Submission 21

Minister for Housing, Local Government and Heritage,

Foreshore Section,

Department of Housing, Local Government and Heritage,

Newtown Road,

Wexford,

CO. WEXFORD

[27/02/2023]

Re: Foreshore Licence Application – Fuinneamh Sceirde Teoranta, FS007543

Galway Bay Inshore Fishermen's Association

Dear Sirs,

We are submitting an objection to the Foreshore Licence application in our capacity as local fishermen.

We are part of the Galway Bay Inshore Fishermen's Association. We operate in the Galway Bay area and will be directly effected by the proposed survey activity

We are objecting to the Licence application on the following grounds:

1. Lack of consultation.

There has been no consultation with the members of Galway Bay Inshore Fishermen Association in respect of the proposed survey activities despite the proximately of the survey area to our shoreline and active fishing grounds. The application submitted makes very little reference to our way of life which we believe will be detrimentally affected by the proposed survey activity. The application states that consultation commenced in 2022 but this statement is incorrect for all of our members.

We have been fishing this area for in excess of 50 years and our families have been fishing for five generations before. We operate 16 vessels in the area and employ 32 crew. We are concerned about the damage this survey will cause to our ability to earn a livelihood, our loss of income and the long-term effect this surveying and subsequent build will have on the local fishing industry. Fishing has been passed down through the generations of our community and we hope to protect the industry so future generations can follow in our footsteps. If the applicant had consulted with the fishermen in our group, we would have been in a position to advise the applicant of the nature of our long term fishing activities in the area including the species we fish, the spawning periods and the conservation methods we have been engaging in over a number of years which we feel are now at risk.

The applicant has noted concerns about the effect that other surveys will have on commercial fishermen if the surveys overlap. This concern is real and the impact of same cannot have been adequately assessed due to the lack of consultation and inaccurate data put forward by the applicant relating to commercial fishermen and the species fished. The applicant has submitted both this application along with Foreshore Licence application FS007161. We are concerned that if both licences are granted, there will be significant cumulative disturbance and damage and the effects have not been properly considered. It is well accepted that the proposed licence area contains rich fishing grounds. If fishermen are displaced from this licence area or indeed nearby licensed areas, it will cause significant friction in the fishing community and ultimately economic loss, this has not been evaluated or considered. I am concerned about the long-term plans for the area, including potential expansion of any windfarm built. If a cable is laid in this area or surrounding areas, it could cause issues for the species we fish and our right to earn a livelihood.

We as a group have a significant level of static fishing gear in the area amounting to approximately 12,000.00 pots. We are concerned that our gear will be damaged by the survey boats and equipment. Each of the fishermen rely upon this gear heavily in order to make a living. If any of the strings containing the pots are damaged by survey boats or gear, they become extremely dangerous to haul and could put fishermen's lives at risk. The application documentation has been prepared with no regard to the extensive fishing gear in the area and contains no proposals about how the applicant will deal with fishermen and gear in the area.

We are proud of our fishing heritage in Galway Bay and need to strive to protect it. The local community and families rely on the fishing. Any disruption to our fisheries would have a negative socio-economic effect and this has not been considered or assessed by the applicant, in relation to this survey activity or indeed future construction work.

Environmental Impact of the Proposed Surveying

We as a group fish lobster, shrimp, velvet crab, whelk, brown crab, scallops, prawns and clams. in the proposed Foreshore Licence area. Parts of the areas contained in and around the Licence are considered a Special Area of Conservation (SAC) and a Biologically Sensitive Area (BSA).

It is accepted that the Galway Bay SAC (and other SACs) are within the zone of influence for this project and we are concerned about such invasive surveying and ultimately construction work taking place around this sensitive area.

We are attaching a report produced by the Marine Institute and Bord Iascaigh Mhara, in collaboration with the fishermen in Galway Bay. This is the most comprehensive description of inshore fisheries in Galway Bay. The report highlights the distribution and location of lobster, crab, and shrimp fisheries in particular and assess the economic value of these fisheries to vessel owners in the Bay. We note that the Marine Institute continue to work in this area and relies on continued collaboration with fishermen to complete this work. It is difficult to understand that the Marine Institute, as the State agency responsible for marine research, technology development and innovation in Ireland are fully aware that collaboration with the local fishermen is essential in order to produce reliable scientific information, yet the applicant has produced and relied upon the documentation submitted to you without any consultation with the Galway Bay Inshore Fishermen, resulting in many inaccuracies and deficiencies in the documentation.

We understand that the Marine Institute work closely with the Galway Bay Inshore Fishermen's Association and West Regional Inshore Fisheries Forum to carry out work in the area including the following;

1. Obtaining observer data on crab and lobster boats in the Greater Galway Bay area;
2. Evaluating the conservation benefits of the lobster v-notch programme that fishermen in the Bay participate in
3. Tagged genetically screened and released v-notched lobsters in 2017-2018. This study was a collaboration between fishermen in the inner Bay, Aran Islands, Clare and Connemara and Queens University Belfast and the Marine Institute. The results of this work will soon be available. It shows that lobsters in the inner Bay are generally resident in the inner Bay and there is little emigration or immigration to and from the outer Bay
4. Assessed the risk posed by fisheries and aquaculture to habitats and species designated in the Special Area of Conservation and Special Protection Area of the inner Bay. We have identified that pot fisheries for shellfish do not pose a significant risk to habitats and species in the Bay
5. Since 2017 the Marine Institute has worked with oyster fishermen, local private enterprises and community organisations to restore and manage endangered native oyster stocks in the south east of the Bay. A full report of this work will be available in March 2023.
6. Completed a disease and parasite screening programme of velvet crab in response to concerns raised by the industry on the decline of velvet crab stocks.

It is noted by the applicant that the increased suspended solids resulting from coring fluids and cuttings may result in direct irritation to certain types of marine benthic organisms, abrading protective mucous coatings and increasing their susceptibility to parasites and infections, as well as affecting growth, reproduction and feeding. In circumstances where the Marine Institute have already raised concerns about disease and parasites in velvet crabs and decline in stock, we are most concerned that the applicant has failed to carry out a proper assessment on the effects that this survey activity will have on crustaceans. It is notable that brown crab is on the decline since 2016. In addition, a female lobster will spend approximately 9-11 months carrying eggs, the report does not assess the effect this direct irritation will have on a female lobster carrying eggs, or indeed any of the other sensitive stages of the lobster life cycle. We say that these species deserve protection, and the applicant has failed in its obligations to these species as part of this process.

There is no data or research completed that would allow the applicant to estimate and reassure about the effects of power cables coming from ORE developments on fish or shellfish and confirm that the survey activity will not adversely affect the integrity of the site. The applicant should be proceeding in a precautionary manner as a result which is not the case here. Scientific updates on the effects of ORE on the environment including fish and shellfish have been developed elsewhere such as the USA.

We are attaching an article published in the Journal of Marine Science and Engineering which is an international, peer reviewed, open access journal of marine science and engineering, investigating the effects of different strength Electromagnetic Field exposure on the commercially important crab species. We would refer the Minister to this study in full and the conclusions which set out that:

"increased physiological stress will occur if C. pagurus is exposed to EMF of 500 _T or above with data obtained at 1000 _T, 2.8 mT and 40 mT confirming this trend. This is mirrored in the behavioural trends noted, which showed an attraction to EMF sources at the same levels despite the physiological ramifications.
This suggests that a working limit of a maximum of 250 _T could result in minimal physiological and behavioural changes within this species and should be considered during MRED design and implementation. Additional research is required to further identify sensitivities to EMF in different life stages and conditions within this species and benthic crustaceans in general."

Research has shown that certain crustaceans are attracted to the electromagnetic waves emitted from the cables which can have a knock-on detrimental effect for migration, spawning, and movement of crab and lobster and prawns.

Taking the precautionary approach, the applicant should be carrying out full and proper assessments into the various crustaceans accepted to be in the area before this Licence is granted. Alternatively, the Minister should direct the Marine Institute to carry out full, up to date and researched studies. In the event that this licence is granted and successful survey activity takes place, it is clear that the applicant will proceed to the planning and development stage. We say that before a survey licence is granted, the applicant should be carrying out an environmental assessment in relation to all stages of the project, including connection to the national grid. The licence activity should not be carried out in a piecemeal fashion, causing environmental damage along the way for projects that may or may not result in a build.

The applicant is investigating a landing point at Kilcolgan Point, along with the other landing points, it is entirely unclear as to what the next step will be to bring power ashore as there is additional foreshore that would have to be traversed east of Kilcolgan Point. The effects of this additional work would need to be considered, particularly with respect to effects on habitats and birds for which the SAC and SPA are designated.

We are attaching a report on the Galway Bay Complex SAC, prepared on behalf of the National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht dated 16th April 2013, as part of the Conservation Objectives Series which also includes maps detailing the Galway Bay SAC area, We are concerned that both benthic, CPT and vibrcore surveying is due to take place in or around this area and is likely to have a significant effect. We do not accept the conclusion in the applicant's documentation that the survey works are likely to not have significant effect, this area has been subject to protection for many years and we are concerned about the environmental damage that will occur, which we say has not been properly assessed.

We are concerned about other protected species in the area. A bottle nose dolphin has resided in the area for circa 10 years at this stage and goes between the proposed landing point at Kilcolgan Bay and Salthill. A large breeding population of common seals are located in the inner Galway Bay. Grey seals are known to frequent the bay and a humpback whale migrates through the west of the proposed licence area. Otters are also located in the bay. In the event that the landfall area is designated at Kilcolgan Bay, we believe significant damage could occur to these protected species and that further environmental assessments will be required for the foreshore not referenced in this application that will form part of the connection path to the national grid.

We have been engaging in conservation methods, along with the Galway Bay Inshore Association for many years now, some of our members have been involved in v-notching lobsters for the last 30 years. V-notching is when a "V" shaped notch is clipped from the tail of a female lobster We have all participated in the v-notching scheme and released 1500 kilos of lobsters back into this area last year alone. For at least 20 years, we have been returning juvenile lobster to enhance stock. The juveniles remain hidden on the seabed for several years before joining the fishery. Our experienced and expert fishermen are well aware that the proposed licence area contains a lobster nursery ground however the applicant has failed to address and assess this sensitive issue. The assessment makes no reference to the damage that will be caused by the disturbance to the seabed and hidden juveniles or indeed any stage of the sensitive life cycles.

The applicant has attempted to justify damage to the area based on the fact that it is limited to a small area of $1,392M^{2.}$ We do not accept that this area is small, or indeed whether it is an accurate figure to put forward, taking into consideration the cumulative effect of all elements of the survey and overall project. There is no reference to the Atlantic Surf Clam (Spisula Solidssima) in the assessment put forward by the applicant. The complete failure to mention this species and address and assess the impact on the clam and ultimately on the food chain is an issue in this application.

It is accepted as part of the appropriate assessment determination that the equipment used to sample sediments may lead to an increase in suspended sediment concentrations and can lead to the clogging of the feeding apparatus of filter feeders, smothering of sessile species, increase in scouring and rendering hard surfaces for epibenthic settlement and it is noted that there can be both physical disturbance and habitat loss. We say that no proper assessment has taken place for the Atlantic Surf Clam species and as an expert fisherman, we believe significant damage to the species will occur. This species will not move during disturbance and will filter whatever water they are in. We say that due to a combination of the survey activity and strong west and north west winds, along with strong currents, the silt and debris from drilling will be carried by tides to other areas that we fish. We have a very stringent testing protocol for E-coli in the bay, with both private testing and testing by the SFPA taking place each month in order to keep the bay at category A water for water purity. We have spent many years monitoring our water quality and believe that the proposed survey activity will affect water quality, causing environmental damage and damage to the shellfish. In the event that the shellfish become contaminated, this could have serious public interest concerns as the shellfish may not be fit for human consumption. We note that the applicant has submitted that there is no risk to human health in the information provided under Section 7A and Schedule & in the

Environmental Assessment and EIA Screening Report and we say that this submission does not adequately assess the effect on filter fish which will reach the food chain along with the water quality issue.

The assessment put forward by the applicant accepts that there will be issues with the marine water quality as a result of discharges from the vessels and discharges from coring fluids and cuttings. It is noted that the discharges could potentially affect the water quality in terms of highly localised increases in turbidity and chemical impacts (toxicity) at the borehole locations. We do not accept the conclusion in the report which states that this will have no likely significant effect on marine quality and are concerned about the lack of assessment and scientific data provided. Again, this assessment has completely left out any reference or assessment to Atlantic Surf Clam as the species will not move during disturbance and will filter whatever water they are in. Our activity in the Foreshore Licence area is already considerably limited due to its protected status. We do not use water pumps and are limited to a dry dredge. We only use a regenerative style fishing, limiting our fishing to harvesting mature clams and returning juveniles to spawn and grow to full size. We are most concerned that the delicate balance we have worked so hard to achieve in the area will be changed by the survey activity. It is known that juvenile lobsters can be particularly difficult to research and review and we not believe a precautionary approach has been taken in this situation.

In relation to prawns, we are most concerned about the survey activity restricting access to the fishing grounds. The vessels currently fishing prawns are restricted to current locations and will be disproportionately effected by the proposed surveying. This again should have been investigated and considered by the applicant as part of the impact statement however the applicant failed to consult. The Minister should note there is a bed of prawns all along the North side of Galway Bay and the proposed site investigations are mapped to go run through this important area. Experiments with larval prawns have demonstrated that electromagnetic fields may cause deformities and effect survival rates, we say that this needs to be investigated and assessed. Recruitment to this prawn bed depends solely on adult prawns and the potential damage to the life cycle of the prawn could seriously and permanently damage this fishery.

We are concerned about the noise generated from the survey activity. It is notable that the applicant has not included all of the major species in the area as part of the assessments. We are concerned about the effect of the noise in this SAC and also the effect the noise will have on the species we fish which has not been adequately addressed.

We are concerned that the exact geotechnical and benthic sampling locations are not yet confirmed as part of this process and as such the Licence Holder may cause damage to areas that have not yet been specifically identified or assessed. Whilst the applicant has stated that no geotechnical or benthic sampling will be undertaken where the Foreshore Licence Area overlaps with an SAC or SPA, this does not account for contamination or disturbance to the SAC or SPA areas through tides/winds which is a significant factor on the West coast. In addition, the application states that there is uncertainty as to the numbers of sampling locations or the duration or timing of activities. We say that the assessment and potential impact that has been carried out as a result is unsafe.

We say it is impossible for the applicant to have complied with its legislative requirements pursuant to the Foreshore Acts and the Planning and Development Acts and Regulations and the EIA Directive 2011/92/EC and Habitats Directive as critical information and assessments that have either been omitted or not adequately assessed as part of this application.

We say that the complete life cycle of all of the above mentioned species, including larval and nursery stage occurs within the licence area and in particular Galway Bay. It is our position that if damage occurs to any stage of the life cycle, it will have a direct consequence for the species in the area. We say that the fishermen are best placed to understand this effect as we have fished this area for generations, however we have been completely ignored by the applicant in this process, despite the applicant advising the Minister that consultation commenced in 2022.

Socioeconomic damage:

The fishermen in this proposed licence area provide significant employment in the area, both directly and indirectly. We are concerned about the effect the surveying will have our ability to earn a livelihood both during the survey and into the future.

We say that the applicant has made no effort to gather information or statistics from the local fishermen in the area as part of the impact assessment. The assessment relies on data and accepts the data is limited to vessels over 12 meters in length. Our vessels are less than this length and therefore our fishing data is not captured by the information put forward. The Minister should note that vessels fishing the species listed in this submission are almost always less than 12 meters in length. Whilst the report notes and accepts this difficulty, the misleading data is still relied upon in the very short and limited impact assessment on commercial fisherman and is therefore an entirely inadequate assessment of the impact on the industry. We would say that any condition proposed to be attached to a Licence that may be granted simply directing that consultation should take place with local fishermen will not adequately protect our industry from the survey activity due to take place in circumstances where our interest has not been adequately investigated or considered as part of the Licence application process.

At page 35 of the EIA, the applicant makes reference to outdated and inaccurate studies and information relating to spawning and nursery grounds. This representation is highly unsatisfactory and if the applicant proceeds on the basis, will create a dangerous precent. The application could have included more accurate and relevant data in the assessment if consultation with the local fishermen had indeed taken place.

