September 2017.

After the second session of the Oral Hearing, ALAB has now requested a further submission from the applicant, pursuant to Section 47(1)(a) of the Fisheries (Amendment) Act, 1997. ALAB has stated that the purpose of the further submission is to provide a clarification and addendum to the company's previous submissions, on two primary issues. ALAB requires that the submission should take the form of a Supplementary Environmental Impact Statement (EIS). ALAB has stated that the two issues to be covered in the Supplementary EIS are:-

1. The risk (*i.e. posed by the proposed salmon farm installation*) of sea-lice infestation of wild salmonids migrating from/to the Dromogowlane and Trafrask rivers and any resulting implications for local freshwater pearl mussel (FPM) populations.

2. The impact of salmon farm waste on water quality in Bantry Bay, having regard to the maintenance of 'good water status' as required under the Water Framework Directive.

This request was first communicated to the company by ALAB by letter, dated 20th December 2017. This letter was amended by ALAB and resent to the company on 12th January 2018, although still dated 20th December 2017. The company was given three months from the date of the original letter, that is until 20th March 2018, to respond to ALAB's request. This period was extended to 12th April 2018, three months from the despatch date of ALAB's second letter, at the applicant's request.

The existing (original) EIS for the site was submitted with the licence application as long ago as June 2011. In 2015, the applicant, MHI, commissioned a hydrodynamic and dispersal modelling study, from the engineering consultants RPS International of Belfast, to further define the projected impacts of the proposed site on the environs of Bantry Bay. Bearing in mind the amount of time that the licence application had been in process, MHI saw this as a necessary means of confirming and updating the findings of the original EIS, using the most up to date mathematical modelling techniques. The RPS study was submitted to ALAB in September 2015.

Presentation and discussion of the findings of the RPS hydrographic and dispersional study took up a considerable portion of the second session of the Oral Hearing of the appeal, in September 2017. The applicant's responses to the two questions now posed by ALAB are also substantially supported by the RPS study. The applicant therefore now wishes to respond to the two questions posed by reference to:-

1. The original EIS and application documents.
2. RPS hydrodynamic and dispersional modelling studies.
3. Other documents submitted to DAFM and ALAB during the application process
4. Submissions, comments and discussion arising during the written appeals and oral hearing processes.
5. Scientific literature published before and since the original application submission.

As far as is known, all the items listed under bullets 1 to 4 above can be downloaded from the ALAB website. References to the scientific literature referred to can be found within the body of this document.

Section 2.
Qualification and quantification of the risk posed by the proposed salmon farm at Shot Head of sea-lice infestation of wild salmonids, migrating to and from the Dromogowlane / Trafrask river system and any resulting implications for local *Margaritifera margaritifera* (Freshwater Pearl Mussel; FPM) populations.

2.1. The nature and extent of the risks.

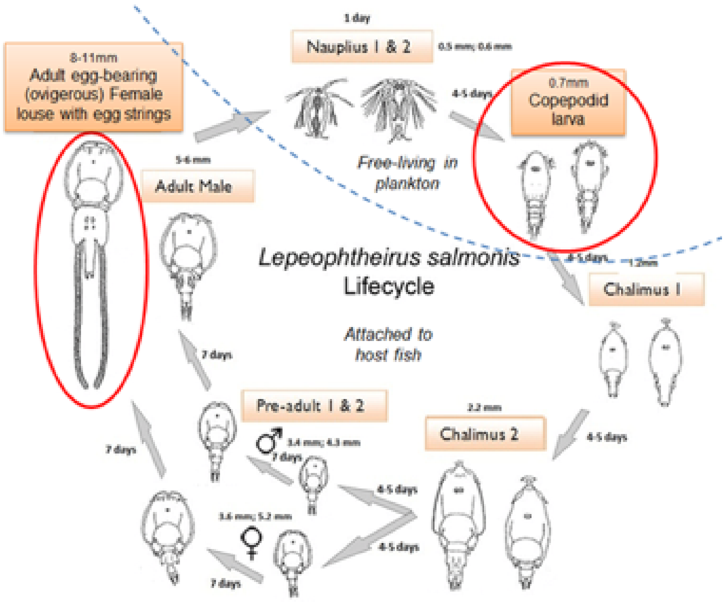
Caligid copepods of the Order Siphonostomatoida are crustacean ectoparasites that feed on the mucus, epidermal tissue and blood of their host marine fish. Two species parasitise wild and farmed salmonid fish in the marine environment in European waters. The sea louse, *Caligus elongatus* is something of a generalist and has been reported as parasitising over 80 teleost and elasmobranch species, including the salmonids, Atlantic salmon, sea trout and Arctic charr in marine conditions. The salmon louse *Lepeophtheirus salmonis* is a more specialised parasite, specifically adapted to infest salmonids in their marine phase, although there are accounts of it infesting at least one other species, the three-spined stickleback[1]. Whilst both lice are natural parasites of salmonids, infesting both wild and farmed fish, *L. salmonis*, is widely regarded as the more problematic of the two on salmon farms and the more prevalent on wild salmonids, even in areas without salmon farms[2]. The life cycle of *L. Salmonis* is explained in Box 1.

[1] Jones SR et al 2006. The occurrence of *Lepeophtheirus salmonis* and *Caligus clemensi* (Copepoda: Caligidae) on three-spine stickleback *Gasterosteus aculeatus* in coastal British Columbia. J. Parasitol. 92(3) 473-480.

[2] Gargan P et al 2016. Sea lice (*Lepeophtheirus salmonis* and *Caligus elongatus*) infestation levels on sea trout (*Salmo trutta* L.) around the Irish Sea, an area without salmon aquaculture. ICES Journal of Marine Science, 73, 2395-2407

Box 1. The life cycle of *Lepeophtheirus salmonis*.

Lepeophtheirus salmonis eggs are carried in paired egg strings on the adult ovigerous (egg-bearing) female louse. The eggs hatch into Nauplius larvae, which are free-living in the water column (i.e. planktonic). Following a second Naupliar stage (Nauplius 2), these metamorphose into planktonic Copepodid larvae, the only infestive stage, 4 days post-hatch at 10°C (roughly the Irish spring ambient water temperature). Copepodids survive for some 10 days, in which time they must locate and attach to a host salmonid fish, otherwise they die on expiry of their internal food (yolk) reserves. In the naturally-evolved wild infestation cycle, ovigerous female lice are carried into estuarine areas on their wild salmonid hosts, returning to their native rivers to breed where the louse eggs hatch into Nauplius larvae. This evolved strategy has the potential to place very large numbers of infestive Copepodid larvae in the same inshore estuarine waters, through which the next generation of wild salmonid smolts swim at their maximum density, as they start their own seawards migration. The coincidence of critical numbers of Copepodids and migrating wild smolt in both time and space at this point maximises the chances of an efficient natural infestation. It is by this means that *L. salmonis* has prospered over its multi-million-year parasitic existence. However, even in an efficient infestation strategy, not all wild copepodids find hosts in their natural infestation zones. It can be assumed that many are swept into open marine waters in the plankton, where dispersal of both parasites and potential wild hosts make further wild infestations very unlikely. However, the advent of salmon farming in the last 50 years or so has shifted the dynamics of this solely natural cycle. This is because at least a small proportion of these ever-dispersing wild Copepodids, which fail to find hosts in their natural infestation zones, now have the potential to encounter salmon farms, downstream of their birth river estuaries, before they expire. Salmon farms offer a wide cross-sectional area to the dispersive currents carrying planktonic organisms. Further, farmed fish are held in fixed locations and at sufficient stock densities to enable the establishment of breeding populations of sea lice from relatively small initial settlements of drifting Copepodids. However, apart from the potential for lice damage to the farm stock, there is a further possible negative prospect for on-farm lice settlement, in that it provides opportunities for the re-infestation of wild fish, if farm-origin Copepodids can drift back into inshore estuarine areas in sufficient numbers to augment wild infestation pressure. However, a range of critical variables may apply:-



1. Lack of adequate, timely on-farm lice treatments, resulting in on-farm epizootics of infestation.
2. Impact of farm fish stock size / numbers on total ovigerous female lice numbers and the consequent potential for increased Copepodid production and dispersal.
3. Local hydrography, e.g. "the hydrographic distance" between infested farm sites and salmonid rivers.
4. Additional forcing factors such as freshwater, stratification and wind may also be involved.

The nature and extent of two risks require qualification and quantification in response to ALAB's first request: -

1. The direct risk of infestation of wild anadromous salmonids, entering or leaving the Trafrask system by Copepodids, primarily by *L. salmonis*, generated from ovigerous female lice that infest the proposed salmon farm site.

2. The indirect risk of an impact arising on the status of *Margaritifera margaritifera* (FPM) stocks, resident in the Trafrask River system, as a result of impacts on the status of Trafrask anadromous salmoidn stocks, which may act as vectors for the glochidial larval stage of FPM. The life cycle of FPM and how impacts on anadromous salmonids could affect this is explained in Box 2.

As Box 1 sets out, relatively small numbers of drifting wild (or farm origin) *L. salmonis* Copepodids are able to initiate a salmon infestation within a salmon farm site if local hydrography enables their passage between birth-estuary and salmon pens before they die (14-days post-hatch). Once settled, these wild-origin lice have the potential to grow to maturity and breed on-farm, if not interrupted by treatment of the farmed stock. As in the wild, farm-grown female lice are fertilised and become ovigerous and extrude paired egg strings, from which infestive Copepodid larvae will arise some 4 days post-hatch. However, farm-origin Copepodids find themselves in a very different situation to wild Copepodids. This is because, unlike wild lice, which use a host vector, farm-origin lice have no evolved mechanism by which to carry high numbers of newly-metamorphosed, infestive Copepodids into close contact with their out-migrating hosts, in their natural infestation zones. Rather, they can be expected to disperse, dilute, be predated upon and age, amongst the plankton, in the open water conditions in which they find themselves. Thus, whilst it may be possible for some farm-origin lice to continue to infest the same farm site or, perhaps to drift downstream into other sites, their fate is largely a matter of chance and hydrography, as their Copepodids drift, in diminishing densities, from their birth-site.

On this basis therefore, the direct risk of infestation of wild anadromous salmonids entering or leaving the Trafrask River system by Copepodids originating from the proposed Shot Head site may be regarded as low and totally subject to chance. However, outcomes are likely to depend, more than anything, on the numerical scale of the dispersal from the proposed site and local hydrography.

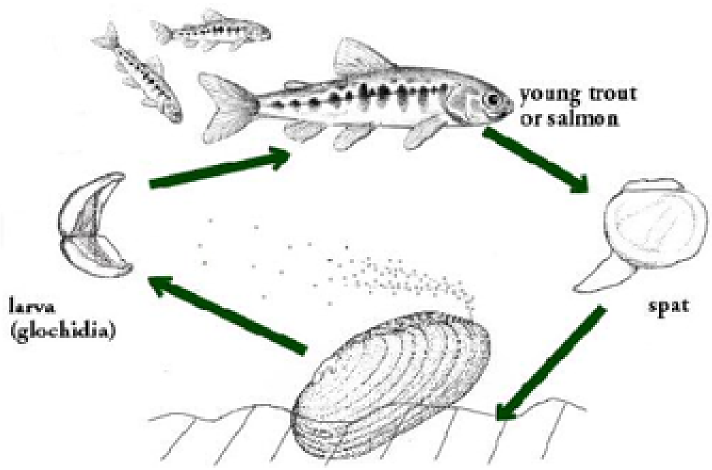
With reference to Box 2, the most vulnerable stage of the life cycle of *Margaritifera* (FPM) stocks is the Glochidia larva, which depends on a freshwater salmonid host vector, both for its dispersal and for its metamorphosis to the adult form. Thus, the indirect risk on FPM is related to the status of local wild anadromous salmonids that may take this vector role whilst in freshwater, which, in turn, is dependent on the absence of any direct risk to wild anadromous salmonids entering or leaving the Trafrask system, arising from farm-origin lice infestations, or any other impact originating from the proposed site, whilst they are at sea.

In order to further quantify and qualify this view, MHI commissioned Watermark and RPS International consulting engineers to investigate the fate of farm origin Copepodids by the use of hydrographic and dispersional modelling studies.

Box 2. Freshwater Pearl Mussel (FPM). Life cycle, hosts and habitat requirements

FPM populations were once very abundant and pearl fisheries were highly prized. The British fishery of the time has been cited as the underlying reason why the Romans invaded Britain. Pearl fishing continued into the early 20th century but FPM is now in very serious decline and is listed in the IUCN red data book as endangered worldwide.

FPM live buried or part-buried in coarse sand and fine gravel in clean, oligotrophic, fast-flowing, unpolluted rivers and streams. They feed by inhaling water through their exposed siphons to filter out minute organic particles. Like other freshwater bivalves, FPM has separate male and female individuals. FPM matures at >10 years and a length of >65 mm. Males shed sperm into the water in June to July, which is inhaled by the females. Once fertilised, the eggs develop in a gill pouch on the female until they are released, between July and September, as Glochidia larvae. Each female ejects 1 - 4 million 60–70µ Glochidia in a highly synchronised burst, usually over one to two days, triggered by temperature and other environmental cues. The proportion of adults producing Glochidia varies between 30–60%, even in sparse populations and numbers released increase with age up to about 50 years. Almost all the Glochidia are swept away and die, but a small proportion are inhaled by juvenile salmonid fish. Glochidia resemble tiny mussels but their shells are held open until they encounter a suitable host, at which point they snap shut onto the host's gill. Once attached, Glochidia encyst, live and grow on the gills until they drop off the following May to early June as spat. Those that land in clean, sandy or gravelly substrates settle and start to grow. The parasite / host association does not appear to harm the host and enables young mussels to colonise new areas upstream. FPM develop very slowly and can live for more than 100 years, to reach up to 15cm in length. The huge losses of Glochidia involved in this unusual life cycle make the freshwater pearl mussel particularly vulnerable to adverse conditions.



Only sea trout, brown trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*) are known to host FPM Glochidia in Europe. Brown trout are the main host species in Ireland. *Salmo trutta* exists in two forms; the resident brown trout and the migratory sea trout. Rivers carry varying population ratios, but their relative importance for FPM is not fully clear, although differences in their reproductive behaviour most probably affects mussel recruitment. Therefore, measures to conserve the mussel must also include the host fish. Host fish become progressively resistant to Glochidial infection with age and those in the first three year-classes (but mostly 0+ and 1+ years) form most of the host population. The minimum density of fish required to maintain mussel population densities in the long-term is generally considered to be in the range of 0.2 – 0.3 fish per m^2 of river but this may still require more research. Increased glochidial success can theoretically be achieved by increasing host numbers or through the artificial infection of host fish. Such measures will only be effective in rivers with appropriate water quality and substrate conditions. Even mild eutrophication can be detrimental to successful reproduction and therefore hamper recovery programmes. Adult FPM are more tolerant of a wider range of in-river conditions than juveniles, which is why, with falling river quality, many populations still contain good numbers of ageing adults (age range say 20 to 100 years) but few or no new recruits.

2.2. The use of the RPS HD Model for Bantry Bay in assessing direct risk.

MHI has been investing in the use Hydrodynamic (HD) and dispersional modelling, to investigate the tides and currents, wave climate, dispersal and impacts of soluble and settleable metabolic wastes, medication and salmon lice around its salmon farm sites since 2005. Watermark, in conjunction with RPS International consulting engineers, who have conducted the computational modelling required, have been commissioned by MHI to carry out this work. The purpose of these investigations is to:-

- Provide objective, numerical projections of farm conditions.
- Project the fate of fish farm wastes and discharges, including sea lice.
- Inform Environmental Impact Statements (EIS).
- Help select sites for new licence applications.
- Inform salmon farm structural specifications, for certification purposes.

RPS uses the latest version of MIKE, MIKE 21/3 Coupled Model FM for MHI's models for this purpose. The MIKE suite of hydrodynamic modules was developed by the Danish Hydrographic Institute (DHI) and is a global standard, used internationally for many environmental, planning, legal, engineering and other predictive applications. MIKE has many separate, coupleable modules, including the Hydrodynamic, Transport, Particle Tracking and Spectral Wave modules. Its basic computational component is the *Hydrodynamic Module*, which predicts the behaviour of tides and currents. Each model is calibrated against empirical data collected in the modelled locality and can be "dynamically coupled" to any of the other module/s, as required, to "drive" their functions. For example, with the Spectral Wave Module, it is used to model the interaction between currents and waves to predict wave climate. With the Particle Tracking Module, it is used to predict the dispersal of discharges of particles from any source, such as a salmon farm site.

The RPS Water Quality modelling study for existing and proposed salmon farm sites in Bantry Bay is available on the ALAB website.

2.2.1. Hydrodynamic (HD) modelling in Bantry Bay; methodology.

RPS' Bantry Bay Hydrodynamic (HD) Model uses a section of the RPS Irish Seas Tidal Surge Model, which employs *flexible mesh technology*. This allows variation in the size of computational grid cells, for greater modelling accuracy where required, for example around fish farm sites. In such areas, individual grid cells can be reduced down to 20m x 20m, one third of the surface area of a single sea pen at the proposed Shot Head site. To further optimise accuracy, the model was built using the most recent, highest resolution digital information available, including the entire INFOMAR database, which incorporates the OSI LiDAR[3] datasets. In

[3] LiDAR or Light Detection and Ranging, is a remote sensing method that uses pulsed laser light to measure distance which can then be used to make digital 3-D representations of the target. It has now been used widely by Geological Survey Ireland / Ordnance Survey Ireland to measure bathymetric depth in Irish coasts and bays. See EIS Section 2.3.1 and RPS report Figures 3.1 to 3.3 (Appendix 1) for LiDAR images of Bantry Bay.

addition, digital data from surveys of Dublin Bay and adjacent areas carried out by Geological Survey Ireland (GSI) were incorporated into the model, along with GSI surveys of the West of Ireland, part of the Irish National Seabed Survey (INSS). Additional digital data were incorporated for banks and coastal approaches around Ireland as well as high resolution, local bathymetric data, collected by sidescan sonar, during local bathymetric surveys commissioned by MHI. The Bantry Bay HD model was also calibrated against 15 recent sets of local, multiple-depth current data, collected by ADCP[4], from stations both close to salmon farm sites and elsewhere throughout the Bantry Bay.

The HD model simulates depth-averaged current in every grid cell, in nominal 10-second time steps over 22 days, to include a full range of neap and spring current conditions. Use of depth-averaged flow is justified by the correlation of the model to the empirical datasets used for calibration. Self-evidently there is little or no stratification in Outer Bantry Bay; see further comments re stratification in Section 2.3.3, Discussion Point 6. The fact that each 22-day simulation contains >8.5 billion datapoints confirms the high resolution of the model.

2.2.2. Hydrodynamic (HD) modelling in Bantry Bay; results.

Figures 2.1 and 2.2 project Ebb and Flood tidal flow at mean spring tide, along with the locations of existing and proposed salmon farm sites and local rivers around the Bantry Bay. Figures 2.3 and 2.4 project the tidal flow around the proposed MHI Shot Head site at higher resolution.

Figures 2.3 and 2.4 show that flow around the proposed Shot Head site is relatively faster on the ebb than on the flood tide at mean spring tide. This trend is further illustrated by an examination of the residual currents in the bay. These result from the differences between the vectoral components of flood and ebb currents over the course of complete tidal cycles and are useful in assessing flow characteristics and dispersion potential in an area. The residual currents for Bantry Bay are projected in Figure 2.5 and for the Shot Head area at higher resolution in Figure 2.6 and show that residual currents are relatively low in the main body of Outer Bantry Bay but increase around the islands and promontories, some where salmon farms are located. High residual currents reduce solids accumulation and encourage solid and soluble wastes dispersal away from such areas.

These plots, together with others in the full RPS report, confirm the relatively complex nature of flow in Bantry Bay. A tidal convergence just outside the bay is a factor in limiting tidal currents overall to less than 10cm sec^{-1}. Tidal flow is also complicated by the presence of Bear and Whiddy Islands, where the tide floods and ebbs from both ends of their inshore channels, leaving neutral current zones in their lee; see Figures 2.1 and 2.2.

4 ADCP; Acoustic Doppler Current Profiler; a hydro-acoustic current meter similar to a sonar, used to measure water current velocities over a depth range (e.g. from water surface to seabed at nominal 1m intervals in MHI surveys) using the Doppler effect of sound waves scattered back from particles within the water column.

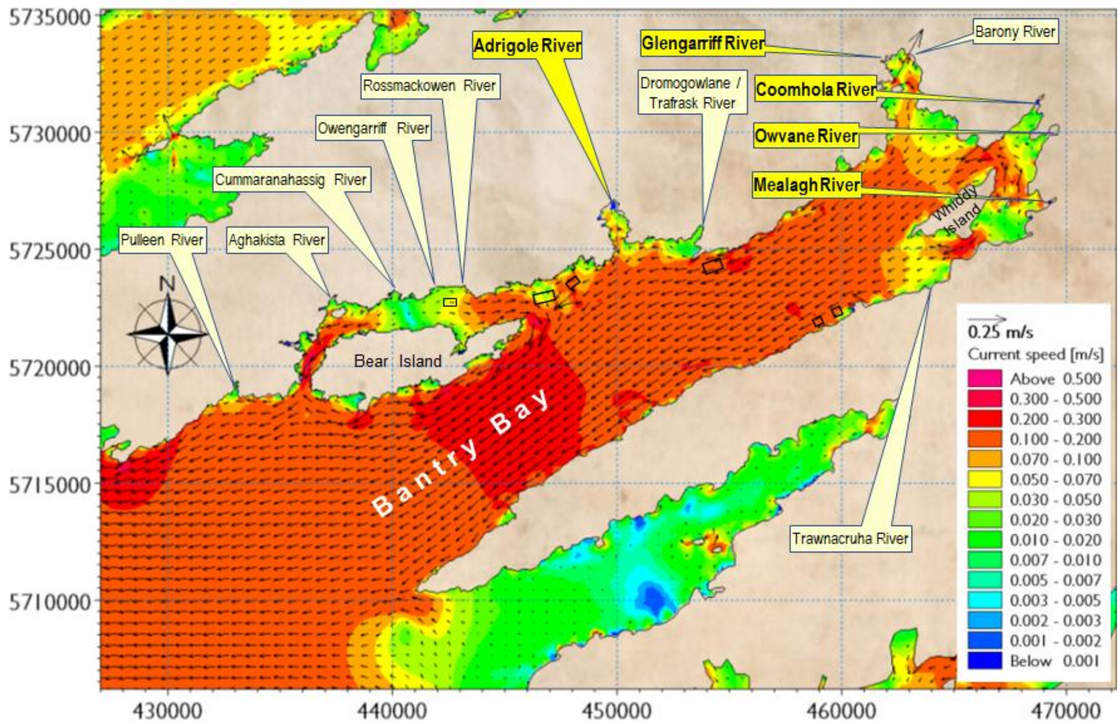


Figure 2.1.
Mean spring tide ebb current flow conditions in Bantry Bay.
Rivers are also shown, with National Salmon Rivers shown in bold type.

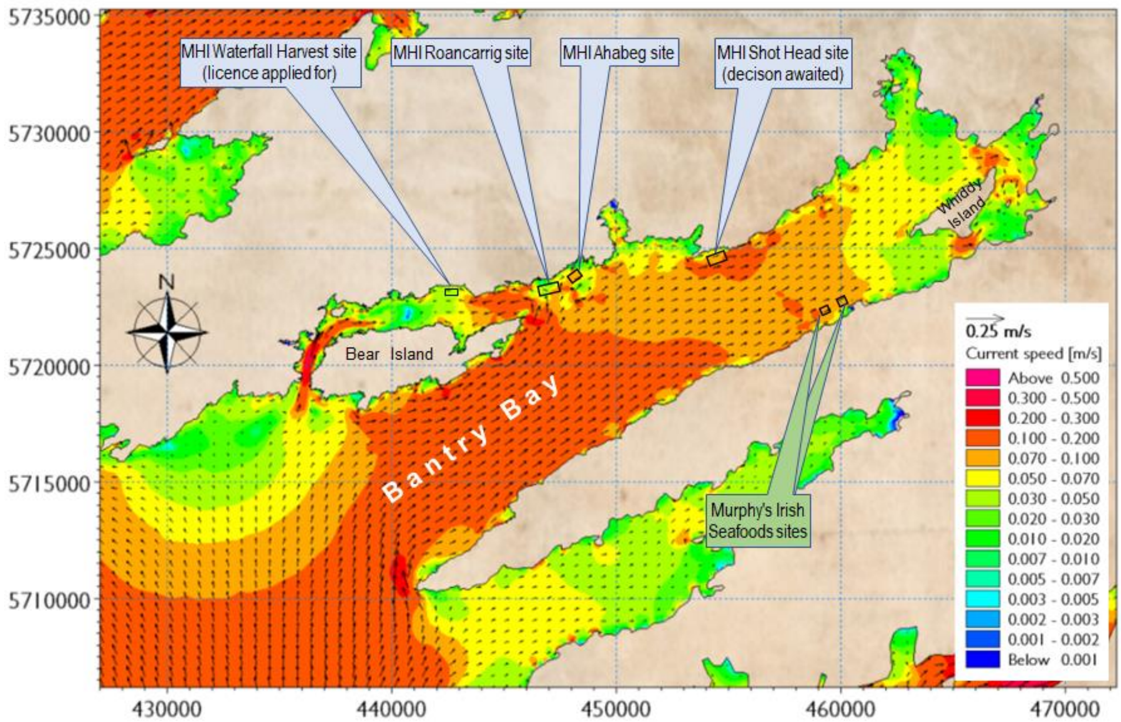


Figure 2.2.
Mean spring tide flood current flow conditions in Bantry Bay.
Exisitng and proposed salmon farm sites are also shown.

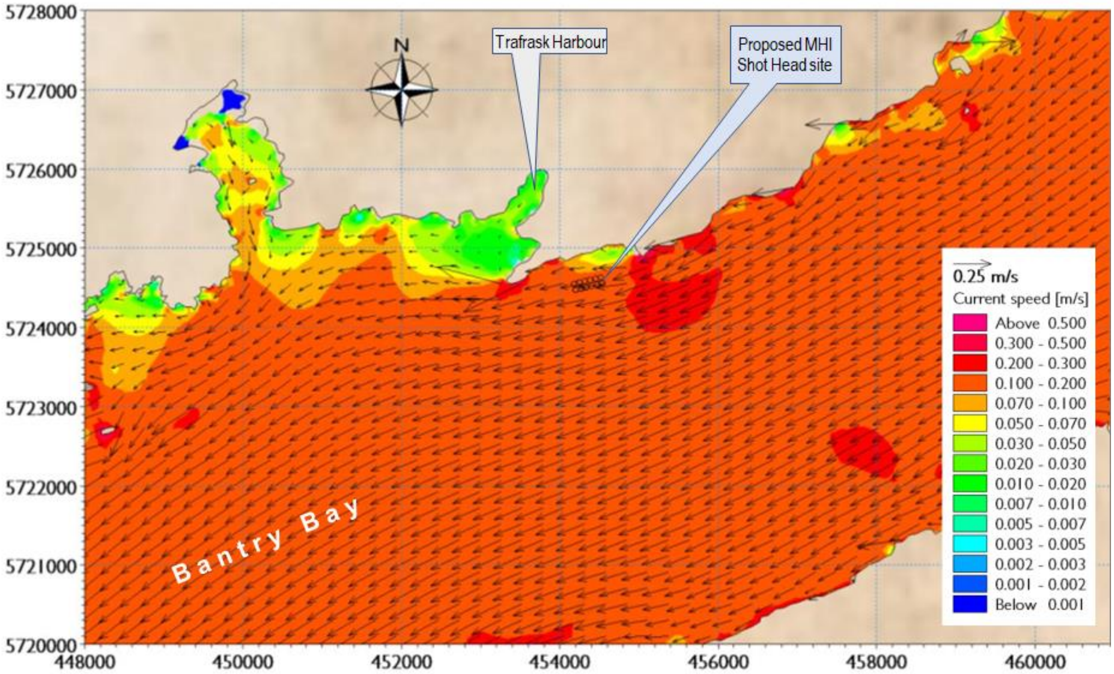


Figure 2.3.
Higher resolution view of mean spring tide ebb current flow conditions in the vicinity of the proposed Shot Head site.

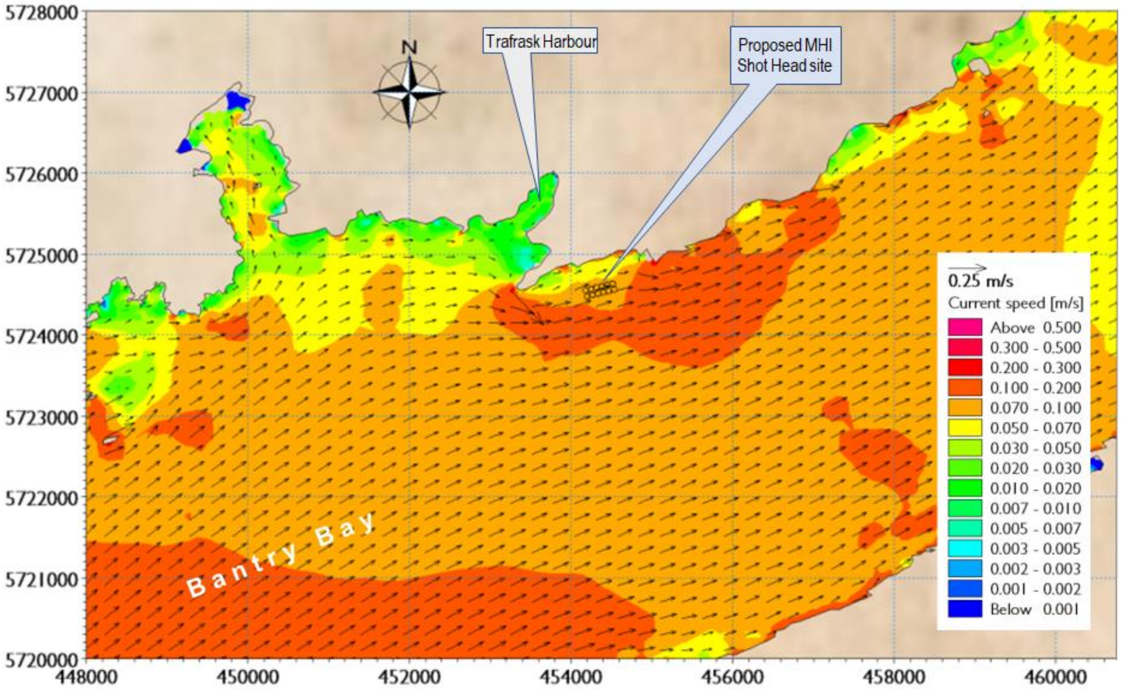


Figure 2.4.
Higher resolution view of mean spring tide flood current flow conditions in the vicinity of the proposed Shot Head site.

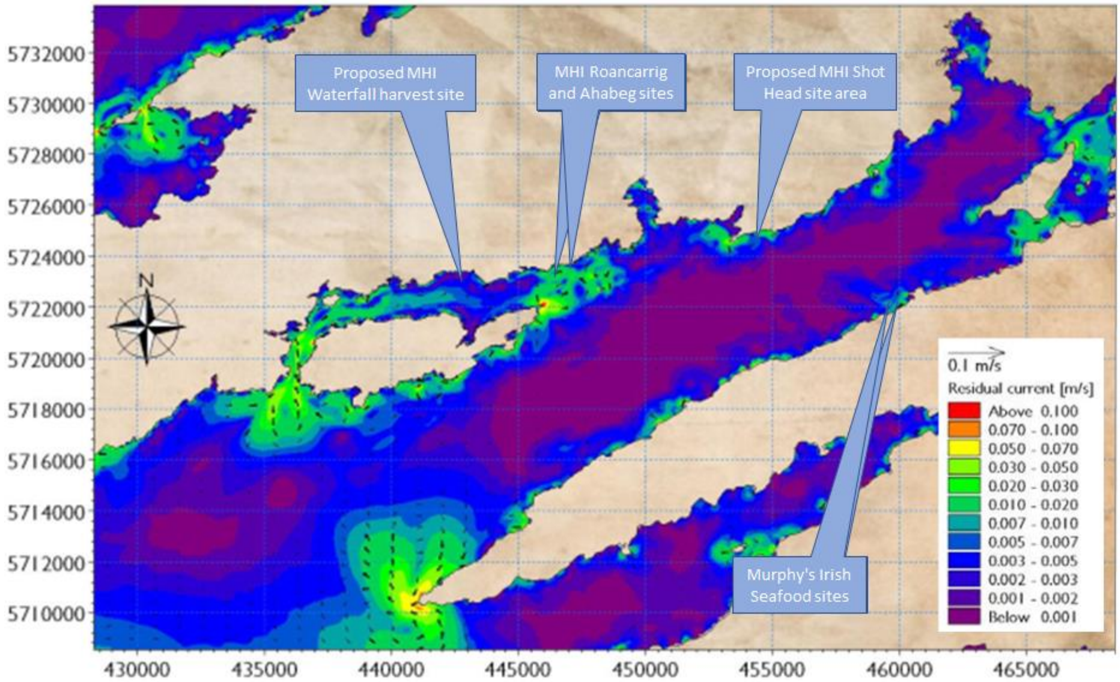


Figure 2.5.
Residual currents for Bantry Bay; Mean Spring Tide.

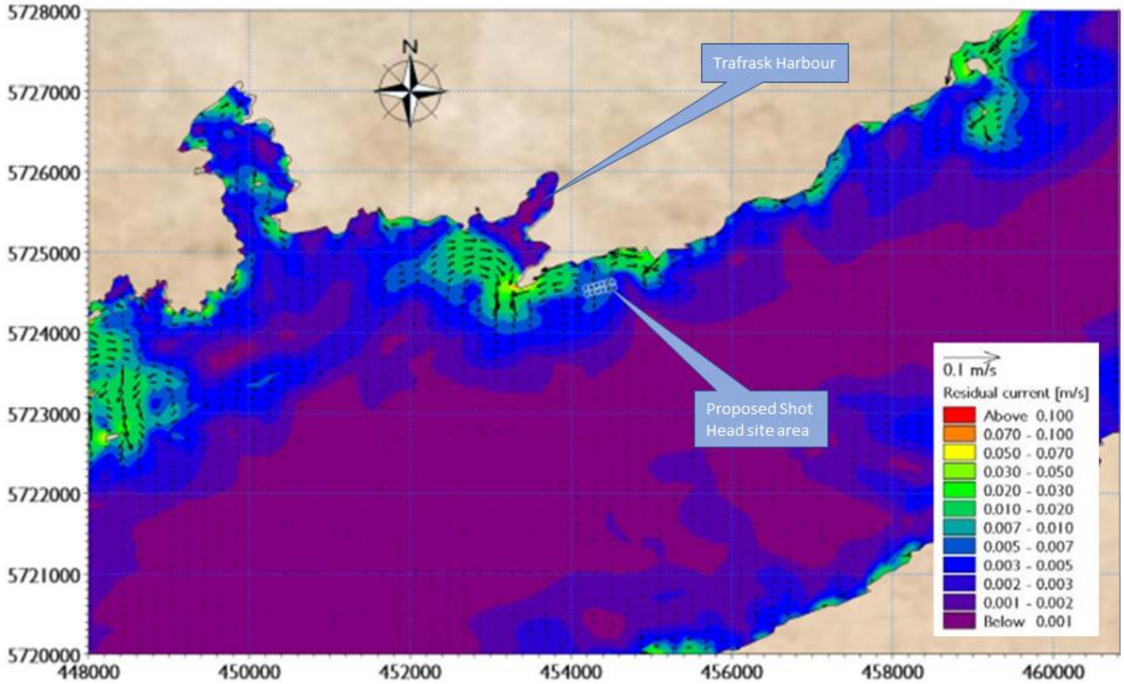


Figure 2.6.
Residual currents for the Shot Head area; Mean Spring Tide.

Figures 2.5 and 2.6 are supported by cumulative vector (residual current) plots calculated from current data, collected by an ADCP, deployed by MHI at the proposed Shot Head site in January 2010; see Figure 2.7. These express residual currents as effective cumulative residual distance travelled by currents at the meter deployment location over the 15-day measurement period. These plots confirm an overall westerly current trend at the site and indicate the unstratified conditions throughout the water column. The full dataset for this deployment was one of the fifteen empirical datasets used to calibrate the HD model; see EIS Section 2.3.2 and the full RPS Report, Section 3.5.

It is further observed that the area of Trafrask Harbour, which is the approach to the Trafrask River system, a primary subject of this examination, has a very low current regime, both in respect of tidal currents on ebb and flood tide and of residual currents. This is likely to hinder the ingress to and egress from the Harbour of any solute, solid or particle, to a considerable degree.

2.3. The RPS dispersion model for *L. salmonis* larvae in Bantry Bay.

2.3.1. Dispersion modelling of *L. salmonis* larvae in Bantry Bay; Methodology.

As for all MHI dispersion models, lice dispersion is driven by the RPS Bantry Bay HD Model, described in Section 2.2. This shows that, whilst discharges (including free-living lice larval stages) would be dispersed quite rapidly from site areas as the result of residual current flow, the current regime in the bay as a whole is relatively slow. This can be expected to impact on the manner and speed of dispersion of lice in the bay.

In order to establish discharge rates of free-living larval lice from the sites, the historical record for the infestation of the farmed salmon on Bantry Bay sites was examined. MHI took over the existing farm sites at Roancarrig and Ahabeg in 2008. The only other active sites in the bay since then have been the Murphy's Irish Seafoods sites, off Gearhies, west of Whiddy Island. Site locations are given in Figure 2.2. Neither the Waterfall site nor the Shot Head site, shown in this figure, have been in operation since 2008; in both cases they await the outcomes of licence applications.

The National Lice Monitoring Program has been operated under statute by the Marine Institute (MI) for many years and the data collected has always been in the public domain[5]. The DAFM Monitoring Protocol Number 3 for *Sea lice monitoring and control* was first issued in May 2000[6]. The program was strengthened in 2008, with the issue of the document *A strategy for improved pest control on Irish salmon farms*[7].

5 For background information and all annual lice monitoring reports since 1995 see https://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice?

6 Monitoring Protocol No. 3 for Offshore Finfish F. Sea lice monitoring and control. DCMNR / DAFF / DAFM, https://agriculture.gov.ie/seafood/aquacultureforeshoremanagement/marinefinfishprotocols/?

7 A strategy for improved pest control on Irish salmon farms https://agriculture.gov.ie/seafood/aquacultureforeshoremanagement/marinefinfishprotocols/?

Figure 2.7.
Cumulative vector (residual current) plots; at 26.3m, 16.4m and 2.0m from seabed.
From ADCP deployment at Shot Head Bantry Bay
ADCP position ING Grid ref 085177.78E 047836.09N.
Period 00:00 14th January 2010 to 00:00 29th January 2010 (GMT); 15 days.

Figure 2.7.1. Current cumulative vector plot; 26.3m from seabed.

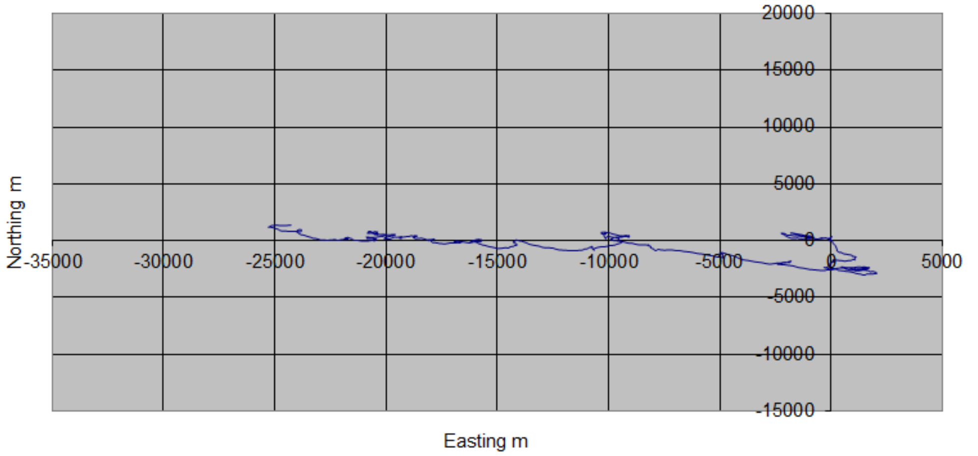


Figure 2.7.2. Current cumulative vector plot; 16.4m from seabed.

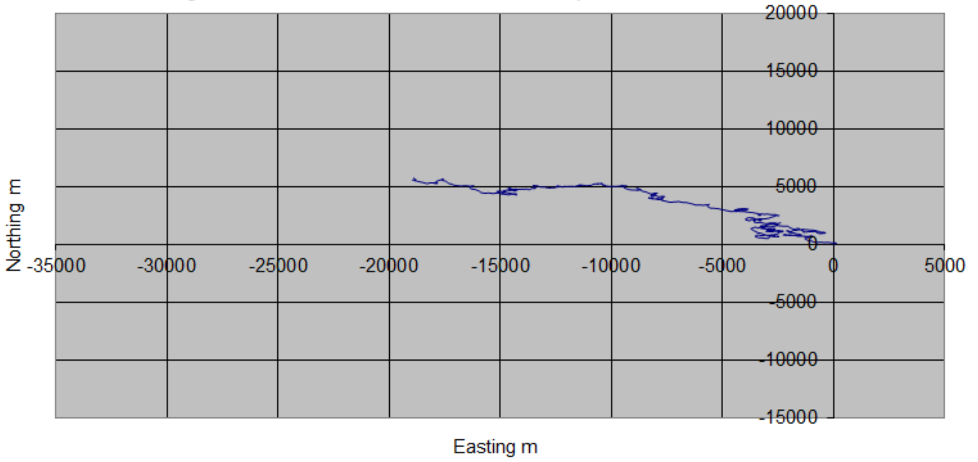
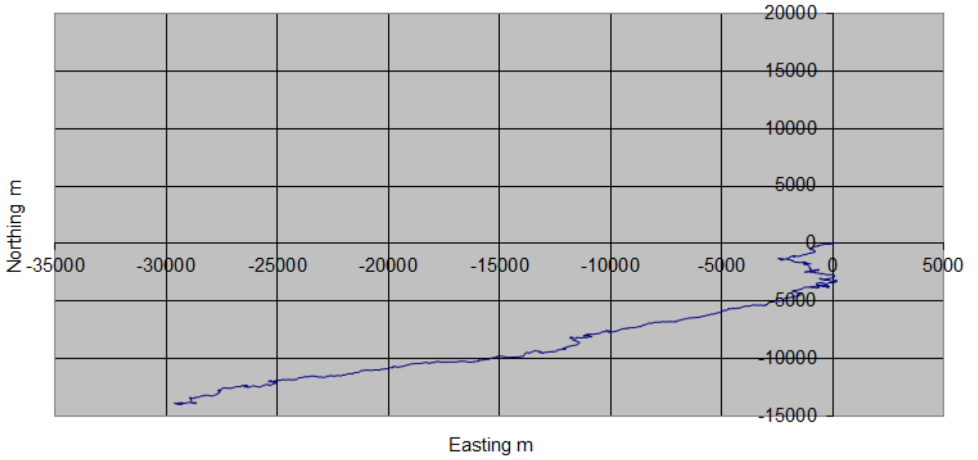
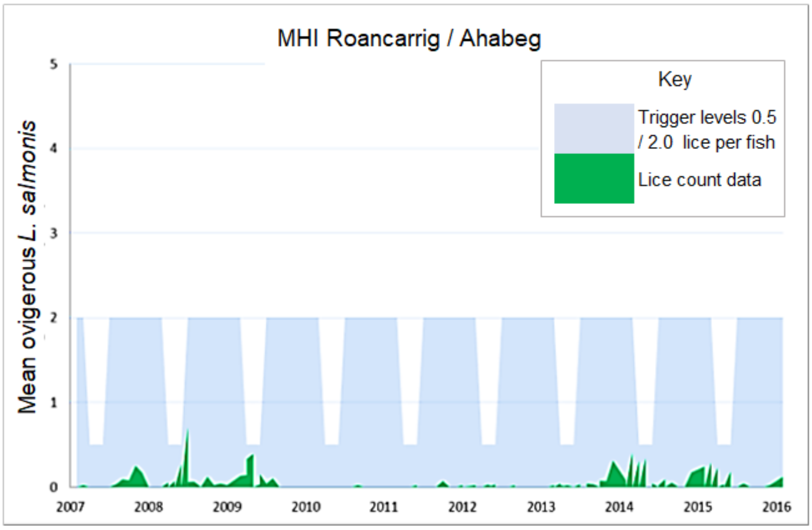


Figure 2.7.3. Current cumulative vector plot; 2m from seabed.



Under the terms of these documents, lice levels are checked 14 times per year by MI officers. Bi-weekly inspections are made in March, April and May, during the "critical period" of smolt migration. Otherwise inspections are monthly, with the exception of December to January, when only one inspection is made. Two, thirty-fish samples are taken on each inspection, one in a standard pen, and the other in a randomly-selected pen. Lice treatment is triggered during the spring period if 0.3 to 0.5 ovigerous female lice per fish are identified, also informed by the numbers of mobile lice on the fish. Where numbers of mobile lice are high, treatments are triggered even in the absence of ovigerous female lice. Outside the critical spring period, the trigger level for treatments is 2.0 ovigerous lice per fish. This is only relaxed where fish are under harvest and with the agreement of the Department. For the purposes of the RPS lice modelling study, the record of ovigerous lice per fish for 2008-2016 was used; see Figure 2.8.

Figure 2.8.
National lice survey counts for mean ovigerous female lice on farmed salmon at the Roancarrig / Ahabeg and Gearhries sites 2008 to 2016.



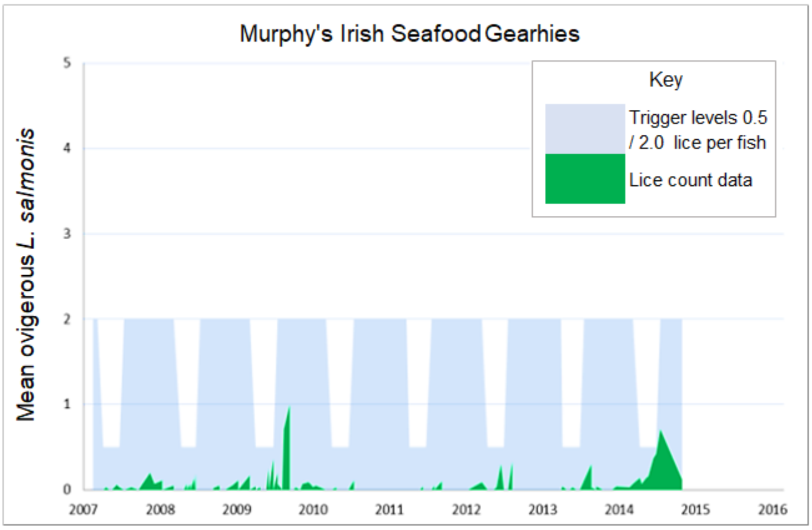


Figure 2.8 shows that ovigerous lice numbers in Bantry Bay have not breached an average of one ovigerous louse per fish at any time and indeed have not even approached 0.5 ovigerous lice per fish during the critical spring period. It is also a matter of record that MHI has only needed to treat stocks at the Roancarrig / Ahabeg sites six times during this period, and this on the basis of their own inspections, which are carried out between statutory inspections, using trigger levels for treatment of 0.3 and 1.0 lice per fish. On this basis, it was decided to base the majority of modelled lice dispersions on a worst-case, for all existing and proposed sites in the bay, at 1 ovigerous louse per fish. However, a smaller range of simulations was run at the lowest statutory trigger level for the "critical spring period" of 0.3 ovigerous lice per fish. Worst-case was further extended by using larval lice discharges from the infestation of the maximum number of second-year fish held on each site. Table 2.1 shows the numbers of Nauplii discharged into the model domain from each site.

Table 2.1.

Discharge models for RPS dispersional modelling for proposed MHI Bantry Bay sites.

Lep nauplius releases from all Bantry Bay sites at 1 ovigerous louse per fish.

Note : Model assumes that Shot Head / Fastnet are stocked in years 1 and 3; Roancarrig / Ahabeg in years 2 And 4.

Key: Critical period, when salmonid smolts may be migrating from freshwater to seawater.
Month of peak fish numbers as used for th emodel, with Shot Head and Fastnet dominant.
Grey text indicates new fish inputs; no lice present.

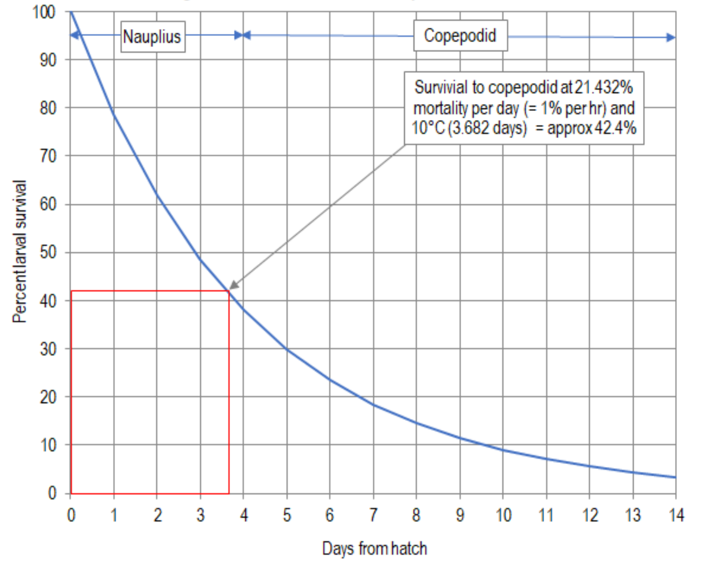
	Proposed Shot Head site			Fastnet site (Murphy's Irish Seafood)			Roancarrig / Ahabeg site			Proposed Waterfall Harvest site		
Month	Mean fish number per month	Total ovigerous lice @ 1 louse / fish	Nauplii hatched per month @ 250/clutch	Mean fish number per month	Total ovigerous lice @ 1 louse / fish	Nauplii hatched per month @ 250/clutch	Mean fish number per month	Total ovigerous lice @ 1 louse / fish	Nauplii hatched per month @ 250/clutch	Mean fish number per month	Total ovigerous lice @ 1 louse / fish	Nauplii hatched per month @ 250/clutch
Sep	Proposed Shot Head site fallow			Fastnet site fallow			732,492	732,492	183,122,973	28,992	28,992	7,247,875
Oct							723,662	723,662	180,915,518	28,992	28,992	7,247,875
Nov	825,435	825,435	206,358,863	206,359	206,359	51,589,750	717,156	717,156	179,288,912	28,992	28,992	7,247,875
Dec	808,874	808,874	202,218,625	202,219	202,219	50,554,750	709,975	709,975	177,493,858	28,992	28,992	7,247,875
Jan	799,551	799,551	199,887,762	199,888	199,888	49,972,000	704,649	704,649	176,162,298	28,992	28,992	7,247,875
Feb	794,349	794,349	198,587,287	198,587	198,587	49,646,750	697,961	697,961	174,490,303	28,992	28,992	7,247,875
Mar	790,377	790,377	197,594,351	197,594	197,594	49,398,500	647,086	647,086	161,771,419	28,992	28,992	7,247,875
Apr	786,426	786,426	196,606,379	196,607	196,607	49,151,750	538,021	538,021	134,505,374	28,992	28,992	7,247,875
May	780,924	780,924	195,231,120	195,231	195,231	48,807,750	406,217	406,217	101,554,331	Proposed Waterfall site fallow		
Jun	772,730	772,730	**193,182,517**	193,183	193,183	**48,295,750**	283,304	283,304	**70,826,100**			
Jul	762,305	762,305	190,576,302	190,576	190,576	47,644,000	174,219	174,219	43,554,868	28,992	28,992	7,247,875
Aug	747,844	747,844	186,961,113	186,961	186,961	46,740,250	59,323	59,323	14,830,674	28,992	28,992	7,247,875
Sep	732,492	732,492	183,122,973	183,123	183,123	45,780,750	Roancarrig / Ahabeg site fallow			28,992	28,992	7,247,875
Oct	723,662	723,662	180,915,518	180,916	180,916	45,229,000				28,992	28,992	7,247,875
Nov	717,156	717,156	179,288,912	179,289	179,289	44,822,250	825,435	825,435	206,358,863	28,992	28,992	7,247,875
Dec	709,975	709,975	177,493,858	177,494	177,494	44,373,500	808,874	808,874	202,218,625	28,992	28,992	7,247,875
Jan	704,649	704,649	176,162,298	176,162	176,162	44,040,500	799,551	799,551	199,887,762	28,992	28,992	7,247,875
Feb	697,961	697,961	174,490,303	174,490	174,490	43,622,500	794,349	794,349	198,587,287	28,992	28,992	7,247,875
Mar	647,086	647,086	161,771,419	161,772	161,772	40,443,000	790,377	790,377	197,594,351	28,992	28,992	7,247,875
Apr	538,021	538,021	134,505,374	134,505	134,505	33,626,250	786,426	786,426	196,606,379	28,992	28,992	7,247,875
May	406,217	406,217	101,554,331	101,554	101,554	25,388,500	780,924	780,924	195,231,120	Proposed Waterfall site fallow		
Jun	283,304	283,304	70,826,100	70,826	70,826	17,706,500	772,730	772,730	193,182,517			
Jul	174,219	174,219	43,554,868	43,555	43,555	10,888,750	762,305	762,305	190,576,302	28,992	28,992	7,247,875
Aug	59,323	59,323	14,830,674	14,831	14,831	3,707,750	747,844	747,844	186,961,113	28,992	28,992	7,247,875
Sep	Proposed Shot Head site fallow			Fastnet site fallow			732,492	732,492	183,122,973	28,992	28,992	7,247,875
Oct							723,662	723,662	180,915,518	28,992	28,992	7,247,875
Nov	825,435	825,435	206,358,863	206,359	206,359	51,589,750	717,156	717,156	179,288,912	28,992	28,992	7,247,875
Dec	808,874	808,874	202,218,625	202,219	202,219	50,554,750	709,975	709,975	177,493,858	28,992	28,992	7,247,875
Jan	799,551	799,551	199,887,762	199,888	199,888	49,972,000	704,649	704,649	176,162,298	28,992	28,992	7,247,875
Feb	794,349	794,349	198,587,287	198,587	198,587	49,646,750	697,961	697,961	174,490,303	28,992	28,992	7,247,875
Mar	790,377	790,377	197,594,351	197,594	197,594	49,398,500	647,086	647,086	161,771,419	28,992	28,992	7,247,875
Apr	786,426	786,426	196,606,379	196,607	196,607	49,151,750	538,021	538,021	134,505,374	28,992	28,992	7,247,875
May	780,924	780,924	195,231,120	195,231	195,231	48,807,750	406,217	406,217	101,554,331	Proposed Waterfall site fallow		
Jun	772,730	772,730	**193,182,517**	193,183	193,183	**48,295,750**	283,304	283,304	**70,826,100**			
Jul	762,305	762,305	190,576,302	190,576	190,576	47,644,000	174,219	174,219	43,554,868	28,992	28,992	7,247,875
Aug	747,844	747,844	186,961,113	186,961	186,961	46,740,250	59,323	59,323	14,830,674	28,992	28,992	7,247,875
Sep	732,492	732,492	183,122,973	183,123	183,123	45,780,750	Roancarrig / Ahabeg site fallow			28,992	28,992	7,247,875
Oct	723,662	723,662	180,915,518	180,916	180,916	45,229,000				28,992	28,992	7,247,875

At the beginning of each simulation, Nauplii were dispersed from mid-depth sources in single grid cells at each pen centre on all farm sites. The proposed MHI Shot Head site and the Fastnet sites were selected as dominant, that is in their second production year in their annual stocking alternation with the Roancarrig / Ahabeg and Waterfall sites, because this is when high farm infestation levels are most likely to occur. The Shot Head and Fastnet sites were selected as dominant because their locations are closer to the wild salmonid rivers at the head of Bantry Bay. This offers a worst-case for Copepodids to reach and infest wild salmonids as they migrate. Worst-case was also increased by only releasing larvae on each flood tide, to favour larval advection towards the head of the bay.

Following the initial modelled discharge of Nauplii from the sites, these metamorphose into infestive Copepodids. The numbers of Copepodids that continue to disperse were calculated using the method set out by Amundrud and Murray[8], who examined the discharge and dispersion of *L. salmonis* from salmon farm sites in Loch Shieldaig, Scotland.

After Amundrud and Murray and Stien[9], Figure 2.9. shows the selected larval mortality rate of 1% / hour from hatch, whilst the modelled development time from hatch to Copepodid is ≈4 days. This means that about 42% of the Nauplii discharged metamorphose into Copepodids. Nauplii can then be removed from the simulation if required, to mimic their metamorphosis. Expiry of Copepodids due to the exhaustion of their feed reserves is factored into the model using a 14-day cut-off.

Figure 2.9. Larval survival, days from hatch.



8 Amundrud T.L. Murray A.G. 2009 Modelling sea lice dispersion under varying environmental forcing in a Scottish sea loch. J. Fish Dis. 32, 27–44.

9 Stien A. et al 2005. Population dynamics of salmon lice *Lepeophtheirus salmonis* on Atlantic salmon and sea trout. Mar. Ec. Prog. Ser. 290, 263-275.

Note also that, again after Amundrud and Murray, that *L. salmonis* larvae are treated as neutrally buoyant, which is regarded as wholly realistic for the destratified, open water conditions of Outer Bantry Bay, where the larval lice are modelled as drifting in the plankton.

Although the RPS HD model used is a 2D model, the particle tracking was undertaken using a Lagrangian scheme. This means that each particle has a defined location in both horizontal and vertical dimensions and the particle's movement is defined by all forces acting upon it and is independent of its grid location. Within these models, the movement of the particle was calculated using the HD model data, interpolated from the grid to the particle location, with an adjustment to account for a bed shear velocity profile through the water column. In unstratified flows, the surface velocities are greater than average and, in all areas, flow at the bed tends towards zero; therefore, a logarithmic profile was applied. This however may not be the case in strongly stratified flows or in areas of counter flow, such as in impounded loughs / lochs and fjords. Additionally, each particle was applied with dispersion characteristics defined as a function of current speed, with a lesser degree of dispersion in the vertical dimension. The dispersion included a random function in order that the particles would exhibit the natural variation shown in reality.

A range of types of dispersion modelling outputs were used for this study. In each case a logarithmic scale colour palette was necessary in order to illustrate the full range of values that occur. Thus at least fifteen colour intervals are applied, and the minimum value is 2,000 times smaller than the maximum value used, of 1 louse larva/m^3.

- Plume envelope plots.
  Plume envelope plots generally show the density contours of dispersing particles over entire simulations and can be useful in giving an overall impression of a dispersion.

  - Maximum plume envelope plot.
    Maximum plume envelope plots are hypothetical, statistical plots. In the present case, they show only the <u>maximum</u> value (in this case larval density) that occurs in each grid cell throughout the 22-day simulation period, no matter how short-lived. The shortest-lived density value may only last for a few seconds but will still show up on a Maximum plume plot.

  - Average plume envelope plot.
    Average plume envelope plots are also hypothetical, statistical plots. In this case, they show the <u>mean</u> density value for every grid cell, for all timesteps during the 22-day simulation period.

    If many grid cells give much lower values in the Average plot than in the Maximum plot, many grid cell values in the Maximum plot must occur very only rarely in the simulation. This is a normal outcome.

- Typical plot.
  Typical plots offer a real representation of dispersal, by providing values for a specific, single timestep only. These are not, strictly speaking, envelope plots but grid cell plots. In the RPS Bantry Bay model, single timestep plots are used to show typical conditions at mid-ebb and mid-flood tide on single tides, during the 22-day simulation, for each plot. Whilst Maximum and Average plots are statistical and are not representative of a simulation-specific moment in time, they can be used to help qualify Typical plots, and to indicate whether or not they can be treated as representative of a simulation as a whole.

- Graphical time series plots at target receptors.
  These plots graph time series of values, for a specific grid cell or group of grid cells (for example in a line), drawn within a model domain, for as much of the simulation period as required. In this study, time series plots for target grid cells along a line across the entrance to Trafrask Harbour were examined and are commented on below.

2.3.2. Dispersion modelling of *L. salmonis* larvae in Bantry Bay Results.

Figures 2.10 and 2.11 show Maximum and Average plume envelope plots for the Copepodid dispersions from all Bantry Bay sites, resulting from a mean infestation of 1 ovigerous female louse per farmed fish.

Figure 2.12 shows a Typical plot series, for single timesteps, on a single, mid-ebb tide (2.12.1 and 2.12.2) and a single, mid-flood tide (Figures 2.12.3 and 2.12.4).

Figures 2.12.1 and 2.12.2 compare the single timestep grid cell density values on mid-ebb tide for the dispersal of Nauplii and Copepodids combined (Figure 2.12.1) against Copepodids only (Figure 2.12.2).

Figures 2.12.3 and 2.12.4 do the same for the mid-flood tide timestep.

The purpose of this comparison is to show that Nauplii, which metamorphose into Copepodids ≈4 days post-hatch, are non-infestive and are therefore not directly part of the risk analysis. Their dispersion is nonetheless relevant to the analysis because comparison of these plume pairs indicates how far Nauplius larvae can be dispersed from their mid-pen sources before they metamorphose into Copepodids. Nauplius dispersal is therefore a factor in the extent of Copepodid dispersion.

A number of observations can be made from the analysis and comparison of Figures 2.10 to 2.12:-

- The differences between the Maximum and Average plume plots in Figures 2.10 and 2.11 are so stark that it is evident that the majority of grid cells with density values >0.0005 Copepodids/m^3 in the Maximum plume plots only retain their values for very short periods of time (i.e. very few timesteps) before diluting to the lowest plotted values (zero to 0.0005 Copepodids/m^3, in pale blue, on the contour scale provided).

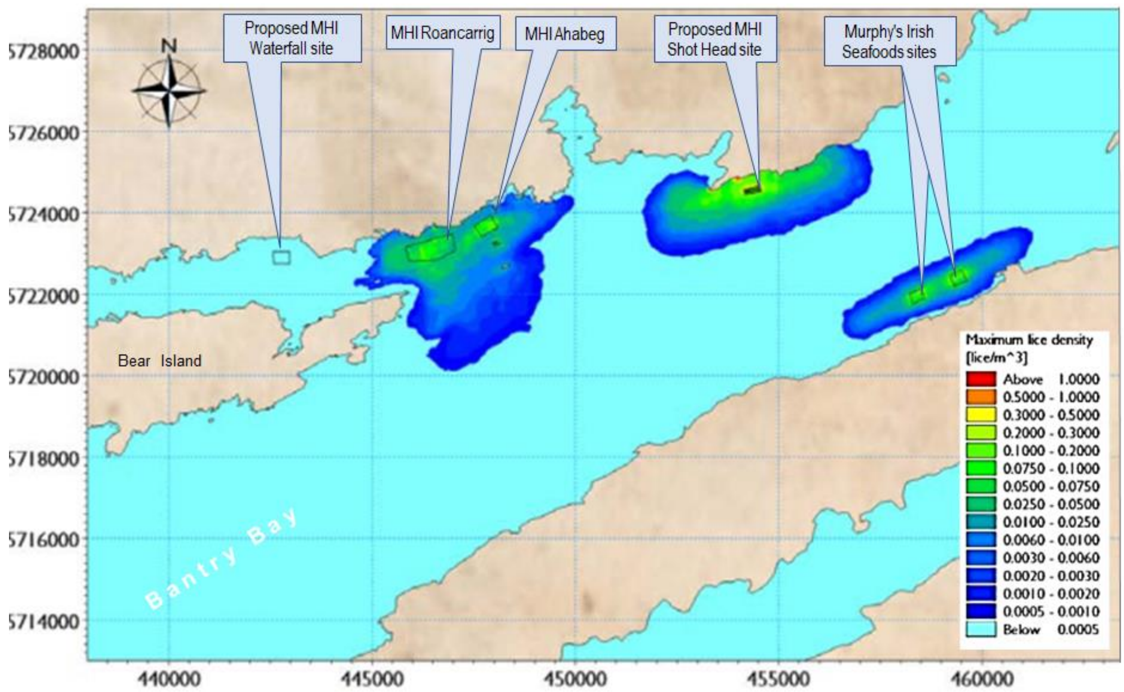


Figure 2.10
Maximum plume envelope plot of dispersing copepodid density, from 1 ovigerous louse per fish for all existing and proposed Bantry Bay salmon farm sites, Shot Head / Fastnet dominent.

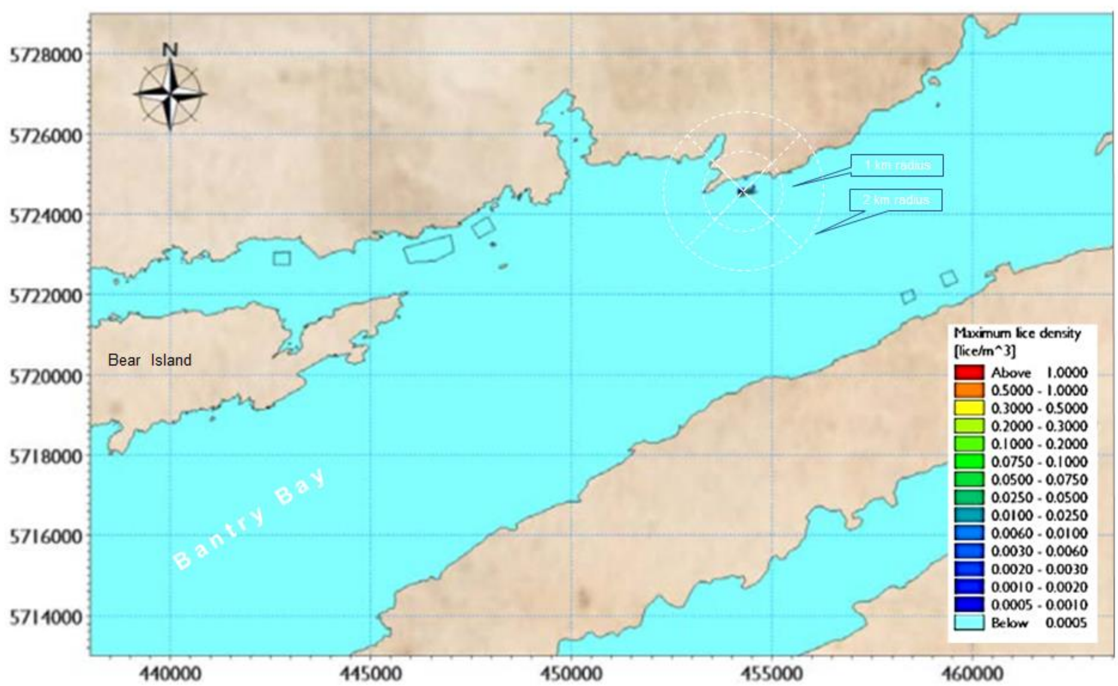


Figure 2.11
Average plume envelope plot of dispersing copepodid density, from 1 ovigerous louse per fish for all existing and proposed Bantry Bay salmon farm sites, Shot Head / Fastnet dominent.

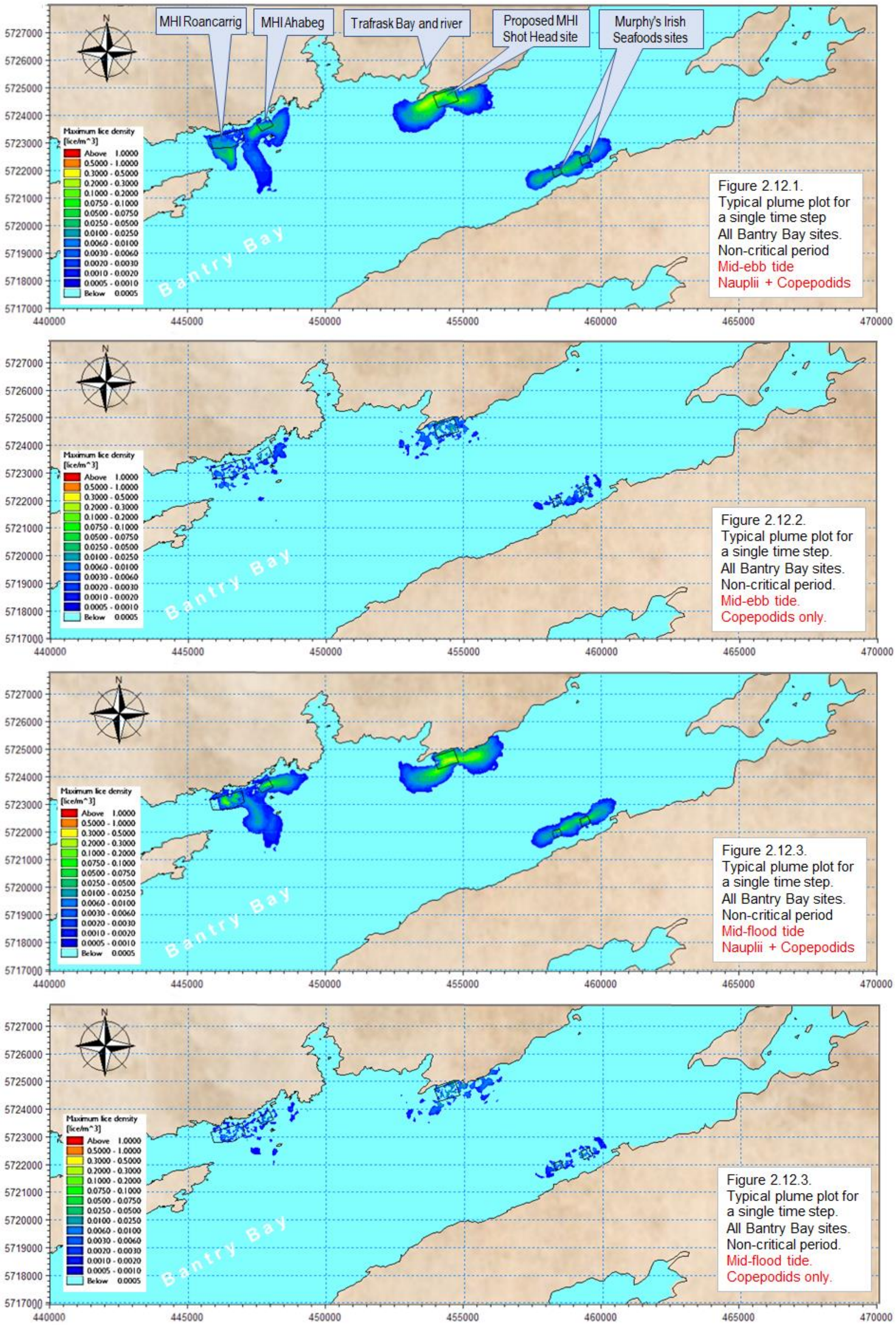
- Comparison between the Average plots in Figure 2.11 and Typical plots in Figure 2.12 show that Average plume densities (which cover the entire duration of the 22-day simulation) are lower than the Typical grid cell densities, which only cover grid cell density for a single instance, as a snapshot, at mid-ebb tide (Figure 2.12.2) and mid-flood tide (Figure 2.12.4). This suggests that, for the whole simulation, the Typical mid-ebb and mid-flood density values are at best intermittent, with lower densities than indicated in the Typical plots occurring during the majority of timesteps. It can therefore be concluded that the adoption of Typical mid-ebb and mid-flood timestep values provides a reasonable (worst-case) basis on which to judge the risks imposed by farm-origin Copepodid dispersal, both in the near-field and in the far field. These plots are therefore adopted for that purpose in the following analysis.

- From Figures 2.12.2 and 2.12.4, it can be seen that Typical plot Copepodid densities fall to a range of zero to 0.01 Copepodids/m^3 within 1km of all licensed site boundaries. Small groups of grid cells between 1 and 2 km from the site boundaries show Copepodid densities between zero and 0.002 Copepodids/m^3. Beyond this, no grid cell density exceeds a value of 0.0005 Copepodids/m^3, on the contour scale provided.

- There is minimal, if any, dispersal overlap (i.e. in the value range zero to 0.0005 Copepodids/m^3 on the contour scale provided) between individual site plumes even at the limits of the hypothetical Maximum plume plots, except in the case of the Roancarrig and Ahabeg sites. The Typical plots suggest that the plume overlap between the Roancarrig and Ahabeg sites (the licensed site boundaries of which are separated by 800m) could cause very low densities of Copepodids to drift intermittently (taking note of the Average plume plots) between these two sites, perhaps of the maximum order of 0.01 Copepodids/m^3. It should be noted however that the statistical plots aggregate lice densities over the entire tide cycle and although the plume envelopes from each site overlap, the discharge plumes do not travel towards one another at any time, i.e. the plumes mobilise in unison on the ebb tide, and again flood tide. However, since cross-farm infestation risks the establishment of new, on-site lice populations, this should be avoided if possible. MHI operates these two sites as a single farming unit but this potential exposure has been brought to the company's attention and steps are now being considered to mitigate this possible risk, since it may increase infestation at either site and therefore increase the need for treatment.

- More to the point in the context of this report, there is only a minimal risk of cross-site infestation, between the proposed Shot Head site and other sites in Bantry Bay (in the range of zero to 0.0005 Copepodids/m^3 on the contour scale provided).

Figure 2.12
Typical plume envelope plots of dispersing larval density, from 1 ovigerous louse per fish fish for all existing and proposed Bantry Bay salmon farm sites, for a single time-step at mid-ebb and mid-flood tide, Shot Head / Fastnet dominent; still weather conditions.