Vessel traffic/Static gear, pot and line fishermen

The applicant has purported to address the effect of the survey on fishing activities and noted the key impacts are from the temporary exclusion of fishing around the survey vessels. The applicant is simply unable to assess this issue using the inaccurate data relating to vessels over 12 meters, when the vast majority of vessels are less than this size and are not included in the data put forward. In addition, the local fishermen have significant levels of valuable static fishing gear in the area which again the applicant has failed to investigate and assess by consulting with the fishermen. The assessment makes reference to the inshore fishery activity however has gathered no data relating to vessels below 12 meters or indeed the level of static gear in the area. This impact assessment is not valid and cannot be relied upon in the decision making process. The assessment notes that the temporary physical presence of survey vessels has the potential to interfere with other sea users however, the level and extent of sea users has not been assessed in the report due to the inaccurate data put forward. The applicant refers to the proposed licence areas as an *"active shipping area"* with no reference to it being an active fishing area. We say that this conveniently excludes the active all year round fishing in the area and has failed to deal with this important and significant industry in the area. At page 7 of the application, it is stated that;

"Given the low number of survey vessels in an already active shipping area, FST is confident that the site investigations will not cause inconvenience to other sea users."

Taking into consideration the exclusion of data from the industry, the lack of consultation and the failure to make reference and assess the species in the area, it is impossible to see how the applicant can stand over this statement.

The applicant proposes to place a 500-meter safety zone around the survey vessel during the estimated 2-5 month activity in different phases over 5 years. No attempt has been made to assess the socioeconomic impact this activity and exclusion will have on local fishermen and we believe damage will occur to an area far wider than the exclusion zone due to the invasive nature of the borehole drilling and vibrocore investigations. The report refers to early and ongoing engagement with the fishery organisations however absolutely no engagement has taken place so far. The assertion that the survey activity is not likely to have a significant effect is not accurate, nor can it be accurate due to the massive holes and omissions in assessment report.

CONCLUSION

We would ask the Minister to consider the information listed in this submission and refuse the licence application. When dealing with fishery related matters, the applicant should be proceeding using a precautionary approach, the assessments carried out do not follow this principle. The report states that several species may use this area as a nursery ground but does not address or assess all of the species. This is an extremely weak assessment and ignores information that is known to the local community and fishermen for generations, information the applicant failed to investigate, reference and assess for the application. We have identified species that use the area as a nursery ground and the applicant has simply left some species out of the assessment in breach of its obligations or in the alternative, failed to carry out an adequate assessment. Taking into consideration the particularly delicate area the applicant proposes to survey in, we would ask that any future application contains a comprehensive and thorough scientific assessment, considering all of the important crustaceans and bivalves. We are concerned about the cumulative effect of the excessive surveying in both this application, and neighbouring applications (including application FS007161), along with a failure to consider the environmental repercussions of all stages of the project, including construction and connection to the national grid.

The application has also entirely disregarded the local fishing community as they are aware that the area is fished almost solely by vessels under 12 meters. In addition, no consultation has taken place with the [18? CLARIFY NUMBER] of this group. As a result, the Applicant has failed to put forward accurate data and has ignored its obligation to consult the fishermen and carry out an impact assessment.

In that the event that the Minister sees fit to grant the Licence as sought, we would ask that conditions are attached to the Licence providing protection for the fishermen and their constitutional right to earn a livelihood, in particular, we would ask for the following:

1. At least 30 days notice of the commencement of survey activity in our areas;
2. Proper consultation, investigation and assessment of the fishing gear in the area to ensure no gear is damaged;
3. In the event that a fisherman is asked to move fishing gear to facilitate survey activity – a condition should be attached to the licence allowing for compensation for loss of earnings and out of pocket expenses, including but not limited to crew costs, buyer and supplier losses and professional advisers.
4. A condition attaching to the licence that the applicant cannot interfere with any other licensed users legal rights.

We accept and understand that there is great support for the off shore wind farms however this development cannot be at the expense of the inshore fishing industry, nor can it be permitted to cause environmental damage to both the habitats and species in the area.

Signed:

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Minister for Housing, Local Government and Heritage,

Foreshore Section,

Department of Housing, Local Government and Heritage,

Newtown Road,

Wexford,

CO. WEXFORD

27th February 2023

Re: Foreshore Licence Application – Fuinneamh Sceirde Teoranta, FS007161

Galway Bay Inshore Fishermen's Association

Dear Sirs,

We refer to the above application.

We are filing a submission to this Licence Application as we are part of the Galway Bay Inshore Fishermen's Association. We operate in the Galway Bay area, where the proposed cable corridor route is due to cut through as part this project.

We are attaching our submission for Licence Application FS007543 and also rely on the contents of this submission for this project as the licence applications are intrinsically linked.

Signed:

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National Parks and Wildlife Service

Conservation Objectives Series

Galway Bay Complex SAC 000268

An Roinn
Ealaíon, Oidhreachta agus Gaeltachta
Department of
Arts, Heritage and the Gaeltacht

National Parks and Wildlife Service,
Department of Arts, Heritage and the Gaeltacht,

7 Ely Place, Dublin 2, Ireland.

Web: www.npws.ie
E-mail: nature.conservation@ahg.gov.ie

Citation:

NPWS (2013) Conservation Objectives: Galway Bay Complex SAC 000268. Version 1. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht.

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Introduction

The overall aim of the Habitats Directive is to maintain or restore the favourable conservation status of habitats and species of community interest. These habitats and species are listed in the Habitats and Birds Directives and Special Areas of Conservation and Special Protection Areas are designated to afford protection to the most vulnerable of them. These two designations are collectively known as the Natura 2000 network.

European and national legislation places a collective obligation on Ireland and its citizens to maintain habitats and species in the Natura 2000 network at favourable conservation condition. The Government and its agencies are responsible for the implementation and enforcement of regulations that will ensure the ecological integrity of these sites.

A site-specific conservation objective aims to define favourable conservation condition for a particular habitat or species at that site.

The maintenance of habitats and species within Natura 2000 sites at favourable conservation condition will contribute to the overall maintenance of favourable conservation status of those habitats and species at a national level.

Favourable conservation status of a habitat is achieved when:
- its natural range, and area it covers within that range, are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable.

The favourable conservation status of a species is achieved when:
- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

Notes/Guidelines:

1. The targets given in these conservation objectives are based on best available information at the time of writing. As more information becomes available, targets for attributes may change. These will be updated periodically, as necessary.
2. An appropriate assessment based on these conservation objectives will remain valid even if the targets are subsequently updated, providing they were the most recent objectives available when the assessment was carried out. It is essential that the date and version are included when objectives are cited.
3. Assessments cannot consider an attribute in isolation from the others listed for that habitat or species, or for other habitats and species listed for that site. A plan or project with an apparently small impact on one attribute may have a significant impact on another.
4. Please note that the maps included in this document do not necessarily show the entire extent of the habitats and species for which the site is listed. This should be borne in mind when appropriate assessments are being carried out.
5. When using these objectives, it is essential that the relevant backing/supporting documents are consulted, particularly where instructed in the targets or notes for a particular attribute.

Qualifying Interests

**** indicates a priority habitat under the Habitats Directive***

000268 Galway Bay Complex SAC

1140	Mudflats and sandflats not covered by seawater at low tide
1150	Coastal lagoons*
1160	Large shallow inlets and bays
1170	Reefs
1220	Perennial vegetation of stony banks
1310	*Salicornia* and other annuals colonising mud and sand
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1355	Otter *Lutra lutra*
1365	Harbour seal *Phoca vitulina*
1410	Mediterranean salt meadows (Juncetalia maritimi)
3180	Turloughs*
5130	*Juniperus communis* formations on heaths or calcareous grasslands
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco Brometalia)(*important orchid sites)
7210	Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae*
7230	Alkaline fens

Please note that this SAC overlaps with Inner Galway Bay SPA (004031) and adjoins Moneen Mountain SAC (000054). See map 2. The conservation objectives for this site should be used in conjunction with those for the overlapping and adjacent sites as appropriate.

Supporting documents, relevant reports & publications

Supporting documents, NPWS reports and publications are available for download from: www.npws.ie/Publications

Year :	1980
Title :	An assessment of the status of the common seal *Phoca vitulina vitulina* in Ireland
Author :	Summers, C.F.; Warner, P.J.; Nairn, R.G.W.; Curry, M.G.; Flynn, J.
Series :	Biological Conservation 17: 115-123
Year :	1982
Title :	Otter survey of Ireland
Author :	Chapman, P.J.; Chapman, L.L.
Series :	Unpublished Report to Vincent Wildlife Trust
Year :	1983
Title :	An assessment of the breeding populations of common seals (*Phoca vitulina vitulina*) in the Republic of Ireland during 1979
Author :	Warner, P.J.
Series :	Irish Naturalist's Journal 21: 24-26
Year :	1991
Title :	The spatial organization of otters (*Lutra lutra*) in Shetland
Author :	Kruuk, H.; Moorhouse, A.
Series :	J. Zool, 224: 41-57
Year :	1999
Title :	National Shingle Beach Survey of Ireland
Author :	Moore, D.; Wilson, F.
Series :	Unpublished Report to NPWS
Year :	2002
Title :	Distribution of the Harbour Seal (*Phoca vitulina*) in greater Galway Bay
Author :	Doyle,T.
Series :	Unpublished BSc. (hons.) thesis, NUI Galway
Year :	2006
Title :	Otters - ecology, behaviour and conservation
Author :	Kruuk, H.
Series :	Oxford University Press
Year :	2007
Title :	Inventory of Irish coastal lagoons (version 2)
Author :	Oliver, G.
Series :	Unpublished Report to NPWS
Year :	2007
Title :	Saltmarsh Monitoring Project 2006
Author :	McCorry, M.
Series :	Unpublished Report to NPWS
Year :	2009
Title :	Coastal Monitoring Project 2004-2006
Author :	Ryle, T.; Murray, A.; Connolly, C.; Swann, M.
Series :	Unpublished Report to NPWS

Year :	2009
Title :	Saltmarsh Monitoring Project 2007-2008
Author :	McCorry, M.; Ryle, T.
Series :	Unpublished Report to NPWS
Year :	2010
Title :	Monitoring and Assessment of Irish Lagoons for the purpose of the EU Water Framework Directive
Author :	Roden, C.M.; Oliver, G.
Series :	EPA
Year :	2010
Title :	Otter tracking study of Roaringwater Bay
Author :	De Jongh, A.; O'Neill, L.
Series :	Unpublished Draft Report to NPWS
Year :	2010
Title :	Subtidal Benthic Investigations in Galway Bay Complex cSAC (0268) and Inner Galway Bay SPA (4031)
Author :	Aquafact
Series :	Unpublished report for Marine Institute and NPWS
Year :	2010
Title :	Reef Investigations in Galway Bay cSAC (0269)
Author :	Aquafact
Series :	Study for Marine Institute and NPWS
Year :	2012
Title :	Benthic Survey Services Framework. Galway Bay Intertidal Surveys 2009 & 2010
Author :	RPS
Series :	Unpublished report to NPWS & Marine Institute
Year :	1990
Title :	1989 survey of breeding herds of common seal *Phoca vitulina* with reference to previous surveys
Author :	Harrington, R.
Series :	Unpublished report to Wildlife Service
Year :	2004
Title :	Harbour seal population assessment in the Republic of Ireland: August 2003
Author :	Cronin, M.; Duck, C.; O'Cadhla, O.; Nairn, R.; Strong, D.; O'Keeffe, C.
Series :	Irish Wildlife Manual No. 11
Year :	2004
Title :	Summary of National Parks & Wildlife Service surveys for common (harbour) seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*), 1978 to 2003
Author :	Lyons, D.O.
Series :	Irish Wildlife Manual No.13
Year :	2006
Title :	Otter Survey of Ireland 2004/2005
Author :	Bailey, M.; Rochford, J.
Series :	Irish Wildlife Manual No. 23
Year :	2006
Title :	Surveys of sensitive subtidal benthic communities
Author :	MERC
Series :	Unpublished Report to NPWS

Year :	2010
Title :	Harbour seal population monitoring 2009-2012: Report no. 1. Report on a pilot monitoring study carried out in southern and western Ireland, 2009
Author :	NPWS
Series :	Unpublished Report to NPWS
Year :	2011
Title :	Harbour seal pilot monitoring project, 2010
Author :	NPWS
Series :	Unpublished Report to NPWS
Year :	2012
Title :	The Conservation Status of Juniper Formations in Ireland
Author :	Cooper, F.; Stone, R.E.; McEvoy, P.; Wilkins, T.; Reid, N.
Series :	Irish Wildlife Manual No. 63
Year :	2012
Title :	Harbour seal pilot monitoring project, 2011
Author :	NPWS
Series :	Unpublished Report to NPWS
Year :	2013
Title :	Galway Bay Complex SAC (site code 268) Conservation objectives supporting document-coastal habitats V1
Author :	NPWS
Series :	Unpublished report to NPWS
Year :	2013
Title :	Galway Bay Complex SAC (Site code 268) Conservation objectives supporting document-lagoons V1
Author :	NPWS
Series :	Unpublished report to NPWS
Year :	2013
Title :	Galway Bay Complex SAC (site code 268) Conservation objectives supporting document-marine habitats and species V1
Author :	NPWS
Series :	Unpublished report to NPWS
Year :	2013
Title :	Galway Bay Complex SAC (site code 268) Conservation objectives supporting document-turloughs V1
Author :	NPWS
Series :	Unpublished report to NPWS

Year :	Interpolated 2013
Title :	Intertidal survey (2009) and subtidal subtidal surveys (2006, 2010)
GIS Operations :	Polygon feature classes from marine community types base data sub-divided based on interpolation of marine survey data. Expert opinion used as necessary to resolve any issues arising
Used For :	1140, 1170, Marine community types (maps 3, 6, 7)
Year :	2005
Title :	OSi Discovery series vector data
GIS Operations :	High water mark (HWM) and low water mark (LWM) polyline feature classes converted into polygon feature classes and combined; EU Annex I Saltmarsh and Coastal data erased out if present
Used For :	Marine community types base data (map 7)
Year :	2005
Title :	OSi Discovery series vector data
GIS Operations :	High Water Mark (HWM) polyline feature class converted into polygon feature class; clipped to SAC boundary. EPA WFD transitional waterbody data erased from extent. Expert opinion used as necessary to resolve any issues arising
Used For :	1160 (map 5)
Year :	Revision 2012
Title :	National Shingle Beach Survey
GIS Operations :	Clipped to SAC boundary. Expert opinion used as necessary to resolve any issues arising
Used For :	1220 (map 8)
Year :	Revision 2010
Title :	Saltmarsh Monitoring Project 2007-2008. Version 1
GIS Operations :	QIs selected; clipped to SAC boundary; overlapping regions with Coastal CO data investigated and resolved with expert opinion used
Used For :	1310, 1330, 1410 (map 9)
Year :	2010
Title :	EPA WFD Waterbodies data
GIS Operations :	Creation of a 20m buffer applied to river and stream centreline data; creation of 80m buffer on the aquatic side of lake data; creation of 10m buffer on the terrestrial side of lake data. These datasets are combined with the derived OSi data and Coastal Lagoon data for the 1355 CO. Overlapping regions investigated and resloved; resulting dataset clipped to SAC boundary. Expert opinion used as necessary to resolve any issues arising
Used For :	1355 (no map)
Year :	2005
Title :	OSi Discovery series vector data
GIS Operations :	Creation of an 80m buffer on the marine side of the high water mark (HWM); creation of a 10m buffer on the terrestrial side of the HWM; combination of 80m and 10m HWM buffer datasets; creation of a 10m buffer on the terrestrial side of the river banks data; creation of 20m buffer applied to canal centreline data. These datasets are combined with the derived EPA WFD Waterbodies data and Coastal Lagoon data for the 1355 CO. Overlapping regions investigated and resolved; resulting dataset clipped to SAC boundary. Expert opinion used as necessary to resolve any issues arising. Creation of 250m buffer on marine side of HWM to highlight potential commuting points
Used For :	1355 (map 11)
Year :	2005
Title :	OSi Discovery series vector data
GIS Operations :	High Water Mark (HWM) polyline feature class converted into polygon feature class; clipped to SAC boundary. Expert opinion used as necessary to resolve any issues arising
Used For :	1365 (map 12)