- Comparison between the combined Nauplius + Copepodid dispersal plots and the Copepodid only dispersal plots in Figure 2.12 shows that Nauplii are dispersed rapidly away from all mid-pen sources during their 4-day lifespan, prior to their metamorphosis. This dispersal is driven by local residual currents (see Figures 2.4 and 2.5) and the wider, open-water hydrography in the outer bay (see Figures 2.1 to 2.6).

- Plots 2.12.1 and 2.12.3 demonstrate the impact of the initial dispersal of Nauplius larvae, away from their in-pen sources, in reducing the infestation pressure residing in the Copepodid population post-metamorphosis. These figures also provide clear evidence that *L. salmonis* is not adapted for optimised infestation of salmon farm sites, or of individual migrating wild salmonids in open waters, because their infestive phase is dispersed and diluted widely in open water currents, in Naupliar dispersal, before having any opportunity to infest, post-metamorphosis. This contrasts with *L. salmonis'* evolved natural infestation strategy, which is optimised for its natural location, by the maintenance of both Nauplius and Copepodid densities in calmer, shallower waters inshore; see Section 2.3.3, Discussion Point 2.

- All plots indicate that insignificant numbers of Copepodids (zero to 0.0005 Copepodids/m^3 on the contour scale provided with these plots) will disperse towards any salmonid river estuary during the 14-day post-hatch dispersal, even in the hypothetical case of Maximum plume plots.

In Figure 2.13, Typical mid-ebb and mid-flood tide grid cell plots are used again to show the impact of wind on Copepodid dispersion, from the Shot Head site only. These plots employ a wider plotting scale than those in all previous plots with both lower and higher values added. The additional upper density values are 1.0000 to 2.0000 and >2.0000 Copepodids/m^3 and the additional lower values are 0.0003 to 0.0006, 0.0002 to 0.0003, 0.0001 to 0.0002 and <0.0001 Copepodids /m^3. Logarithmic plotting scales are still used, the minimum being 20,000 times smaller than the new maximum value (which has increased from >1.0000 to >2.0000).

This analysis was conducted because some recent contributions to the literature have proposed wind as a forcing factor that can drive[10, 11] or even "reconcentrate"[12, 13] farm-origin Copepodids into natural wild infestation

[10] Gillibrand P.A., Willis K.J. 2007. Dispersal of sea louse larvae from salmon farms: modelling the influence of environmental conditions and larval behaviour. Aquat. Biol. 1, 630-75.

[11] Amundrud TL. Murray A.G. 2007. Validating particle tracking models of sea lice dispersion in scottish sea lochs ICES CM 2007/B:00.

[12] Amundrud TL. Murray A.G. 2009. Modelling sea lice dispersion under varying environmental forcing in a Scottish sea loch. J. Fish Dis. 32, 27-44.

[13] Costello M.J. 2009. How sea lice from salmon farms may cause wild salmonid declines in Europe and North America and be a threat to fishes elsewhere. Proc. R. Soc. B. doi:10.1098/rspb.2009.0771

areas, inshore and in estuarine reaches, through which wild salmonid smolt and adults migrate. In fact, this concept, which stems from limited modelling studies, has become part of the vernacular in the broad case now made against salmon farming[14]. The question asked in this document is whether or not this apparent mechanism, which *L. salmonis* is unlikely to be evolved to achieve, applies in the case of Bantry Bay and, in particular, if it impinges on the direct risk of lice infestation, on wild salmonids native to the Trafrask River or, for that matter, any other river in the bay.

Wind has a more significant influence on the hydrography of Bantry Bay than is the case for perhaps the majority of the embayments where salmon farms are located, although there certainly are some other, similar bays, in Ireland at least. Bantry Bay is funnel-shaped, with a wide unsilled mouth. It narrows and shallows, more or less symmetrically, towards its head. The bay faces directly into the prevailing SW wind direction, with an unimpeded fetch length of up to 6,500km, within which south-westerly Atlantic storms can initiate and gather strength. Wind-induced currents start to develop after only four hours in a Force 4 wind. Overall, winds of greater than Force 4 blow for 50% of the time in Bantry Bay, irrespective of direction. 35% of all winds that affect the bay blow from the southwest. This is also the quarter from which the longest durations of the strongest winds arises. Force 4-6 (5.5 to 13.8 $msec^{-1}$) winds blow from the south to west for 33% of the time and winds of over Force 7 (over 13.9$msec^{-1}$) blow for 3% of the time. Subject to wind strength, the consequences of elevated offshore and local overwater windspeeds include wind-induced current elevation in both horizonal and vertical planes and increased wave climate[15], including increase in the onshore overturning wave profile. Elevated windspeeds also induce sediment resuspension and transport, subject to water depth and direction[16]. See wind rose in Figure 2.22.

The wind sensitivity simulations included the impact of wind penetration into the water column. The behaviour of particles within the zone of wind influence was modelled accordingly, i.e. those closest to the surface were subjected to the greatest wind influence. The resulting particle location was a result of the combination of both tidal current advection and wind-induced advection and dispersion. In shallow nearshore areas, where the potential wind influence depth is deeper than actual water depth, an overturning current was applied, as occurs in reality (as onshore currents cannot persist without some returning flow). It should however be noted

[14] Shephard S. et al 2016. Aquaculture and environmental drivers of salmon lice infestation and body condition in sea trout. Aquacult Environ Interact 8, 597-610.

[15] See Shot Head EIS Section 2.4.

[16] See Main RPS Report 2015 : Water Quality Modelling for all existing and currently proposed salmon farm sites in Bantry Bay IBE07/R07/ Rev02/NS.

that these wind conditions would be accompanied by wave climate and Reynolds stresses would impose much greater turbulent mixing, as well as overturning currents to the water column. In this case, wave-induced overturning and littoral currents were not applied within the model, to provide a worst-case scenario.

Figure 2.13 compares Typical one-timestep tidal current (i.e. still weather), Copepodid density plots at mid-ebb tide (Figure 2.13.1) and mid-flood tide (Figure 2.13.2), with similar plots, where the currents are forced by a sustained Force 5 wind, blowing from the southwest (Figures 2.13.3 for mid-ebb and 2.13.4 for mid-flood). A sustained SW Force 5 was selected for several reasons, in order to generate worst-case outcomes:-

- It is known that a Force 5 wind, in particular from the SW, will create wind-induced currents. The likely range of impacts on in-bay hydrography are set out above.

- South-westerly winds are the most likely to occur in the West Cork area, being from the prevailing direction.

- Wind induction can be expected to be greatest over the longest fetch in the bay, that is in its long axis (i.e. SW) relative to across-bay fetches

- Note, however, that the wind-forcing in this modelled case was sustained over the entire, 22-day simulation period. This is highly unlikely to occur under natural climate conditions.

These four plots show dispersions originating from an infestation of 0.3 ovigerous female lice per farmed fish, rather than 1.0 ovigerous female lice per fish, as used in Figures 2.10 to 2.12. Figures 2.13.5 (for mid-ebb tide) and 2.13.6 (for mid-flood tide), show similar plots to Figures 2.13.3 and 2.13.4, but, again, with Copepodid dispersal originating from a mean, on-farm infestation level of 1.0 ovigerous female lice per fish.

To assist in the interpretation of Figures 2.10 to 2.13, Figure 2.14 gives time series plots of the introduction, metamorphosis, dispersal and mortality of larvae (2.14.1) within the Shot Head site area. In Figure 2.14.2, introduced Nauplii are removed from the plot from day 4, to show Copepodid densities post-metamorphosis. Note that larval mortality and dispersal reduces Copepodid in-site densities to about 10% of total larval densities. Figure 2.4.3 shows the tidal fluctuation, with Nauplius inputs on the flooding tide highlighted in blue. The process of input, mortality, metamorphosis and dispersal continues throughout each 22-day simulation. For further clarification, Table 2 gives the modelled Copepodid density ranges shown Figures 2.13 and 2.14, in tabular form.

Figure 2.13.
Typical grid cell plots of dispersing Copepodid larval density from Shot Head site only to show impact of sustained Force 5 SW wind through simulation on dispersion.
0.3 vs 1.0 ovigeorus lice, no wind vs. wind, for single mid-ebb and mid-flood timestep.
Key : 1km and 2km radius circles from site centres shown to scale Table 2.2.

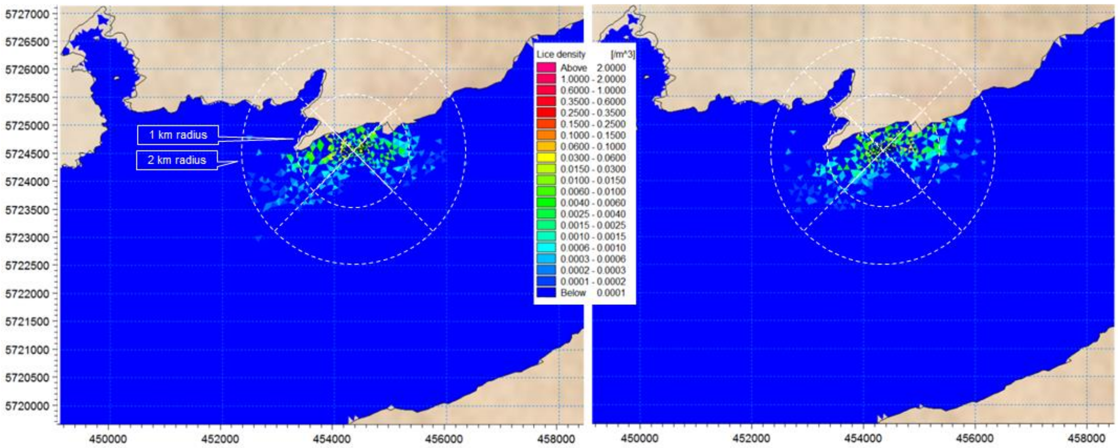


Fig. 2.13.1. Dispersion from 0.3 ovig. lice/fish, no wind, mid-ebb.

Fig. 2.13.2. Dispersion from 0.3 ovig. lice/fish, no wind, mid-flood.

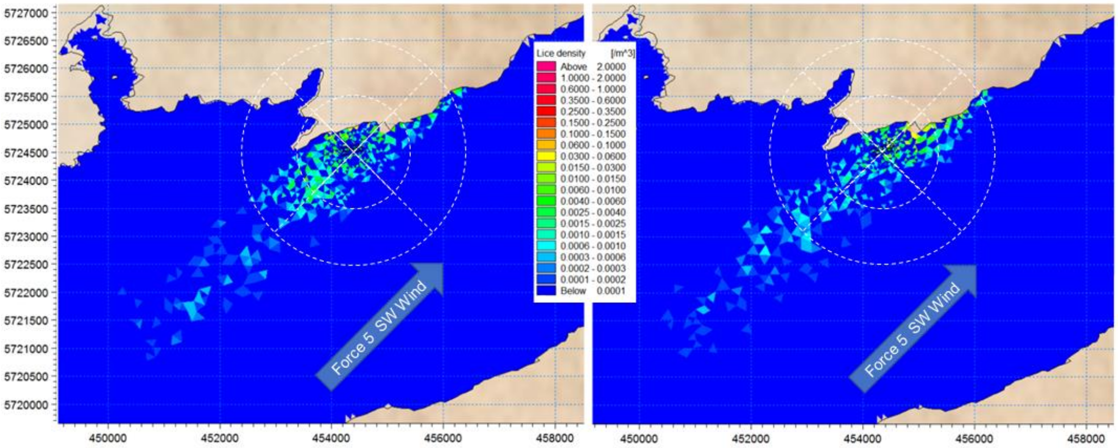


Fig. 2.13.3. Dispersion from 0.3 ovig. Lice/fish, F5 SW wind, mid-ebb.

Fig. 2.13.4. Dispersion from 0.3 ovig. Lice/fish, F5 SW wind, mid-flood.

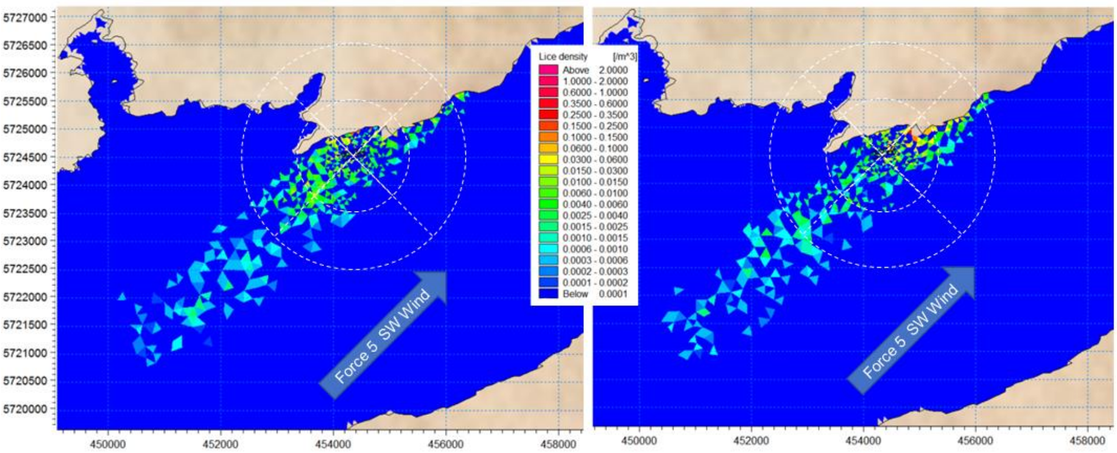


Fig. 2.13.5. Dispersion from 1.0 ovig. Lice/fish, F5 SW wind, mid-ebb.

Fig. 2.13.6. Dispersion from 1.0 ovig. lice/fish, F5 SW wind, mid-flood.

Figure 2.14.
Time series plot of larval lice density per pen across the Shot Head site resulting from Nauplius discharges (from 0.3 oviferous female lice per farmed fish) and dispersal.
Note there are 12 coloured plots, each representing an in-pen density.

Figure 2.14.1.
Total larval densities per pen, resulting from Nauplius hatches from 0.3 ovigerous female lice per farmed fish, and their discharges on each flooding tide over 14 tides and Nauplius and Copepodid (post metamorphosis) dispersal and mortalities.

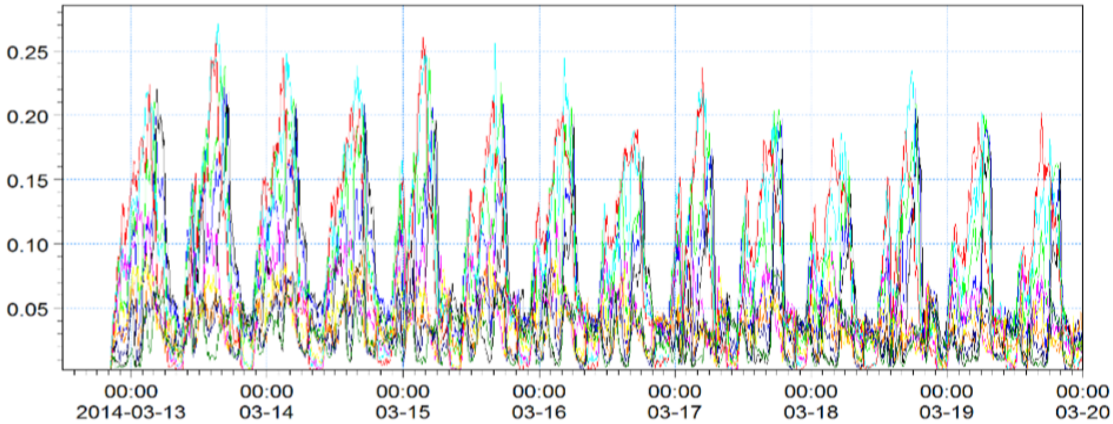


Figure 2.14.2.
Total Copepodid densities per pen; Nauplius population removed from the plot from Day 4, (i.e. post-Nauplius metamorphosis). Note losses from pens due to dispersal and mortalities still apply.

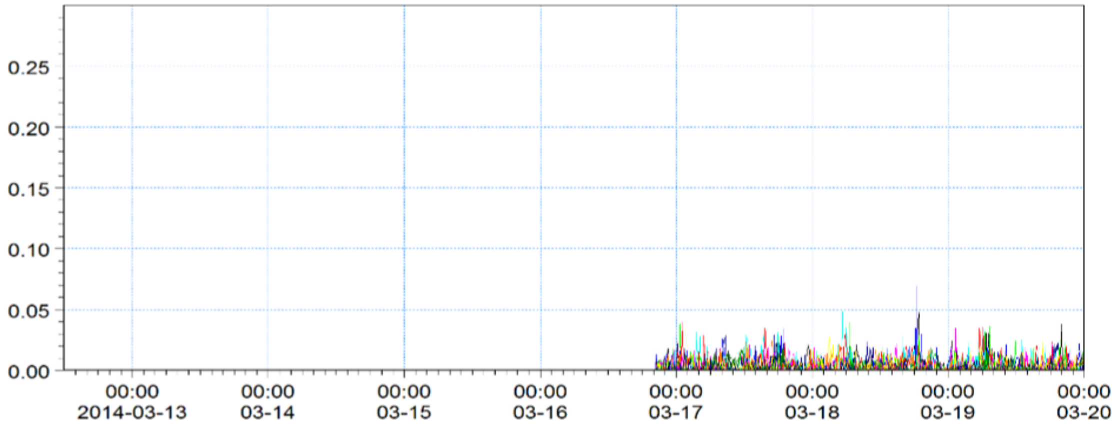


Figure 2.14.3.
Tidal elevation plot.
Duration of larval discharges at pen centres over rising flood tides only, as indicated by blue columns.

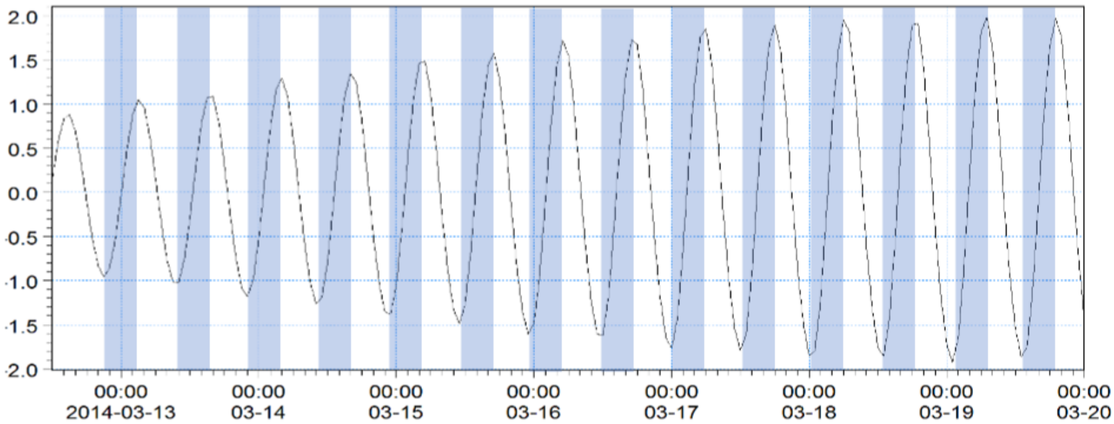


Table 2.2.
Estimates of grid cell value ranges in still weather and Force 5 wind in Typical and Time Series plots. See in particular Figures 2.13 and 2.14.

	Tidal state	Copepodids / m^3 mid-ebb tide		Copepodids / m^3 mid-flood tide		Comments
	Mean ovigerous female lice per farmed fish	0.3	1.0	0.3	1.0	
Still weather tidal ccurrents	Within site boundary	Zero to 0.050	Zero to 0.165	Zero to 0.040	Zero to 0.0132	Read from Figure 2.14.2. Highest values in individual pens, for few single timesteps only
	Offshore, within 1 km of site centre	Zero to 0.030	Zero to 0.100	Zero to 0.030	Zero to 0.100	0.3 levels from Figure 2.13.1, 2.13.2. 1.0 level = 0.3 levels * 3.3. Maximum cell values just west of site on ebb, just east of site on flood
	1-2km from site centre (open waters)	Zero to 0.0040	Zero to 0.0132	Zero to 0.0040	Zero to 0.0132	0.3 levels from Figure 2.13.1, 2.13.2. 1.0 level = 0.3 levels * 3.3. Maximum cell values west of site on ebb, just over 1km east of site on flood
	>2km from site centre (open waters)	Zero to 0.0002*	Zero to 0.0006*	Zero to 0.0001	Zero to 0.0003	* Applies to highest value in each case on ebb applies to one single grid cell just over 2km SW of site. Otherwise max as for flood current
	Outside plume axis (open waters)	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	
	In salmon river estuaries	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	As for all open waters except *. However line plots across nearest estuary (Trafrask) suggest estuary values at lower end of given range, if not zero.
Force 5 sustained SW wind	Within site boundary	Zero to 0.0300	Zero to 0.1000	Zero to 0.040	Zero to 0.132	Read from Figures 2.13.3 to 2.13.6. SW Plume. Slightly lower grid cell values in site area on mid-ebb tide than on mid-flood. High values intermittant.
	Offshore, within 1 km of site centre	Zero to 0.030	Zero to 0.100	Zero to 0.010	Zero to 0.033	Read from Figures 2.13.3 to 2.13.6. Higher grid cell values become more intemittant and dispersed with distance from site. Plume maintained to SW. No grid cell over minimum value beyond 5km from site. Overriding majority of grid cells <0.0001 Copepodidis /m^3 from 1km out, even from 1 ovigerous female per farmed fish.
	1-2km from site centre (open waters)	Zero to 0.0100	Zero to 0.0300	Zero to 0.0025	Zero to 0.010	
	>2km from site centre along axis of plume	Zero to 0.0006	Zero to 0.0025	Zero to 0.0015	Zero to 0.006	
	Outside plume axis (open waters)	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	
	In salmon river estuaries	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Read from Figures 2.13.3 to 2.13.6. Effectively zero Copepodid density in all salmon river locations from all sites.

The following observations and comments apply to the Typical plots shown in Figures 2.13, 2.14 and Table 2.2:-

- The still-weather plots for mid-ebb and mid-flood timesteps in Figures 2.13.1 and 2.13.2 (from 0.3 ovigerous / farmed fish) show very similar outcomes, although the ebb pattern exhibits a slightly more downstream spread of slightly higher grid cell density values than the mid-flood dispersal pattern, as might be expected.

- Peak grid cell values, between to 0.06 Copepodids/m^3, (from 0.3 ovigerous / farmed fish) occur extremely close to the in-pen dispersion sources from a minority of pens in both 2.13.1 and 2.13.2 plots (see also Figure 2.14.1) and reduce to zero to 0.03 Copepodids/m^3 within 1km of the site centre, higher values are in the minority. This range dwindles to typical values of zero to 0.0001 Copepodids/m^3 within 2km of the site boundary in every direction, in both plots.

- In the Typical plots in Figures 2.13.3 and 2.13.4, (wind-forced, from 0.3 ovigerous lice / farmed fish), it is evident that a sustained Force 5 SW wind forces a wider dispersal but perhaps not as might be expected. In both mid-ebb and mid-flood plots, the dispersion is forced south-westerly, more or less in the axis of, but mostly opposing the wind direction.

- A further apparent outcome is a temporary density elevation in three or four isolated grid cells inshore of the site boundary, to values of the order of 0.1 Copepodids/m^3, in some plots. These are an artefact created in the model, where grid cells become temporarily restricted by shallowing to depths of <1m, because density is measured in the model in m^3. This only applies in individual grid cells, which normalise as they return offshore in subsequent timesteps.

- All individual grid cell density values fall into the range of zero to 0.004 Copepodids/m^3 within 2 km of the site boundary in the plume direction and fall further beyond that, to typically reach the lowest contour value of zero to 0.0001 Copepodids/m^3 within 5km SW of the site boundary, in the predominant plume direction. Beyond the limits of the plume and lateral to the plume, values are invariably in the range zero to <0.0001 Copepodids/m^3, even closer to the dispersion sources.

- Figures 2.13.5 and 2.13.6 are directly comparable with Figures 2.13.3 and 2.13.4 respectively. The only difference between each plot pair is that the numbers of dispersing Copepodids is 3.3 times higher in Figures 2.13.5 and 2.13.6, since they arise from an on-site infestation of 1.0 ovigerous lice / farmed fish, rather than 0.3. The consequences of this difference are evident in the appearance of more grid cells inshore of the site boundary with density values of 0.03 to 0.06 Copepodids/m^3 or higher, and up to 0.150 to 0.250 Copepodids/m^3 for one cell in the mid-flood plot, in Figures 2.13.5 and 2.13.6. Overall however, whilst cell values tend to be 3.3 times higher than in the 0.3 lice counterpart plots in Figures 2.13.3 and 2.13.4, the extent of the plume to the point where the lowest value contour of zero to 0.0001 Copepodids/m^3 is reached is virtually unchanged.

- Even under the worst-case constructed for typical plot dispersions and excluding anomalous cells inshore of the site, the highest Copepodid densities reached (from 1.0 ovigerous / farmed fish) lie in the range of Zero to 0.1 Copepodids/m^3. The higher values occur close to the source and dissipate well within 1km of the site centre. Density values typically fall to the lowest contour levels mapped, in the range of zero to 0.0001 Copepodids/m^3, within 2km of the site centre and invariably fall to zero to 0.0001 Copepodids/m^3 beyond 2km from the site centre in still weather and beyond the immediate influence of the plume in wind-forced conditions in a Force 5 SW sustained wind.

Collectively, these observations on modelled farm-origin lice dispersion in Bantry Bay show that no grid cells with density values above the lowest contour level mapped travel eastwards much beyond 2.1km from the site centre and this only along the inshore margin, just east of the site. This occurs in a Force 5 sustained wind but not in still weather (see Figure 2.13). Time series plots across the mouth of Trafrask Bay (not illustrated in this report because they just show a zero line) show that zero Copepodids enter Trafrask Bay. These therefore show that no farm origin lice reach the Trafrask River system. Because of their geographic and hydrographic distance from salmon farm sites, much the same is held to be true for other river estuaries in the bay. This indicates that, under all conditions tested, no farm origin Copepodids can augment natural wildlife infestation in Bantry Bay river estuaries.

2.3.3. Dispersion modelling of *L. salmonis* larvae in Bantry Bay; Discussion.

To help qualify and quantify the direct risks of farm-origin salmon louse infestation on wild salmonid stocks migrating to and from the Trafrask River system and other Bantry Bay rivers, mathematical models have been generated using the global standard MIKE suite of modelling software. Such mathematical models are now used very widely indeed to define the impacts of discharges and pollutants across the globe, as well as for a range of other purposes. In the case of salmon farming, modelling is now used to a greater or lesser degree in all salmon farming countries. Modelling on lice dispersal has now been conducted, in at least Norway[17], Scotland[18], Chile[19], Canada[20], and in Ireland, as reported herein.

[17] For example, Asplin A. et al 2014. Dispersion of salmon lice in the Hardangerfjord Mar. Biol. Res. 10, 216-225.

[18] For example, Amundrud T.L. Murray A.G. 2009 Modelling sea lice dispersion under varying environmental forcing in a Scottish sea loch. J. Fish Dis. 32, 27–44.

[19] See http://910.chile.sinmod.com/.

[20] See http://www.dfo-mpo.gc.ca/aquaculture/sci-res/species-especes/sea-lice-poux-eng.htm.

In the light of some submissions to ALAB during the appeals process and of comments made during the oral hearings chaired by the Board, it is felt that a number of issues in respect of the modelling procedures employed and their outcomes, as well as the biology of the salmon louse, (as it applies to the two-way infestation relationship between wild salmonid stocks and salmon farms), require further qualification in order to offer the best advice towards a safe decision by ALAB on the Shot Head licence. These issues are analysed further in the following Discussion Points:-

1. Further qualification and quantification of infestation risk.
2. Biology of the salmon louse as it applies to wild to wild infestation.
3. Biology of the salmon louse as it applies to wild to farm infestation.
4. Biology of the salmon louse as it applies to the potential for farm to wild and farm to farm infestation in Bantry Bay.
5. Salmon lice and the status of wild salmon stocks in Bantry Bay rivers.
6. A “Norwegian opinion” submitted to ALAB by IFI.

These Discussion Points are now dealt with in turn.

Section 2.3.3. Discussion Point 1.
Further qualification and quantification of infestation risk.

Analysis of infestation risk can be achieved in this case by quite simple statistical arguments which examine modelled Copepodid dispersal and Copepodid swimming capabilities, in their efforts at host location. However, modelled plots only offer static images of dispersal at single points in time (Typical plots) or statistical overviews of longer time periods (Maximum and Average plots). In reality, hydrography and dispersion are dynamic, where the water body (and particles carried within it) move constantly through the mesh cell locations in all three dimensions, as the result of tides and other forces, as they disperse. Thus, host fish will encounter constantly-changing infestation pressure, between the minimum and maximum values in the modelled range. Further, by the nature of dispersal, maximum values dwindle with distance from their source, until a uniform zero field is reached.

If stimulated by water movement[21] or semiochemicals[22], [23], or other stimulus from passing salmonids, Copepodids can dart up to 10cm in order to achieve host attachment. The theoretical maximum “attack range” of *L. salmonis* Copepodids can therefore be represented by a

[21] Heuch P.A., Karlsen H.E. 1997. Detection of infrasonic water oscillations by copepodids of *Lepeophtheirus salmonis* (Copepoda: Caligidae). J. Plank. Res. 19,6 735-747.

[22] A pheromone or other chemical that conveys a signal from one organism to another so as to modify the behaviour of the recipient organism.

[23] Devine G.J. et al. 2000. Salmon lice, *Lepeophtheirus salmonis*, exhibit specific chemotactic responses to semiochemicals originating from the salmonid, Salmo salar. J. Chem. Ecol, 26(8), 1833–1847.

sphere of 10cm radius (20cm diameter). 125 such spheres can be close-packed into a one-metre cube ($1m^3$). Thus, infestation of wild salmonids passing through such a cube by the minimum of one Copepodid is only 100% certain when the cube is populated with at least 125 Copepodids, equally dispersed in the cube (i.e. 125 Copepodids/m^3). From this starting point the following risk calculations can be made. For simplicity, all primary calculations below relate to the Copepodid numbers resulting from egg hatches from 1 ovigerous louse per farmed salmon at the Shot Head site.

From Figures 2.13, 2.14 and Table 1, the Copepodid densities that can arise beyond the immediate pen area (where the pens themselves prevent passage of wild fish for infestation), confidence levels for lice attachment can be calculated from grid cell density values as follows (note again that these calculations are based on 1 ovigerous louse per farmed salmon at the Shot Head site:-

Within 1km of the site centre, in both calm weather and Force 5 SW wind conditions, Typical grid cell values lie in the range of:-

Zero and 0.10 Copepodids/m^3 (C/m^3)
At zero to 0.1 C/m^3, the confidence level for attachment of one Copepodid to a passing salmonid lies between:-

Zero and 0.08% (= (0.1 / 125)%), that is between zero chance and one chance in 1,250 of attachment.

1km beyond the site centre, specifically in the direction of the plume, Typical grids cell values lie in the range of zero and 0.004 C/m^3.

At zero to 0.004 C/m^3, the confidence level for attachment of one Copepodid to a passing salmonid lies between:-

Zero and 0.0032% (= (0.004 / 125)%), that is between zero chance and one chance in 31,250 of attachment.

In all areas outside the plume in outer Bantry Bay, beyond farm sites, Typical grid cell values lie in the range of Zero and 0.0001 C/m^3.

At zero to 0.0001 C/m^3, the confidence level for attachment of one Copepodid to a passing salmonid lies between:-

Zero and 0.00008% (= (0.0001 / 125)%), that is between zero chance and one chance in 1,250,000 of attachment.

Obviously at the 0.3 ovigerous lice per farmed fish trigger level, which applies during the “critical period”, when smolts are running (see Figure 2.8), the risk values given in red will all be reduced to one third.

These outcomes provide a summary picture of confidence levels for single Copepodid attachment with distance from salmon farm sites in the specific case of outer Bantry Bay, based on data for Shot Head.

The following observations arise:-

In fact, the infestation risks calculated ignore the central purpose of Copepodid attachment, which is development of settled stages to the adult stage and mating, for which at least <u>two</u> lice of opposite sex are required. Even in the case of the greatest chance of infestation by one Copepodid quoted (zero to 0.08% chance within 1 km of the site centre), and assuming that the Copepodid population is 50 : 50 male to female, the chance of attachment of <u>two</u> Copepodids of <u>opposite sex</u> lies between:-

Zero to (0.05/125)*(0.05/125)% = Zero to 0.000016% or
Zero chance to 1 chance in 6,250,000 of attachment
of one male and one female Copepodid to a single host fish.

Thus, in the case of the open, destratified waters of Bantry Bay and the locations of its existing and proposed salmon farm sites, the risk of a farm-origin infestation of wild salmonids by a potentially mating pair of lice will always lie in the range of zero to many millions to one, even close to the farm larval source.

The only conclusion that these findings can lead to is that there is effectively zero direct risk of infestation of wild salmonids by one or more mating pairs of lice, either of wild smolt within any natural inshore infestation zone of any river, or of in-migrating adults or out-migrating smolt in the open waters of Bantry Bay

<u>These results apply only to the specific case of Bantry Bay. It is not the task of this document to investigate other salmon farm locations, in very different embayments, with different hydrographies and far more sites and far greater production levels, where infestation risks could be very different.</u>

Section 2.3.3. Discussion Point 2.
The biology of the salmon louse as it applies to wild to wild infestation.

In contrast to the low infestation potential from farm sites modelled in the open waters of Outer Bantry Bay illustrated in Discussion Point 1, wild to wild *L. salmonis* infestations in natural, inshore infestation zones, which are well-documented, frequently show numerous Chalimus larvae (see Box 1) settled on individual fish. This indicates that wild Copepodids can reach sufficiently high densities inshore for many to achieve more or less simultaneous settlement on individual fish, such that matings will occur.

There are records of wild *L. salmonis* epizootics from many years before the advent of salmon farming[24], [25], just as there are of wild stock reductions and collapses. The question that therefore arises is not if, but how wild *L. salmonis* might achieve its evolved infestation objectives in its natural, inshore infestation zones.

Whilst empirical evidence of precise mechanisms seems to be incomplete in the literature, it has long been agreed that ripe, wild ovigerous female lice reach their natural, inshore infestation zones attached to wild salmonid hosts, returning to their natal rivers release to breed. Nauplii first hatch from the egg sacs of ovigerous female lice whilst attached to host fish. These metamorphose into Copepodids in the relatively still and shallow waters through which the next generation of wild smolt emerge in spring, to commence their migrations. Thus, right from the outset, there is a natural vector mechanism in place to facilitate the coincidence of critical masses of out-migrating wild smolt hosts with wild parasites, in the right time and place. This advantage is lacking for farm-origin Copepodids, which disperse directly into the plankton in open-sea locations, without a vector and generally distant from natural inshore infestation zones.

L. salmonis has another means to maintain and boost Copepodid numbers in natural infestation zones to await smolt descent, on which the literature is sparse. As in other caligid copepods, *L. salmonis* female lice possess a *receptaculum seminis*, variously described as single or paired, in which spermatozoa are maintained and stored, post-fertilisation[26]. Whilst on the vector host, only one male-female fertilisation occurs, and females are monogamous. Fertilised ovigerous lice separated from their host in the laboratory, fertilise up to 11 new egg batches via the receptaculum seminis, at a minimum interval of 9 days at 10ºC. Ovigerous lice can survive for up to 210 days[27], [28] in this state. This offers several possible benefits for the natural infestation process in *L. salmonis*:-

[24] White, H.C. 1940. Sea lice (*Lepeophtheirus*) and death of salmon." J Fish. Res. Bd. Can. 5: 172-175.

[25] Johnson S.C. et al. 1996. Disease-induced by the sea louse (*Lepeophtheirus salmonis*) (Copepoda; Caligidae) in wild sockeye salmon (*Oncorhynchus nerka*) stocks of Alberni Inlet, British Columbia. Can. J. Fish and Aqu Sc., 1996, 53, 12, 2888-2897.

[26] Ritchie G. et al. 1996. Morphology and ultrastructure of the reproductive system of Lepeophtheirus salmonis (Kroyer, 1837) (Copepoda: Caligidae). J. Crust. Biol., 16 (2) 330-346.

[27] Heuch P.A. et al 2000. Egg production in the salmon louse [Lepeophtheirus salmonis (Krøyer) in relation to origin and water temperature. Aquaculture Research, 31: 805-814.

[28] Mustafa, A., Conboy, G. A., & Burka, J. F. (2001). Life-span and reproductive capacity of sea lice, Lepeophtheirus salmonis, under laboratory conditions. Special Publication Aquaculture Association Of Canada, (4), 113-114.

- Reduction of generation time for new egg strings, from about 63 days if adult male / female fertilisation is required, down to 9 days at 10 ºC (see Figure 2.15) following *receptacular* fertilisation.