Year :	Revision 2011
Title :	Inventory of Irish Coastal Lagoons. Version 3
GIS Operations :	Creation of 80m buffer on the aquatic side of lagoon data; creation of 10m buffer on the terrestrial side of lagoon data. These datasets are combined with the derived OSi data and EPA WFD Waterbodies data for the 1355 CO. Overlapping regions are investigated and resolved; resulting dataset clipped to SAC boundary. Expert opinion used as necessary to resolve any issues arising
Used For :	1355 (no map)
Year :	2005
Title :	OSi Discovery series vector data
GIS Operations :	High water mark (HWM) and low water mark (LWM) polyline feature classes converted into polygon feature classes and combined; EU Annex I Saltmarsh and Coastal data erased out if present
Used For :	Marine community types base data (map 7)
Year :	2013
Title :	Internal NPWS files
GIS Operations :	Spatial location created from easting and northing Irish Grid coordinates
Used For :	5130 (map 10)
Year :	2013
Title :	Turloughs Database 2013
GIS Operations :	Relevant turloughs identified; clipped to SAC boundary
Used For :	3180 (map 10)
Year :	Revision 2011
Title :	Inventory of Irish Coastal Lagoons. Version 3
GIS Operations :	Clipped to SAC boundary
Used For :	1150 (map 4)
Year :	2013
Title :	NPWS rare and threatened species database
GIS Operations :	Dataset created from spatial references in database records. Expert opinion used as necessary to resolve any issues arising
Used For :	1365 (map 12)

1140 Mudflats and sandflats not covered by seawater at low tide

To maintain the favourable conservation condition of Mudflats and sandflats not covered by seawater at low tide in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	The permanent habitat area is stable or increasing, subject to natural processes. See map 3	Habitat area was estimated using OSi data as 744ha
Community distribution	Hectares	Conserve the following community types in a natural condition: Intertidal sandy mud community complex; and Intertidal sand community complex. See map 7	Based on intertidal surveys undertaken in 2009 and 2010 (RPS, 2012). See marine supporting document for further information

1150 Coastal lagoons

To restore the favourable conservation condition of Coastal lagoons in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable, subject to slight natural variation. Favourable reference area 76.7ha. See map 4	Areas calculated from spatial data derived from Oliver, 2007. Site codes IL037, IL038, IL039, IL046, IL047, IL048, IL049, IL050, IL051, IL052. NB there may be more, as yet unmapped, lagoons within this SAC. See lagoon supporting document for further details
Habitat distribution	Occurrence	No decline, subject to natural processes. See map 4 for mapped lagoons	Sites IL037, IL038, IL039, IL046, IL047, IL048, IL049, IL050, IL051, IL052 in Oliver, 2007. NB there may be more, as yet unmapped, lagoons within this SAC. See lagoon supporting document for further details
Salinity regime	Practical salinity units (psu)	Median annual salinity and temporal variation within natural ranges	The lagoons in the site vary from oligohaline to euhaline. See lagoon supporting document for further details
Hydrological regime	Metres	Annual water level fluctuations and minima within natural ranges	Most of the lagoons listed for this site are considered to be shallow; however, Aughinish lagoon and Lough Atalia do have deeper (at least 3m) parts. See lagoon supporting document for further details
Barrier: connectivity between lagoon and sea	Permeability	Appropriate hydrological connections between lagoons and sea, including where necessary, appropriate management	The lagoons within this site exhibit a variety of barrier types including cobble/shingle, karst and artificial embankment/causeway. Several are recorded as having sluices. See lagoon supporting document for further details
Water quality: Chlorophyll *a*	µg/L	Annual median chlorophyll *a* within natural ranges and less than 5µg/L	Target based on Roden and Oliver (2010). See lagoon supporting document for further details
Water quality: Molybdate Reactive Phosphorus (MRP)	mg/L	Annual median MRP within natural ranges 0.1mg/L	Target based on Roden and Oliver (2010). See lagoon supporting document for further details
Water quality: Dissolved Inorganic Nitrogen (DIN)	mg/L	Annual median DIN within natural ranges and less than 0.15mg/L	Target based on Roden and Oliver (2010). See lagoon supporting document for further details
Depth of macrophyte colonisation	Metres	Macrophyte colonisation to at least 2m depth	For shallow lagoons, it is expected that macrophytes should extend to their deepest points. See lagoon supporting document for further details
Typical plant species	Number and m²	Maintain number and extent of listed lagoonal specialists, subject to natural variation	Species listed in Oliver, 2007. See lagoon supporting document for further details
Typical animal species	Number	Maintain listed lagoon specialists, subject to natural variation	Species listed in Oliver, 2007. See lagoon supporting document for further details
Negative indicator species	Number and % cover	Negative indicator species absent or under control	Low salinity, shallow water and elevated nutrient levels increase the threat of accelerated encroachment by reedbeds. See lagoon supporting document for further details

1160 Large shallow inlets and bays

To maintain the favourable conservation condition of Large shallow inlets and bays in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	The permanent habitat area is stable or increasing, subject to natural processes. See map 5	Habitat area was estimated as 10,825ha using OSi data and the Transitional Water Body area as defined under the Water Framework Directive
Community extent	Hectares	Maintain the extent of the *Zostera*-dominated community complex and the maërl-dominated community, subject to natural processes. See map 7	Based on 2006 diver observation and dropdown camera data (MERC, 2006). See marine supporting document for further details
Community structure: *Zostera* density	Shoots per m^2	Conserve the high quality of *Zostera*-dominated communities, subject to natural processes	2006 diver observation and dropdown camera data (MERC, 2006). See marine supporting document for further details
Community structure	Biological composition	Conserve the high quality of the maërl-dominated community, subject to natural processes	2006 diver observation and dropdown camera data (MERC, 2006). See marine supporting document for further details
Community distribution	Hectares	Conserve the following community types in a natural condition: Intertidal sandy mud community complex; Intertidal sand community complex; Fine to medium sand with bivalves community complex; Sandy mud to mixed sediment community complex; Mixed sediment dominated by Mytilidae community complex; Shingle; Fucoid-dominated community complex; *Laminaria*-dominated community complex; and Shallow sponge-dominated community complex. See map 7	Based on intertidal and subtidal surveys undertaken in 2009 and 2010 (Aquafact, 2010a, b; RPS, 2012). See marine supporting document for further information

1170 Reefs

To maintain the favourable conservation condition of Reefs in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Distribution	Occurrence	The distribution of reefs is stable or increasing, subject to natural processes. See map 6 for mapped distribution	Based on information from 2009 and 2010 intertidal survey data and 2009 subtidal survey data (Aquafact, 2010a, b; RPS, 2012). See marine supporting document for further details
Habitat area	Hectares	The permanent habitat area is stable, subject to natural processes. See map 6	Habitat area estimated as 2773ha using 2009 and 2010 intertidal survey data and 2009 subtidal survey data (Aquafact, 2010a, b; RPS, 2012)
Community extent	Hectares	Maintain the extent of the *Mytilus*-dominated reef community, subject to natural processes. See map 7	Area established from 2009 intertidal survey (RPS, 2012)
Community structure: *Mytilus* density	Individuals per m^2	Conserve the high quality of the *Mytilus*-dominated reef community, subject to natural processes	Based on intertidal survey 2009 (RPS, 2012) and intertidal walkover 2012
Community structure	Biological composition	Conserve the following community types in a natural condition: Fucoid-dominated community complex; *Laminaria*-dominated community complex; and Shallow sponge-dominated community complex See map 7	Reef mapping based on information from 2009 subtidal reef survey (Aquafact, 2010b) and 2009 and 2010 intertidal surveys (RPS, 2012). See marine supporting document for further details

1220 Perennial vegetation of stony banks

To maintain the favourable conservation condition of Perennial vegetation of stony banks in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes, including erosion and succession	Current area unknown. It was recorded from Rinville Point, Tawin Point and coastline from Blackhead to Carrickada during the National Shingle Beach Survey (Moore and Wilson, 1999), but the extent was not mapped. Two areas of vegetated shingle were recorded during the Coastal Monitoring Project (Ryle et al., 2009): Bishopsquarter - 0.18ha and Barna (Whitestrand) - 0.45ha. NB further unsurveyed areas maybe present within the site. See coastal habitats supporting document for further details
Habitat distribution	Occurrence	No decline, or change in habitat distribution, subject to natural processes. See map 8 for mapped locations	Full distribution unmapped at present, although the habitat has been recorded at Rinville Point, Tawin Point and coastline from Blackhead to Carrickada (Moore and Wilson, 1999). It has also been recorded from Barna and Bishopquarter by Ryle et al. (2009). See coastal habitats supporting document for further details
Physical structure: functionality and sediment supply	Presence/ absence of physical barriers	Maintain the natural circulation of sediment and organic matter, without any physical obstructions	The Galway Bay shoreline supports good examples of shingle beaches along the more exposed shores to the south and west of Galway city and to the north-east of Finnavara, County Clare. Shingle features are relatively stable in the longterm (Moore and Wilson, 1999). See coastal habitats supporting document for further details
Vegetation structure: zonation	Occurrence	Maintain range of coastal habitats including transitional zones, subject to natural processes including erosion and succession	Based on data from Moore and Wilson (1999). See coastal habitats supporting document for further details
Vegetation composition: typical species and sub-communities	Percentage cover at a representative sample of monitoring stops	Maintain the typical vegetated shingle flora including the range of sub-communities within the different zones. Typical species include sea sandwort (*Honckenya peploides*), sea beet (*Beta vulgaris* ssp *maritima*), rock samphire (*Crithmum maritimum*), sea mayweed (*Tripleurospermum maritimum*), yellow-horned poppy (*Glaucium flavum*) and sea campion (*Silene uniflora*)	Based on data from Moore and Wilson (1999). See coastal habitats supporting document for further details
Vegetation composition: negative indicator species	Percentage cover	Negative indicator species (including non-natives) to represent less than 5% cover	Based on data from Moore and Wilson (1999). Negative indicators include non-native species indicative of changes in nutrient status and species not considered characteristic of the habitat. See coastal habitats supporting document for further details

1310 Salicornia and other annuals colonising mud and sand

To maintain the favourable conservation condition of *Salicornia* and other annuals colonizing mud and sand in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes, including erosion and succession. For sub-sites mapped: Barna House - 0.067ha, Seaweed Point - 0.003ha, Roscam West and South - 0.023ha, Kilcaimin - 0.015, Kileenaran - 0.007ha, Kinvara West - 0.017ha, Scanlan's Island - 0.117ha, Tawin Island - 1.098ha. See map 9	Based on data from Saltmarsh Monitoring Project (SMP) (McCorry and Ryle, 2009). Habitat recorded at eight of the ten sub-sites surveyed and mapped, giving a total estimated area of 1.347ha. N.B. Further unsurveyed areas may be present within this site. See coastal habitats supporting document for further details
Habitat distribution	Occurrence	No decline, or change in habitat distribution, subject to natural processes. See map 9 for known distribution	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). *Salicornia* is an annual species, so its distribution can vary significantly from year to year. See coastal habitats supporting document for further details
Physical structure: sediment supply	Presence/ absence of physical barriers	Maintain/restore, natural circulation of sediments and organic matter, without any physical obstructions	Sediment supply is particularly important for pioneer saltmarsh community, as the distribution of this habitat depends on accretion rates. See coastal habitats supporting document for further details
Physical structure: creeks and pans	Occurrence	Maintain, or where necessary restore creek and pan structure, subject to natural processes, including erosion and succession	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). Creeks deliver sediment throughout saltmarsh system. Creeks and pan structures well developed at Kileenaran and Tawin Island. See coastal habitats supporting document for further details
Physical structure: flooding regime	Hectares flooded; frequency	Maintain natural tidal regime	This pioneer saltmarsh community requires regular tidal inundation. See coastal habitats supporting document for further details
Vegetation structure: zonation	Occurrence	Maintain the range of coastal habitats including transitional zones, subject to natural processes including erosion and succession.	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: vegetation height	Centimetres	Maintain structural variation within sward	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for details
Vegetation structure: vegetation cover	Percentage cover at a representative sample of monitoring stops	Maintain more than 90% of area outside creeks vegetated	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for details
Vegetation composition: typical species and sub-communities	Percentage cover	Maintain the range of species-poor communities with typical species listed in SMP (McCorry and Ryle, 2009)	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: negative indicator species - *Spartina anglica*	Hectares	There is currently no common cordgrass (*Spartina anglica*) in this SAC. Prevent establishment of cordgrass	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details

1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)

To restore the favourable conservation condition of Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area increasing, subject to natural processes, including erosion and succession. For sub-sites mapped: Barna House - 2.33ha, Seaweed Point - 1.41ha, Roscam West and South - 3.30ha, Oranmore North - 4.24ha, Kilcaimin - 6.82ha, Tawin Island - 53.85ha, Tyrone House-Dunbulcaun Bay - 9.83ha, Kileenaran - 15.37ha, Kinvara West - 13.33ha, Scanlan's Island - 4.13ha. See map 9	Based on data from Saltmarsh monitoring Project (SMP) (McCorry, 2007; McCorry and Ryle, 2009). Ten sub-sites that supported Atlantic salt meadow were mapped (114.612ha) and additional areas of potential saltmarsh (149.18ha) were identified by an examination of aerial photographs, giving a total estimated area of 263.80ha. NB further unsurveyed areas maybe present within the site. See coastal habitats supporting document for further details
Habitat distribution	Occurrence	No decline or change in habitat distribution, subject to natural processes. See map 9 for known distribution	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Physical structure: sediment supply	Presence/ absence of physical barriers	Maintain/restore natural circulation of sediments and organic matter, without any physical obstructions	See coastal habitats supporting document for further details
Physical structure: creeks and pans	Occurrence	Maintain creek and pan structure, subject to natural processes, including erosion and succession	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). The efficiency of sediment circulation throughout a saltmarsh depends on the creek pattern. Creeks and pans are well developed at both Tawin Island and Kileenaran. See coastal habitats supporting document for further details
Physical structure: flooding regime	Hectares flooded; frequency	Maintain natural tidal regime	See coastal habitats supporting document for further details
Vegetation structure: zonation	Occurrence	Maintain range of coastal habitats including transitional zones, subject to natural processes including erosion and succession	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: vegetation height	Centimetres	Maintain structural variation within sward	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: vegetation cover	Percentage cover at a representative sample of monitoring stops	Maintain more than 90% area outside creeks vegetated	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation composition: typical species and sub-communities	Percentage cover at a representative sample of monitoring stops	Maintain range of sub-communities with typical species listed in SMP (McCorry and Ryle, 2009)	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: negative indicator species - *Spartina anglica*	Hectares	There is currently no common cordgrass (*Spartina anglica*) in this SAC. Prevent establishment of cordgrass	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). McCorry and Ryle, 2009). See coastal habitats supporting document for further details