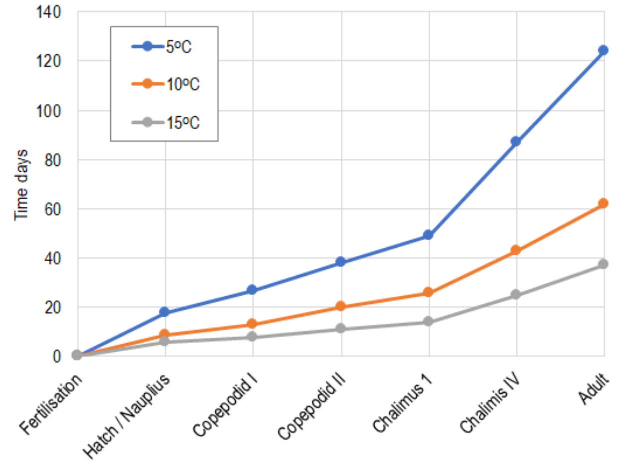


Figure 2.15. *L. salmonis* development time vs. temperature. After Bjorn Midttun, Pharmaq Ltd., Inverness 2005.

- If host salmon ascent and smolt descent of natal rivers is delayed (e.g. due to low river levels), receptacular fertilisation can extend the period for which viable Copepodids can await smolts or extend the "overlap period" during which wild smolt can be infested wild Copepodids.

- There is also the potential to maintain or boost Copepodid numbers inshore whilst host fish await their ascent in readiness for descending smolt. (This could explain reported wild sea lice epizootics prior to the advent of salmon farming, for example where migrations were delayed by low river levels)[29].

- Ovigerous females may drop from their hosts and continue to produce egg strings / Nauplii / Copepodids in near-full salinity conditions on the sea bed in their natural infestation zone and continue to infest wild smolts, which remain inshore prior to migration (in particular sea trout), whilst former host fish ascend their natal river to breed. Normal hatching has been demonstrated from separated female lice and egg strings in the laboratory but, whilst there have been anecdotal accounts, there are no published field observations as far as is known.

- Whether ovigerous female lice are attached or detached from host fish, serial *receptacular fertilisation* offers greater flexibility as to the timepoint of optimal infestation and reduces the need for synchronicity of in-migrating host arrival with out-migrating smolt presence in the infestation zone.

[29] Johnson S.C. et al. 1996. Disease-induced by the sea louse (Lepeophtheirus salmonis) (Copepoda; Caligidae) in wild sockeye salmon (Oncorhynchus nerka) stocks of Alberni Inlet, British Columbia. Can. J. Fish and Aquat. Sc., 1996, 53, 12, 2888-2897.

- *Receptacular fertilisation* may also have a function in maintaining or even spreading parasite loads on adult salmonids in their feeding grounds, either in the Northern Atlantic or more locally, in preparation for their return to their estuarine infestation zones.

The following passage examines a conservative biological / numerical approach to wild *L. salmonis* infestation of wild Atlantic salmon in a natural inshore infestation zone.

The following assumptions are made:-

- As widely reported, marine survival of wild Atlantic salmon now stands at only about 5% of escapement.

- Each returning host fish carries 5 wild ovigerous female lice (Grimnes et al[30] suggest a "normal" abundance of 10 ovigerous female lice on wild salmon in Norway)

- On wild lice, there are about 500 fertile eggs in a pair of egg strings (Costello[31] estimated that wild lice carry 1,000 eggs, although some[32] regard this estimate as conservative).

Then, for every 100-smolt escapement from a salmon river, only 5 salmon per 100 return to their natal rivers to breed the following season.

If carrying 5 wild ovigerous female lice each, these could hatch enough Nauplii (5 x 5 x 500 = 12,500 Nauplii) to generate up to 5,000 Copepodids (≈ 12,500 x 42.4%; see Figure 2.9), on metamorphosis at day 4, to await the next 100-smolt escapement.

Thus, a hatch from a single receptacular fertilisation could yield a likely maximum mean infestation per 100 smolt escapement of:-

≈ 50 lice per escaping smolt (≈ 5,000 ÷ 100).

Receptacular fertilisation repeats every nine days or so, which is shorter than Nauplius / Copepodid longevity, which expires 14 days post-hatch. Thus, receptacular fertilisations could increase Copepodid numbers / densities, above the calculated level, in particular because, as far as is known, hatches from different lice are not synchronised.

30 Grimnes A. et al. 1999. Registration of salmon lice on Atlantic salmon, sea tout and Arctic char in 1999. Nina Oppdragsmelding 634: 1-34.

31 Costello M.J. 2006. Ecology of sea lice parasitic on farmed and wild fish. Trend. Parasit. 22 475-483.

32 Heuch P.A. et al 2000. Egg production in the salmon louse (Lepeophtheirus salmonis, Krøyer) in relation to origin and water temperature. Aquacult. Res., 31, 805 -814.

Twenty-five years ago, wild salmon marine survival was about 20% of escapement, four times the current level. A range of factors including climate, the North Atlantic Oscillation, illegal catch and fragility of feed species stocks, is believed to be responsible for this reduction. Using the simple sum shown above, this 20% survival would have resulted in 200 Copepodids or more to await every descending smolt.

To put this into perspective, various authors estimate how many settled lice out-migrating salmonids can tolerate. Broad consensus suggests that salmon postsmolts with <10 lice can survive infestation[33]. Recent studies also show that high levels of natural infestation can be fatal to all European salmonid species[34].

It is reported that wild Copepodids that infest successfully during natural infestation episodes are likely to be spread heteroscedastically or unevenly or (also defined as overdispersed) between hosts, where host health or other factors may be the governing variables. This means that some hosts will naturally carry pathological infestations of lice. For obvious reasons, no parasitic species aims to overstress its vector or host by excess infestation. However, parasitism is not an exact process and it is normal and expected that, for example, in elevated temperatures or low rainfall or, in recent years, possibly related to climate change, high infestations or epizootics can and will occur. From the calculations provided, the numbers of Copepodids that are likely to be released in natural infestation zones offer more than adequate scope for challenging natural infestations, even at 95% marine mortality.

L. salmonis Copepodids are phototactic; Nauplii less so. Copepodids also congregate at salinity discontinuities in stratified waters, such as those found in sheltered, shallow estuarine reaches around Bantry Bay, where river water and seawater meet. In such conditions, Nauplii are therefore found lower in the water column in daylight, whilst Copepodids are found closer to the surface (note salinity must be > 29‰). This behaviour may help maintain Nauplius larvae inshore and closer to the seabed, away from dispersive currents, until metamorphosis to the infestive Copepodid stage. Copepodids may then rise the relatively short distance to the surface in daylight. This has been reported to increase their chances of interception of potential smolt hosts, which move away from the surface light in daylight

The purpose of these paragraphs is simply to clarify that, as would surely be expected, *L salmonis* has evolved a multi-million-year-old strategy to ensure that it has the vectoral, temporal, locational and numerical means to maintain its life cycle through the infestation of wild salmonids. This is bound to involve the production of adequate numbers of Copepodids, to

33 Holst J.C. et al 2007. Mortality of seaward-migrating post-smolts of Atlantic salmon due to salmon lice infection in Norwegian salmon stocks. In Salmon at the edge, pp. 136–137. Blackwell Science Ltd, Bodmin, Cornwall.

34 Berglund A.K. 2013. Effects of infections with salmon lice (*Lepeophtheirus salmonis*) on wild smolts of salmon (*Salmo salar* L.) and trout (*Salmo trutta* L.). Master thesis, University of Tromsø, Norway. 61 pp

maintain high local densities, when and where required. As a result, wholly natural, high levels of infestation, whilst not necessarily normal, can be expected to occur under certain circumstances.

In reality, most wild Copepodids, which metamorphose inshore, fail to find hosts and drift into open waters with the plankton, either to expire once their yolk reserves are exhausted (10 days post-metamorphosis at 10ºC; see Figures 2.9 and 2.15) or, much less likely, to encounter a farm site by chance and establish and on-farm breeding population.

There has been a remarkably sustained and focused campaign to blame salmon farming with wild salmonid lice infestations and stock reductions and collapses over almost three decades. During this period, the abilities of a planktonic organism of just 0.7mm in length and with limited energy reserves, to independently travel many kilometres upstream, in open sea conditions, to target wild salmon river estuaries in just 10 days, from well outside its natural infestation zone, and with no vector support, has been greatly overestimated. Over the same period, the natural ability of wild *L. salmonis* to cause high infestations of wild fish in its natural infestation grounds has been very much under-studied and underestimated.

This focus has been such that elements of the basic natural history of *L. salmonis* have been largely overlooked and gaps in our knowledge the species still remain. In its place, a significant part of the effort to incriminate salmon farming has relied on statistics. For the most part, such studies have generalised impacts, over numerous salmon farming areas, often in different countries and in a wide range of hydrographic, bathymetric, climatic and topographic conditions. Even so, there is something of a consensus in the results. Even the most damning studies, estimate that only 1 to 2% of additional marine mortality is caused by “lice” where wild marine mortality from all other causes currently stands at about 95% of total escapement.

Even so, the copious literature on the subject to date cannot specify whether the infestations, losses and statistical outcomes in question are due to anything more than just “lice”. This is because there is still no means to distinguish wild-origin from farm-origin *L. salmonis* in the field, at any stage of their life cycle[35],[36]. Nor has it been possible to establish a causal link to any specific infestation event. This fact has had a considerable influence on the debate because there are examples in the scientific literature where “lice” have been labelled as “farm-origin” when there is a strong likelihood that this is not the case.

[35] Bjorn PA et al 2007 Differences in risks and consequences of salmon lice, *Lepeophtheirus salmonis* (Krøyer) infection on sympatric populations of Atlantic salmon, brown trout and Arctic char within northern fjords. ICES J. Mar. Sci., 64, 386-393.

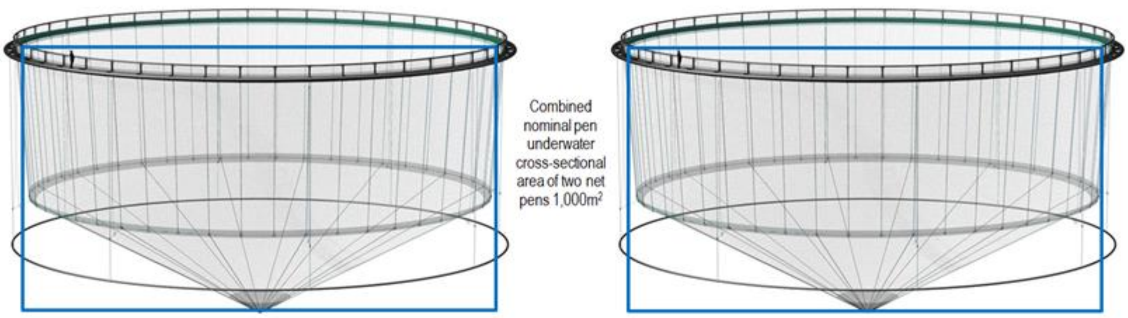
[36] Todd CD. 2007. The copepod parasite (Lepeophtheirus salmonis (Krøyer), Caligus elongatus Nordmann) interactions between wild and farmed Atlantic salmon (Salmo salar L.) and wild sea trout (Salmo trutta L.): a mini review. J. Plank. Res. 29, Supp1, i61-i71

Section 2.3.3. Discussion Point 3.
Biology of the salmon louse as it applies to wild to farm infestation.

As set out above, *L. salmonis* has evolved a range of specialised strategies over many millions of years aimed at the efficient infestation of out-migrating wild salmonid smolts in the relatively shallow, still, stratified inshore zones of river estuaries. Such strategies do little or nothing to aid their infestation of farmed salmon, held in open, unstratified marine conditions such as those around existing and proposed salmon farm sites in Bantry Bay, or indeed wild fish, once they are adequately dispersed beyond their immediate inshore inward / outward migration zone.

However, wild-origin *L. salmonis* Copepodids, which fail to locate wild hosts in their natural infestation zones, drift into open waters, and may simply encounter salmon farms located downstream by chance. This is because salmon farms present a very large, fixed cross-sectional area for copepodids (of either wild or of farm origin), and a range of other organisms to encounter as they drift with the plankton in tidal (or wind-forced) currents. In the cases of bays modelled by RPS, including Bantry Bay, the nominal cross-sectional area of two neighbouring salmon pens, facing the current, (the normal configuration) is approximately 1,000m^2; see Figure 2.16.

Figure 2.16.
Underwater cross-sectional area of two pens (as they face the prevailing tidal current direction) of the type deployed in Bantry Bay; nomial pen diameter 40m.



The mean tidal current in Bantry Bay is 0.03msec^{-1}. From this, it can be calculated that the mean flood / ebb water volume that could enter the given pen cross-sectional area would be:-

$\approx 2.6 \times 10^6$ m^3 / day (= 0.03 x 3,600 x 24 x 1,000)

Using, for example, the modelled maximum open-water farm-origin Copepodid density for Bantry Bay of 0.0001 Copepodids / m^3 (see Figure 2.13 and Table 2), the maximum Copepodid numbers that could enter the pens through the calculated cross-sectional area in Figure 2.16 would be:-

= (2.6M x 0.0001) ≈ 260 wild Copepodids / day

Similar calculations for other sites with a range of current regimes show that, in destratified waters and given the same Nauplius discharge conditions, the key factor in such calculations is current speed. Such calculations suggest that the mean current range across salmon farm locations in Ireland is of the order of 0.3 to $25cmsec^{-1}$ and that the consequent maximum numbers of Copepodids that could enter such a pen cross-section per day is likely to be of the order of 200,000 Copepodids per day. Thus, subject to the locations of river estuaries and salmon farm sites within an embayment, as well as hydrographic and other considerations, wild-origin Copepodids can reach pens more rapidly in faster currents. As a result, greater numbers of Copepodids have the potential to enter salmon farm sites, prior to their expiry, at 14 days post hatch. On this estimated scale, Bantry Bay is very much at bottom of the range, both in terms of current regime and estimated wild-origin Copepodid exposure.

Whilst this argument is somewhat simplistic and ignores a number of other factors that could also force such outcomes, such as a closer hydrographic relationship between sites and river locations, the empirical evidence is very strong that farm sites subjected to faster current regimes are much more readily infested from wild sources. However, these only serve to demonstrate again that Bantry Bay is close to the bottom of this scale, primarily due to its slow current regime.

Thus, whilst on-farm lice settlement on Bantry Bay sites rarely breaks trigger levels, even without treatment (only 6 lice treatments have been conducted in the last eight years), wild-origin lice are known to settle more rapidly and in greater numbers on some other sites, and, as a result, infestations are more persistent and require management intervention much more frequently.

It is speculated that not all Copepodids that encounter salmon pens will locate hosts. However, potential captive host numbers and individual host surface area on second-year farmed salmon probably exceed the critical smolt mass requirement for efficient wild to wild infestations, even in natural infestation zones.

Thus, the more Copepodids that enter farm pens and the larger and more numerous their farmed hosts, the greater the chances of encounters and settlements on salmon farm sites will be.

Section 2.3.3. Discussion Point 4.
Biology of the salmon louse as it applies to the potential for farm to wild and farm to farm infestation in Bantry Bay.

This topic has largely been covered in previous sections, in particular along with the modelled outcomes of Copepodid dispersal from Bantry Bay farm sites, described in Section 2.3.2. It has also been pointed out that the dispersal of Copepodid larvae from any source in Bantry Bay can be expected to be mitigated by the bay's relatively slow current regime. The open waters of Bantry Bay (through which Copepodids must travel to reach any wild infestation area or farm site) may therefore reasonably be regarded as a "low lice density area"

However, this is an appropriate point at which to further consider that, whilst the literature includes descriptions of the anatomy and function of the receptaculum seminis and the in-vivo extrusion and hatching of egg strings post-*receptacular fertilisation*, the likely consequences of its biological role do not seem to have been fully considered. *Receptacular fertilisation* short-circuits the reproductive process in *L. salmonis*, from some 63 days where direct male to female fertilisation is involved, to serial fertilisation of eggs by sperm stored in the receptaculum seminis every 9 days or so at 10ºC. As has already been pointed out, this could be an evolved strategy to increase wild to wild infestation pressure in natural infestation zones. However, it undoubtedly also has the "non-evolved" potential to increase the rate and spread of infestation within farm sites and thereby to increase Copepodid discharges and dispersal from them, if an adequate monitoring and proactive treatment regimen are not employed. Both would be regarded as standard requirements in the management of any domestic livestock. An Integrated Pest Management (IPM) Plan, (such as that submitted to ALAB by MHI for Bantry Bay) and the Statutory National Sea Lice Monitoring Program are essential tools in the particular case of sea lice management in salmon farming in Ireland.

If and when wild- or farmed-origin Copepodids drift into a farm site and infest on-farm hosts, they then progress through attached Chalimus and mobile pre-adult and adult stages until fertilisation has been effected. From settlement as Chalimus to fertilisation takes some 36 days at 10ºC (see Figure 2.15). Once male to female fertilisation has occurred, eggs are fertilised, egg strings are extruded, and eggs hatched. Following this, egg batches continue to hatch from new egg strings every nine days via sperm released from the receptaculum. Therefore, to avoid increased on-fam infestation levels due to rapid serial fertilisations, it is essential that over-trigger level infestations of adult female and ovigerous female lice stages are treated as soon as they appear. Chalimus stages at least are also able to move between hosts. This ability is likely to be optimal in the relatively high stock conditions of salmon in farm pens and could also increase both infestation rate and subsequent larval production levels.

To repeat Section 2.3.1, the Statutory National Sea Lice Management Program conducts inspections on all stocked Irish salmon farm sites once every nominal 28 days in February and between June and November, once in the December to January period and once every 14 days in the "Critical Spring Period" between March and May, when wild salmonid smolt are migrating. Thus, there are a total of 14 statutory inspections per annum. MHI also conducts its own lice management inspections in between the statutory inspections.

Given that the maximum time from Chalimus settlement to adult is 36 days at 10ºC, the monitoring regime used gives adequate time to confirm the presence of adult ovigerous female lice relative to the relevant trigger levels and to treat, well before the rapid sequence of receptacular fertilisations and hatches commences, some nine days later. Examination of the lice monitoring data in Figure 2.8 and the record of only six lice treatments in Bantry Bay since 2008 strongly indicates that this has been regularly achieved, on existing Bantry Bay salmon farm sites, prompted by the dual incentive of maintaining on-farm stock health and protecting wild stocks.

Section 2.3.3. Discussion Point 5.
Salmon lice and the status of wild salmon stocks in Bantry Bay rivers.

There has now been salmon farming in Bantry Bay for forty years, since the first establishment of the Roancarrig site. As an indication of possible future risks to the status of wild salmon stocks in Bantry Bay rivers, the question arises; has 40 years of salmon farming impacted negatively on these stocks over this period?

In the past, Bantry Bay has been a significant source of commercially-caught wild salmon, primarily by driftnetting. The numbers of driftnets in use peaked in the 1972 season at 150 and, as recently as 1974, just four years prior to the establishment of the Roancarrig salmon farm site, the commercial salmon landings registered through Bantry Bay ports was over 21,000 fish per annum. Cork and Kerry Districts were two of the largest contributors to the national commercial salmon catch, which peaked at almost 700,000 fish in 1975. The fact is, Ireland's wild salmon stocks were plundered with little thought of sustainability for decades. In the early 1990's, mediated through NASCO[37], a number of nations started to buy out their commercial fisheries, in particular driftnets, in the face of growing international concern. Ireland was one of the last countries to take this step, which it did, at the end of the 2006 netting season.

The Irish National Salmon Commission (NSC) was established in 2001, with the task of issuing annual advice to the Government, through its Standing Scientific Committee (SSC), on the Total Allowable Catch (TAC) for the commercial fishery, and on exploitation by angling.

[37] North Atlantic Salmon Conservation Organisation

Atlantic salmon is an Annex II species under the terms of the Habitats Directive 92/43/EEC and member states must submit an Article 17 Assessment to the EC every six years, detailing the conservation status of all Annex II species. Ireland first Assessment was submitted in 2007, immediately after the drift net ban. The Assessment stated:-

"The salmon population in Ireland has declined by 75% in recent years and although salmon still occur in 148 Irish rivers, only 43 of these have healthy populations".

Factors blamed for the decline included reduced marine survival, thought probably to be due to of climate change, diseases, parasites and marine pollution, poor river water quality (resulting from inadequate sewage treatment, agricultural enrichment, acidification, erosion and siltation), forestry-related pressures and over-fishing. Although geographical range was classified as good, the population size was considered Bad, and habitat conditions were described as Poor. The overall classification for Atlantic salmon in Ireland was described as "Bad".

From 2007, following the closure of the driftnet fisheries, the NSC / SSC's advice was provided for individual river stocks rather than for aggregated district stocks. The NSC was abolished in 2008 but the SSC continued to sit annually to advise the Minister on the annual byelaws on which the exploitation limits for wild salmonid stocks in individual National Salmon Rivers were set. Angling for salmon is now only allowed where there is a surplus above the Conservation Limit calculated for each river. Conservation limits (CLs) are defined by ICES as the number of spawning fish that will achieve the long-term average maximum sustainable yield (MSY) in a river, which should not be allowed to fall[38]. By the time of the next Article 17 Assessment in 2013, an improvement was noted:-

"The period of recent relative stability in salmon numbers has coincided with the removal of drift net fisheries from the Irish coast after 2006. Therefore, the qualifier has been set as stable".

However, the assessment also pointed to a decreasing trend in salmon stocks from 1988 to 2012. There are some 147 rivers given National Salmon River status in Ireland, largely identified from information collated by McGinnity et al in 2003[39]. This document identified five National Salmon Rivers in Bantry Bay; the Adrigole, the Glengarriff, the Coomhola, the Owvane and the Mealagh (see also Figure 2.1). Notably, the Trafrask River is not listed, being described, by McGinnity et al, as "not considered a significant producer of salmonids". It was therefore excluded from the McGinnity analysis; see Figure 2.17, taken from this report.

[38] For information on calculation of conservation limits for National Salmon Rivers, see for example The Standing Scientific Committee on the Status of Irish Salmon Stocks in 2016 with Precautionary Catch Advice for 2017. Independent Scientific Report to Inland Fisheries Ireland April 2017.

[39] McGinnity P. et al 2003. Quantification of the freshwater habitat asset in Ireland using data interpreted in a GIS platform. Irish freshwater fisheries ecology and management series Number 3. CFB, Dublin, Ireland.

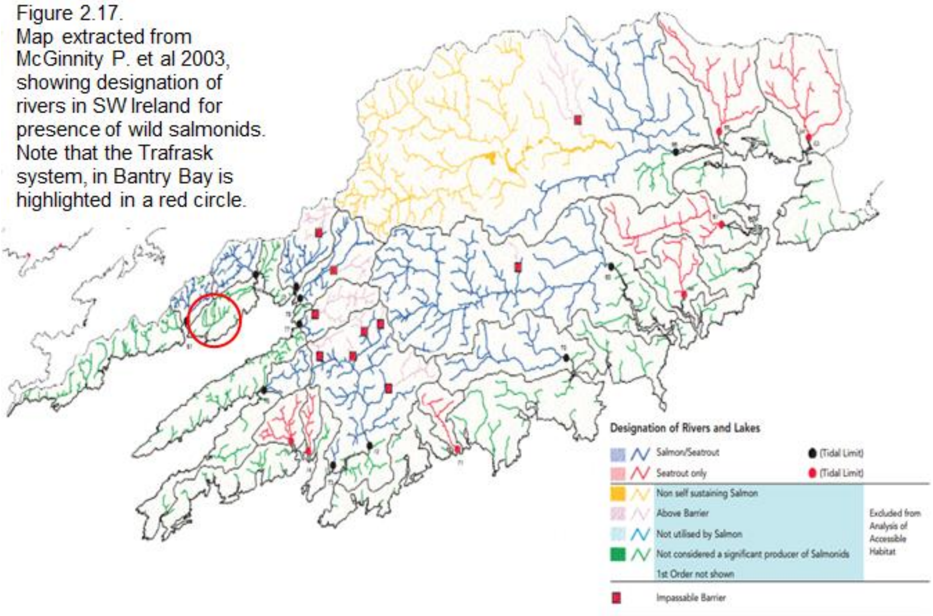


Figure 2.17.
Map extracted from McGinnity P. et al 2003, showing designation of rivers in SW Ireland for presence of wild salmonids. Note that the Trafrask system, in Bantry Bay is highlighted in a red circle.

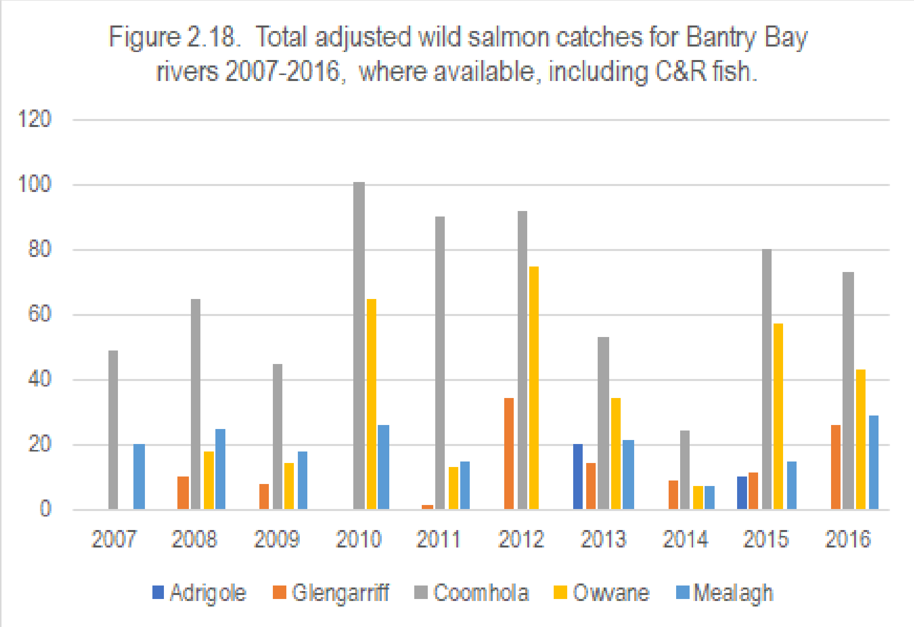
As Figures 2.1 and 2.17 show, there are a number of other small rivers in Bantry Bay with salmonid populations that were also excluded. Little is known about the stock status of these, including the Trafrask, since stocks have only ever been monitored on National Salmon Rivers.

On the closure of the commercial fisheries, over 70 National Salmon Rivers remained closed nationally on the advice of the NSC, in areas both with and without salmon farms. These included the Adrigole and the Glengarriff Rivers in Bantry Bay, whilst the Coomhola, Owvane and Mealagh Rivers were on the open list. In 2012, the Adrigole and the Glengarriff Rivers were both opened for catch and release angling. The Glengarriff River subsequently opened for full angling in 2016. On a national basis, out of the total of 143 rivers now classified in the 2018 byelaws, only 40 (28%) rivers are fully open, 36 (25%) are open for catch and release angling only and some 67 rivers (47%) remain closed.

Thus, despite the presence of salmon farming in Bantry Bay for forty years, four out of the bay's five National Salmon Rivers are fully open for angling, the other one being open for catch and release angling. Perhaps most significantly, the four open rivers constitute 10% of the entire national complement of open rivers for the 2018 season.

Whilst none of Bantry Bay's National Salmon rivers are large or important in terms of the relative extent of their salmonid habitat, their conservation status is nonetheless good, and their angling returns remain well within their calculated surpluses, available for exploitation. Salmon angling catches since the closure of the commercial fisheries, abstracted from Inland Fisheries Ireland[40] publications are shown in Figure 2.18.

[40] Wild Salmon and Seatrout Statistics reports; 2006 / 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016; published by Inland Fisheries Ireland, 3044 Lake Drive, Citywest Business Campus, D24Y265.



There is also some minor variance in data between rod catches recorded in the IFI statistics reports and the NSC / SSC reports. Only IFI report data is graphed in Figure 2.18. Although IFI have published catch statistics reports since 2001 / 2003, the angling data prior to 2007 is sparse and inconsistent and is therefore not included in Figure 2.18. Although the Adrigole River has been open for catch and release angling for the entire period graphed, little data is available. It is not known whether this is due to zero catches or whether the record is incomplete. With reference to Section 2.4 and Figures 2.31 and 2.32, it may be that the Adrigole River's failure to reach its CL may in part be due to its Ecological Status, of Good (At Risk), suggesting that riverine habitat conditions may be impacting on juvenile fish recruitment, in this case.

Unfortunately, no catch effort data is available against which fishery performance can be compared, either locally or nationally for these or any other rivers in the country. Annual sea trout catches in Bantry Bay rivers are generally in single figures but, as with salmon data, it is suspected that catches relate to the effort that is being expended, on both species, on these rivers. Overall, catches in Bantry Bay rivers are similar to those in other open rivers with broadly similar salmonid habitat characteristics elsewhere in the country.

The following observations apply:-

- It is very clear that, despite concerns expressed as long ago as the reports of the Inland Fishery Commission, which sat between 1933 and 1935 and again in 1975, that commercial over-exploitation caused huge damage to the status of Irish wild salmonid stocks, and indeed of those throughout the geographical range of the species. Bantry Bay rivers were mentioned specifically in the 1975 report:-

"the number of spawning redds in the Coomhola, Owvane and Mealagh rivers (Bantry Bay) had dropped from 99 in 1971 / 72 to only 6 in 1972 / 73. Electro-fishing surveys in 1973-1975 yielded no salmon and almost no fry in Bantry Bay rivers."

- Bearing in mind the levels of commercial exploitation in Bantry Bay, it can be assumed that salmon stocks were in a fragile state when this practice ceased. However, despite this, there is a higher percentage of rivers now open for angling in Bantry Bay than in any other similar embayment in the country. Conservation limits for salmon (the only ones calculated) are being readily achieved and rod catches have been relatively consistent ever since the closure of the commercial fisheries. This suggests that, although natural infestations may arise from natal wild lice in each river estuary, there is no indication that farm-origin lice have impacted on these rivers in the 40-year history of salmon farming in the bay.

- It is noted that all five National Salmon Rivers in Bantry Bay also support populations of the Freshwater Pearl Mussel (FPM), *Margaritifera margaritifera,* although monitoring has been sparse or non-existent and their precise stock status has not been ascertained. Evidence of lack of impact on anadromous salmonids populations in these rivers also supports the likelihood that vector fish for the dispersal of FPM Glochidia larvae are also unaffected, by marine-origin impacts at least; see Sections 2.4 and 3.

- The achievement of positive Conservation Status on four out of five of Bantry Bay's National Salmon Rivers suggests that, as well as lack of salmon farm-origin impacts, catchment impacts are also within sustainable limits. This suggests that much the same will apply to the smaller, unmonitored rivers in the bay, as long as catchment impacts are equally well-sustained in these cases. See however Sections 2.4 and 3.

- These findings concur with the findings of lice dispersional modelling reported in Section 2.3 of this document. This shows that, even in the worst-case modelled, *L. salmonis* Copepodids from any existing or currently proposed salmon farm site in Bantry Bay could not penetrate into any river estuary, anywhere in the bay at a density of any more than in the range of zero to 0.0001 Copepodids/m^3. This density is far too low to augment natural infestations by wild lice.

- Nothing published on the status of Bantry Bay rivers supports a case for turning down the Aquaculture and Foreshore Licences granted by the Minister for the proposed MHI Shot Head salmon fam site, in September 2015.

Section 2.3.3. Discussion Point 6.
Response to a "Norwegian opinion" submitted to ALAB by IFI.

In the process of the oral hearings a written submission was made to ALAB by Inland Fisheries Ireland (IFI) in September 2017, which is reproduced below:-

"Written Statement by IFI to second session of the ALAB Oral Hearing of the Shot Head licence appeal September 2017

Inland Fisheries Ireland consider, and have concerns that the particle tracking simulations in the sea lice dispersion study are inadequate and not scientifically robust enough as sea lice are known to exhibit a different behaviour than that assumed in the model. The fundamental premise of the model assumes that sea lice particles are neutrally buoyant, where in reality sea lice exhibit a vertical movement in the water column and therefore, consideration of the vertical position of sea lice in the water column is necessary in order to simulate realistic lice dispersal. It is known that sea lice in the water column can avoid freshwater layers, move towards host fish, away from predators and are attracted to light near the surface during the day and sink away from the surface during the night. It is our opinion, that the conclusions drawn in the assessment of sea lice dispersion based on the assumption of the parasite as neutrally buoyant particles is not an accurate reflection of potential sea lice dispersion in Bantry Bay. IFI are currently working with Norwegian and Scottish scientists on the EU funded Lice Track study which is developing an integrative bio-hydrodynamic sea lice dispersal model, and this is based on existing such modelling tools that have already been developed and validated in Norway by the Institute of Marine Research, which do consider the active vertical behaviour of sea lice in the water column as a component of their models. This active vertical behaviour of sea lice is important to consider as it will influence dispersal where typically currents are not uniform across the water column. We have consulted with these colleagues, on the appropriateness of assuming that sea lice are neutrally buoyant particles, and they are in agreement that this is an inadequate assumption to make and thus compromises the output of the sea lice particle tracking simulations in providing an accurate reflection of their potential dispersal in the bay."

With due respect to IFI's opinion, the Norwegian Institute of Marine Research (IMR) colleagues with whom they have consulted will be well aware that the aim in any HD-driven modelling exercise is to replicate the natural hydrodynamic conditions in the water body under examination as accurately as possible. This will have been their first step, in developing the HD models which drive the dispersion simulations, that they have developed for Norwegian salmon farming conditions, just has it was RPS' first step, in HD modelling in Bantry Bay. We are not sure that IMR is as familiar with conditions in Bantry as RPS is.

The tidal flow simulations within the RPS Irish Seas Tidal Surge Model are undertaken using the MIKE21 FMHD Hydrodynamic Flow Model, developed by the Danish Hydraulics Institute, which is a global standard in HD modelling. This simulates water level and flow variations in a water body in response to a variety of forcing functions, including but not limited to flooding and drying, momentum dispersion, bottom sheer stress, Coriolis Force, wind sheer stress, and precipitation and evaporation.

The RPS Irish Seas Tidal Surge Model also incorporates an extremely wide range of local, national, European and global tidal, bathymetric, topographical, meteorological, climatic, astronomic and atmospheric databases, in order to replicate natural conditions across the model domain as accurately as possible. The extent of the RPS Irish Seas Tidal Surge Model is shown in Figure 2.19. The extent of the Bantry Bay HD model, a fully-linked subdomain of the larger model, which RPS used for its MHI studies, is illustrated in Figure 2.20.

As further explained in the RPS reports on HD and Water Quality Modelling around the salmon farm sites in Bantry Bay, commissioned by MHI[41], [42], the use of flexible mesh technology enables increased modelling resolution where required in the dedicated Bantry Bay HD model, for example in the vicinity of the salmon farm sites themselves. As far as is known, this results in considerably higher resolutions across the model domain than used so far in Norwegian models. The Bantry Bay model is further verified and calibrated against local data, including 15 empirical hydrographic datasets and purpose-collected local bathymetric datasets in the immediate vicinities of the salmon farm sites. Other information on conditions in Bantry Bay was also consulted, where relevant[43], [44].

This provides a solid hydrodynamic basis for the computation of the dispersion of nutrients and settleable solids and particle tracking, undertaken in RPS' Bantry Bay studies, which uses the MIKE 21/3 Coupled Model FM software package. This package enables the simulation of the mutual interaction of waves and currents, using *dynamic coupling* between the Hydrodynamic Module and the Spectral Wave Module. The MIKE 21/3 Coupled Model FM also employs *dynamic coupling* between separate Mud Transport, Particle Tracking and Sand Transport Modules and the Hydrodynamic and Spectral Wave Modules, as required. Hence, a full feedback of bed level changes on wave and flow calculations can be included.

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41 RPS 2016. Water Quality Modelling for all existing and currently proposed salmon farm sites in Bantry Bay. Document No. IBE0744/R07/Rev 3/NS. RPS Group Ireland

42 RPS 2015. Water Quality Modelling for a proposed salmon farm site in Bantry Bay (Waterfall harvest site). Document No. IBE0744/R06/Rev 2/NS. RPS Group Ireland.

43 Grainger R.J.R. 1984. Investigations in Bantry Bayt following the Betelgeuse oil tanker disaster. Irish Fisheries Investigations Series B (Marine) No27. Stationary Office Dublin.

44 Anon. 1988. Water Quality Management for Bantry Bay. John B Barry & Ptns., Irish Hydrodata Ltd., Reid McHugh & Ptns., for Cork County Council. 117pp.

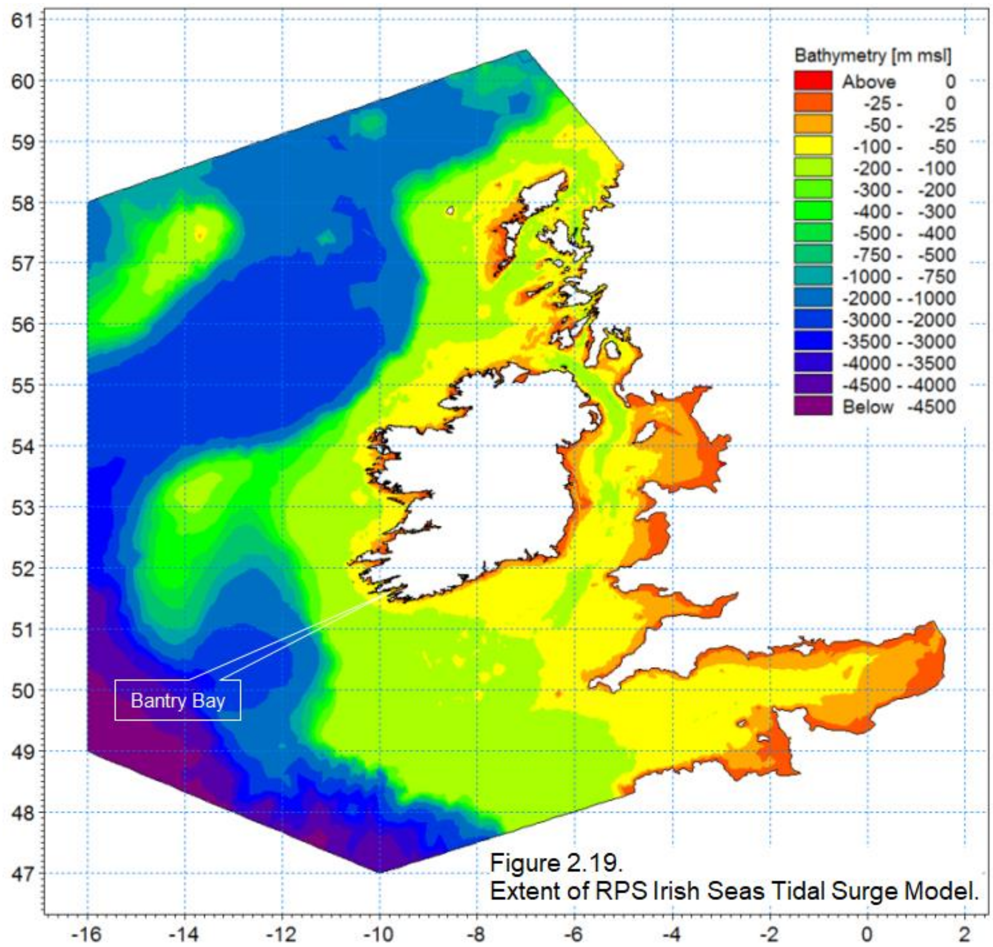


Figure 2.19.
Extent of RPS Irish Seas Tidal Surge Model.

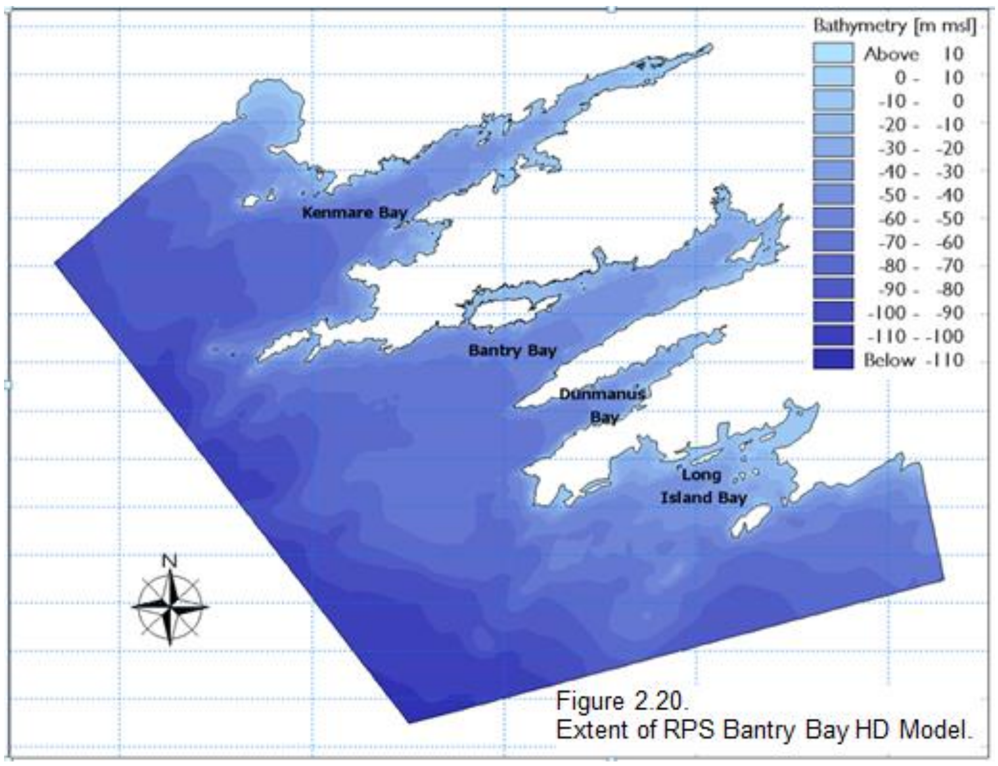


Figure 2.20.
Extent of RPS Bantry Bay HD Model.

In respect of RPS' judgement regarding the fundamental hydrographic characteristics of the bay, in the first instance, the RPS Irish Seas Tidal Surge HD model and its subdomain HD model for Bantry Bay themselves both confirm the oceanic, unstratified nature of the outer bay area. The dispersion of all discharges considered from salmon farm sites in the bay are therefore modelled accordingly.

Secondly, further empirical verification of the oceanic and unstratified nature of the outer bay area is provided by the geological origins of the bay and its well-documented hydrographic and climatological characteristics, as described below.

Bantry Bay is a *Ria*[45] or *Ria estuary*, defined as a *drowned non-glaciated river valley, where the estuarine parts are restricted to the upper reaches whilst the outer parts are little diluted with freshwater and are defined as shallow inlets or bays*[46]. Bantry Bay has a wide, unimpeded mouth to the Atlantic Ocean (some 11km between Sheep's Head to Fair Head, just to the west of Bear Island), which, in this case, faces directly into the prevailing wind direction. The bay shallows steadily and narrows slightly from its mouth to its head, some 33km inland; see Figure 2.21. The bay deviates little from its central longitudinal axis and has no sills and no basins. Mean current is of the order of 0.03msec^{-1}. Mean low water depth is about 45m and its mean low water sea area 230km^2. The mean neap tidal range is 1.3m and at spring tide is 2.9m. Maximum tidal range is in excess of 4.5m.

In the tidal (i.e. calm weather) flushing model set out in Section 2.5 of the original EIS document, the mean flushing volume per tide for Bantry Bay is estimated at 465M m^3 per tide. This volume is likely to be regularly enhanced by wind induction, since winds blow across Bantry Bay at >Force 4 from all directions for 50% of the time and from S to W only, at Force 4-6, for 33% of the time; see the offshore wind rose for Bantry Bay in Figure 2.22.

From precipitation data over the terrestrial catchment area and the sea area of the bay and taking account of evaporative transpiration over its terrestrial catchment, total freshwater input to the bay can be estimated at 400M m^3 per annum. On the basis of these figures, despite the fact that the higher parts of the terrestrial catchment area of the bay experience quite high rainfall in national terms, annual freshwater input volume into Bantry Bay estuaries totals less than one single oceanic tidal input.

45 Wikipedia: A **ria** is a coastal inlet formed by the partial submergence of an unglaciated river valley. It is a drowned river valley that remains open to the sea. Typically, rias have a dendritic, treelike outline although they can be straight and without significant branches. This pattern is inherited from the dendritic drainage pattern of the flooded river valley. The drowning of river valleys along a stretch of coast and formation of rias results in an extremely irregular and indented coastline. Often, there are islands, which are summits of partly submerged, pre-existing hill peaks.

46 Marine Irish Digital Atlas; mida.ucc.ie.

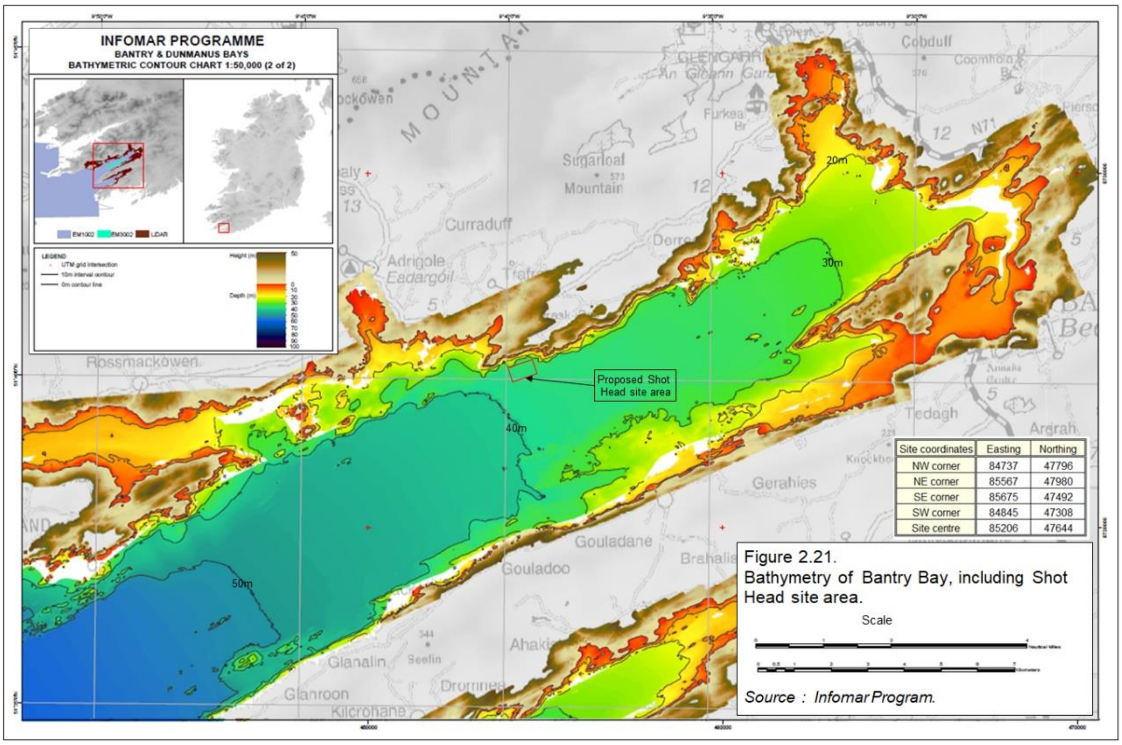
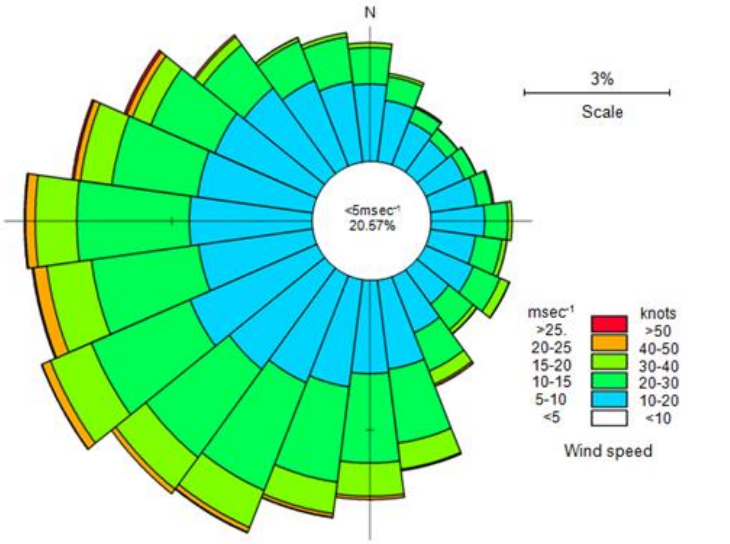


Figure 2.21.
Bathymetry of Bantry Bay, including Shot Head site area.

Source : Infomar Program.

Figure 2.22.
Offshore windrose for Bantry Bay.



This is more a consequence of the high tidal range off Ireland's west coast than it is of the bay's low freshwater input and is a feature of a number of other Irish marine inlets. This is a relationship which is entirely reversed in the case of Norwegian fjords, as further discussed below. These features underpin the oceanic environment of Outer Bantry Bay which is also recognised under the Water Framework Directive, which classifies Outer Bantry Bay as a Coastal Water Body rather than as a Transitional Water Body; see also Section 4.

In summary, whilst it can be assumed that there is some seasonal influence of freshwater inputs close inshore, in the somewhat enclosed locations of the bay's river estuaries, which lie in WFD Transitional Water Bodies (and where natural wild lice infestations undoubtedly occur), freshwater inputs have no significant influence, either on overall salinities or on freshwater stratification anywhere in the open waters of the outer bay, where the salmon farms (as sources of farm-origin lice) are situated. This is further confirmed by water sampling data (for example temperature and salinity data), which has been regularly collected in Bantry Bay by the aquaculture community over decades and also by the Marine Institute, in more recent times. See original Shot Head EIS document.

The destratified status of Outer Bantry Bay is also confirmed by empirical hydrographic data, collected as part of a multitude of hydrographic surveys conducted in the bay, against which the Bantry Bay HD model is calibrated. All datasets collected show little variation from near-surface to near-seabed, for example in cumulative vector plots (see Figure 2.7), horizontal current data or vertical current data. Examples of the latter are given in Figure 2.23 for an ADCP deployed at the MHI Roancarrig site in December 2010 and in Figures 2.24 and 2.25, for ADCPs deployed at two different locations near Shot Head, on two separate dates, in December 2010 and January 2011 respectively. These traces show the vertical current profile at three different depths, between the near surface and near-seabed in each case. In effect, as with Typical grid cell plots (see for example Figure 2.13), these show a snapshot from a dynamic current profile moving past the ADCP, within which the plankton is propelled. The vertical current amplitude differs between plots from a nominal minimum of some 4cmsec^{-1}, to a maximum of some 7cmsec^{-1}, between upper and lower values where in all but one case the maximum value is positive (i.e. upward current), and the minimum value is zero or negative (i.e. downward current). This provides further evidence that the water column of Bantry Bay is vertically mixed, from surface to bed, and not stratified.

It is submitted that the HD-modelled and empirical data provided above fully supports the view that Outer Bantry Bay is an open oceanic sea inlet, with high oceanic flushing due to a high tidal amplitude relative to its depth. This, together with frequent wind induction, low freshwater input, and significant levels of vertical water movement and mixing prevent long-lived stratification of any type throughout Outer Bantry Bay, where salmon farms are located.

Figure 2.23.
MHI Roancarrig site, Bantry Bay.
RDCP position ING Grid ref 077713.978E 046238.225N.
Vertical current speed (cmsec^{-1}) at 24m, 15.5m and 2m from the seabed.
Period 00:00 5th December to 00:00 20th December 2009 (GMT); 15 days.

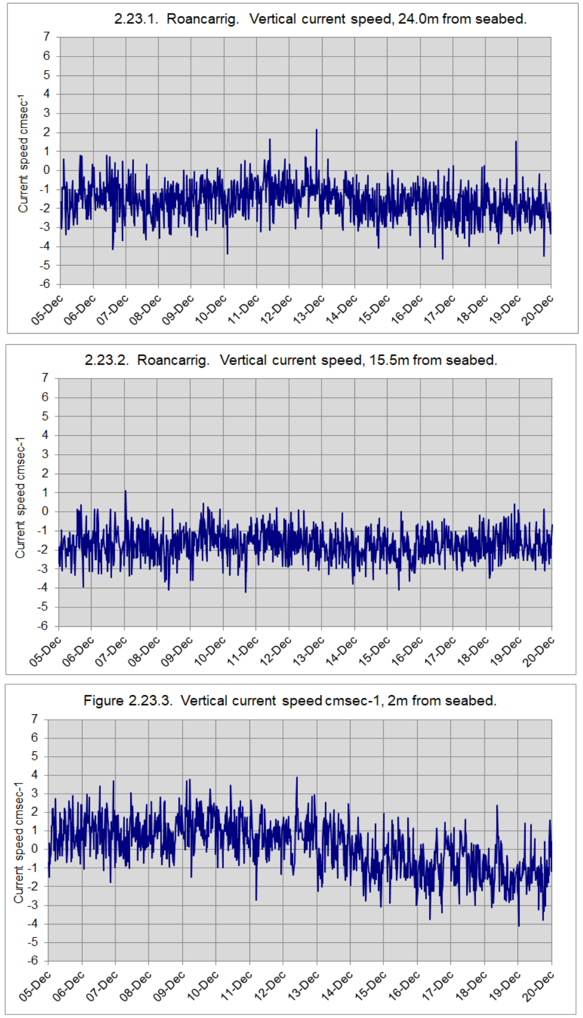


Figure 2.24.
Shot Head Bantry Bay; Deployment 1.
RDCP position ING Grid ref 085280.35E 047781.20N.
Vertical current speed (cmsec^{-1}) at 26.0m, 17.0m, and 2.0m from seabed.
Period 00:00 5th December 2009 to 00:00 20th December 2009 (GMT); 15 days.

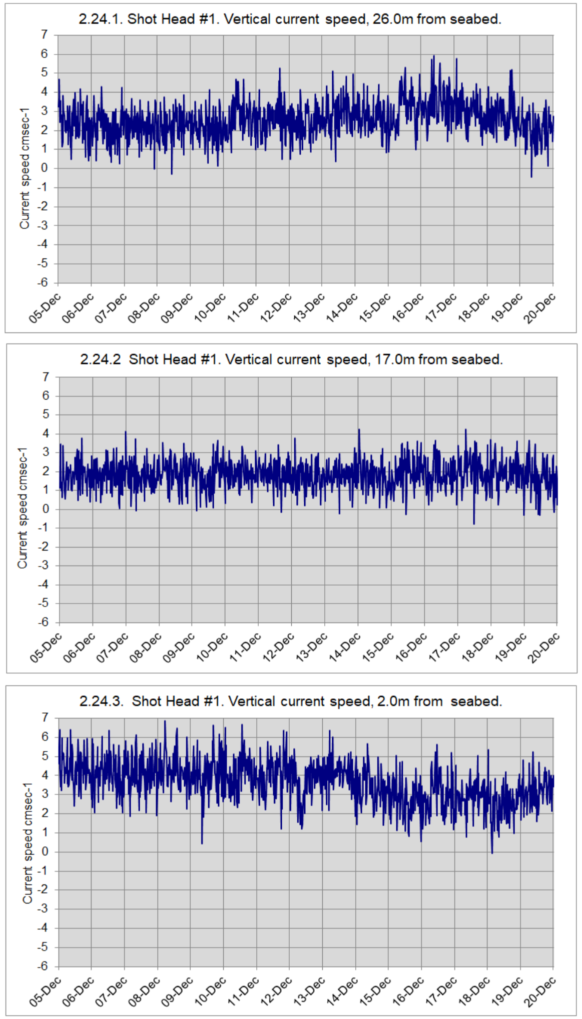
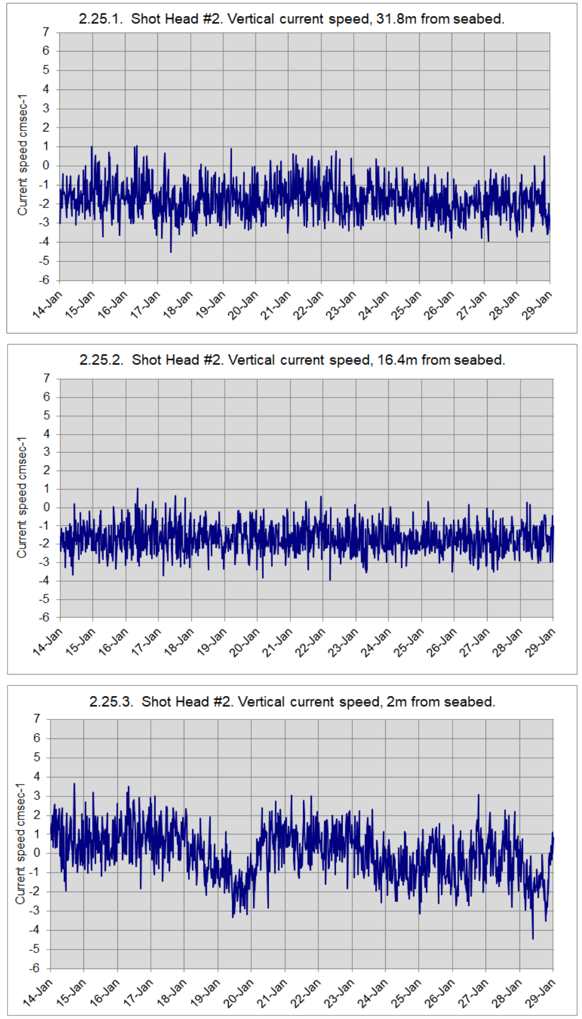


Figure 2.25
Shot Head Bantry Bay; Deployment 2.
RDCP position ING Grid ref 085177.78E 04783609N.
Vertical current speed (cmsec^{-1}) at 31.8mm, 16.4m and 2.0m from the seabed.
Period 00:00 14th January 2010 to 00:00 29th January 2010 (GMT); 15 days.



The literature refers to the ability of *L. salmonis* Nauplius and Copepodid larvae to respond to a variety of stimuli by directional swimming or looping, either towards or away from a stimulus source, although Nauplii and Copepodids respond differently. Much of this work has been carried out either in mesocosms suspended in the sea, or in aquaria. Larvae for experimentation were generally obtained from fertilised egg strings detached from ovigerous female lice, taken from host fish. Heuch et al demonstrated diel vertical migration towards light in free-swimming larvae[47] in such systems and also showed swimming in response to ultrasonic stimuli, similar to those created by the bow wave in front of swimming host fish.

Heuch's observations regarding Copepodid phototaxis and aggregation at the surface during light conditions in homogenous, 30‰ salinity suggested that to him that Copepodids are highly competent at sensing salinity levels, are able to tolerate low salinity conditions, and may actively orientate towards haloclines. This behaviour may allow them to come into contact with odour trails in the water (that tend to be carried further above haloclines) and orientate towards river mouths, where they are more likely to come into contact with migrating smolts. Whilst most of Heuch's conclusions are regarded as correct by other authors, Bricknell et al[48] and others have since shown that, in salinity gradients, Copepodids avoid salinities below 27‰, by both altering their swimming behaviour and passive sinking, in order to aggregate below haloclines in inshore coastal waters such that this could aid host location. Bailey[49] demonstrated the role of semiochemicals in Copepodid host location and also predator avoidance, whilst Johnsen[50] has shown that Copepodids also exhibit a thermotaxis which may cause a further vertical migration.

Various authors have contributed on swimming and sinking speeds of free-swimming *L. salmonis* larvae in response to the stimuli described above. Gravil[51] showed that Nauplii have a mean swimming speed of $1.25\pm0.16 cmsec^{-1}$ and a mean sinking speed (both Nauplii and Copepodids are negatively buoyant in full strength sea water) of $0.09\pm0.01 cmsec^{-1}$. Copepodid mean swimming speed is 2.14 ± 0.24 $cmsec^{-1}$ and mean sinking speed $0.1\pm0.03 cmsec^{-1}$. Copepodids spend

47 Heuch P.A. et al 1995. Diel vertical migration: a possible host-finding mechanism ion salmon louse (Lepeophtheirus salmonis) copepodids? Can. J. Fish. Aquat. Sci. 52, 681-689.

48 Bricknell I.R. et al. 2006. Effect of environmental salinity on sea lice Lepeophtheirus salmonis settlement success. Dis. Aquat. Org 71, 201-212.

49 Bailey RJE et al. 2011. The role of semiochemicals in host location and non-host avoidance by salmon louse (Lepeophtheirus salmonis) copepodids. Can. J. Fish. & Aquat. Sci., 2006, Vol. 63, 448-456.

50 Johnsen I.A. 2014. Vertical salmon lice behaviour as a response to environmental conditions and its influence on regional dispersion in a fjord system. Aquacult. Environ. Interact. 5, 127-141.

51 Gravil H.R. 1996. Studies on the biology and ecology of the free swimming larval stages of Lepeophtheirus salmonis (Kroyer, 1838) and Caligus elongatus Nordmann, 1832. PhD thesis, University of Stirling.

more time sinking than swimming, resulting in a maximum net upward movement of 1.38cmsec^{-1}. Gravil also reported a burst swimming speed in Copepodids of 10.23cmsec^{-1}, on stimulation, whilst Heuch et al[52] found a burst swimming speed of 9cmsec^{-1}, which could be maintained for 1 second during a burst length of up to 3 seconds, after which swimming speed reduced to a background (unstimulated) level 1.55mm±0.17sec^{-1}.

Gravil regarded the "hop and sink" behaviour that she observed as the means by which both Nauplii and Copepodids could rise in the water column, subject to the differences in the stimuli to which they respond. Both Wooten et al[53] and Bron et al[54] observed similar behaviour. Wooten regarded it as having value in seeking out free-swimming hosts in the upper layers of the water column.

To refer back to IFI's submission that prompted this discussion point, IFI have expressed the view to ALAB, apparently supported by the IMR Norway lice modelling group that *"…..sea lice in the water column can avoid freshwater layers……..and are attracted to light near the surface during the day and sink away from the surface during the night. It is our opinion, that the conclusions drawn in the assessment of sea lice dispersion based on the assumption of the parasite as neutrally buoyant particles is not an accurate reflection of potential sea lice dispersion in Bantry Bay"…. this (*opinion*) is based on…....modelling tools that have already been developed and validated in Norway by the Institute of Marine Research, which do consider the active vertical behaviour of sea lice in the water column as a component of their models".*

To go through IFI's points in turn:-

Regarding freshwater, it is submitted that freshwater inputs are so low into Outer Bantry Bay relative to oceanic influx and mixing that there are no freshwater layers for farm-origin Copepodids to avoid, or haloclines under which to accumulate, anywhere between Bantry Bay salmon farm sites and the near-coastal zone. Thus, this cannot play any part in farm-origin Copepodid dispersal or accumulated infestation pressure in this case.

Whilst under favourable conditions, free-living Copepodids may be able to respond to light by a positive phototaxis, with a maximum sustainable daytime "hop and sink" swim speed of 1.38cmsec^{-1}, vertical current speed amplitudes (i.e. between upward and downward flow), at all depths of the

52 Heuch P.A. et al 1997. Detection of infrasonic water oscillations by copepodids of Lepeophtheirus salmonis (Copepoda Caligida). J. Plank Res, 19(6), 735–747.

53 Wootten R., Smith J.W. and Needham E.A. (1982) Aspects of the biology of the parasitic copepods Lepeophtheirus salmonis and Caligus elongatus on farmed salmonids, and their treatment. Proc. Roy. Soc.Edin. 81B, 185-197.

54 Bron, J. E., Sommerville, C., & Rae, G. H. (1993). Aspects of the behaviour of copepodid larvae of the salmon louse. In G. A. Boxshall & D. Defaye (Eds.), Pathogens of wild and farmed fish: Sea lice (2nd ed., pp. 125–142). New York: Ellis Horwood Ltd

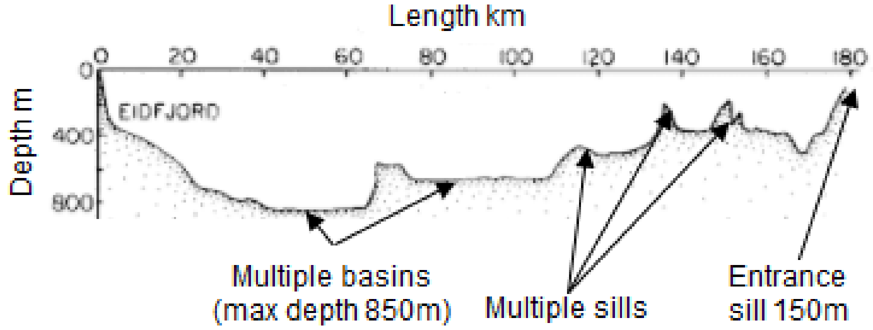
water column in Bantry Bay are of the order of 3 to 5 times this. Under these circumstances, such a phototaxis can only be disrupted and can therefore have no role in the vertical position or concentration of *L. salmonis* larvae in the water column. It should also be noted that phototactic larvae sink at night. Thus, it is submitted that, under these circumstances and in the specific case of Bantry Bay, as further explained in preceding sections, treatment of free-living *L. salmonis* larvae as neutrally buoyant particles is a reasonable and justifiable approach to their dispersion modelling, in contradiction of the view expressed by IFI.

As previously explained, the hydroactive environment of Outer Bantry Bay disperses farm-origin Copepodid larvae to such low densities that they are rendered harmless as parasites to wild salmonids, both in open bay waters and in natural inshore infestation zones. Because of the novelty of salmon farming relative to its evolutionary timescale, *L. salmonis* can have no evolved mechanisms to carry its larvae from salmon farm sites to specifically target natural infestation zones. In the hydrographic and salmon farming conditions of Bantry Bay, such targeting could only be achieved by wild adult ovigerous lice, with the aid of a homing vector host which is capable of directional swimming to its target through any hydrographic forces that it encounters. This is an evolutionary step too far, for farm-origin *L. salmonis* Copepodids.

As a postscript to this discussion point, a brief explanation of the characteristics of fjords and the consequent Norwegian approach to HD and lice dispersion modelling, to the best or out knowledge, may be useful to help explain the "Norwegian opinion" offered in the IFI submission.

A fjord is long, narrow sea inlet with high, steep sides or cliffs, created by glaciation. Fjords are generally very deep and characterised by a shallow entrance sill, comprising terminal moraine left during glacial retreat, and one or more basins in their length. Figure 2.24 shows a section through Hardangerfjord, one of Norway's most productive salmon farming areas and the current central focus of IMR's modelling program.

Figure 2.26.
Longitudinal section through Hardangerfjord, Norway.
Not to scale



In contrast to the non-stratified *Ria* exemplified by Outer Bantry Bay, fjords are defined as *Highly Stratified Estuaries*. This is primarily as a result of very high seasonal freshwater input, due to the spring ice melt (which coincides with smolt migration), plus high autumn rainfall. Taking the example of the Hardangerfjord, Norway's second longest fjord (179km long x 860m deep), tidal amplitude is low (one third of that for Bantry Bay), relative to its great depth, which is twenty times that of Bantry Bay. Annual mean freshwater input is quoted at 400m^3/second[55], that is about thirty-two times that for Bantry Bay. Thus, the total volume of Bantry Bay's annual freshwater input could enter the Hardangerfjord in a maximum of 11.6 days, or probably much less, bearing in mind its seasonality.

Fjord waters are divided into layers (i.e. stratified); broadly a surface layer, from 0-5m, an intermediate layer, to the depth of the entrance sill and a fjord basin, below the sill depth. The surface layer is brackish with salinity increasing with depth and subject to seasonal freshwater runoff. This can create seaward currents, which can run for weeks, with huge potential to transport viable lice Copepodids great distances. Currents are strongest and most variable in the upper 10-20m of water depth, driven by river runoffs, winds, tides and water exchange due to offshore density differences. Wind-driven currents are most evident when there is a strong vertical stratification. These stratified hydrographic characteristics can have a strong influence on larval lice dispersal, including the fact that, whilst some larvae may be "lost" by sinking, most remain in the upper strata by phototactic swimming in stratified layers and due to the increasing density of basin water.

Hardangerfjord currently accommodates over 60 salmonid farm sites and a farmed salmon standing stock of over 50,000 tonnes, yielding over 80,000 tonnes of salmon production per annum. This approaches 8% of Norway's entire salmon production and is five or more times Ireland's entire annual salmon output, in a single body of water.

Scientists from the Institute of Marine Research (IMR) and other Norwegian state institutions have been involved in a multidisciplinary research program, which started in the Hardangerfjord and is now radiating outwards to take in all Norwegian salmon farming areas, since the millennium. The objective of the Hardangerfjord initiative has been to establish Coastal Zone Management (CZM) strategies with the ambition that the Norwegian aquaculture industry and wild fish interests can live side by side, in particular in respect of lice control. The Phase 1, (2004 to 2007) final report on this initiative was issued in 2008[56] and the Phase II, (2008 to 2009) final report was issued in 2010[57].

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55 Johnsen I. A. 2011. MSc thesis. Dispersion and abundance of salmon lice (Lepeophtheirus salmonis) in a Norwegian fjord system.

56 Finstad B. (Coordinator) 2008. Final report for NFR-project No.163869: "The Hardangerfjord salmon lice project 2004-2007".

57 Finstad B. (Coordinator) 20010. Final report for NFR-project No.163869: "The Hardangerfjord salmon lice project 2008-2009.

Work has continued since, in data collection, lice monitoring and model development, with increasing numbers of contributions to the technical literature, many by the same caucus of IMR scientists. This has all been prompted by the fact that the sheer numerical scale of the Norwegian salmon farming industry results in ambient levels of farm-origin lice larvae that run into into billions upon billions[58], despite the fact that individual sites may well operate within their (Norwegian) legal limits as far as lice densities on famed fish are concerned. This situation, which is far from the reality in Bantry Bay, has been known to apply to Norwegian salmon farming for many years.

As the IFI submission and the Shot Head appeal process may both indicate, one unfortunate consequence of this for Irish salmon farmers is that this "Norwegian circumstance" has been transplanted and applied (by some) into Ireland's small and broadly sustainable salmon farming industry with absolutely no scientific foundation, whilst the pragmatic Norwegian approach to the development of a workable socio-economic solution for its rural coastal communities, which includes both sustainable salmon farming and a viable wild fisheries sector has not.

Following a number of seminal papers on HD and lice modelling in Hardangerfjord and elsewhere[59], [60], [61], attention has now turned to finding a means of control, primarily by limiting salmon production levels by production zone in order to limit lice infestation pressure, using a so-called Traffic Light System[62], [63]. This system has been ratified by a Norwegian government white paper, for the environmental sustainability of salmon farm production within independent production zones, based largely on modelled outcomes of the risk assessment of lice impact. The system was introduced for assessment in 2017 and, as far as is known the outcomes are still awaited. See Figure 2.27.

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57 Heuch P.A. et al 2001. A model of salmon louse production in Norway; effects of increasing salmon production and public management measures. Dis. Aquat. Org. 45, 145-0152.

59 Johnsen I.A. et al. 2014. Vertical salmon lice behaviour as a response to environmental conditions and its influence on regional dispersion in a fjord system. Aquacult. Environ. Interact. 5. 127-141.

60 Johnsen I.A. et al 2016. Salmon lice dispersion in a northern Norwegian fjord system and the impact of vertical movements. Aquacult. Environ. Interact. 8, 99-116.

61 Asplin A. et al. 2014. Dispersion of salmon lice in the Hardangerfjord. Mar. Biol. Res. 3, 216-225

62 Taranger G.L. 2015 Risk assessment of the environmental impact of Norwegian Atlantic salmon farming ICESjms. 72(3). 997 1021.

63 Vollset K.W. 2017. Food for Thought. Disentangling the role of sea lice on the marine survival of Atlantic salmon. ICESjms 2017, doi:10.1093/icesjms/fsx104.

Figure 2.27.
Table of suggested traffic lights that will regulate regional biomass in 13 salmon farm production zones in Norway according to "Government white paper".
After Vollsett KW ICES Journal of Marine Science 2017, doi:10.1093/icesjms/fsx104.

	Rule
	It is likely that <10% of the population dies because of lice infestations.
	It is likely that 10–30% of the population dies because of lice infestations.
	It is likely that >30% of the population dies because of lice infestations.

	Consequence
	Increase biomass in production zone.
	No reduction or increase of biomass in production zone.
	Reduce biomass in production zone

It should be pointed out that the wild salmon mortality for each Traffic Light (Green <10%, Amber 10% to 30% and Red >30% is based on the % loss to salmon recruitment, that is post-marine migration. These loss figures are equivalent to losses on escapement of wild smolts, over and above the current marine mortality figure, which the Norwegians also accept, of 95%, of Green 0.5%, Amber 0.5% to 1.5%, and Red >1.5%. Thus, the scientists behind the development of the Traffic Light system seem to find broad agreement that a loss on escapement in the range 0.5% to 1.5% caused by all lice, is sustainable in respect of the impacts of wilds stocks from salmon farm production zones in Norway. It is notable that that this is close to the figure established by Jackson el al[64], [65] of 1%, across eight locations in Ireland (but not including Bantry Bay) which he understandably regarded as "*small as a proportion of the overall marine mortality rate*". What is not presently clear (outside IMR circles at least) is where production zones within the Hardangerfjord lie on this scale.

By way of final comment on this subject, it is submitted that farm-origin larval lice infestation pressure exerted on wild salmonids in Norway is no more dependent on any infestation mechanism evolved by *L. salmonis* than it is in Bantry Bay. However, a powerful anthropogenic mechanism has been provided by the salmon farming industry in the Norwegian case; the sheer magnitude of larval lice numbers. Since the Traffic Light system is all about scaling, the consequences of lice discharge rates from so-called Local Biomass Densities, the Norwegians themselves should have no difficulty in concluding, like RPS, that the risk to wild salmonids in Bantry Bay is so low that the Traffic Light system is simply not applicable.