1410 Mediterranean salt meadows (Juncetalia maritimi)

To restore the favourable conservation condition of Mediterranean salt meadows (*Juncetalia maritimi*) in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes, including erosion and succession. For sub-sites mapped: Barna House - 0.282ha, Seaweed Point - 0.931ha, Kilcaimin - 0.005ha, Tawin Island - 1.799ha. Tyrone House- Dunbulcan Bay - 8.184ha, Kileenaran - 0.271ha. See map 9	Based on data from the Saltmarsh Monitoring Project (SMP) (McCorry, 2007; McCorry and Ryle, 2009). Six sub-sites that support Mediterranean salt meadow were mapped (11.472ha) and additional areas of potential saltmarsh (8.415ha) were identified from an examination of aerial photographs, giving a total estimated area of 19.887ha. NB further unsurveyed areas maybe present within the site. See coastal habitats supporting document for further details
Habitat distribution	Occurrence	No decline, subject to natural processes. See map 9 for known distribution	See coastal habitats supporting document for further details
Physical structure: sediment supply	Presence/absence of physical barriers	Maintain/restore natural circulation of sediments and organic matter, without any physical obstructions	See coastal habitats supporting document for further details
Physical structure: creeks and pans	Occurrence	Maintain creek and pan structure, subject to natural processes, including erosion and succession	Based on data from the SMP (McCorry, 2007; McCorry and Ryle, 2009). [Site-specific info.]. See coastal habitats supporting document for further details
Physical structure: flooding regime	Hectares flooded; frequency	Maintain natural tidal regime	Mediterranean salt meadows is found high up in the saltmarsh but requires occasional tidal inundation. [Site-specific info.] See coastal habitats supporting document for further details
Vegetation structure: zonation	Occurrence	Maintain range of coastal habitats including transitional zones, subject to natural processes including erosion and succession	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: vegetation height	Centimetres	Maintain structural variation in the sward	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details
Vegetation structure: vegetation cover	Percentage cover at a representative sample of monitoring stops	Maintain more than 90% of area outside creeks vegetated	Based on data from SMP (McCorry, 2007; McCorry and Ryle (2009). See coastal habitats supporting document for further details
Vegetation composition: typical species and sub-communities	Percentage cover at a representative sample of monitoring stops	Maintain range of sub-communities with typical species listed in SMP (McCorry and Ryle, 2009)	Based on data from SMP (McCorry, 2007; McCorry and Ryle (2009). See coastal habitats supporting document for further details
Vegetation structure: negative indicator species - *Spartina anglica*	Hectares	There is currently no common cordgrass (*Spartina anglica*) in this SAC. Prevent establishment of cordgrass	Based on data from SMP (McCorry, 2007; McCorry and Ryle, 2009). See coastal habitats supporting document for further details

3180 Turloughs

To maintain the favourable conservation condition of Turloughs in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable at c.59ha or increasing, subject to natural processes. See map 10	Based on measured area of four known turloughs. NB there may be more, as yet unmapped, turloughs within this SAC. See turloughs supporting document for further details
Habitat distribution	Occurrence	No decline, subject to natural processes. See map 10	NB there may be more, as yet unmapped, turloughs within this SAC. See turloughs supporting document for further details
Hydrological regime: flood duration, frequency, area, depth; permanently flooded area	Various	Appropriate natural hydrological regimes necessary to support the natural structure and functioning of the habitat	Hydrological regime is sub-divided into more detailed attributes in the turloughs supporting document
Soil type: area	Hectares	Variety, area and extent of soil types necessary to support turlough vegetation and other biota	See turloughs supporting document for further details
Soil nutrient status: nitrogen and phosphorous	N and P concentration in soil	Nutrient status appropriate to soil types	See turloughs supporting document for further details
Physical structure: bare ground	Presence	Sufficient wet bare ground, as appropriate	See turloughs supporting document for further details
Chemical processes: calcium carbonate deposition and concentration	CaCO3 deposition rate/soil concentration	Appropriate CaCO3 deposition rates and concentration in soil	See turloughs supporting document for further details
Water quality: nutrients; colour; phytoplankton; epiphyton	Various	Appropriate water quality to support the natural structure and functioning of the habitat	Water quality is sub-divided into more detailed attributes in the turloughs supporting document
Active peat formation	Flood duration	Active peat formation, where appropriate	See turloughs supporting document for further details
Vegetation composition: area of vegetation communities	Hectares	Maintain area of sensitive and high conservation value vegetation communities/units at each turlough	See turloughs supporting document for further details
Vegetation composition: vegetation zonation	Distribution	Maintain vegetation zonation/mosaic characteristic of each turlough	See turloughs supporting document for further details
Vegetation structure: sward height	Centimetres	Sward heights appropriate to the vegetation unit, and a variety of sward heights across each turlough	See turloughs supporting document for further details
Typical species: terrestrial, wetland and aquatic plants, invertebrates and birds	Presence	Maintain typical species within and across all turloughs	Typical species is sub-divided into more detailed attributes in the turloughs supporting document
Fringing habitats: area	Hectares	Maintain marginal fringing habitats that support turlough vegetation, invertebrate, mammal and/or bird populations	See turloughs supporting document for further details

Vegetation structure: turlough woodland	Species diversity and woodland structure	Maintain appropriate turlough woodland diversity and structure	See turloughs supporting document for further details

5130 Juniperus communis formations on heaths or calcareous grasslands

To restore the favourable conservation condition of *Juniperus communis* formations on heaths or calcareous grasslands in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Occurrence	Area stable or increasing, subject to natural processes. At least 1.4ha at mapped location. See map 10	Minimum area from one mapped location. Based on site visit in March 2013. Appropriate management might encourage expansion of the area. NB further unsurveyed areas maybe present within the SAC
Habitat distribution	Hectares	No decline. Known location shown on map 10	Distribution based on NPWS site visits in 2002, 2003 and 2013 (internal NPWS files). NB further unsurveyed locations maybe present within the SAC
Juniper population size	Number	At least 50 plants	To classify as a juniper fomation, at least 50 plants should be present (Cooper et al., 2012). A site visit in March 2013 estimated c.130 plants
Formation structure: cover and height	Percentage and metres	Well-developed structure with an open to closed cover of juniper up to or exceeding 0.5 m in height with associated species	Structure currently open with most plants less than 0.5m in height (February 2013)
Formation structure: community diversity and extent	Hectares	Appropriate diversity and extent of formation	Suitable management could lead to expansion of the formation and increased diversity of associated species
Formation structure: cone-bearing plants	Percentage	At least 10% of plants bearing cones	Target based on Cooper et al., 2012. c.23% of plants were fruiting, some prolifically, during a site visit in March 2013
Formation structure: seedling recruitment	Percentage	At least 10% of juniper plants within the formation are seedlings	Target based on Cooper et al., 2012. No seedlings were recorded in February 2013
Formation structure: dead plants	Percentage	Not more than 10% of plants dead	Target based on Cooper et al., 2012. Only a few dead plants observed February 2013
Vegetation composition: typical species	Occurrence	A variety of typical native species with a minimum of 10 species present (excluding negative indicator species)	The area appears to fall into the *Carex flacca-Succisa pratensis* vegetation group as classified by Cooper et al. (2012), who also list positive indicator species. Few of these species have been recorded but a detailed survey has not been undertaken. Lack of suitable management at this site has resulted in a dominance of gorse (*Ulex europaeus*) and purple moorgrass (*Molinia caerulea*)
Vegetation composition: negative indicator species	Occurrence	Negative indicator species, particularly non-native invasive species, absent or under control	Gorse (*Ulex europaeus*) and purple moorgrass (*Molinia caerulea*) are currently competing strongly with the juniper. Blackthorn (*Prunus spinosa*) and the non-native cotoneaster (*Cotoneaster integrifolius*) also pose a threat

6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco Brometalia)(*important orchid sites)

To maintain the favourable conservation condition of Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco Brometalia*) in Galway Bay Complex, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes	Extent of this habitat in the SAC is currently unknown. Areas are likely to be small and often in mosaic with other habitats such as limestone pavement and scrub (Dwyer et al., 2007; internal NPWS files). Dwyer et al. (2007) surveyed a number of sub-sites in 2006. The Irish semi-natural grasslands survey undertook survey work in Counties Clare and Galway in 2012 and additional information is likely to be available for this SAC following data analysis
Habitat distribution	Occurrence	No decline, subject to natural processes	Full distribution of this habitat in this SAC is currently unknown- see note above
Vegetation composition: broadleaf herb: grass ratio	Percentage	Broadleaf herb component of vegetation between 40 and 90%	Attribute and target based on O'Neill et al. (2010)
Vegetation composition: typical species	Number	At least 7 positive indicator species present, including 2 "high quality" species	List of positive indicator species, including high quality species, identified by O'Neill et al. (2010)
Vegetation composition: negative indicator species	Percentage	Negative indicator species collectively not more than 20% cover, with cover by an individual species not more than 10%. Non-native invasive species, absent or under control	List of negative indicator species identified by O'Neill et al. (2010)
Vegetation structure: sward height	Percentage	30-70% of sward 5-40cm high	Attribute and target based on O'Neill et al. (2010)
Vegetation structure: woody species and bracken (*Pteridium aquilinum*)	Percentage	Cover of bracken (*Pteridium aquilinum*) and woody species (except juniper (*Juniperus communis*)) not more than 5% cover	Attribute and target based on O'Neill et al. (2010)
Physical structure: bare ground	Percentage	Not more than 10% bare ground	Attribute and target based on O'Neill et al. (2010)

7210 Calcareous fens with Cladium mariscus and species of the Caricion davallianae

To maintain the favourable conservation condition of Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes	The full extent of this habitat within the SAC is currently unknown. Fen vegetation occurs in wetland areas to the east of Oranmore (Internal NPWS files). It has also been recorded in Ballindereen Lough (see turloughs supporting document for further details). This habitat is found in mosaic with another habitats including the Annex I habitat: Alkaline fens (7230) (Internal NPWS Files). NB further areas of fen are likely to occur within the SAC
Habitat distribution	Occurrence	No decline, subject to natural processes	Full distribution of this habitat in this SAC is currently unknown- see note above
Hydrological regime	Flow rates, metres	Appropriate natural hydrological regime necessary to support the natural structure and functioning of the habitat	Maintenance of groundwater, surface water flows and water table levels within natural ranges is essential for this wetland habitat
Peat formation	Flood duration	Active peat formation, where appropriate	In order for peat to form, water levels need to be slightly below or above the soil surface for c.90% of the time (Jim Ryan, pers. comm.)
Water quality: nutrients	Water chemistry measures	Appropriate water quality to support the natural structure and functioning of the habitat	Fens receive natural levels of nutrients (e.g. iron, magnesium and calcium) from water sources. However, they are generally poor in nitrogen and phosphorus with the latter tending to be the limiting nutrient
Vegetation composition: typical species	Presence	Maintain vegetation cover of typical species including brown mosses and vascular plants	Mosses listed for fen at this site include *Campylium stellatum*, *Fissidens adianthoides* and *Ctenidium molluscum*. Other species recorded include saw sedge (*Cladium mariscus*), black bog rush (*Schoenus nigricans*), purple moor-grass (*Molinia caerulea*), water mint (*Mentha aquatica*), wild angelica (*Angelica sylvestris*) and bogbean (*Menyanthes trifoliata*) (Internal NPWS files)
Vegetation composition: trees and shrubs	Percentage	Cover of scattered native trees and shrubs not more than than 10%	Scrub and trees will tend to invade if fen conditions become drier. Internal NPWS files report scattered multi-stemmed trees over much of the habitat. Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)
Physical structure: disturbed bare ground	Percentage	Cover of disturbed bare ground not more than 10%. Where tufa is present, disturbed bare ground not more than 1%	While grazing may be appropriate in this habitat, excessive areas of disturbed bare ground may develop due to unsuitable grazing regimes. Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)
Physical structure: drainage	Percentage	Areas showing signs of drainage as a result of drainage ditches or heavy trampling not more than 10%	Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)

7230 Alkaline fens

To maintain the favourable conservation condition of Alkaline fens in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Habitat area	Hectares	Area stable or increasing, subject to natural processes	The full extent of this habitat within the SAC is currently unknown. Fen vegetation occurs in wetland areas to the east of Oranmore (Internal NPWS files). It has also been recorded in Ballindereen Lough (see turloughs supporting document for further details). This habitat is found in mosaic with another habitats including the Annex I habitat: Calcareous fens with *Cladium mariscus* and species of the Caricion davallianae (7210). NB further areas of fen are likely to occur within the SAC
Habitat distribution	Occurrence	No decline, subject to natural processes	Full distribution of this habitat in this SAC is currently unknown- see note above
Hydrological regime	Flow rates, metres	Appropriate natural hydrological regime necessary to support the natural structure and functioning of the habitat	Maintenance of groundwater, surface water flows and water table levels within natural ranges is essential for this wetland habitat
Peat formation	Flood duration	Active peat formation, where appropriate	In order for peat to form, water levels need to be slightly below or above the soil surface for c.90% of the time (Jim Ryan, pers. comm.)
Water quality: nutrients	Water chemistry measures	Appropriate water quality to support the natural structure and functioning of the habitat	Fens receive natural levels of nutrients (e.g. iron, magnesium and calcium) from water sources. However, they are generally poor in nitrogen and phosphorus with the latter tending to be tbe limiting nutrient
Vegetation composition: typical species	Presence	Maintain vegetation cover of typical species including brown mosses and vascular plants	Mosses listed for fen at this site include *Campylium stellatum*, *Fissidens adianthoides* and *Ctenidium molluscum*. Other species recorded include black bog rush (*Schoenus nigricans*), purple moor-grass (*Molinia caerulea*), sedge species (*Carex* spp.), water mint (*Mentha aquatica*), butterwort (*Pinguicula* spp.) and ling heather (*Calluna vulgaris*) (Internal NPWS files)
Vegetation composition: trees and shrubs	Percentage	Cover of scattered native trees and shrubs less than 10%	Scrub and trees will tend to invade if fen conditions become drier. Internal NPWS files report scattered multi-stemmed trees over much of the habitat. Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)
Physical structure: disturbed bare ground	Percentage	Cover of disturbed bare ground less than 10%. Where tufa is present, disturbed bare ground less than 1%	While grazing may be appropriate in this habitat, excessive area of disturbed bare ground may develop due to unsuitable grazing regimes. Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)
Physical structure: drainage	Percentage	Areas showing signs of drainage as a result of drainage ditches or heavy trampling less than 10%	Attribute and target based on upland habitat conservation assessment criteria (Perrin et al., in prep.)