64 Jackson. et al 2013. Impact of Lepeophtheirus salmonis infestations on migrating Atlantic salmon, Salmo salar smolts at eight locations in Ireland with an analysis of lice-induced marine mortality. J Fish. Dis. 2013. doi:10.1111/jfd.12054.

65 Jackson D et al. 2014. Response to M Krkosek, C W Revie, B Finstad and C D Todd's comment on Jackson et al. 'Impact of Lepeophtheirus salmonis infestations on migrating Atlantic salmon, Salmo salar L., smolts at eight locations in Ireland with an analysis of lice-induced marine mortality. J Fish. Dis. 2014. doi:10.1111/jfd.12239.

2.3.4. Dispersion modelling of *L. salmonis* larvae in Bantry Bay. Conclusions.

This section has examined the dynamics of the two-way interrelationship between wild origin and farm origin *L. salmonis*. It sets out the stark differences between the highly efficient, natural wild infestation process, following millions of years of evolution, to be specifically targeted to river estuarine areas, where evolved strategies can assist in generating and maintaining high Copepodid densities to maximise infestation, as against the serendipity of Copepodid dispersions across open seas, resulting from chance encounters with salmon farm sites. *L. salmonis* has no evolved strategies to enable their Copepodid larvae to target river estuaries in adequate numbers from salmon farm locations. This can only be achieved if specific numerical, spatial and hydrographic conditions apply, as may be the case in Norway

The models created for this application process apply only to Bantry Bay and show that, largely as a result of its highly ocean- and wind-influenced, destratified characteristics, Nauplius and Copepodid larvae can do no more than disperse throughout the water column at ever-dwindling densities, within the plankton, during their short lives. It is observed that Bantry Bay conditions do not apply to larval lice dispersal in the Norwegian salmon farming industry, for a number of reasons. This requires an entirely different approach, both to salmon farm and lice management and to hydrographic and to dispersional modelling.

The RPS Bantry Bay WQ model shows that the chances of Copepodid attachment to isolated salmonids in the open waters of the bay, and more particularly to wild smolt emerging from rivers into river estuaries, are so low that no farm-origin augmentation of wild salmon lice infestation levels is anticipated, either in Trafrask Harbour or its immediate estuarine area or in any other river estuary in the bay.

For these reasons it is concluded that, in particular in view of the historical maintenance of low lice levels on farm sites and the naturally low lice infestation potential of Bantry Bay open waters as a whole, there is effectively no lice risk projected from the proposed Shot Head site, to wild salmonids at any location, either in the open waters of Bantry Bay or in the immediate vicinity of the Trafrask River or any other estuary in the bay.

It is further submitted that there is zero risk that anadromous salmonids will be reduced in numbers in their freshwater phase, as a result lice larva dispersal from the proposed Shot Head site, to impact on the availability of vector hosts for FPM Glochidia larval development and dispersal.

However, a cautionary note is added. Those FPM stocks in the Trafrask system and elsewhere around Bantry Bay and indeed further afield in Ireland that are not currently listed in SI 296 2009 are under huge risk of extinction. <u>This will largely occur through neglect of their freshwater habitat</u>. It is strongly recommended that a concerted effort be made by the local community, via local and national authorities and pressure groups, to rectify this situation, if they wish this Annex II species to endure in their river.

2.4. The Freshwater Pearl Mussel (FPM); *Margaritifera margaritifera* in the Trafrask river system; evaluation of risk exposure.

2.4.1. Introduction.

See Box 2, in Section 2.2 for an overview of *Margaritifera margaritifera* (FPM) life history and biology. FPM is categorised as highly threatened and critically endangered, both across Europe[66] and in Ireland[67]. An estimated 90% of all European FPM populations died out during the 20th Century. FPM produce freshwater pearls, and, due to its historic over-exploitation, as well modern threats to its pristine habitat requirements, the species is protected under Annex II of the EU Habitats Directive 92/43/EEC, by the creation of Special Areas of Conservation (SACs) where "important" populations occur, and under Annex V, which restricts their exploitation or removal from the wild, as well as under the Wildlife Acts, 1976 and 2000 and SI 296 2009, the EC Environmental Objectives (Freshwater Pearl Mussel) Regulations 2009. This lists the 27 Irish FPM populations within SAC areas, to which this SI applies. Bantry Bay rivers are not in SACs (except the Glengarriff, which is not designated for its FPM) and therefore are not covered by the SI, or for that matter by the Strategic Environmental Assessment (SEA)[68] for the same 27 FPM populations, completed in 2010; see Figures 2.28, from the SI and SEA, and Figure 2.29.

Of 150 non-marine mollusc species extant in Ireland in 2016, FPM is one of six on the Global IUCN red list of threatened species and is one of three species in critical danger of regional extinction in Ireland[69].

The Article 17 Assessment submitted to Europe by NPWS in 2013[70] describes Irish FPM status in detail. Between 2000 and 2012, FPM populations and habitats within SAC's were assessed under the terms of SI 296 2009. This includes the largest and fittest populations in the country. Under the SI, populations were assessed under four criteria:-

1. Number of live mussels.
2. Number of dead mussels.
3. Population % of approximately five years of age or younger.
4. Population % of approximately 10-15 years of age or younger.

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66 Cuttelod A. et al., 2011. European Red List of non-marine molluscs. Luxembourg: Publications Office of the European Union.

67 Byrne AW. et al., 2009. Ireland Red List No. 2. 2009. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government

68 Anon. 2010. Freshwater Pearl Mussel Strategic Environmental Assessment. DEHLG March 2010.

69 Byrne A. et al. 2016. Ireland Red List No. 2; Non-Marine Molluscs. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

70 NPWS (2013) The Status of EU Protected Habitats and Species in Ireland. Overview Volume 1, Habitats Assessments Volume 2, Species Assessments Volume 3. Version 1.0. Unpublished Report, National Parks & Wildlife Services. Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

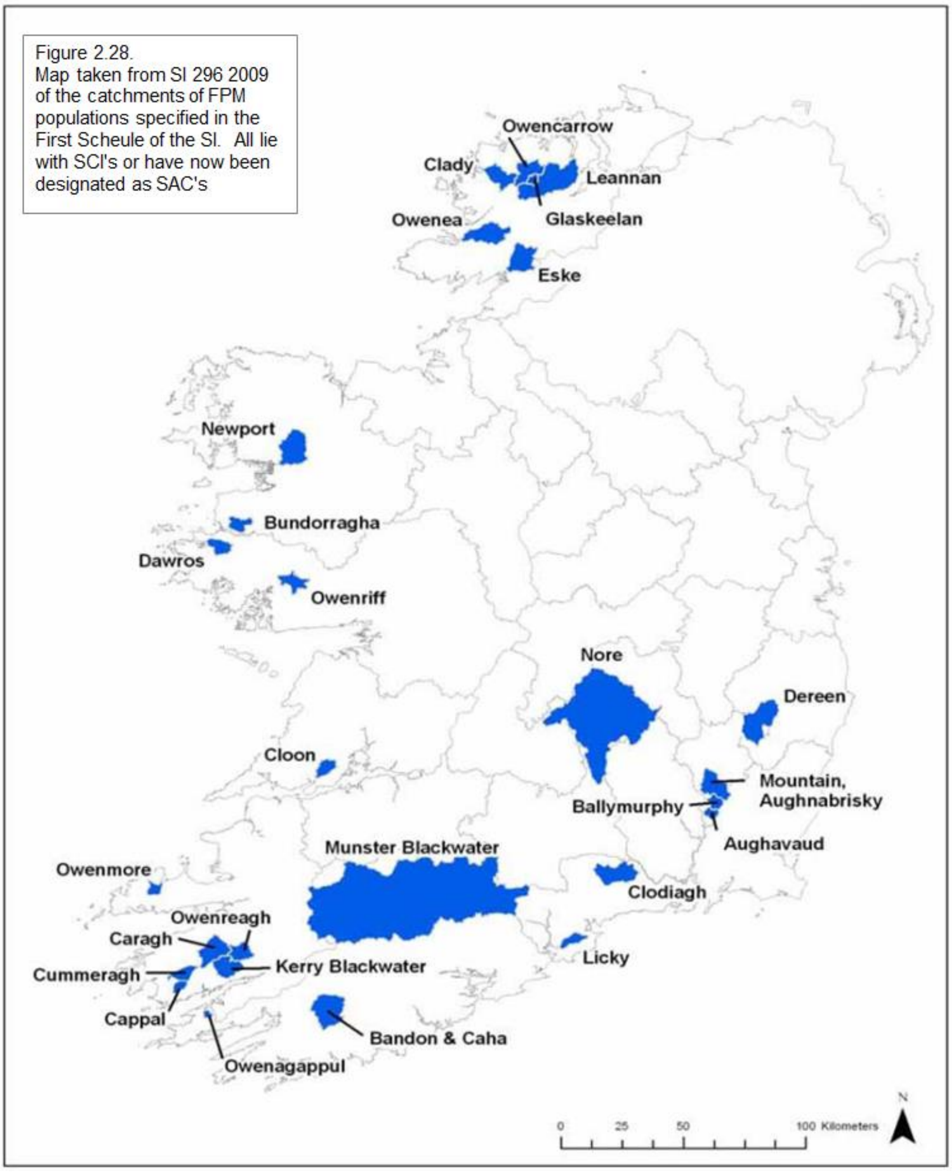


Figure 2.28.
Map taken from SI 296 2009 of the catchments of FPM populations specified in the First Scheule of the SI. All lie with SCI's or have now been designated as SAC's

Five attributes were used to assess the habitats surveyed, selected to highlight overall water quality, nutrient enrichment and siltation, with the following results:-

1. Macrobenthos 92% failed.
2. Phytobenthos / diatoms 31% failed.
3. Macroalgae cover 69% failed.
4. Macrophyte cover 92% failed.
5. Siltation 92% failed.

The results of the assessment showed that juvenile recruitment was insufficient to replace lost adults in all populations surveyed, and that adult mortality was still generally high. As a result, Irish FPM status was described as unfavourable / bad. The population was estimated to have reduced by 8% in just 6 years, since the previous assessment, in 2006.

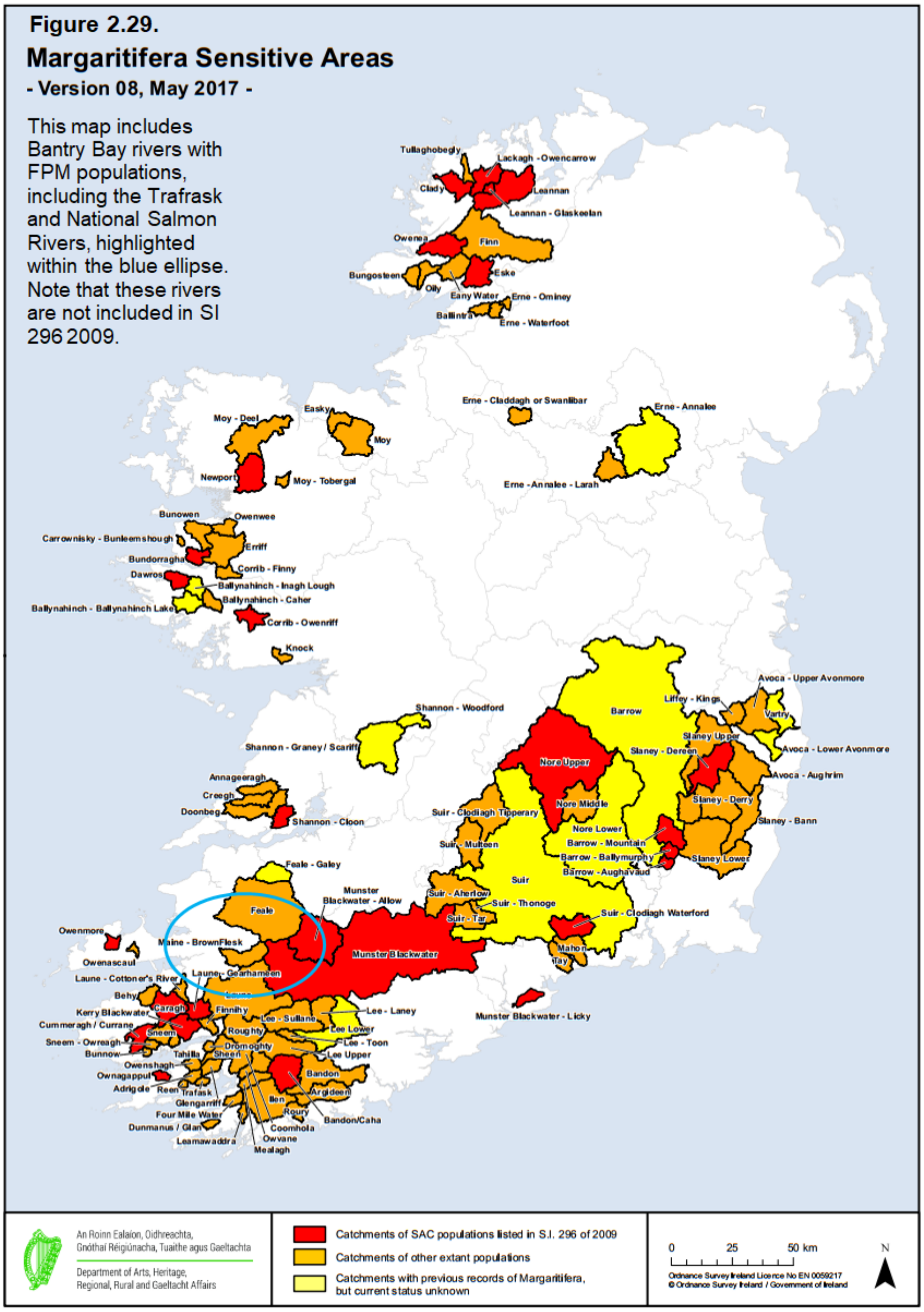


Figure 2.29.
Margaritifera Sensitive Areas
- Version 08, May 2017 -

This dedicated surveillance data, along with EPA river water quality data demonstrate that sedimentation and / or nutrient enrichment are the main causes of the FPM's decline across Ireland. The overall quality of the habitat for FPM was therefore assessed as unfavourable / bad.

Surprisingly, the assessment states that a number of important conservation measures, detailed in the assessment, are now in place, and suggests that future prospects are improving. Nonetheless, owing to various age class gaps, due to lack of breeding over a considerable period, no significant or national recovery is expected before 2028.

In view of the extent of pressures and threats and Ireland's current growth agenda[71] and proposals for rural repopulation, it is submitted that this may be a forlorn hope, in particular for catchments such as those around Bantry Bay where FPM are outside of, or not designated in SAC areas and, therefore, their status has not yet even been fully assessed.

<u>This is the true background against which the risk exposure of FPM in the Trafrask River, must be judged</u>.

It is highly relevant that all the pressures and threats which FPM are considered to face (see for example Article 17 Assessments) are of terrestrial or riverine origin. It is also important to note that, whilst juvenile (freshwater) salmonids are essential to the life cycle of FPM, as the vector hosts for the dispersion and development of FPM glochidia larvae (see Box 2), salmonid stock status in relation to FPM is not a subject of either the 2007 or the 2013 Article 17 Assessments for FPM, although Atlantic salmon (the only salmonid species protected by Annex II of the Habitats Directive) has its own, separate Article 17 Assessment; see Section 2.3.3, Discussion Point 5. Juvenile (freshwater) salmonids are threatened by exposure to the same catchment-derived threats as FPM, that is sedimentation and nutrient enrichment[72] and this certainly may be an issue in some if not most catchments

2.4.2. The status of the Trafrask River.

The Trafrask River (also known and the Dromogowlane River) enters Bantry Bay at the head of Trafrask Harbour, some 2.5km by sea north of the proposed Shot Head salmon farm site. Approximately 1km upstream from its discharge to the sea, to the north of the R572 road, the river divides, with a tributary, the Leitrim More River, entering the main channel from the west. The Trafrask River then runs roughly NE for about 300m, before another tributary, the Curragh River, enters the river from the NE, whilst the Trafrask River runs in a more northerly direction. There are numerous other, smaller tributaries higher up the system which, by and large, drain the foothills of the Caha Mountains, SAC 000093. Much of the lower Trafrask River runs towards the sea through raised blanket bog, protected within a National Heritage Area, Trafrask Bog NHA 002371. The Curragh River drains raised blanket bog at Leahill, protected by a further National Heritage Area, Leahill Bog NHA 002417. A further tributary of the Curragh River drains the only lake in the system, Lough More; see Figures 2.30 and 2.31.

71 Anon 2018. Project Ireland 2040 National Planning Framework. Department of Housing Planning and Local Government. gov.ie/2040.

72 Walsh, N et al. 2012. River sediment studies in relation to juvenile pearl mussels and salmonids. http://www.epa.ie/downloads/pubs/water/rivers/EPA_River_Sediment_Studies.pdf.

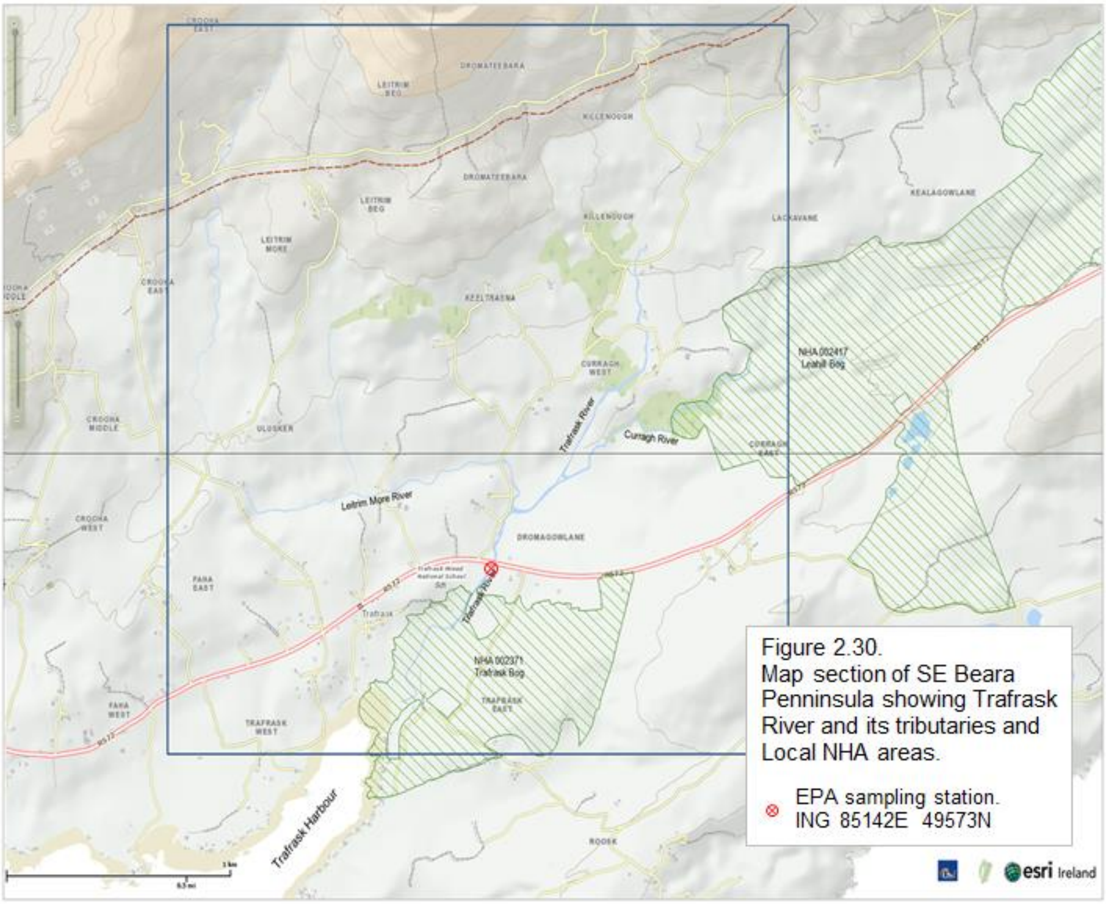


Figure 2.30.
Map section of SE Beara Penninsula showing Trafrask River and its tributaries and Local NHA areas.

EPA sampling station.
ING 85142E 49573N

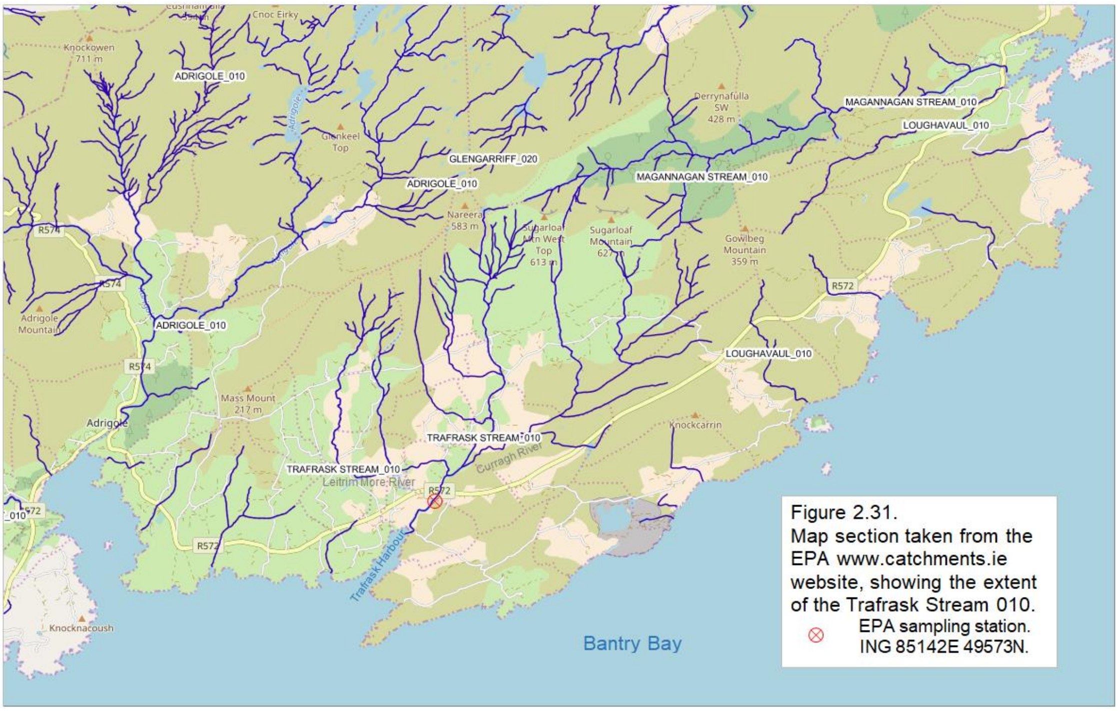


Figure 2.31.
Map section taken from the EPA www.catchments.ie website, showing the extent of the Trafrask Stream 010.

EPA sampling station.
ING 85142E 49573N.

Under the second 6-year operational program cycle of the of the Water Framework Directive (WFD) in Ireland (2015-2021), Bantry Bay and the Trafrask River now lie within a newly defined catchment area, the Dunmanus-Bantry-Kenmare catchment. Further, the number of water bodies within the Trafrask system has been revised down, from four separate river waterbodies under Cycle 1, to just one under Cycle 2, the Trafrask Stream 010, Waterbody Code IE_SW_21T030300.

According to EPA reports, the water quality of the Trafrask system has been assessed by a single, bankside-sorted infaunal sample, collected every 3 years since 1994 under the EPA's countrywide, triennial river sampling program. The sampling station is just downstream of the R572 road bridge; see Figures 2.28 and 2.29. The sampling results, expressed as Q-Index have been consistently 4-5, indicating High Ecological Status. These are shown in Table 2.3.

Table 2.3.
EPA report of Q-Values collected from Trafrask Stream 1994 to 2015.

TRAFRASK STREAM

Date Surveyed (last survey year only): 11/08/15

Biological Quality Rating (Q Values)

Station Code	1994	1997	2000	2003	2006	2009	2012	2015
RS21T030300	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

Most Recent Assessment:

Stream continuing satisfactory with High ecological quality

Station Details

Station Code	Station Location	WFD Waterbody Code	Easting	Northing	Local Authority
RS21T030300	Trafrask Br	IE_SW_21T030300	85142	49573	Cork County Council

It is noted that the EPA's most recent assessment, based on these sample results, gives the Trafrask Stream a continued High Ecological Status.

SI 272 2009 is the legislation under which the EPA assesses and grants Ecological Status, for all surface waters. Part IV of the legislation states that Ecological Status of all surface water bodies shall be assigned by the EPA under the following terms:-

"36. The ecological status of a body of surface water shall be represented by the lower of the quality element values for the biological and physico-chemical status calculated for each relevant quality element, except for the purpose of assigning high status in which case ecological status shall be determined by the lowest of the status values obtained for the biological, physico-chemical and hydromorphological quality elements."

A question therefore arises as to whether the Trafrask Stream water body has been sufficiently surveyed to allow the granting of High Ecological Status, throughout the entire water body, from a single triennial infaunal sample collected in its lower reaches, when no physicochemical or hydromorphological data seems to be available to support the assessment, as required by the SI. This is an issue in this case because of the presence of FPM, which requires the highest of water quality and, as will be made clear, this is unlikely to be the case in the Trafrask system.

A number of Bantry Bay rivers have populations of FPM, defined by NPWS in 2014, amongst other populations, as "….*not considered of sufficient quality to warrant designation for the species and detailed restoration objectives, targets, plans or measures are* <u>*unlikely to be developed*</u>*. However, the potential effects of any plans, developments or activities on the populations, including the potential to cause 'environmental damage' as per the Environmental Liability Directive and Regulations* (SI 547 2008)*, must be determined. The NPWS holds some detailed information on the distribution and abundance of freshwater pearl mussels in a small number of these catchments*."[73] These areas are shown in the map, updated by NPWS in 2017, in Figure 2.29, where they are highlighted orange. So far, it would seem, because these areas have not been granted SAC status and are therefore described by NPWS as "*not considered of sufficient quality",* either to be included within an SAC or otherwise to be covered by SI 296 2009, nothing has been done by way of *"SEA, EIA or other ecological assessment"* to thoroughly assess the status of the FPM stocks in the Trafrask system, or in any other Bantry Bay FPM river. This seems a perverse judgement on the part of the Government and NPWS because, under the terms of Habitats Directive, Annex II species should have protection as if included within an SAC, wherever they occur (to quote the Habitats Directive: "A*nnex II* (species are) *animal and plant species of Community interest whose conservation requires the designation of Special Areas of Conservation"*).

Figure 2.32 shows that the Bantry Bay rivers highlighted as containing FPM are all the National Salmon Rivers, that is the Adrigole, Glengarriff, Coomhola, Owvane and the Mealagh, as well as the Reen and the Trafrask (there may well be other small rivers in the locality with FPM that have never been surveyed). With the exception of the Reen, which is very small and is not currently assigned an Ecological Status (and, according to Ross, now probably has only three FPM extant; see also Section 2.4.3), these rivers are all assigned an Ecological Status by the EPA, as shown in Figure 2.32, although the range of Quality Elements contributing to the assigned status in each case is not listed here. It is nonetheless of interest that both the Adrigole and the Owvane only reached Good Status for the period 2010-2015 rather than High Status, which may be regarded in itself as insufficient for the needs of FPM.

[73] *Margaritifera* Sensitive Areas Version 06, October 2014 Explanatory text Áine O Connor, NPWS updated October 2014.

In addition, the EPA's WFD Risk map for these rivers in Figure 2.33 shows that the maintenance of Good Status is the Adrigole River is At Risk, where a principal pressure arises from forestry plantings (apparently since 2008 since forestry was not considered a threat in this catchment in the FPM rapid survey conducted in 2008; see Section 2.4.3). All this suggests that National Initiatives proposed in the 2013 Article 17 Assessment are overdue for the FPM rivers of Bantry Bay.

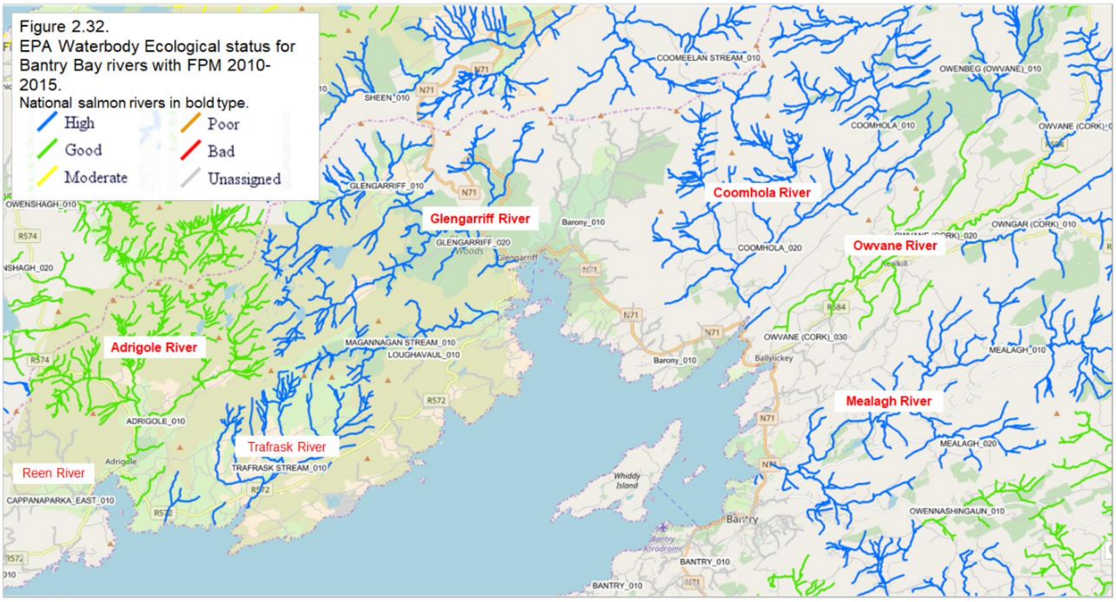


Figure 2.32.
EPA Waterbody Ecological status for Bantry Bay rivers with FPM 2010-2015.
National salmon rivers in bold type.

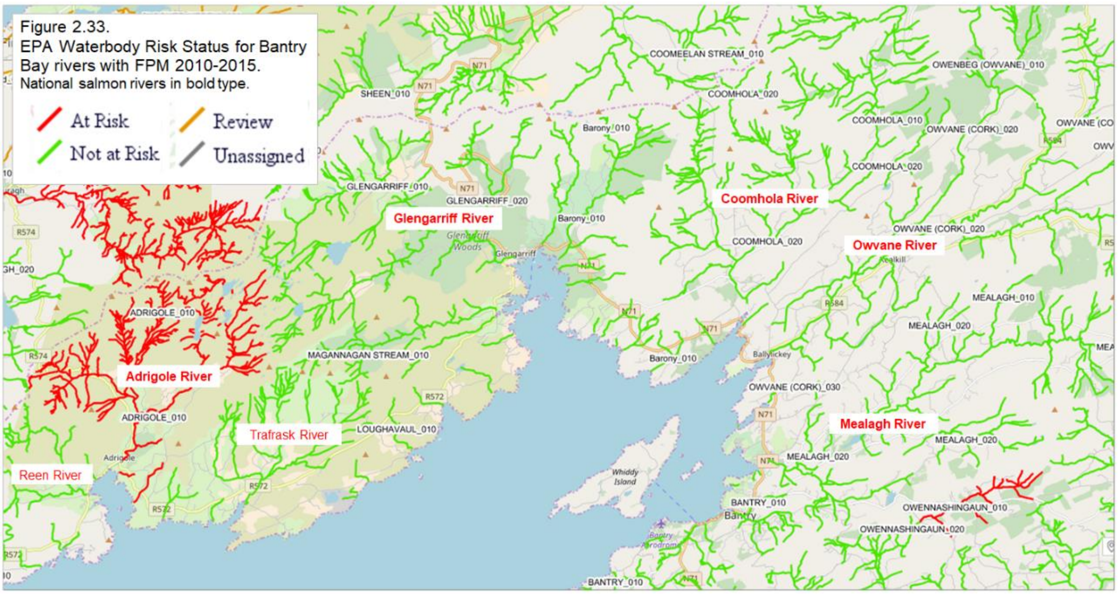


Figure 2.33.
EPA Waterbody Risk Status for Bantry Bay rivers with FPM 2010-2015.
National salmon rivers in bold type.

The EPA also provides environmental pressure maps[74] for the Trafrask catchment and those of other Bantry Bay rivers; see Figures 2.34 and 2.35. Figure 2.34 shows that there may be a considerable area of high

[74] See EPA website www.catchments.ie

near-surface Nitrate susceptibility in the Trafrask catchment, relative to some other local rivers. Figure 2.35 shows that this is unlikely to be the case for near-surface Phosphate susceptibility. Since, in the presence of adequate riverine Phosphorus, Nitrate is a source of eutrophication in freshwater, it would seem appropriate that physico-chemical and nutrient parameters are monitored and included in the Quality Elements (Physicochemical Quality Elements) that contribute to the overall Ecological Status for the Trafrask system, in particular as this is required under the terms of SI 272 2009 and is a recognised risk in FPM habitats.

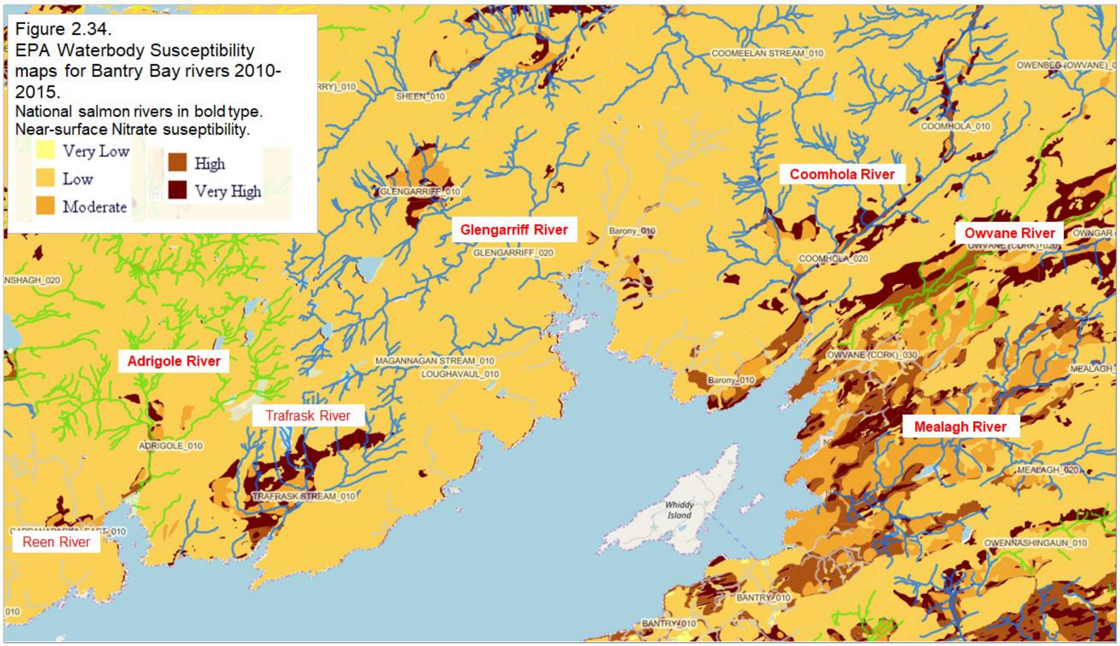


Figure 2.34.
EPA Waterbody Susceptibility maps for Bantry Bay rivers 2010-2015.
National salmon rivers in bold type.
Near-surface Nitrate suseptibility.

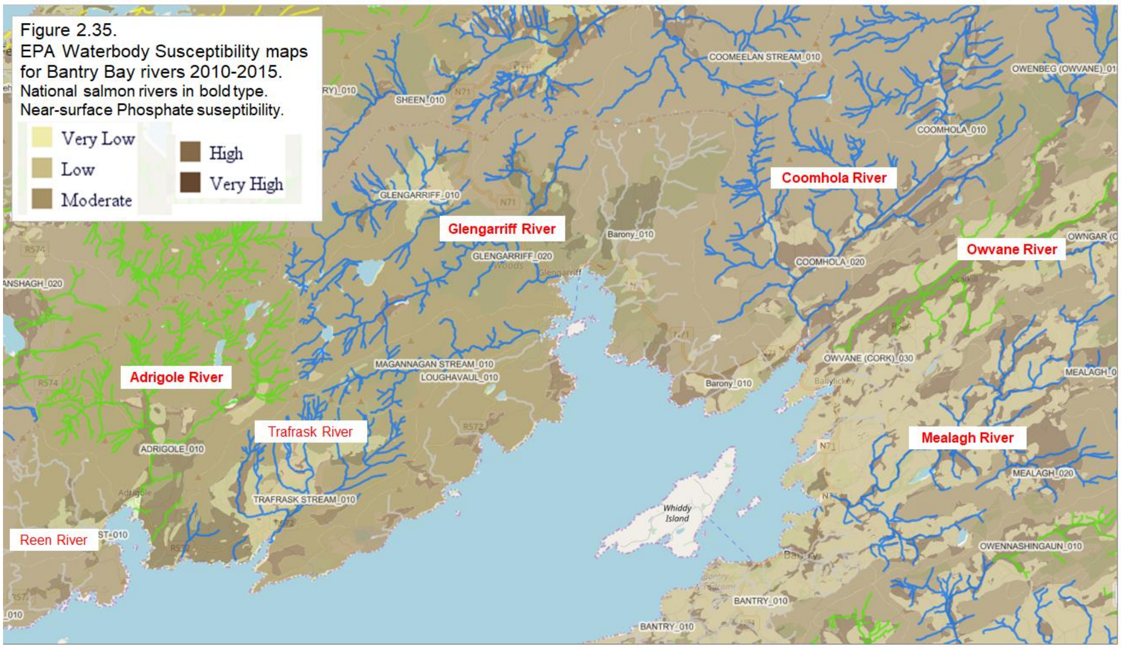


Figure 2.35.
EPA Waterbody Susceptibility maps for Bantry Bay rivers 2010-2015.
National salmon rivers in bold type.
Near-surface Phosphate suseptibility.