1355 Otter *Lutra lutra*

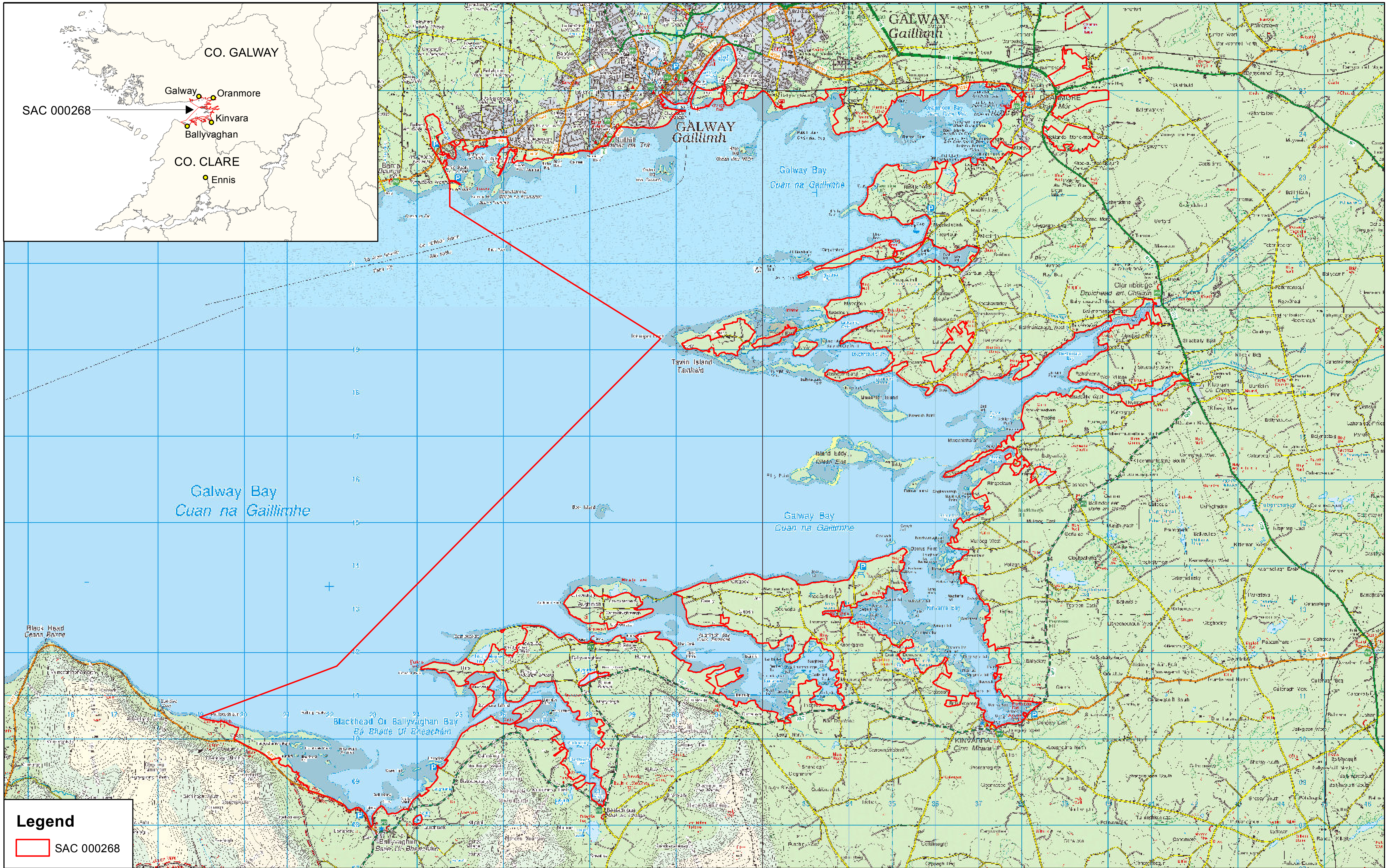
To restore the favourable conservation condition of Otter in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Distribution	Percentage positive survey sites	No significant decline	Measure based on standard otter survey technique. FCS target, based on 1980/81 survey findings, is 88% in SACs. Current range in the west is estimated at 70% (Bailey and Rochford, 2006).
Extent of terrestrial habitat	Hectares	No significant decline. Area mapped and calculated as 262ha above high water mark (HWM); 14ha along river banks/around ponds	No field survey. Areas mapped to include 10m terrestrial buffer along shoreline (above HWM and along river banks) identified as critical for otters (NPWS, 2007)
Extent of marine habitat	Hectares	No significant decline. Area mapped and calculated as 2040ha	No field survey. Area mapped based on evidence that otters tend to forage within 80m of the shoreline (HWM) (NPWS, 2007; Kruuk, 2006)
Extent of freshwater (river) habitat	Kilometres	No significant decline. Length mapped and calculated as 4km	No field survey. River length calculated on the basis that otters will utilise freshwater habitats from estuary to headwaters (Chapman and Chapman, 1982)
Extent of freshwater (lake/lagoon) habitat	Hectares	No significant decline. Area mapped and calculated as 21ha	No field survey. Area mapped based on evidence that otters tend to forage within 80m of the shoreline (NPWS, 2007)
Couching sites and holts	Number	No significant decline	Otters need lying up areas throughout their territory where they are secure from disturbance (Kruuk, 2006; Kruuk and Moorhouse, 1991)
Fish biomass available	Kilograms	No significant decline	Broad diet that varies locally and seasonally, but dominated by fish, in particular salmonids, eels and sticklebacks in freshwater (Bailey and Rochford, 2006) and wrasse and rockling in coastal waters (Kingston et al., 1999)
Barriers to connectivity	Number	No significant increase. For guidance, see map 11	Otters will regularly commute across stretches of open water up to 500m e.g. between the mainland and an island; between two islands; across an estuary (De Jongh and O'Neill, 2010). It is important that such commuting routes are not obstructed

1365 Harbour seal *Phoca vitulina*

To maintain the favourable conservation condition of Harbour Seal in Galway Bay Complex SAC, which is defined by the following list of attributes and targets:

Attribute	Measure	Target	Notes
Access to suitable habitat	Number of artificial barriers	Species range within the site should not be restricted by artificial barriers to site use. See map 12	See marine supporting document for further details
Breeding behaviour	Breeding sites	Conserve breeding sites in a natural condition. See map 12	Attribute and target based on background knowledge of Irish breeding populations, review of data summarised by Summers et al. (1980), Warner (1983), Harrington (1990), Doyle (2002), Lyons (2004), and unpublished NPWS records. See marine supporting document for further details
Moulting behaviour	Moult haul-out sites	Conserve moult haul-out sites in a natural condition. See map 12	Attribute and target based on background knowledge of Irish populations, review of data from Doyle (2002), Lyons (2004), Cronin et al. (2004), NPWS (2010, 2011, 2012) and unpublished NPWS records. See marine supporting document for further details
Resting behaviour	Resting haul-out sites	Conserve resting haul-out sites in a natural condition. See map 12	Attribute and target based on background knowledge of Irish populations, review of data from Doyle (2002), Lyons (2004) and unpublished NPWS records. See marine supporting document for further details
Disturbance	Level of impact	Human activities should occur at levels that do not adversely affect the harbour seal population at the site	See marine supporting document for further details



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MAP 1:
GALWAY BAY COMPLEX SAC CONSERVATION OBJECTIVES SAC DESIGNATION

Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

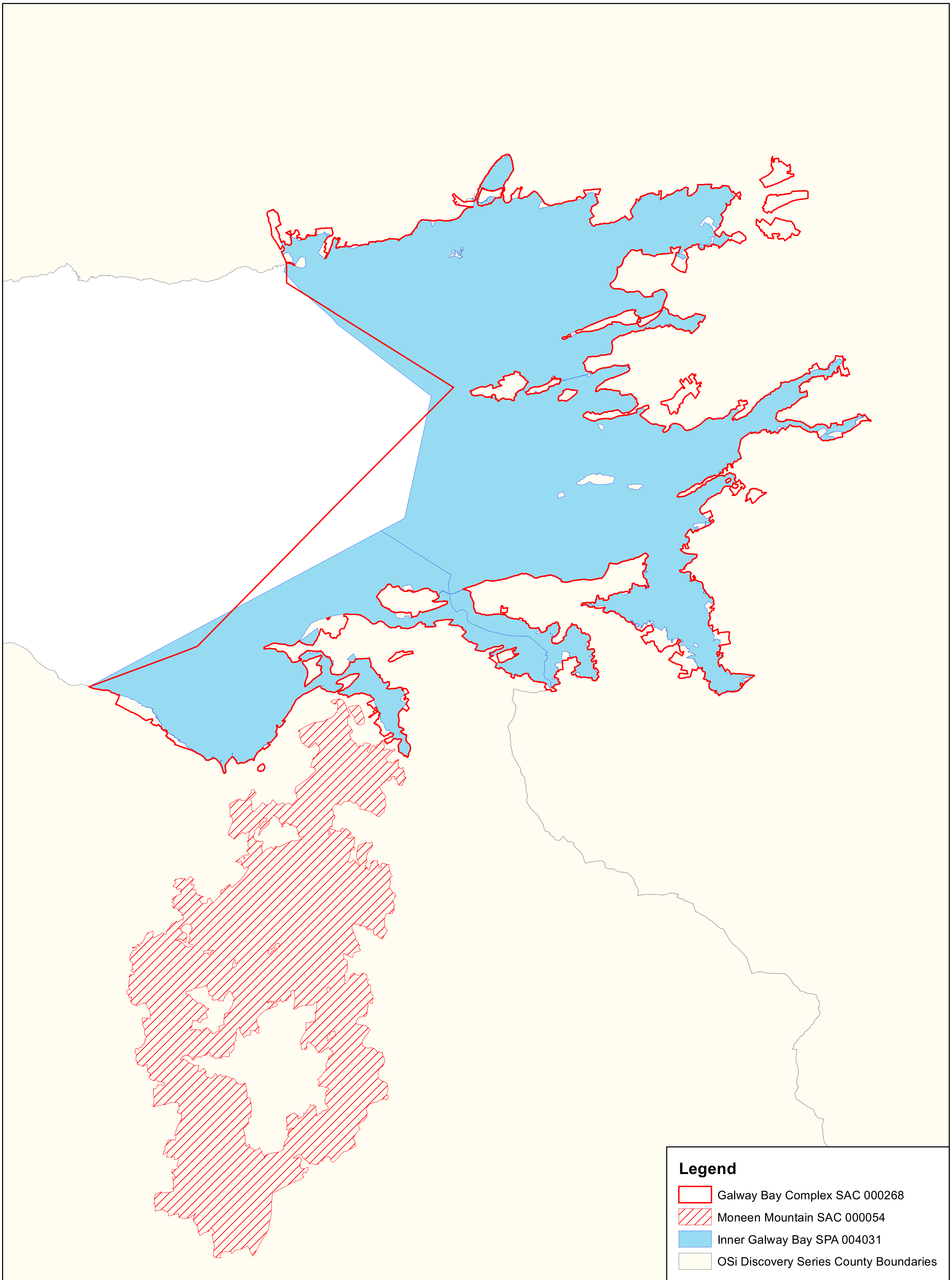
0 1 2 3 4 5 km

The mapped boundaries are of an indicative and general nature only. Boundaries of designated areas are subject to revision. Reproduced from Ordnance Survey material by permission of the Government (Permit number EN 0059208).

Níl sna teorainneacha ar na léarscáileanna ach nod garshuíomhach ginearálta. Féadfar athbhreithnithe a déanamh ar theorainneacha na gceantar comharthaithe. Macasamhail d'ábhar na Suirbhéarachta Ordonáis le chead ón Rialtas (Ceadunas Uimh. EN 0059208)

N

Map Version 1
Date: Nov 2012



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MAP 2:
GALWAY BAY COMPLEX SAC CONSERVATION OBJECTIVES ADJOINING / OVERLAPPING DESIGNATIONS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE:
SAC 000054 CO.CLARE; version 1.02
SAC 000268 CO.CLARE; version 1.01, CO.GALWAY; version 1.08
SPA 004031 CO.CLARE; version 1.03, CO.GALWAY; version 1.06

0 1 2 3 4 5 km

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Féadfar athbhreithnithe a déanamh ar theorainneacha na gceantar comharthaithe. Macasamhail d'ábhar na Suirbhéarachta Ordonáis le chead ón Rialtas (Ceadunas Uimh. EN 0059208)

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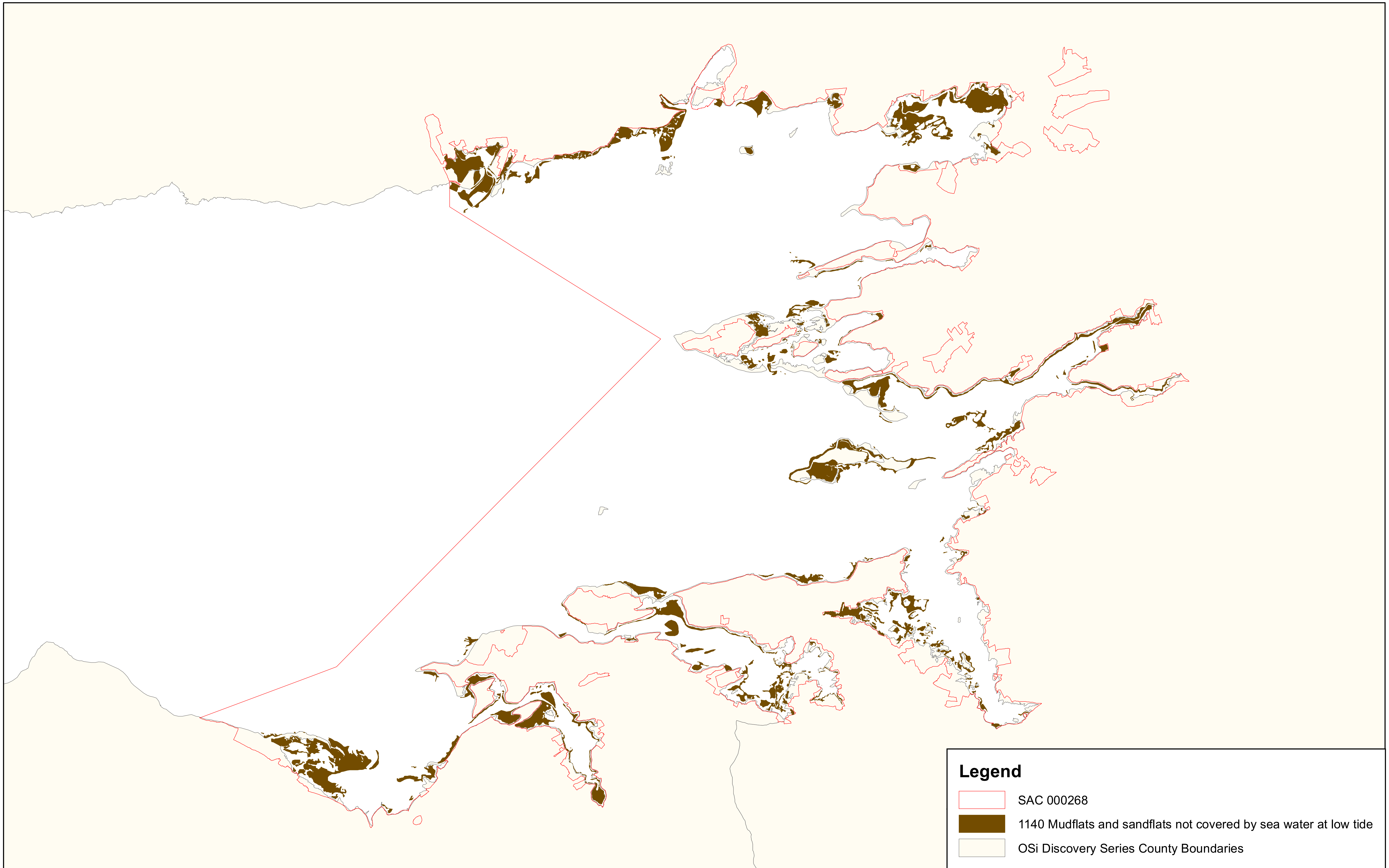

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MAP 3:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
TIDAL MUDFLATS AND SANDFLATS

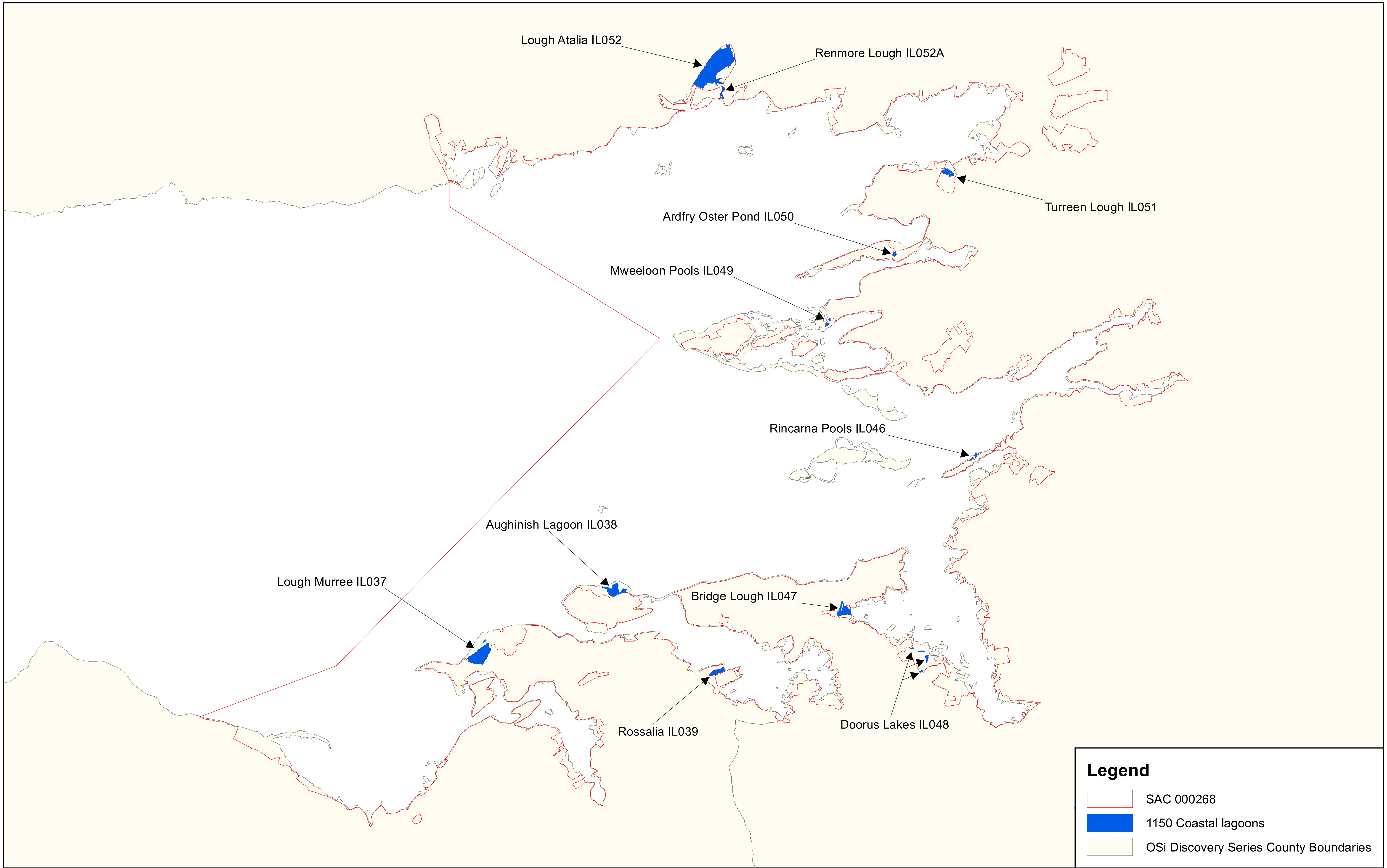
Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