National trends in FPM status, pressures on FPM habitats, lack of adequate monitoring, even to the extent of overlooking legal requirements, all lead to the conclusion that the Trafrask system is monitored inadequately to ensure protection of its FPM population. This, it is submitted, leaves it exposed to very considerable risk of extinction, largely as a result of neglect, despite its Annex II status. This is further confirmed by the findings of the only reported FPM survey on the Trafrask to date, which was carried out on 2008, as described in Section 2.4.3.

2.4.3. The Status Freshwater Pearl Mussel in the Trafrask River System.

The National Parks and Wildlife Service (NPWS) records the first observations of the presence of FPM in the Trafrask system in 2002 at ING coordinates 85400E 49800N. Bearing in mind the accuracy of GPS at the time, this could refer either to the Curragh River or the Trafrask River, near to their point of confluence. NPWS also records a Rapid Assessment FPM Survey carried out by Dr Eugene Ross in a number of Irish Rivers, including the Trafrask, which was surveyed in 2008[75], along with the Rivers Adrigole and Reen.

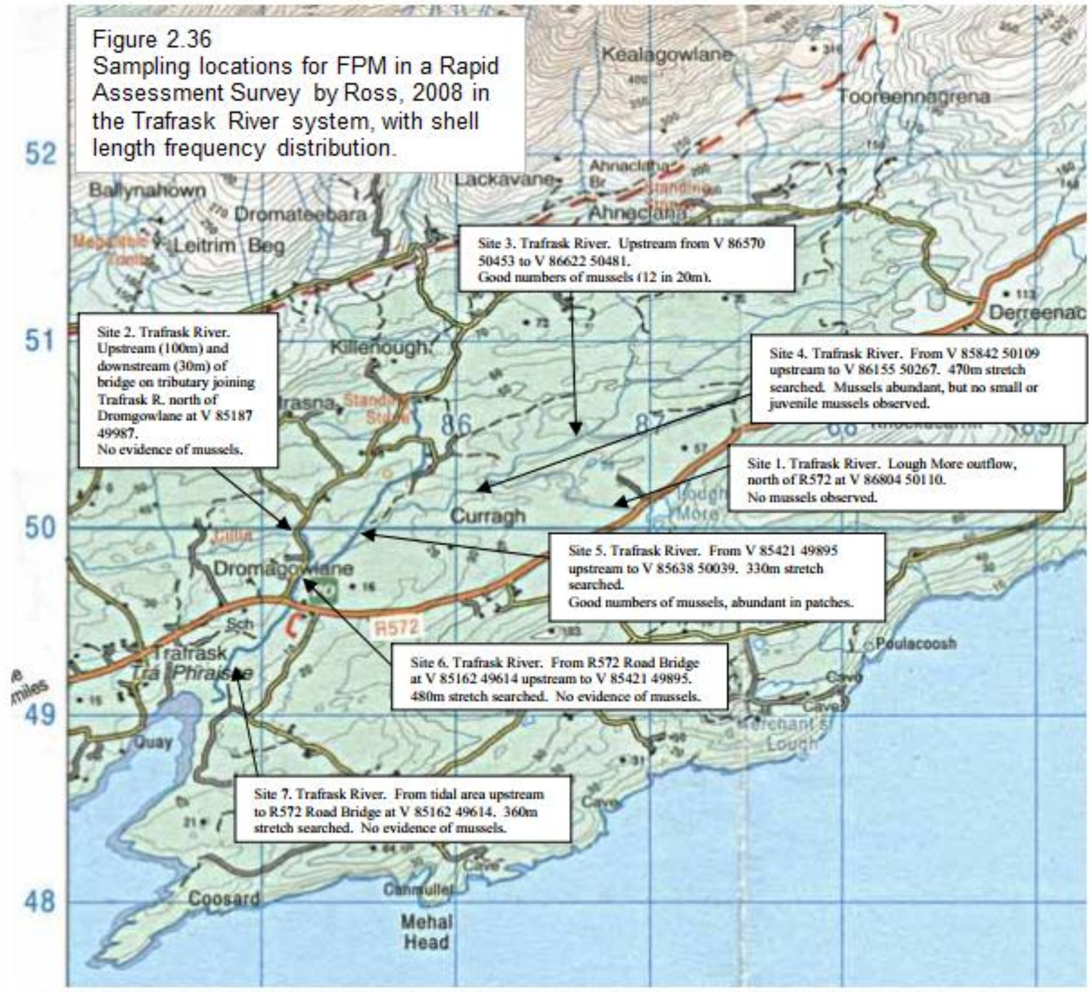
The results of the 2008 survey are summarised below and illustrated in Figure 2.35. All the FPM found were situated in large patches along the main Curragh River tributary of the Trafrask system, extending over a river stretch of some 1.5km above the confluence of the Curragh with the main Trafrask River. No mussels were found in the Lower Trafrask River, or in the Leitrim More tributary, or in the tributary draining Lough More, although this does not necessarily fully confirm their complete absence from these sections of the system, albeit subject to availability of suitable substrate.

The size of the FPM population and its high density in 3 of the 7 sections of the Trafrask River surveyed (Sites 3, 4 and 5) was felt to be significant, although the shell length frequency distribution of a sample of 114 individuals was limited to a range of 60 to 120mm. This suggests an absence of juveniles and therefore an absence of recruitment to the population in recent years. This was confirmed by the analysis of a single 0.25m^2 quadrat, which, whilst containing a dense population of adult specimens, yielded no juveniles. The report concludes that the apparent absence of recruitment in recent years, although typical of Irish populations, is worrying and requires further investigation in this case.

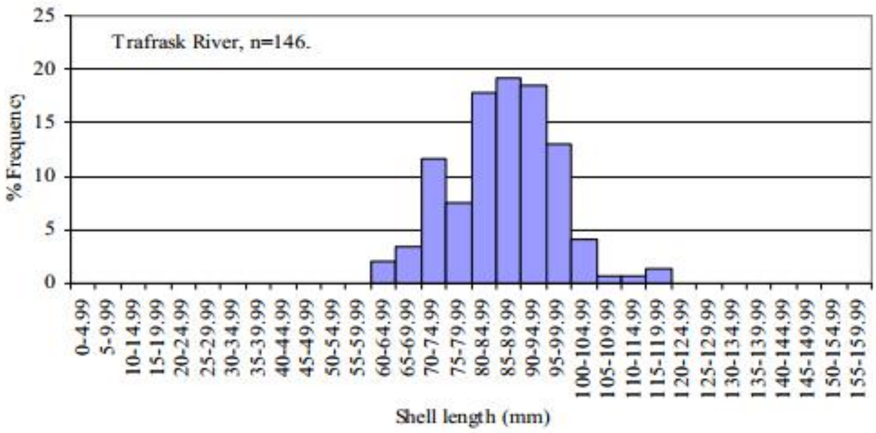
Macrophytes were present at one of the stations surveyed (Site 3), whilst filamentous algae were present at two others (Sites 6 and 7). According to the report, both indicate some eutrophication, which is inimical to the survival and recruitment of juvenile FPM. Riparian conditions ranged from scattered woodland shade to rough grazing with willow scrub. Cattle access was noted at one survey site, where good densities of FPM occurred (Site 3).

[75] Ross, E.D. (2009a) Rapid Assessment of *Margaritifera margaritifera* (L.) populations in Ireland: Rivers assessed in 2008. Report submitted to National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin January 2009.

Figure 2.36
Sampling locations for FPM in a Rapid Assessment Survey by Ross, 2008 in the Trafrask River system, with shell length frequency distribution.



Locations and results of *Margaritifera* search sites on the Trafrask River (Co. Cork).



Shell length frequency distribution recorded for the Trafrask River.

The survey found a sizeable population of FPM in the Trafrask system for the size of the river, but that conservation status is uncertain. The report concludes that, of the 14 Cork and Kerry rivers assessed, the populations in the Trafrask and Adrigole rivers were two of the four most significant populations identified and may be of national significance. The report therefore recommended that Stage 2 and 3 surveys should be completed in these rivers. However, in the ten years since this survey was conducted this has not happened, despite national concern for FPM status.

A principle recommendation of the report is that the observed absence of many age/size classes from all the *Margaritifera* populations investigated during the study indicates that <u>habitat conditions in the rivers concerned are not satisfactory and are not of sufficiently high quality to allow maintenance of the resident *Margaritifera* populations</u>. The report proposes a mechanism to incorporate increased significance for *Margaritifera* into the estimation of biological quality indices of rivers as essential, so that rivers where the biological quality is insufficient to support a fully functional and normally recruiting *Margaritifera* population <u>are not classified as "satisfactory" (or as of High Ecological Status as now granted to the Trafrask).</u>

Whilst FPM status is not used as a biological Quality Element within the terms of SI 272 2009 surface waters legislation, it is certainly within the requirements of SI 296 2009 FPM legislation, for FPM populations within SAC areas, which states quite specifically that "*the EPA, when classifying surface waters in accordance with the ecological objectives approach of the Water Framework Directive, to assign a status of "less than good ecological status" where Margaritifera is found to be in unfavourable conservation status. This will trigger further actions as waters classified as less than good must be restored to at least good status within a prescribed timeframe*". Clearly, in the case of the Trafrask, which has been granted High Ecological Status since 1994 on foot of the monitoring of a single Quality Element, this legal requirement does not hold, simply because the population in not within an SAC. However, it is submitted that this is an anomaly which legislators should give further thought to, because FPM, wherever they occur, justify such support, as an Annex II species.

Thus, it is submitted that it was made clear as long ago as 2008 that the Trafrask (and Adrigole) FPM populations may be significant in national terms yet is at severe risk of failing due to lack of recruitment. Both local and national evidence and experience has shown clearly that the causes lie within the river catchment and that the FPM population is likely to continue to age without recruitment to the point of extinction, if the steps recommended for FPM populations within SACs are not applied.

It is clear that local concern over the Trafrask FPM population has been stimulated in the process of the appeals against the licence for a salmon farm site at Shot Head. Bearing in mind the conclusions of the 2008 FPM Rapid Survey Report, it would be appropriate for this local concern to be focussed on approaches at both local and national levels to seek designation of the area as a Site of Community Importance (SCI), with a view to its elevation to SAC status, in order that local FPM can be protected under SI 296 2009, as a matter of urgency. There is some local precedent in the presence of the Glengarriff Harbour and Woods SAC 000090, which covers an adjacent catchment, although this SAC is not currently designated for FPM, despite their presence, and Annex II status.

2.4.4. The status of salmonid fish in the Trafrask system.

The status of wild salmonid stocks in the five Bantry Bay National Salmon Rivers was reviewed on the basis of their Conservation Limits, set by the Standing Scientific Committee and incorporated into the angling byelaws, in Section 2.3.3, Discussion Point 5. It was observed that, with four out of the five National Salmon Rivers in Bantry Bay fully open and the fifth open for catch and release angling, salmon stocks appear healthy around the bay and that, in the event of lack of adequate in-river monitoring data, this may provide an indication of the health of stocks in the Trafrask River.

Salmonids are important in the present context because, as explained in Box 2 in Section 1, they act as vector hosts for the growth and dispersal of Glochidial larvae, released from female FPM following egg fertilisation and early development on the female. Only juvenile brown trout (freshwater resident *Salmo trutta*), sea trout (anadromous *Salmo trutta*, which smoltify and migrate seawards, returning to freshwater to breed) and Atlantic salmon (*Salmo salar*) whilst in freshwater are known to host FPM Glochidia in Europe. Brown trout are said to be the main host species in Ireland[76]. Rivers carry varied population ratios of these species, and their relative importance for FPM is not fully clear and it may be that differences in their reproductive behaviour affect mussel recruitment. Therefore, measures to protect FPM must also include the monitoring and assessment of host fish status. Host fish become progressively resistant to Glochidial infection with age and those in the first three year-classes (but mostly 0+ and 1+ years) form most of the host population. The minimum density of fish required to maintain FPM population densities in the long-term is generally considered to be in the range of 0.2 – 0.3 fish per m^2 of river but this may still require more research[77].

Just as FPM are neglected in the Trafrask, because it is not a National Salmon River, there has been almost no assessment of the salmonid populations in the Trafrask to date, despite *Salmo salar's* Annex II status.

Stretches of the Trafrask River were walked by an Inland Fisheries Ireland (IFI) officer for the Southwestern River Basin District (SWRBD) in 2012. He tentatively identified two *Salmo trutta* redds close together in the Curragh River, a tributary of the Trafrask, see Figures 2.30 and 2.31. The IFI Environmental Officer for the SWRBD has stated that no catchment-wide electrofishing surveys had been carried out pre-2017, although a single site just below the R572 road bridge was spot-electrofished in about 2014, when salmon, sea trout and brown trout were found to be present.

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[76] Beasley CR 1996 The distribution and ecology of the freshwater pearl mussel *Margaritifera margaritifera* L. 1758 in County Donegal, Ireland, and implications for its conservation. Unpublished PhD Thesis, Queen's University, Belfast.

[77] Skinner A. et al. 2003. Ecology of the Freshwater Pearl Mussel. Conserving Natura 2000 Rivers. Ecology Series No. 2. Scottish Natural Heritage 2003.

At ALAB's request, a fuller electrofishing survey was carried out by IFI officers on 9th May 2017 at 6 sites, for which the coordinates are given in Table 2.4. The site locations, IFI 1 to IFI 6, are superimposed onto the FPM Rapid Assessment Survey map prepared by Dr Eugene Ross, in Figure 2.37, (see also Figure 2.36). The results of the survey are shown in Table 2.5.

Table 2.4.
Coordinates of IFI electrofishing survey sites 9th May 2017.

Electrofishing Sample No.	WGS 84 DD.DDD		WGS 84 DD MM.MMM				WGS 84 DD MM SS.SS				Irish National Grid	
	N	W	N		W		N		W		E	N
IFI 1	51.68851	-9.65852	51	41.3106	-9	39.5112	51	41 18.636	-9	39 30.672	85356.9377	49691.4278
IFI 2	51.69006	-9.65748	51	41.4036	-9	39.4488	51	41 24.216	-9	39 26.928	85432.7665	49862.2391
IFI 3	51.69025	-9.65859	51	41.415	-9	39.5154	51	41 24.9	-9	39 30.924	85356.4932	49885.1210
IFI 4	51.7013	-9.64857	51	42.078	-9	38.9142	51	42 04.68	-9	38 54.852	86077.0961	51098.7923
IFI 5	51.70726	-9.61895	51	42.4356	-9	37.137	51	42 26.136	-9	37 08.22	88139.4344	51716.0369
IFI 6	51.68995	-9.66884	51	41.397	-9	40.1304	51	41 23.82	-9	40 07.824	84646.9751	49867.8997

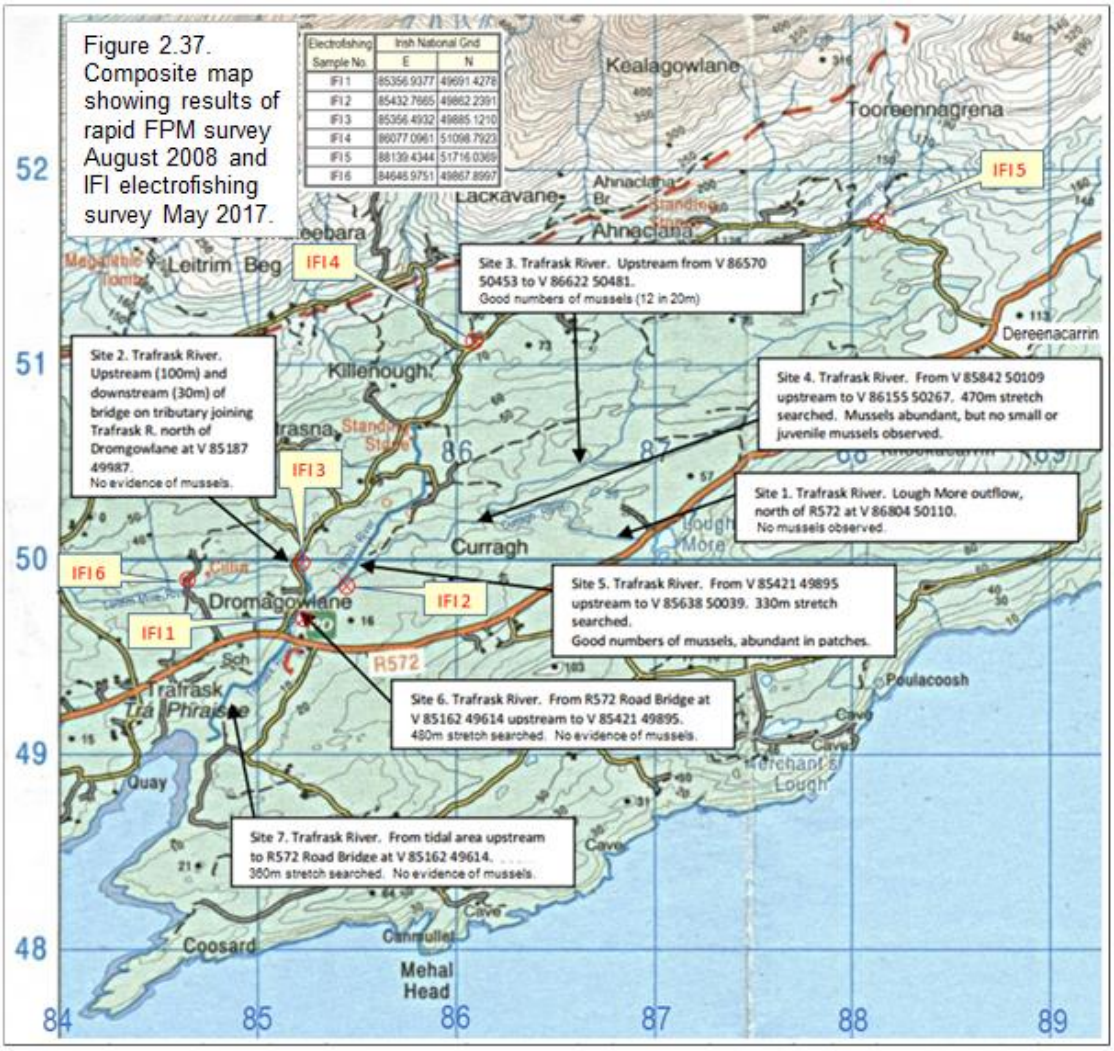

Figure 2.37. Composite map showing results of rapid FPM survey August 2008 and IFI electrofishing survey May 2017.

Table 2.5.
Results of IFI electrofishing survey 9th May 2017.

Site	Site description	Number of Salmo salar (6-9cm)	Number of Salmo trutta (4-15cm)	Salmo salar density per m^2	Salmo trutta density per m^2
IFI 1	On Trafrask above R572, just below confluence with Leitrim More River. No FPM present.	2	4	0.018	0.035
IFI 2	On Trafrask further N, just below confluence with Curragh River. Good numbers of FPM (FPM Site 5).	1	9	0.009	0.086
IFI 3	On Leitrim More River. Not surveyed for FPM.	3	6	0.052	0.103
IFI 4	On Upper Trafrask; not surveyed for mussels.	0	11	0	0.076
IFI 5	On a tributary of the Curragh River, in the upper Trafrask catchment, in the foothills of the Caha Mountians . Not surveyed for FPM.	0	4	0	0.047
IFI 6	Further W along Leitrim More River than IFI Site 3. Not surveyed for FPM.	0	10	0	0.079

Because the survey was commissioned by a third party and only described in outline, it is uncertain what the conditions for the survey were and the short report provided by IFI does not compare results with those for other local catchments. However, what the survey does confirm is that salmonids are extant in the Trafrask system. Nonetheless, because they are all juvenile fish, there is no differentiation which might indicate whether some of the brown trout found will smoltify into sea trout, although sea trout were identified in the spot fishing exercise carried out in about 2014.

The most material outcome of the survey is that the density of fish found seems to be low, for both salmon and trout, in addition to which salmon were only found in the lower reaches of the river. Although this is not unusual in small rivers in mountainous areas, it may indicate that brown trout are better dispersed in the system to take on the role of Glochidial vectors. Fish densities of both species appear somewhat lower than the stated requirement for glochidial hosting of 0.2-0.3 fish per m^2 of river. This suggests more than anything that more electrofishing is required but the densities found may in part explain the lack of FPM recruitment in recent years and therefore add further to the concern over the fragility of the Trafrask FPM stock.

A highly relevant precedent was set in 2009 when two Irish Non-Governmental Organisations (NGOs) submitted a legal complaint against Ireland to the EU Commission[78]. The thrust of the complaint was that the

78 Anon. 2009. Complaint to the Commission of the EC on the Government of Ireland's failure to comply with Community Law as regards the Habitats Directive and the EIA Directive for the species Atlantic salmon, for and on behalf of the Delphi Fishery, the Newport Fishery and the Ballynahinch Fishery. Legal complaint reference number 2006/4652, SG (2006) /6058. Prepared and submitted by Salmon Watch Ireland 64pages.

State had not complied with the terms of the Habitats Directive (92/43/EC) and EIA Directive (85/337/EEC) and, in the licensing of salmon farm sites, had failed to protect both wild salmon and FPM, which are both Annex II species, in three specified fisheries. The State mounted a defence which, in part, comprised an examination of the status of wild salmon stocks, as advised annually by the Standing Scientific Committee (described in Section 2.3.3, Discussion Point 5), at River Basin District (RBD) level, nationally. This data was then compared with the records of statutory lice monitoring on salmon farm sites (see Section 2.3.1) and with freshwater habitats status, taken from EPA data (see Section 2.4.2), all at a River Basin District (RBD) level.

In respect of FPM, the complainant cited the loss of juvenile wild host fish for glochidial attachment and the consequent loss of FPM in the three fisheries. However, the FPM SEA compiled by the Department of Housing, Environment and Local Government in 2009[79] showed that, out of the 27 FPM populations examined in the SEA (see Figures 2.28 and 2.29), 26 were of unfavourable conservation status but that of 26 of the catchments surveyed for juvenile salmon, they were present in 25 of them and that glochidial attachment was present in 12. Thus, evidence to support the claim was lacking in these respects. In contradiction to the claim, the overwhelming evidence from the FPM SEA, and other sources, including previous NPWS studies, is that sedimentation and eutrophication of juvenile and adult FPM habitats is the primary cause of FPM declines.

At the same time, Marine Institute scientists had embarked on the analysis of a long-term study, to assess the potential impact of lice infestation on outwardly migrating salmon smolt. The methodology involved the trapping of numerous individual river smolt stocks pre-release and splitting each group into a treated and a control group. Treated groups were dosed with Slice®, an oral treatment which protects salmon from lice infestation for up to 120 days. The separate groups were identified by the use of tags and adipose fin clipping. The fish were then released to migrate seawards. Survivors were trapped on their return and identified and counted. The study covered the release and return of groups of treated and control fish, mainly from Irish Western rivers (the area of the complaint) every year between 2001 until 2009.[80]

The findings of this long-term study are that whist sea lice-induced mortality of outwardly migrating smolt can be significant, it is a minor and irregular component of marine mortality (of the order of 1%) in the stocks studied and is unlikely to significantly influence the conservation status of wild salmon stocks. The study also indicated that, for the population of salmon represented by the total samples provided, total salmon marine mortally was almost 95% over the period studied.

[79] Anon. 2010. Freshwater Pearl Mussel Strategic Environmental Assessment (SEA). DEHLG March 2010.

[80] Jackson D. et al. 2011. An evaluation of the impact of early infestation with the salmon louse *Lepeophtheirus salmonis* L., on the subsequent survival of outwardly migrating Atlantic salmon, *Salmo salar* L., smolts. Aquaculture 320, 159-163.

On the proportion of rivers open for angling in each RBD, Jackson et al[81] found considerable variation, as illustrated in Figure 2.38.

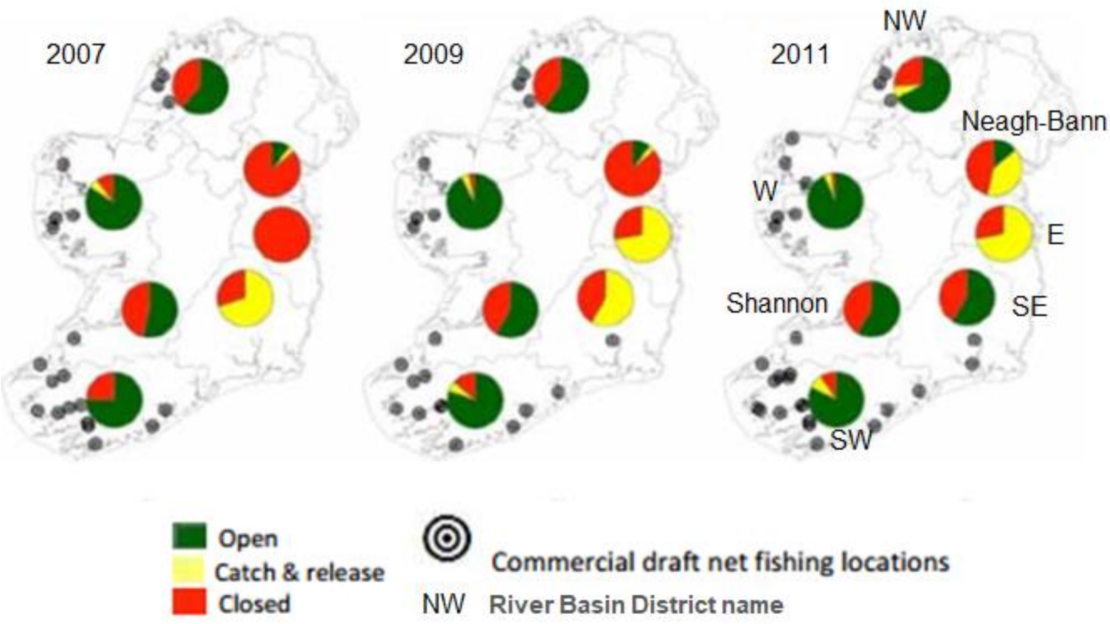

Figure 2.38.
Maps showing the proportion of rivers, measured as fluvial area accessible to salmon (m^2) in each RBD, which are fully open, open for catch & release, or closed to angling for the 2007, 2009 and 2011 seasons. Commercail draft net sites are also shown (after Jackson et al 2013b).

This study found that the W and SW RBD's consistently have the highest proportion of rivers open for angling, with the next highest being the NW. These are also the RBDs which continue to support the ongoing pressure of draft net fisheries. The SW (which includes Bantry Bay), W and NW RBDs are also the main salmon farming areas in the country

In terms of Habitat Quality, Jackson et al (2013b) found a significant correlation between water quality in each RBD catchment and the percentage of A-Class channel length and proportion of rivers meeting their Conservation Limit (i.e. also open for angling); see Figure 2.39.

In the examination of farm-origin lice on wild salmon stocks in the context of this case, the State defence first noted that that statutory lice monitoring indicated a substantial improvement in critical period lice levels since the introduction of the DAFF National Pest Management Strategy during the 2007 season.

81 Jackson D. et al. 2013b. Evaluation of the impacts of aquaculture and freshwater habitat of the status of Atlantic salmon stocks in Ireland, Ag Sci. 2013, 4, 62-67.

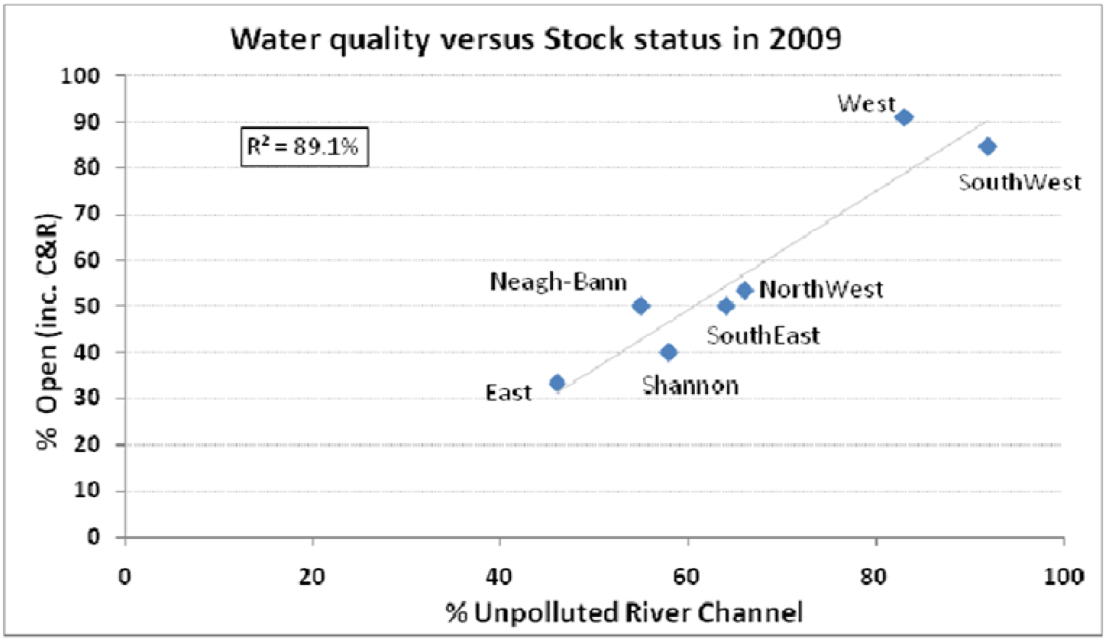

Figure 2.39.
Relationship between salmon stock status as measured by percentage of rivers open for exploitaion and water quality of river channels, grouped by RBD (after Jackson et al 2013b).

The full methodologies, results and outcomes of this case are described in Jackson et al 2013[82], which is itself a summary of several contributing papers, primarily by Jackson et al.

On the basis of the results obtained from detailed scientific investigation of all challenges raised by the complainant, the complaint was closed in favour of the State in October 2011.

The scientific outcomes of this case offer a considerable body of information relevant to the likely status of both FPM and juvenile salmonids in Bantry Bay rivers, including the Trafrask, as bulleted:-

- The SWRBD is one of the RBD's (with WRBD) showing the highest proportions of A-Class river channel length and percentage of rivers meeting their Conservation Limit (see also Section 2.3.3 Discussion Point 5).

- In consequence, the SWRBD has one of the highest proportions of rivers fully open for angling and catch and release, in the country. In addition, it supports the added exploitation pressure of commercial draft nets; see Figure 2.38. Bantry Bay lies within this RBD.

82 Jackson D. et al. 2013. Report on sea lice epidemiology and management in Ireland with particular reference to potential interactions with wild salmon (*Salmo salar*) and freshwater pearl mussel (*Margaritifera margaritifera*) populations. Irish Fisheries Bulletin No. 43, Marine Institute 2013.

- The FPM SEA shows that in general, conservation status is poor for FPM across all RBD's in the State but that absence of adequate juvenile salmonids or lack of glochidial attachment were not the cause.

- Overwhelmingly poor status of FPM stocks is related to widespread sedimentation and eutrophication in the RBD catchments including those containing FPM, which require pristine waters.

- Across the range of salmon stocks tested, marine mortality averaged 95% over the period 2001 to 2009 (as found elsewhere in salmon's geographic range) but marine mortality due to "all lice" was of the order of 1% of escapement and insufficient to affect conservation limits.

There is no reason to expect that total marine mortality will be any greater or less for salmon migrating from Bantry Bay rivers or to expect that sea lice will have any greater impacts on Bantry Bay CL's than they do elsewhere in the country. Indeed, the findings of the work of Jackson et al, illustrated by Figure 2.38, amply demonstrates this and, by the same measure, it can be concluded that the apparently poor conservation status of FPM in the Trafrask system is as a result of the same impacts as suffered by other FPM stocks throughout the range of the species; sedimentation and eutrophication. It should also be remembered that FPM stocks have been decimated across Europe and, indeed, in many countries with no salmon farming industry at all.

That this case was taken to the European Court and was overturned on the basis of the examination of findings described, lends considerable weight the opinion that, whilst the Trafrask FPM stocks are in a fragile condition, this is as a result of catchment-origin impacts that will not be augmented by any impact risks arising from the proposed salmon farm at the Shot Head site.

2.4.5 Evaluation of Risk Exposure of FPM in the Trafrask system; Conclusions.

The RPS Bantry Bay model shows that the chances of Copepodid attachment to isolated salmonids in the open waters of the bay, and more particularly to wild smolt emerging from rivers into river estuaries, are so low that no farm-origin augmentation of wild salmon lice infestation levels is anticipated, either in Trafrask Harbour or in any other river estuary in the bay.

As a result, it is submitted that there is also a zero risk that anadromous salmonids will be reduced in numbers in their freshwater phase, as a result of the presence of the Shot Head site, to impact on the availability of vector hosts for FPM Glochidia larvae.

The risks for the Trafrask FPM lie within their freshwater environment.

Section 3.
Qualification and quantification of the impact of salmon farm waste on water quality in Bantry Bay, having regard to the maintenance of “Good Water Status” as required under the Water Framework Directive.

3.1. Introduction; EQS or WFD?

A widely adopted means of expressing a waste impact is to compare the result of the impact against an Environmental Quality Standard (EQS), as generally set out in 2008/105/EC, the EU Directive on Environmental Quality Standards in the field of water policy. Commonly known as the EQS Directive, this repealed a number of earlier directives and amended others, including the Water Framework Directive (WFD), 2000/60/EC in some respects.

The March 2003 OECD definition of Environmental Quality Standard (EQS) states that an “*Environmental Quality Standard is a limit for environmental disturbances, in particular from ambient concentration of pollutants and wastes, that determines the maximum allowable degradation of environmental media”.* An improvement of this definition is suggested by the addition of the phrase “*for the maintenance of environmental stability*”

EQS was the method adopted for waste impact assessment in the RPS WQ Modelling Report and in the Shot Head EIS, because this was the method of choice in Ireland when the Shot Head EIA was executed and the EIS was compiled, primarily before and during 2010. The first 6-year cycle of River Basin District Management Plans under the Water Framework Directive commenced in Ireland in December 2009. The governing legislation supporting the WFD in Ireland, SI 272 2009, the European Communities Environmental Objectives (Surface Waters) Regulations 2009, emerged concurrently, enabling the assessment of water bodies in terms of their *Ecological Status* for the first time.

EQS is as valid now as it ever was and indeed many nutrient and physicochemical Quality Elements required for the derivation Ecological Status depend on EQS values or something very close to them. Nonetheless, WFD methodologies have greatly expanded the scope of ecological assessment by enabling overviews of Ecological Status across all the water bodies which contribute to entire River Basin District catchments and subcatchment areas. The combination of this huge database with the requirements of the Habitats and Birds Directives, in respect of the designation and protection of designated habitats, flora and fauna, coupled to the informative power of recently developed mapping technologies, has greatly improved the scope and cross-referencing power of the *Ecological Toolbox* across Europe.

As part of this Supplementary EIS, required by ALAB under Section 47 of the Fisheries (Amendment) Act 1997, the Qualification and Quantification of the impacts of salmon farm waste (from the Shot Head site) on water quality in Bantry Bay, under the terms of the Water Framework Directive has been requested. This entails the conversion of earlier findings, expressed relative to EQS limits, and their re-evaluation, relative to the current Ecological Status of Bantry Bay, under the terms of the WFD and SI 272 2009.

3.2. The Ecological Status of Bantry Bay and associated water bodies under the Water Framework Directive (WFD).

Under the terms of SI 272 2009, all water bodies in Ireland, be they rivers, lakes, groundwater bodies, coastal or transitional (estuarine) waters, or artificial water bodies, require assessment in terms of their *Ecological Status*. SI 272 sets out all the required standards for such assessments, which are under the remit of the Environmental Protection Agency (EPA). This has already been referred to in Section 2.4.2 in respect of river waters.

Under SI 272 2009 water body quality is classified by the assessment of a required range of Quality Elements, selected for each water body type. Bantry Bay as a whole comprises both transitional and coastal waters. The Quality Elements that apply to these water body types are set out in full in the SI but are summarised in Table 3.1.