N

Map Version 1
Date: Nov 2012



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MAP 4:
GALWAY BAY COMPLEX SAC CONSERVATION OBJECTIVES COASTAL LAGOONS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

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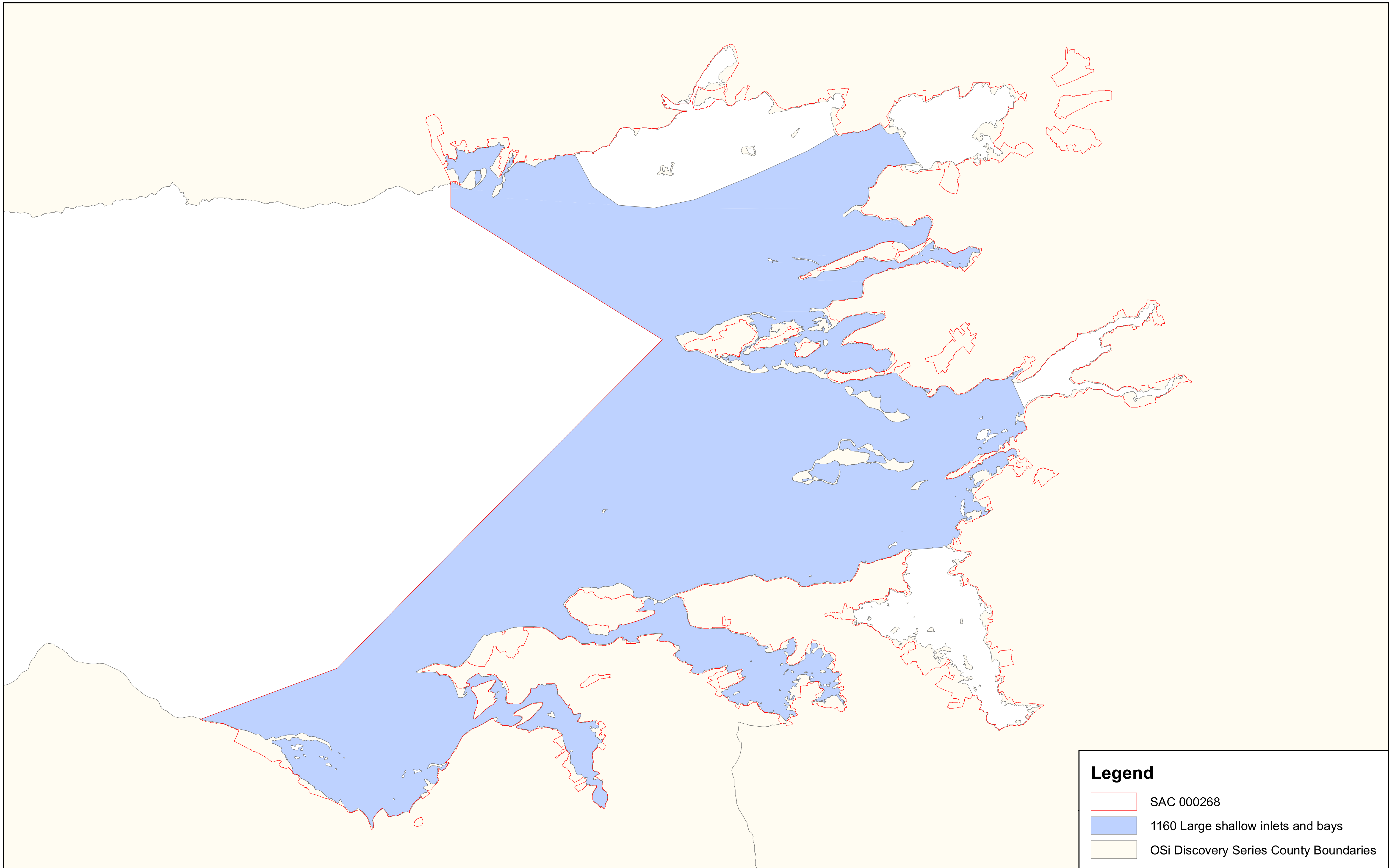
Map Version 1
Date: Nov 2012



Legend

- SAC 000268
- 1160 Large shallow inlets and bays
- OSi Discovery Series County Boundaries

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MAP 5:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
LARGE SHALLOW INLETS AND BAYS

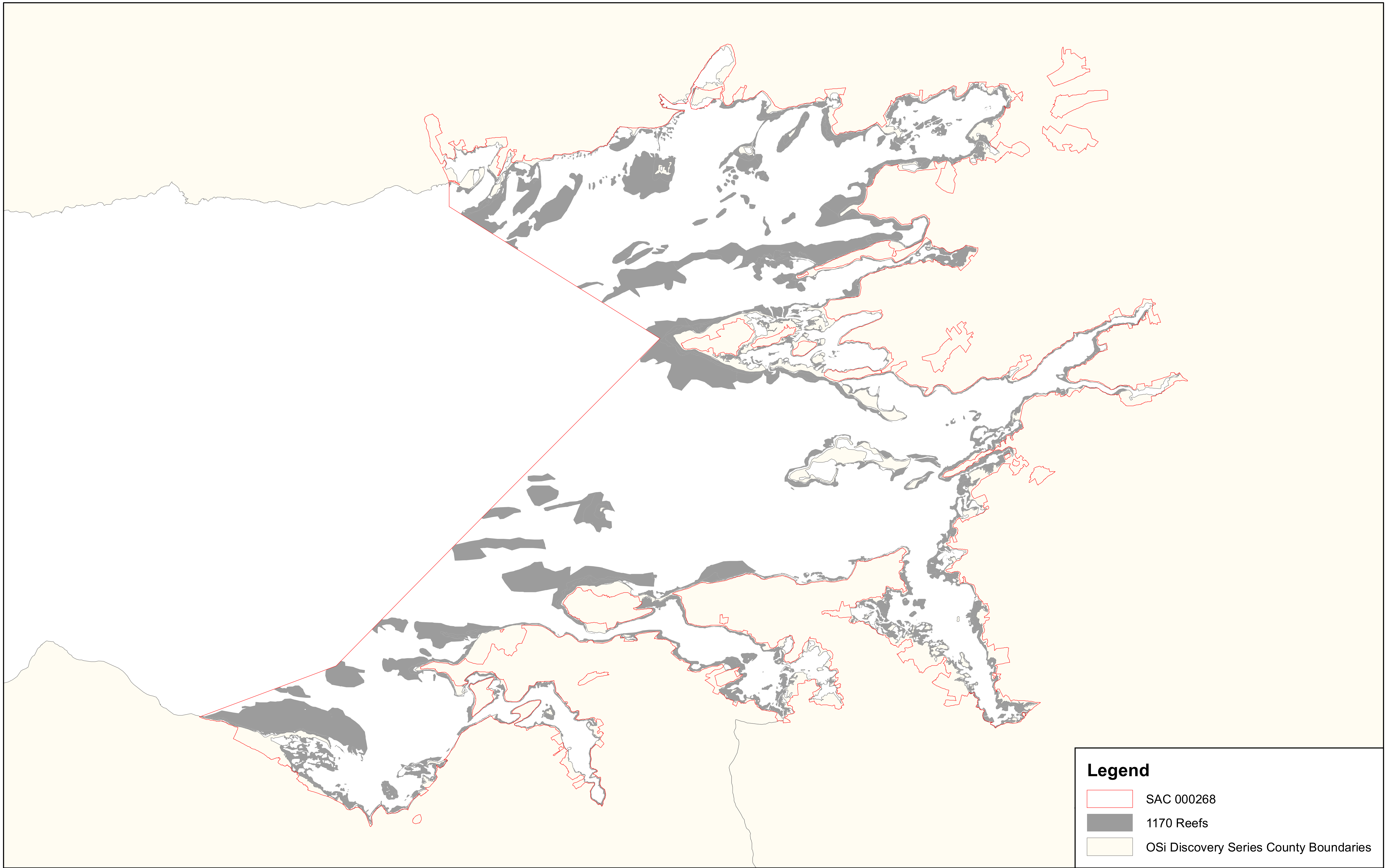
Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

N

Map Version 1
Date: Nov 2012



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MAP 6:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
REEFS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

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CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

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Níl sna teorainneacha ar na léarscáileanna ach nod garshuiomhach ginearálta. Féadfar athbhreithnithe a déanamh ar theorainneacha na gceantar comharthaithe. Macasamhail d'ábhar na Suirbhéarachta Ordonáis le chead ón Rialtas (Ceadunas Uimh. EN 0059208)

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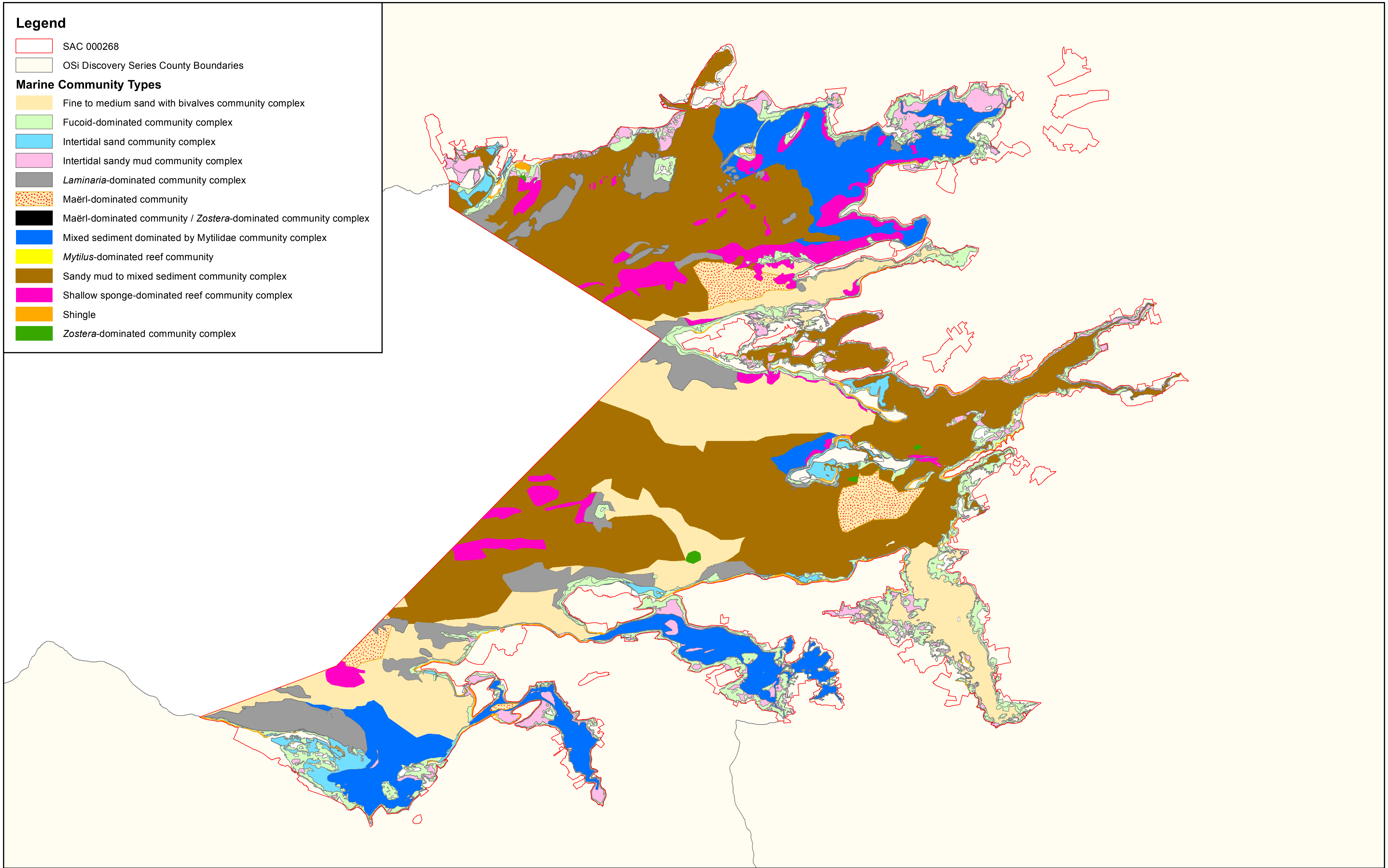
Map Version 1
Date: Nov 2012



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MAP 7:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
MARINE COMMUNITY TYPES

Map to be read in conjunction with the NPWS Conservation Objectives Document.

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CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

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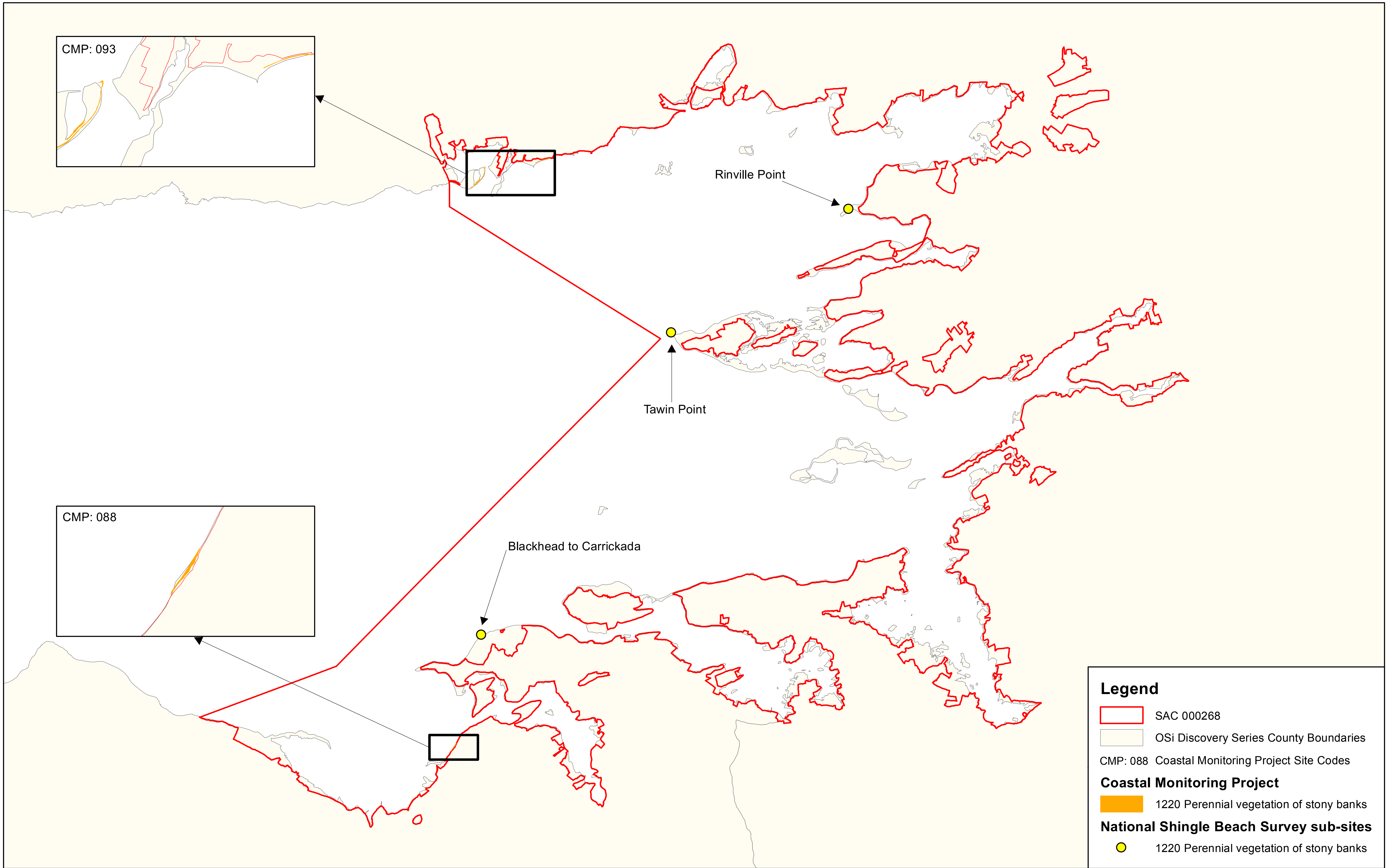
Map Version 1
Date: Nov 2012



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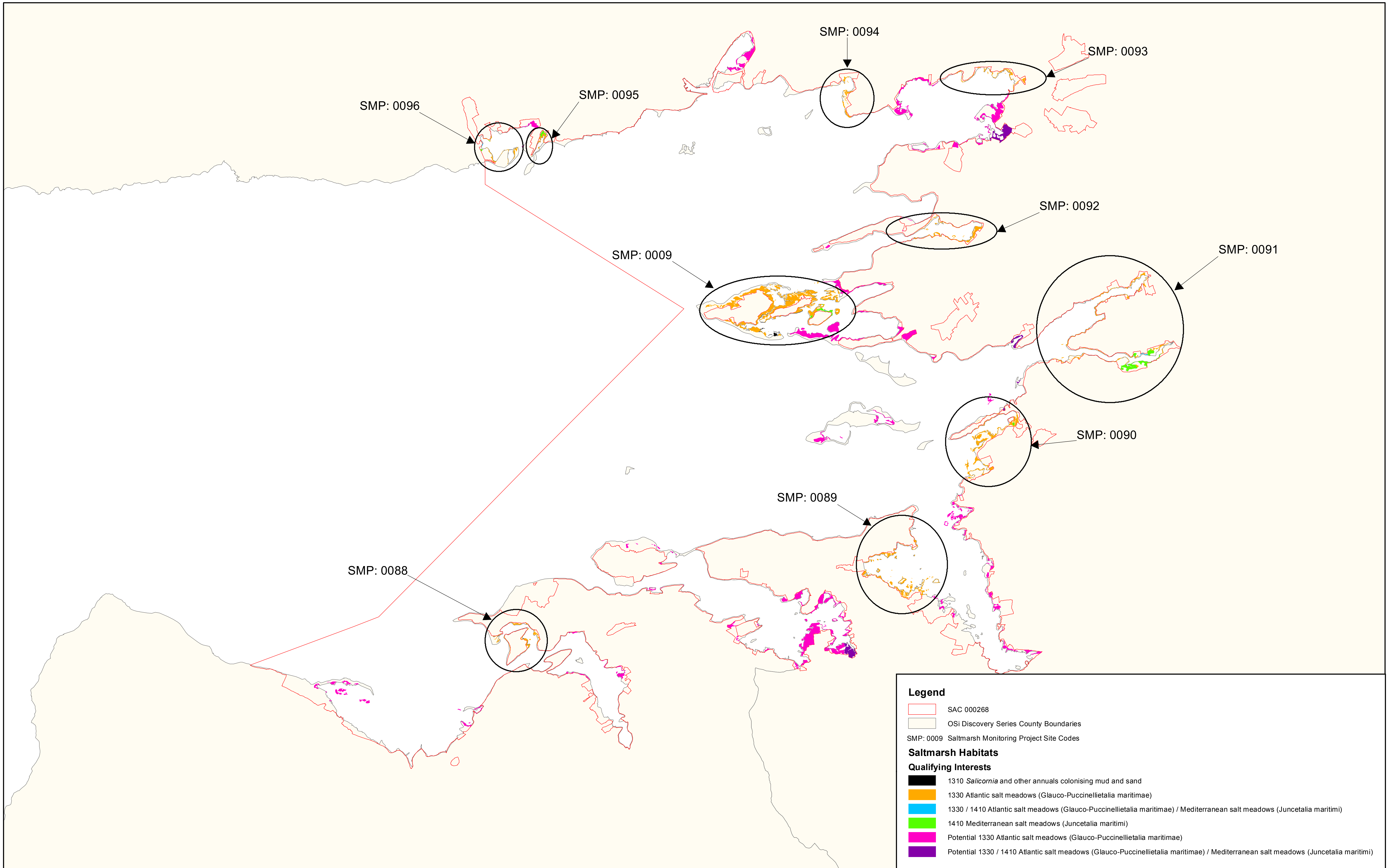
MAP 8:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
PERENNIAL VEGETATION OF STONY BANKS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

Map Version 1
Date: Nov 2012



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MAP 9:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
SALTMARSH HABITATS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

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Níl sna teorainneacha ar na léarscáileanna ach nod garshuíomhach ginearálta. Féadfar athbhreithnithe a déanamh ar theorainneacha na gceantar comharthaithe. Macasamhail d'ábhar na Suirbhéarachta Ordonáis le chead ón Rialtas (Ceadunas Uimh. EN 0059208)

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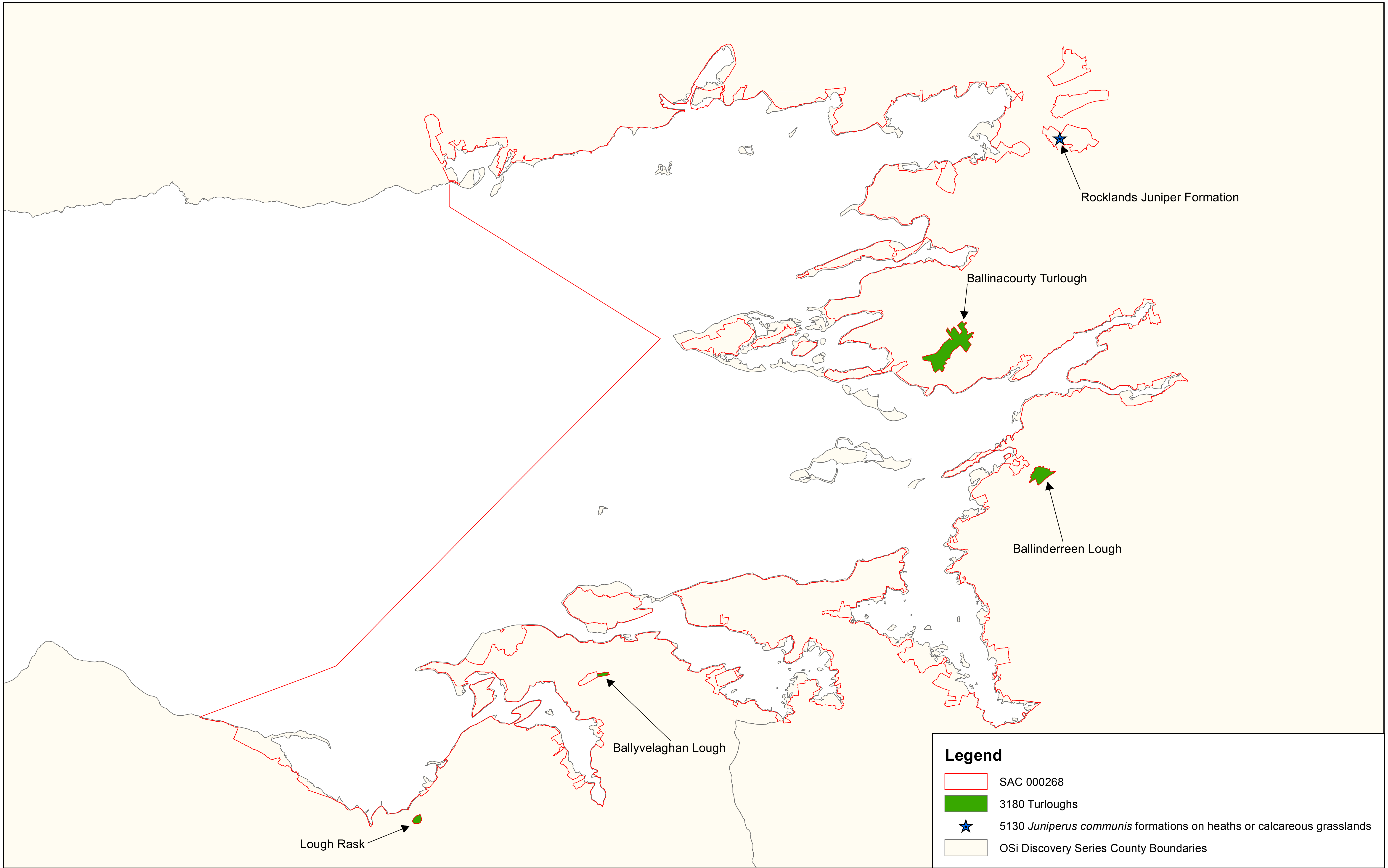
Map Version 1
Date: Nov 2012



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MAP 10:
GALWAY BAY COMPLEX SAC CONSERVATION OBJECTIVES TURLOUGHS & JUNIPER FORMATIONS

Map to be read in conjunction with the NPWS Conservation Objectives Document.

SITE CODE: SAC 000268
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

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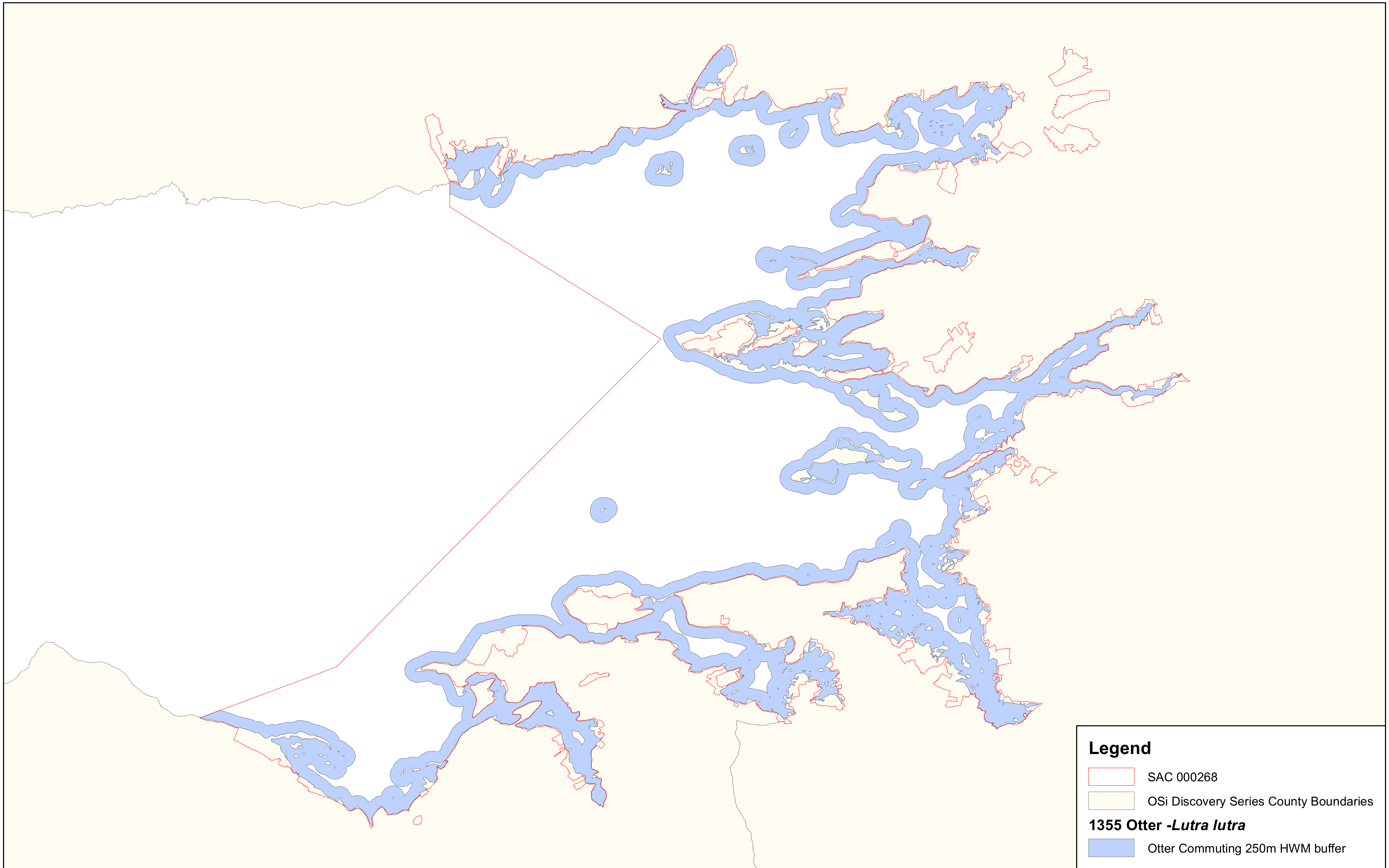
Map Version 1
Date: Nov 2012



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MAP 11:
GALWAY BAY COMPLEX SAC
CONSERVATION OBJECTIVES
OTTER

Map to be read in conjunction with the NPWS Conservation Objectives Document.

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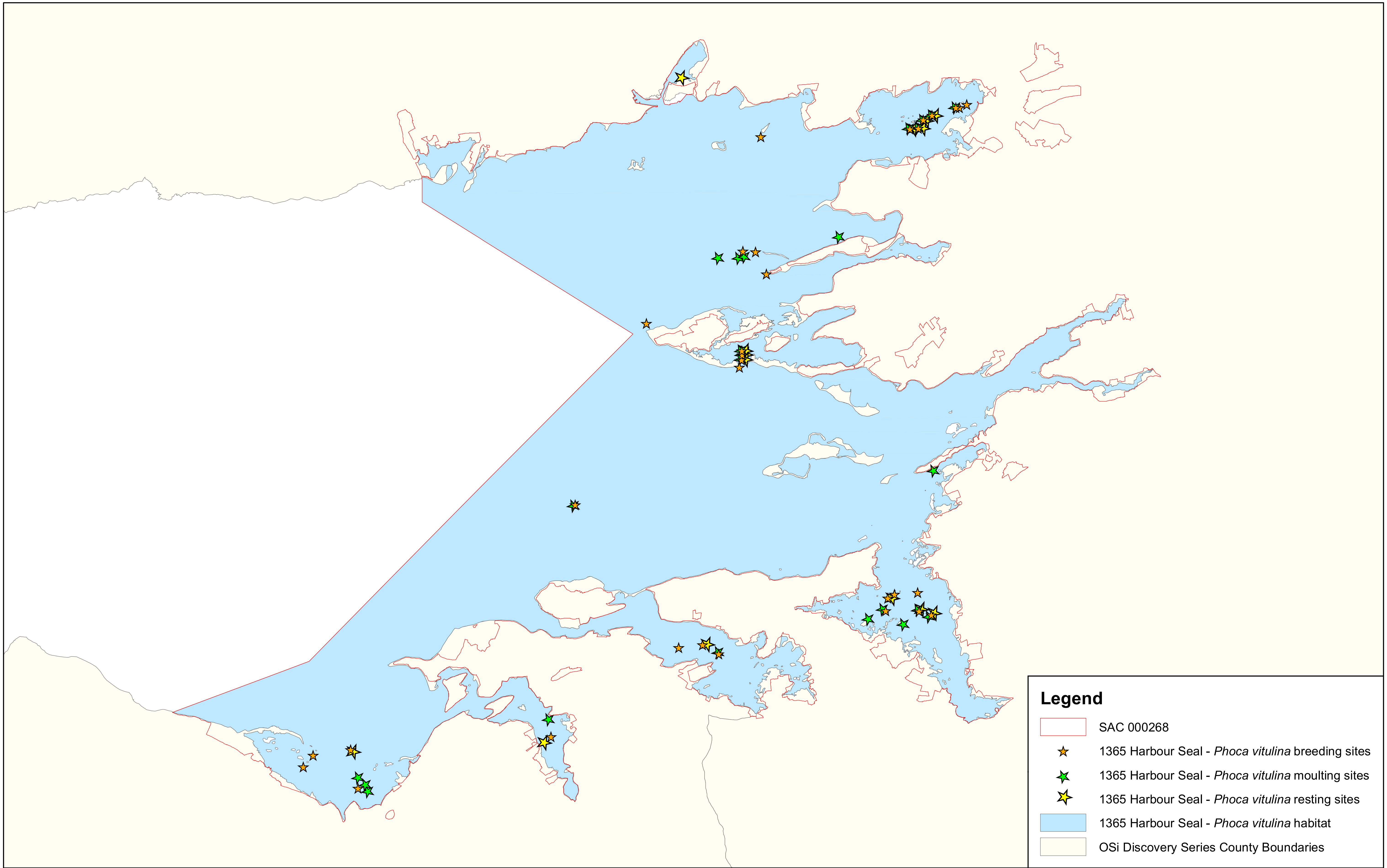
CO. CLARE; version 1.1, CO. GALWAY; version 1.08

Map Version 1
Date: Nov 2012



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MAP 12: GALWAY BAY COMPLEX SAC CONSERVATION OBJECTIVES HARBOUR SEAL

Map to be read in conjunction with the NPWS Conservation Objectives Document.