Table 3.1.
Quality Element list for Transitional and Coastal Waters.

Quality Element			Transitional Waters	Coastal Waters
Biological Quality Elements		Composition, abundance and biomass of phytoplankton		
		Composition and abundance of other aquatic flora		
		Composition and abundance of benthic invertebrate fauna		
		Composition and abundance of fish fauna		
Hydromorphological Quality Elements	Morphological conditions	Depth variation		
		Quantity structure and bed substrate		
		Structure of intertidal zone		
	Tidal regime	Freshwater flow		
		Dominant direction of currents		
		Wave exposure		
Physicochemical Quality Elements	General conditions	Transparency, thermal, oxygenation,salinity and nutrient conditions		
	Specific pollutants	Listed synthetic or non-synthetic substances		

The SI sets value ranges and limits for each Quality Element in order that water body quality can be evaluated on a scale running between high and good quality, through moderate and poor, to bad quality. The water body is then granted an Ecological Status on this scale on the basis of the lowest-scoring of the Quality Elements assessed. For the purposes of mapping, Ecological Status is graded on a colour scale; see, for example, its use for freshwater bodies around Bantry Bay in Figure 2.32 and in the map of the Bantry Bay Coastal and Transitional water bodies in Figure 3.1. WFD Risk (of failing Ecological Status) is also assessed and mapped on a colour scale; see in Figure 3.2. The maps provided in Figures 3.1 and 3.2, based on monitored data for the period 2010-2015[83], are the most recent generated by the EPA and apply to the commencement of the second WFD 6-year cycle in Ireland, between end 2015 and end 2021.

83 *Pers. Comm.* R. Wilkes, Scientific Officer, EPA, February 2018.

Table 3.2.
Water Bodies in Bantry Bay with WFD Codes, Ecological Status and Risk Status.

Location			WFD Code	Ecological status	Risk Status
Bantry Bay	Coastal waters	Outer Bantry Bay	IE_SW_170_0000	High	Not at Risk
		Berehaven	IE_SW_180_0000	Good	Not at Risk
	Transitional waters	Inner Bantry Bay	IE_SW_170_0100	Unassigned	Not at Risk
		Glengarriff Harbour	IE_SW_170_0400	Unassigned	Not at Risk
		Adrigole Harbour	IE_SW_170_0500	Unassigned	Not at Risk

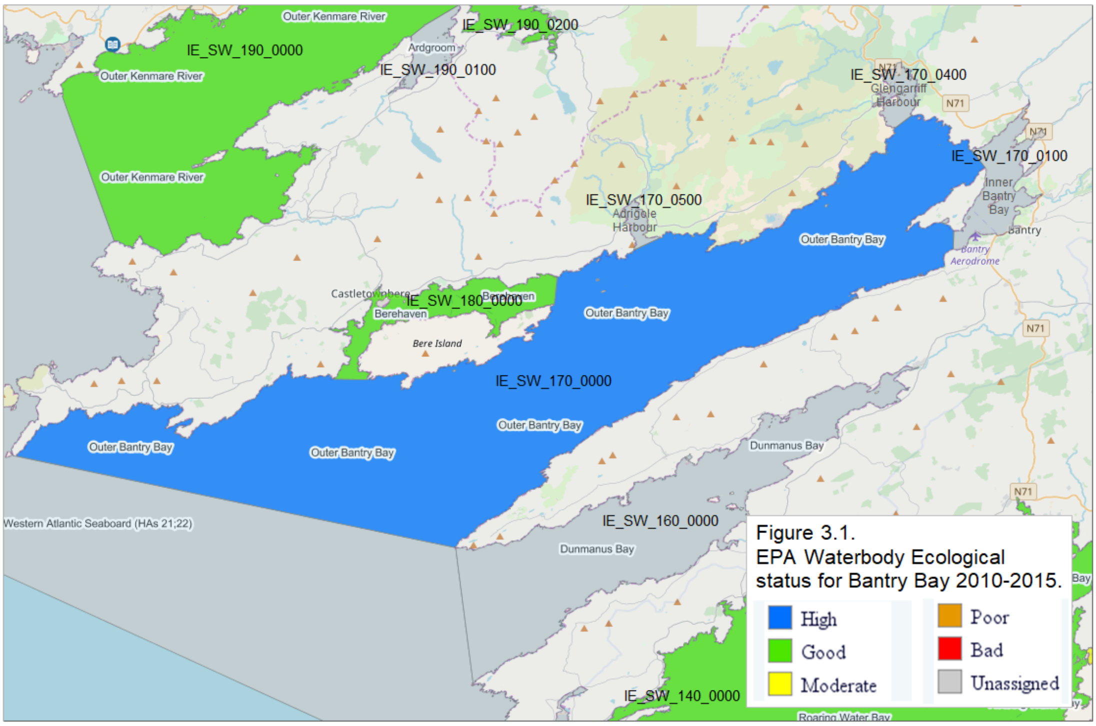

Figure 3.1.
EPA Waterbody Ecological status for Bantry Bay 2010-2015.

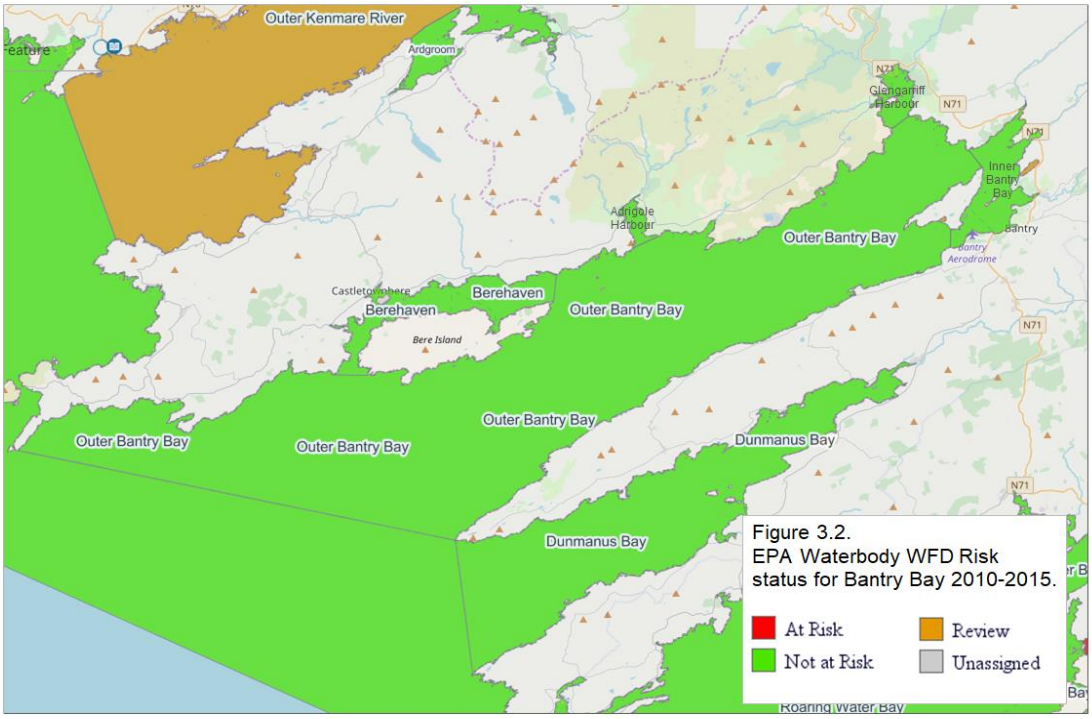

Figure 3.2.
EPA Waterbody WFD Risk status for Bantry Bay 2010-2015.

In fact, Bantry Bay as a whole comprises two Coastal and three Transitional water bodies, shown in Figures 3.1 and 3.2. The names of these are shown in Figure 3.1 and Table 3.2. It should be noted that all three Transitional Water Bodies encompass the inshore and estuarine areas of the five National Salmon Rivers in the bay. Currently these three Transitional Bodies are unassigned. Inner Bantry Bay, which accommodates the Coomhola, Owvane and Mealagh River estuaries, also includes the whole Bantry Harbour area to the east Whiddy Island. The main Coastal Water Body of Outer Bantry Bay is the location of the proposed Shot Head site. This is extensively described in terms of its hydrodynamic and physical characteristics in Section 2. A subsidiary Coastal Water Body has been created for Berehaven which has considerably different hydromorphological characteristics to the main Outer Bantry Bay area, primarily due to the presence of Bear Island. Berehaven also encompasses the town of Castletownbere and the entire Castletownbere Fishery Harbour Centre, which includes the fishery industrial estate on Dinish Island, in Berehaven Sound. These activities and the lack of adequate wastewater treatment in the area are likely to account for its Good, rather than High Ecological Status, in contrast to Outer Bantry Bay.

In the Section 47 request raised in respect of the Ecological Status of Bantry Bay (see Section 3 title), ALAB refer to the maintenance of “Good” status in the bay. In fact, the main water body in the bay, Outer Bantry Bay, where all existing and proposed salmon grower sites are located, has maintained “High” Ecological Status, ever since the introduction of SI 272, in 2009, as Figure 3.1 demonstrates. The question to be answered in this section is therefore whether High Ecological Status will be maintained in Outer Bantry Bay, once the Shot Head site is fully operational, if the licence is upheld.

3.3. Discharge and dispersal of wastes from the proposed Shot Head site.

3.3.1. Introduction.

The EIS for the Shot Head site, Volumes 1 (Main text), 2 (Appendices) and 3 (Non-technical summary), can be found on the MHI website[84] and the RPS Water Quality Modelling Report, can be found on the ALAB website[85]. These documents qualify and quantify the projected discharges and dispersals of waste streams from the Shot Head site, based on the salmon Maximum Allowable Biomass (MAB) of 2,800 tonnes, applied for in the licence application. As in the case of the dispersal of lice, described in Section 2, the modelling of discharged solid and soluble wastes dispersal is driven by the RPS Bantry Bay HD model. This is fully described in the RPS document and described in summary in Sections 2.2 and 2.3 herein.

84 Environmental Impact Statement (EIS) for a proposed salmon farm site at Shot Head, Bantry Bay, County Cork. http://marineharvestireland.com/globalassets/about-us/ireland/our-locations/vol-1-main-eis-doc-may-2011.pdf

85 Water Quality Modelling for all existing & currently proposed salmon farm sites in Bantry Bay IBE0744/R07/Rev02/NS Marine Harvest Ireland November 2015 http://www.alab.ie/media/alab/content/technicalreports/ap22015/MHIsubmissionRPSreportNov2015150217.pdf

3.3.2. Adoption of worst case approach.

All the dispersional models generated as part of this commission give projected outcomes based on a multi-level worst-case scenario. This is to provide safety and confidence in the modelled results. In the case of nutrient dispersals, the following worst-case layers augment modelled outcomes:-

- Only the stocking month which provides the greatest discharges was chosen for the dispersal simulations, whereas the lowest monthly discharges are <2% of this. Discharges of feed and faecal waste and metabolites, peak in the peak biomass month.

- Although the Roancarrig, Ahabeg and Fastnet sites are already in full production and augmenting bay ambient nutrient and physicochemical parameters, discharges for these existing sites was "double accounted for" in the dispersal models by creating "new" discharges, in order to track their dispersals, as well as those from Shot Head.

- The production model proposed for Bantry Bay in the EIS document is that the proposed sites at the eastern end of the Bay (Shot Head and Fastnet sites) will alternate on biennial cycles with those at the seaward end of the bay (Roancarrig and Ahabeg). The Shot Head and Fastnet sites are shown as "dominant" in the dispersional models; that is, they are in their second year whilst Roancarrig and Ahabeg are in their first. This is because the higher biomass and discharges at the eastern end of the bay can be expected to generate greater impacts further up the bay than those from the sites closer to the open sea.

- For nutrient dispersals, both soluble nutrients and settleable nutrients (bound to settleable solids in feed and faecal waste) are both treated as part of the settleable solid load and also dispersed as if soluble. This is to give confidence to the projected levels of total nutrient load discharged from the site.

- All discharges are treated as conservative, that is they are not assimilated as they disperse. In reality, assimilation of all biological discharges is an ongoing, dynamic process in biological molecules re grazed down by plankters and bacteria in the water column.

It is submitted that this is an important point to make at this juncture in order that those considering the outcomes of the modelled data do not regard them as minimal values. It is our contention that they should be regarded as maximum values, which underpin the safety of the projections provided.

3.3.3. Salmon farm waste outputs and monitored parameters.

The waste outputs used in the EIS and in the RPS WQ Report, employ the same, widely accepted range of organic waste parameters to describe soluble metabolic waste discharges, namely Dissolved Inorganic Nitrogen, (DIN), Dissolved Inorganic Phosphorus (DIP) and Biological Oxidation Demand (BOD). All three are modelled in terms of the change that they will cause to ambient concentrations in the bay. For DIN and DIP, results are then compared with established Environmental Quality Standards (EQS) for DIN and DIP in coastal waters, to establish where the resulting elevated ambient concentration lies relative to the EQS level. In the case of BOD, the consequence of its potential impact, as its name implies, is in the reduction, rather than the elevation of ambient dissolved oxygen saturation (DO) in the water column.

Although DIN is amongst the parameters used to derive Quality Elements (QE), in Coastal Waters under SI 272 2007, DIP and BOD are not. DIP is an important QE for rivers and transitional water bodies, where elevated levels are the main driver of primary production (subject to salinity level). This role is taken by DIN in Coastal water bodies. Thus, DIP is not considered here, however see the Shot Head EIS and RPS WQ Report for EQS assessment of DIP discharges.

In the case of BOD, this also is not considered by SI 272 as a QE for Coastal water bodies, although it is an important QE in respect of River and Transitional water bodies. Thus, BOD itself is not considered further here, than as projected in the Shot Head EIS and the RPS WQ Report. However, because BOD impacts on DO saturation any resulting reaction in measured ambient levels will be included herein on the basis of the DO limit values for High Status Coastal water bodies, set out in Schedule 5, Part A Table 9 of SI 272.

In the case of solids settlement, this is modelled against an EQS of Allowable Zones of Effects developed by The Scottish Environmental Protection Agency (SEPA) for use in salmon farm licensing in Scotland. Table 3.1. shows that Settled Solids are not currently used as a Quality Element for deriving Ecological Status for Coastal or Transitional water bodies under SI 272 and are therefore not considered here, further than as projected in the Shot Head EIS and the RPS WQ Report.

The RPS WQ Report also considers the dispersal of two anti-lice medications, the oral treatment Slice®, which contains the active ingredient Emamectin Benzoate (EmBZ) and the immersion treatment medication Alphamax®, which contains the active ingredient Deltamethrin. Neither of these chemicals is listed as a priority substance in the EQS Directive or in SI 272. However, their use is controlled via EQS, as set down in the SI 466 2008, the European Communities (Control of Dangerous Substances in Aquaculture) Regulations 2008. Since they are not listed as specific pollutants amongst the Physicochemical Quality Elements in SI 272 (see Table 3.1) they too are not considered here, any further than as projected in the RPS WQ Report.

It is understood from the EPA that the database used to assess WFD Status for Outer Bantry Bay is based on monitoring in the bay. All monitored data from all stations and depths is pooled to assess the Water Body. Only winter values (December to March) are assessed, since this is when nutrients are most mineralised. For example, in the case of DIN, median winter values are checked against the Quality Element data for DIN, set out in Schedule 5, Table 9, Part A of SI 272[86].

The EPA also monitor phytoplankton as an eligible QE for Coastal Water Bodies in SI 272. MHI and Hensey Glan Uisce monitor Chlorophyll in Bantry Bay as an indicator of phytoplankton biomass. This is not elevated directly by any discharge arising from salmon farming but could be elevated in the event of nutrient EQS's or QE value limits being breached, in particular for DIN in marine conditions.

Analytical results for winter water column samples acquired from all open water control stations since the introduction of the WFD in Ireland in late 2009 are tabulated in Table 3.3. Median values identified for each parameter. The EPA tests a much wider range of parameters than required under the DAFM Protocol for water column monitoring on salmon farms [87], which currently only requires measurement of winter values for ammonia, nitrite, nitrate, phosphate, water temperature and salinity.

3.3.4. Mixing zones

Directive 2008/105/EC, the EQS Directive, Article 19, gives guidance on mixing zones, within which pollutant concentration may be higher than ambient concentrations. It advises that allowances may be made for mixing zones so long as they do not affect the compliance of the rest of the water body with the relevant EQS. It continues that mixing zones should be restricted to the area of the point of discharge and that they should be proportionate. SI 272 makes similar points in Paragraph 51. From the point of view of dispersional modelling (which is the source of impact data used herein for comparison with both EQS and Ecological Status assessments), mixing zones are applied (in regulation), for solids and medication EQS standards. It is submitted that the same view should be taken with other parameters, for example for DIN and BOD and even for lice dispersal. It was noticeable during the Shot Head appeal oral hearings process, that there was a tendency by some participants to pick the highest parameter value, for example within the immediate Shot Head site area, in their interpretation of whole-bay impacts. It is submitted that this is not an appropriate or valid scientific interpretation of the circumstances of dispersal. It should further be noted that the EPA avoid sampling in what might be regarded as a "reasonable mixing zone" in their monitoring exercises[88], in their assessments of Ecological Status.

86 *Pers. Comm.* R. Wilkes, Scientific Officer, EPA, February 2018.

87 Anon 2000. Monitoring Protocol No. 2 for Offshore Finfish Farms – Water Column Monitoring. https://agriculture.gov.ie/media/migration/seafood/aquacultureforeshoremanagement/marinefinfishprotocols/Water%20Column%20Monitoring%20Protocols%202.pdf

88 *Pers. Comm.* R. Wilkes, Scientific Officer, EPA, February 2018; *"For our assessments* (EPA doesn't) *have a formal consideration of mixing zones.* (EPA doesn't) *sample directly beside known discharges and for an assessment of a waterbody we pool all the available data together".*

Table 3.3

Table of all water control site samples taken in Outer Bantry Bay since introduction of SI 272 2009.

Includes Median Values, used for Quality Element determination, if and where required.

Note. Where number of values is even, median is determined by taking mean of two middle values.

Sampler	Station	Season	Survey Date	Sample Depth m	Salinity S ‰	Temp S °C	pH	Secchi m	DO ppm	DO S % Sat	B.O.D. mg/l O_2	TON Nmg/l	NH3 Nmg/l	PO_4 Pμg/l	Chloroph a mg/l	Si_est μg/l Si	DIN	Nitrite Nmg/l	Free NH_3 Nmg/l
EPA	Roancarrigmore	Winter	16/02/2011	32.6	34.78	8.4	7.96	3	9.4	100.1	0.4999	0.118	0.169	19	1.4	309	0.287		0.00303
	Roancarrigmore	Winter	16/02/2011	0	33.96	7.86	7.96	3	9.9	103.5	0.4999	0.121	0.178	17	1.4	340	0.299		0.00306
MHI	Roancarrig	Winter	Dec-14	Midwater									0.0098	12.23			0.07077	0.002	
	Roancarrig	Winter	Jan-15	Midwater									0.00808	13.7			0.02155	0.00335	
	Roancarrig	Winter	Feb-15	Midwater									0.00553	25.75	0		0.04121	0.00404	
	Roancarrig	Winter	Mar-15	Midwater									0.01749	10.11	0		0.00418	0.00216	
	Roancarrig	Winter	Dec-15	Midwater									0.0071	62.48	0		0.08038	0.00098	
	Roancarrig	Winter	Jan-16	Midwater									0.00392	70.82	0		0.08054	0.0017	
	Roancarrig	Winter	Feb-16	Midwater									0.00388	21.4	0.08		0.02298	0.00277	
	Roancarrig	Winter	Mar-16	Midwater									0.01154	55.33	0		0.00877	0.00759	
	Roancarrig	Winter	Dec-16	Midwater															
	Roancarrig	Winter	Jan-17	Midwater									0.00763	2.35	0		0.009537	0.00218	
	Roancarrig	Winter	Feb-17	Midwater															
	Roancarrig	Winter	Mar-17	Midwater									0.00798	17.44	0.66		0.005158	0.00338	
Hensey Glasn Uisce	Gearhies 0m	Winter	Jan-09	0m	34.8	8.7		7					0.01442	13.64			0.1323	0.00518	
	Gearhies 10m	Winter	Jan-09	10m	34.8	9.0							0.01358	14.88			0.1477	0.0049	
	Gearhies 20m	Winter	Jan-09	20m	34.8	9.0							0.02072	18.29			0.15064	0.00476	
	Gearhies 0m	Winter	Feb-09	0m	34.5	7.5		3					0.01204	16.12			0.18172	0.00238	
	Gearhies 10m	Winter	Feb-09	10m	34.5	8.0							0.00882	14.26			0.1806	0.00182	
	Gearhies 20m	Winter	Feb-09	20m	34.5	8.2							0.01036	24.18			0.18494	0.00154	
	Gearhies 0m	Winter	Mar-09	0m	34.3	8.1		4						13.02			0.08442	0.00308	
	Gearhies 10m	Winter	Mar-09	10m	34.3	8.4								14.26			0.09492	0.00322	
	Gearhies 20m	Winter	Mar-09	20m	34.3	8.4								17.67			0.09562	0.00308	
	Gearhies 0m	Winter	Dec-10	0m	33.6	9.9		5					0.01036	21.08			0.13356	0.0021	
	Gearhies 10m	Winter	Dec-10	10m	33.6	10.0							0.00882	22.01			0.13454	0.00224	
	Gearhies 20m	Winter	Dec-10	20m	33.7	10.1							0.00798	22.32			0.13678	0.00252	
	Gearhies 0m	Winter	Jan-10	0m	34.2	7.7		4					0.0056	20.77			0.16198	0.00182	
	Gearhies 10m	Winter	Jan-10	10m	34.5	7.9							0.00714	22.94			0.168	0.00224	
	Gearhies 20m	Winter	Jan-10	20m	34.4	7.9							0.00798	23.25			0.15428	0.00238	
	Gearhies 0m	Winter	Feb-10	0m	34	7.6		3					0.01596	18.91			0.13664	0.00336	
	Gearhies 10m	Winter	Feb-10	10m	34	7.7							0.01204	20.77			0.14756	0.00308	
	Gearhies 20m	Winter	Feb-10	20m	34.2	8.1							0.01204	18.29			0.13174	0.0028	
	Gearhies 0m	Winter	Mar-10	0m	34.2	7.5		5					0.01274	17.36			0.07252	0.0049	
	Gearhies 10m	Winter	Mar-10	10m	34.1	7.5							0.01358	18.60			0.112	0.00476	
	Gearhies 20m	Winter	Mar-10	20m	34.2	7.5							0.00952	17.05			0.11424	0.0049	
	Gearhies 0m	Winter	Dec-10	0m	34.5	8.6		6					0.01274	22.32			0.10892	0.00238	
	Gearhies 10m	Winter	Dec-10	10m	34.6	8.6							0.01442	21.08			0.11354	0.00252	
	Gearhies 20m	Winter	Dec-10	20m	34.5	8.6							0.01596	19.84			0.10878	0.0021	
	Gearhies 0m	Winter	Jan-11	0m	34.2	7.5		8					0.00952	18.91			0.11032	0.00308	
	Gearhies 10m	Winter	Jan-11	10m	34.2	7.5							0.00714	17.67			0.11256	0.00294	
	Gearhies 20m	Winter	Jan-11	20m	34.4	7.8							0.00322	18.29			0.1134	0.00336	
	Gearhies 0m	Winter	Feb-11	0m	33.5	8.1		3					0.01036	16.43			0.1148	0.00294	
	Gearhies 10m	Winter	Feb-11	10m	34.4	8.2							0.00798	16.43			0.11536	0.00322	
	Gearhies 20m	Winter	Feb-11	20m	34.4	8.4							0.00798	14.26			0.11354	0.00294	
	Gearhies 0m	Winter	Mar-11	0m	34.6	9.2		7					0.01036	13.02			0.07196	0.00378	
	Gearhies 10m	Winter	Mar-11	10m	34.7	9.2								14.88			0.0861	0.00462	
	Gearhies 20m	Winter	Mar-11	20m	34.7	9.2							0.01036	13.95			0.08946	0.00406	
	Gearhies 0m	Winter	Dec-11	0m	32.1	9.3		6					0.02002	21.39			0.15428	0.00406	
	Gearhies 10m	Winter	Dec-11	10m	33.6	9.7							0.01512	24.18			0.14224	0.00224	
	Gearhies 20m	Winter	Dec-11	20m	34	10.7							0.0112	22.32			0.13594	0.00238	
	Gearhies 0m	Winter	Jan-12	0m	32.9	9.5		4					0.01204	24.80			0.10724	0.0028	
	Gearhies 10m	Winter	Jan-12	10m	33.2	9.7							0.02002	24.49			0.11984	0.00238	
	Gearhies 20m	Winter	Jan-12	20m	33.8	9.7								30.07			0.1155	0.00224	
	Gearhies 0m	Winter	Feb-12	0m	34.3	9.5		5					0.0175	19.22			0.1288	0.00294	
	Gearhies 10m	Winter	Feb-12	10m	34.3	9.6							0.01512	22.94			0.13118	0.00294	
	Gearhies 20m	Winter	Feb-12	20m	34.6	9.9							0.01834	19.53			0.12838	0.00252	
	Gearhies 0m	Winter	Mar-12	0m	33.8	9.8		4					0.01204	6.82			0.02814	0.00168	
	Gearhies 10m	Winter	Mar-12	10m	33.9	9.8								8.37			0.0245	0.0028	
	Gearhies 20m	Winter	Mar-12	20m	34.6	9.9							0.01036	19.22			0.1001	0.00588	
	Gearhies 0m	Winter	Dec-12	0m	34.1	10.8		7					0.02548	20.46			0.10052	0.00644	
	Gearhies 10m	Winter	Dec-12	10m	34.1	11.2							0.02156	21.39			0.09674	0.00616	
	Gearhies 20m	Winter	Dec-12	20m	34.3	11.3							0.02072	20.46			0.09828	0.0063	
	Gearhies 0m	Winter	Jan-13	0m	33.9	8.9		7					0.0112	29.45			0.14896	0.00252	
	Gearhies 10m	Winter	Jan-13	10m	34.4	9.5							0.028	29.45			0.15246	0.00154	
	Gearhies 20m	Winter	Jan-13	20m	34.7	9.7							0.01442	29.76			0.1589	0.00182	
	Gearhies 0m	Winter	Feb-13	0m	34.6	9.1		4					0.02548	26.04			0.14224	0.00294	
	Gearhies 10m	Winter	Feb-13	10m	34.6	9.1							0.03836	23.25			0.14476	0.0021	
	Gearhies 20m	Winter	Feb-13	20m	34.7	9.1							0.02072	24.49			0.13706	0.00238	
	Gearhies 0m	Winter	Mar-13	0m	34.3	8.1		6					0.01274	23.87			0.11816	0.00364	
	Gearhies 10m	Winter	Mar-13	10m	34.4	8.1							0.01358	23.87			0.11438	0.00364	
	Gearhies 20m	Winter	Mar-13	20m	34.5	8.1							0.01204	23.87			0.1267	0.00322	
	Gearhies 0m	Winter	Dec-13	0m															
	Gearhies 10m	Winter	Dec-13	10m															
	Gearhies 20m	Winter	Dec-13	20m															
	Gearhies 0m	Winter	Jan-14	0m	32.5	8.0		3	9.15				0.01036	21.39	0.001		0.12726	0.00294	
	Gearhies 10m	Winter	Jan-14	10m	33.2	8.3							0.0175	21.39	0.001		0.11998	0.0028	
	Gearhies 20m	Winter	Jan-14	20m	34	9.0			8.99				0.01274	22.01	0.001		0.11522	0.00224	
	Gearhies 0m	Winter	Feb 14	0m															
	Gearhies 10m	Winter	Feb 14	10m															
	Gearhies 20m	Winter	Feb 14	20m															
	Gearhies 0m	Winter	Mar-14	0m	31.6	8.5		3	9.9				0.01358	4.34	0.00694		0.04914	0.00168	
	Gearhies 10m	Winter	Mar-14	10m	32.1	8.5								3.72	0.00401		0.05838	0.00238	
	Gearhies 20m	Winter	Mar-14	20m	34.6	9.0			9				0.02548	19.22	0.001		0.13258	0.0028	
Sampler	Station	Season	Survey Date	Sample Depth m	Salinity S ‰	Temp S °C	pH	Secchi m	DO ppm	DO S % Sat	B.O.D. mg/l O_2	TON Nmg/l	NH3 Nmg/l	PO_4 Pμg/l	Chloroph a mg/m	Si_est μg/l Si	DIN	Nitrite Nmg/l	Free NH_3 Nmg/l
Median value					34.3	8.6	7.96	4	9.275	101.8	0.4999	0.1195	0.012	19.84	0.001	324.5	0.1152	0.0028	0.003

3.3.4. Dissolved Inorganic Nitrogen (DIN).

As pointed out in Section 3.3.3, DIN is a widely accepted organic pollution parameter. Its EQS is a winter limit value of 168µg/l. In SI 272, the winter DIN limit value for High Ecological Status is 170µg/l (actually stated as 0.17mg/l at 34.5‰ median salinity in Section 5, Table 9, p40 of SI 272).

Concern was expressed by a number of participants at the Shot Head appeal oral hearing in September 2017, at the choice of ambient data selected as the equilibrium constant concentration from which elevation by dispersed DIN from the proposed salmon farm site would be calcuated. The choice of ambient data for this purpose at the time of the EIS was long term, ambient DIN data. Only two local long-term DIN datasets were available, one at the so-called Boatyard control site, inside the Berehaven Coastal Water Body and the other at Lambs Head, in Outer Kenmare Bay. The data in these was expressed as mean monthly DIN µg/l. However, concern had been expressed by RPS and Watermark at the choice of the Boatyard as a control site for salmon farms in Bantry Bay because nutrient parameters appeared to be elevated, presumably due to impacts arising from Castletownbere and the Fishery Harbour Centre within the Sound. This fear has now presumably been borne out by the Good Status granted to the Berehaven Coastal Water Body, as opposed to the High Status granted to Outer Bantry Bay, as shown in Figure 3.1.

SI 272 and the EPA offer a solution to this impasse by the use of median values for pooled data from all stations and depths to assess the area[89].

Median values for all pooled control site data available in Outer Bantry Bay since 2009 are shown in Table 3.3. The median value for DIN is 0.1152mg/l and median salinity value is 34.3‰.

Selected from a range of DIN dispersal plots available in the RPS WQ document, Figure 3.3 shows a Typical DIN plume plot on flood tide, where the peak value just clear of the proposed Shot Head site is 0.04mg/l DIN. This has reduced to <0.0002 mg/l DIN with a maximum distance of 3km of the site centre in all directions. Takin the highest value of 0.04 and adding the median ambient for DIN for the bay of 0.1152 DIN/l, from Table 3.3, this gives a peak elevated ambient of 0.1552 mg/l DIN (0.1152 + 0.04) for up to 3km from the site, flowing east on the flood tide and similarly, to the west, on the ebb. This gradually reduces to <0.1154 mg/l DIN, (= 0.1152 + <0.0002) within a maximum of 3km from the site centre.

The Quality Element standard for High Ecological Status waters is a winter DIN concentration of 0.17mg DIN/l, at a median salinity of 34.5‰. Thus, the elevation of ambient DIN to 0.1552 DIN/l close to the site and <0.1154 DIN/l in the open waters of the bay are both well within the set QE standard for High Ecological Status, on a worst-case basis, with the proposed Shot

89 *Pers. Comm.* R. Wilkes, Scientific Officer, EPA, February 2018.

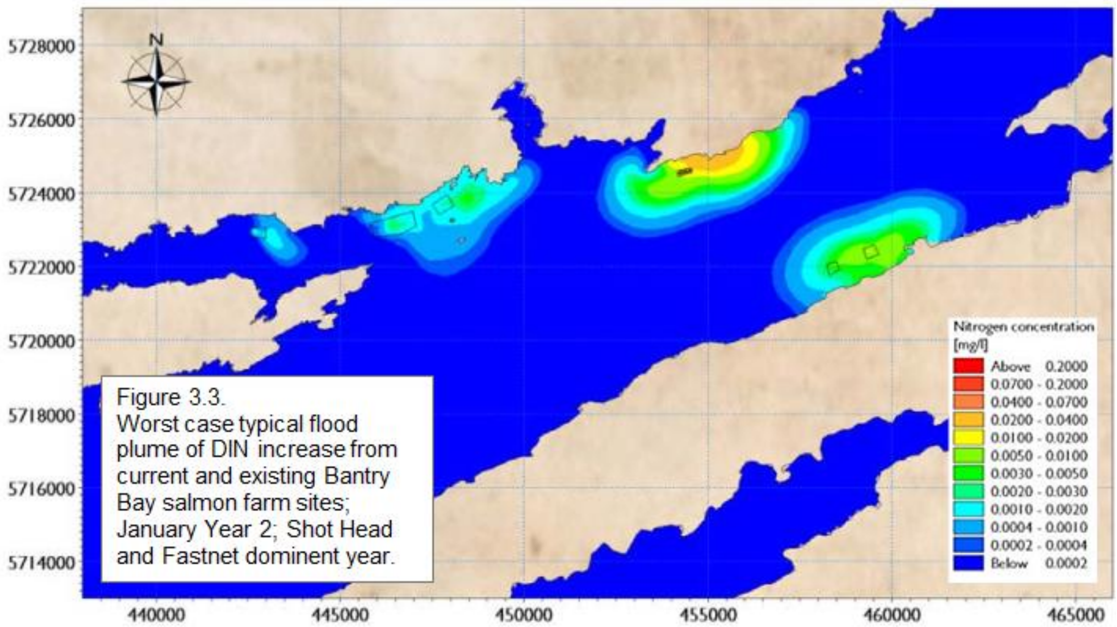

Figure 3.3. Worst case typical flood plume of DIN increase from current and existing Bantry Bay salmon farm sites; January Year 2; Shot Head and Fastnet dominent year.

Head site fully operational. More than anything else, this demonstrates that DIN dispersing from the Shot Head site at worst case will not elevate ambient DIN to the extent that any enviromental disturbance, such as elevated primary production, will result and High Ecological Status will be maintained.

In the case of Dissolved Oxygen (DO) saturation, with no elevated primary production, no elevation of summer DO levels will be expected to arise as a result of the operation of the site. What remains is the possibility that ambient DO will be impacted by Biological Oxydation Demand (BOD) dispersing from the site, mainly in organic carbon and nitrogen-based molecules in the discharges, which consume oxygen as they break down. Reference to the RPS WQ Model document and the original EIS demonstrates that the DO saturation in the bay and the quantity discharged and rate of dispersal of BOD from the site cause only a minor reduction of DO in the bay, leaving the DO saturation well within the High Ecological Status Quality Element standard for coastal water bodies of a 95%ile of >80% DO saturation at a median salinity of 35‰, once the Shot Head site is fully operational, if the licence is upheld by ALAB

In the case of Benthic Infauna, these are regularly sampled, at all MHI sites, in respect of the requirements of the DAFM Protocol No.1 for Offshore Finfish Farms – Benthic Monitoring and as well as under the requirements of The Aquaculture Stewardship Council (ASC) Audit process, to which MHI subscribes for all its sites. Both existing MHI sites in Bantry Bay, at Roancarrig and Ahabeg, pass the annual DAFM audit and both achieve the ASC Standard.

Modelling of solids settlement at the proposed Shot Head site is fully covered, both in the Shot Head EIS and in the RPS Bantry Bay WQ Document. This projects low levels of settlement at the Shot Head site, due mainly to the use of large pens with low, organic standard, stocking densities, high feed digestibility and due to the wind-wave assisted deep water current regime in the bay. As a result, benthic infaunal composition is only impacted within the Acceptable Zones of Effects established for salmon farming operations. Beyond these limits, benthic infaunal composition is projected to be normal throughout the Outer Bantry Bay Water Body, if the Shot Head site is licenced for full operation. Thus, the benthic infauna Quality Element is satisfied under the standards which apply to salmon farm installations, as agreed by the Scottish Environmental Protection Agency (SEPA), DAFM and the ASC.

In conclusion, in answer to the question raised, the High Ecological Status of Outer Bantry Bay will remain well within its QE value limits after the Shot Head site is fully operational should ALAB decide to uphold its licence. Further with retention of High Ecological Status, the wild salmonid stocks of Bantry Bay will suffer no additional impacts, over and above those caused by existing freshwater impacts, marine mortality, angling and commercial draft netting.

Freshwater Pearl Mussel in the Trafrask River will be exposed to no further risks, over and above those present within their freshwater habitat, as a result of degradation of the terrestrial catchment of the river. However, the cautionary note added at the end of Section 2 is repeated. Those FPM stocks in the Trafrask system and elsewhere around Bantry Bay and indeed further afield in Ireland that are not currently listed in SI 296 2009 are under huge risk of extinction, despite their Annex II status. This will largely occur through neglect of their freshwater habitat. It is strongly recommended that a concerted effort be made by the local community, via local and national authorities and pressure groups, to rectify this situation, if they wish this protected species to endure in their local rivers.