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CO. CLARE; version 1.1, CO. GALWAY; version 1.08

0 1 2 3 4 5 km

N

Map Version 1
Date: Nov 2012

Journal of
Marine Science and Engineering

MDPI

Article

Exposure to Electromagnetic Fields (EMF) from Submarine Power Cables Can Trigger Strength-Dependent Behavioural and Physiological Responses in Edible Crab, *Cancer pagurus* (L.)

Kevin Scott [1,*], Petra Harsanyi [1,2,3], Blair A. A. Easton [1], Althea J. R. Piper [1], Corentine M. V. Rochas [1] and Alastair R. Lyndon [2]

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[3] Institute of Biology, Eötvös Loránd University, H-1053 Budapest, Hungary
* Correspondence: kevin.scott@marinestation.co.uk

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Citation: Scott, K.; Harsanyi, P.; Easton, B.A.A.; Piper, A.J.R.; Rochas, C.M.V.; Lyndon, A.R. Exposure to Electromagnetic Fields (EMF) from Submarine Power Cables Can Trigger Strength-Dependent Behavioural and Physiological Responses in Edible Crab, *Cancer pagurus* (L.). *J. Mar. Sci. Eng.* **2021**, *9*, 776. https://doi.org/10.3390/jmse9070776

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Abstract: The current study investigated the effects of different strength Electromagnetic Field (EMF) exposure (250 µT, 500 µT, 1000 µT) on the commercially important decapod, edible crab (*Cancer pagurus,* Linnaeus, 1758). Stress related parameters were measured (L-Lactate, D-Glucose, Total Haemocyte Count (THC)) in addition to behavioural and response parameters (shelter preference and time spent resting/roaming) over 24 h periods. EMF strengths of 250 µT were found to have limited physiological and behavioural impacts. Exposure to 500 µT and 1000 µT were found to disrupt the L-Lactate and D-Glucose circadian rhythm and alter THC. Crabs showed a clear attraction to EMF exposed (500 µT and 1000 µT) shelters with a significant reduction in time spent roaming. Consequently, EMF emitted from MREDs will likely affect crabs in a strength-dependent manner thus highlighting the need for reliable in-situ measurements. This information is essential for policy making, environmental assessments, and in understanding the impacts of increased anthropogenic EMF on marine organisms.

Keywords: *Cancer pagurus*; edible crab; electromagnetic field; haemolymph parameters; circadian rhythm; L-Lactate; D-Glucose; windfarm; environmental stressor

1. Introduction

Anthropogenically induced climate change through the burning of fossil fuels has a significant evidence base, which has led to many governments initiating programs for increased production of renewable or 'green' energy [1]. Marine Renewable Energy (MRE) promises to assist by providing clean, inexhaustible energy and aid in the reduction of Greenhouse Gas (GHG) emissions [2]. It is expected that, with the current implications of climate change, the number of Marine Renewable Energy Devices (MREDs) will increase, especially for locations that have wind and wave resources [1,3]. The increase in offshore renewables in Europe is expected to contribute to 10% of the continent's energy requirements by 2030 [4,5], with a current rise in installed wind power capacity from 0.7 GigaWatts (GW) in 2005 to 22 GW in 2019 [6,7]. Currently, the UK, which has the largest offshore windfarm in the world, has more projects in planning and construction than any other country [8].

There are both social and environmental concerns with the development of MREDs including habitat loss, perceived aesthetic problems, collision risks, increased anthropogenic noise, and exposure to increased electromagnetic fields (EMF) [1,9–13]. The continued assessment of the implications of these structures is essential in contributing to the existing knowledge gaps surrounding the potential impacts of MREDs in the marine environment.

The number of subsea power cables connecting turbines, storage banks and export cables to shore will subsequently rise with the increase in deployments. These cables generate both an electric field (E-field) and a magnetic field (B-field) [10]. Through industry standard insulation, E-fields can be successfully contained within the cable with no leakage, however, there is no industry standard insulation that is able to prevent B-field leakage [10]. The leaked B-field interacts with surrounding cables emissions, due to common cable configurations, leading to the creation of an induced electromagnetic field (iE-field) which is subsequently influenced by saltwater ions moving via underwater currents i.e., Lorentz force [14].

There is a great variation in the EMF arising from different deployments which are the result of different currents (alternating (AC), or direct (DC)), cable length, distance from conductors, and energy output from the turbines [15]. Despite the large variations in strength, it is agreed that the highest strengths are likely to be found around the cables compared to turbine bases, particularly export cables [16]. EMF strengths predicted around subsea power cables, as reported in the literature, vary from 140–8000 μT [15,17,18]. A commonly utilised cable operating at 1600 A is expected to produce an EMF of 3200 μT in a perfect wire, at the cable surface [17]. As with all EMF, the values will decrease with distance from the source, resulting in a field strength of 320 μT and 110 μT at 1 m and 4 m respectively [17]. EMF values used previously in similar scientific studies range from 65–165 mT [13,18–22].

The edible crab, *Cancer pagurus*, is a commercially important decapod found throughout western Europe from Norway to Portugal, from the intertidal to depths of around 400 m [23]. *C. pagurus* are heavily exploited throughout their geographic range and are the second most important shellfish fishery in the UK [24]. Studies have shown that, given the life cycle and behavioural patterns of this species, they are highly likely to experience subsea power cables, either by attraction to EMF [13] or by the creation of scour protection zones around turbine bases, which may subsequently act as artificial reefs [25–29]. The sensory mechanisms involved in magneto-detection in *C. pagurus* is unknown, however, the leading theory behind EMF detection in crustaceans is magnetite magnetoreception. Magnetite (Fe_3O_4), a mineral found in the tissues of many organisms including crustaceans [30,31], reorientates during exposure to magnetic fields which subsequently acts upon secondary sensors [32,33]. A study conducted on Caribbean spiny lobsters, *Palinurus argus*, found changes in orientation after exposure to magnetic pulses [31,34]. Previous studies on *C. pagurus* have concluded that exposure to EMF, at strengths of 2.8 mT and 40 mT, elicits both behavioural and physiological changes in commonly used stress parameters [13]. In crustaceans, analysis of haemolymph enables the detection of abnormalities in internal chemical processes caused by increased stress, allowing accurate assessment of stress response via L-Lactate, D-Glucose, and THC [35–38]. Behavioural and response parameters (shelter preference, time spent roaming/resting) have been shown to be reliable indicators of stress, particularly in relation to EMF exposure [13].

The high variability in EMF strengths predicted around cables and those applied in scientific research, combined with no standardisation across studies and a lack of in-situ measurements makes the topic of EMF research problematic. As a result of these limitations, along with a lack of knowledge on detection limits within these species, there is a need to utilise a variety of strengths to begin the practice of using 'dose–response' studies to enhance reliability.

The aims of the current study are to build upon previous work undertaken to further assess the impacts of multiple EMF strengths, via previously confirmed stress parameters, on *C. pagurus* [13].

2. Materials and Methods

Intermoult crabs were collected from Berwickshire Marine Reserve (St Abbs, Berwickshire, UK) by local fishermen for experimentation. Crabs were kept in 1000 L flow through tanks with ambient sea temperature and a natural photoperiod for a minimum acclimation period of 1 week at densities of no greater than 5 crabs per tank. Crabs were sexed, weighed (g), carapace width measured (mm), and assigned a condition to ensure only intact, healthy crabs assigned a value of 1 and 2 were utilized [13]. Only crabs that were at minimum landing size (≥150 mm) were used during experimentation. Experimentation was conducted between May–June 2019.

2.1. Physiological Analysis

2.1.1. Helmholtz Coils

Two Helmholtz coils were utilised throughout the experiment with one set to produce a homogeneous EMF of the required strengths and the second remaining unpowered to act as a control. Building upon previous research conducted where 2.8 mT and 40 mT were utilised, strengths of 250 µT, 500 µT, and 1000 µT were utilised to represent the lower values predicted in specific models [13,15,39,40]. Each Helmholtz coil was mapped using a gaussmeter (AlphaLab, Inc, Salt Lake City, Utah, USA, Gaussmeter Model GM-2) prior to experimentation.

Within each Helmholtz coil, six 30 L glass tanks were set up within 60 L black ABS water baths to ensure temperature stability and reduce visual stimuli of other crabs in the neighbouring tanks. Each tank contained an individual air stone, received a constant supply of temperature controlled (TECO TK2000) flow through seawater (ultraviolet (UV) sterilised and filtered). Temperature and dissolved oxygen were constantly measured via data loggers (Onset HOBO temperature pendant) and a multiprobe (YSI ProDSS) and kept constant at 13 ± 0.2 °C and >98% respectively.

2.1.2. Haemolymph Analysis

Individual crabs were placed into the tanks in the Helmholtz coils and allowed to acclimate for a period of 24 h before one coil was switched on. To obtain baseline data, haemolymph was collected before exposure (0 h–09:00 a.m.) then again after 4 h (13:00 p.m.), 8 h (17:00 p.m.) and 24 h (09:00 a.m.). All haemolymph collection was staggered with 5 min between each sample to ensure time consistency throughout the experiment. Haemolymph samples were collected, within 60 s, from the arthrodial membrane at the base of the fifth walking leg using sterile 1 mL pre-chilled syringes with 25-gauge (G) needles. A total of 800 µL was collected from each crab and immediately transferred to a 1.5 mL cryogenic vial and frozen in liquid nitrogen. Samples were then stored in a freezer (−25 °C) until use. A total of 20 crabs were analysed at each field strength with 10 acting as control and 10 exposed to EMF. Due to the lack of clarity concerning the potential carryover effects of EMF exposure, combined with animal behavioural habituation, separate individuals were used as control groups and EMF exposed groups with no individuals reused throughout the experiment.

Haemolymph was deproteinated based on the procedure by Paterson and Spanoghe [35]. Samples were mixed with an equal volume of chilled 0.6 M perchloric acid (BDH 10175). Denatured proteins were separated by centrifugation at 25,000× g for 10 min (Eppendorf 5417C, rotor 30 × 1.5–2 mL). The supernatant was mixed with 3 M potassium hydroxide (BDH 29628) and centrifuged at 25,000× g for a further 10 min to remove precipitation. The samples were then frozen and stored at −25 °C.

D-Glucose

D-Glucose concentration was determined using the D-Glucose assay kit (GAGO20-1KT) [38]. The stored haemolymph was thawed before analysis, 150 µL of the sample was mixed with 300 µL of reagent assay and incubated for 30 min at 37 °C in a water bath. The reaction was stopped using 300 µL of 12 N sulphuric acid (BDH). Absorbance was then measured in parallel measurements in microcuvettes at 540 nm. D-Glucose concentrations were then calculated using a calibration curve of standards with a known concentration.

L-Lactate

Deproteinated haemolymph samples were analysed for L-Lactate concentration using a colorimetric L-Lactate assay kit (Abcam ab65331). 50 µL of reaction mix (L-Lactate assay buffer (46 µL), L-Lactate substrate mix (2 µL) and L-Lactate enzyme mix (2 µL)), were added to a 50 µL deproteinated haemolymph sample. The reaction mix and sample mix were then incubated at room temperature for 30 min then spectrophotometrically analysed in parallel measurements at 450 nm. Concentrations were determined using a curve of values produced by spectrophotometrically assessing calibration standards of known concentrations.

Total Haemocyte Count

Fifty microliters of haemolymph were added to 150 µL cooled 5% (*v*/*v*) formaldehyde (Brunel Microscope Ltd. Chippenham, UK) prior to the remaining haemolymph sample being frozen in liquid nitrogen. Haemolymph samples were dispensed to centrifuge tubes, mixed thoroughly, and kept on ice to prevent coagulation. Total Haemocyte Count (THC) of individual crabs were estimated with a Neubauer haemocytometer under magnification (×100) with a Leica (MC170 HD) compound microscope. For accuracy, 9 images were taken of the haemocytometer and 3 images were chosen at random for analysis. THC was expressed as the number of cells in 1 mL of haemolymph.

2.2. Behavioural Analysis

Shelter Selection

A total of eight 70 L experimental tanks were set up for each type of shelter selection trial (single or dual). One (single shelter trials) or two (dual shelter trials) black ABS shelters (300 mm × 200 mm × 100 mm) were constructed and secured to the bottom of the tanks, with 4 solenoid electromagnets under each shelter (Figure 1). Partition screens around the experimental area and opaque tanks were used to reduce visual stimuli.

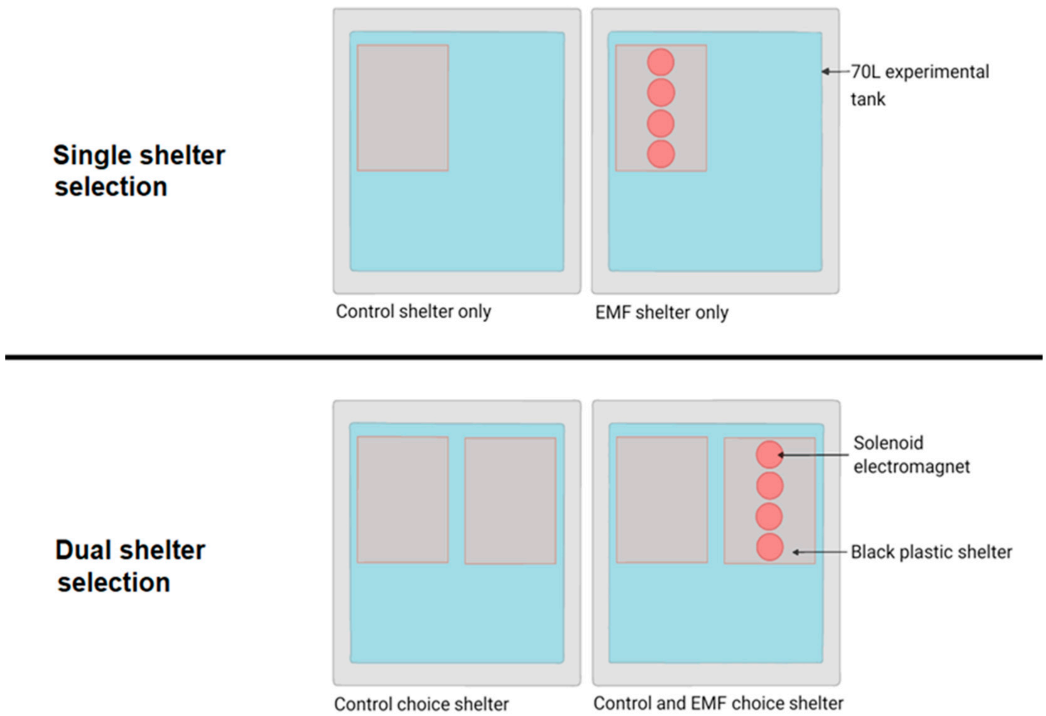

Figure 1. The four shelter experimental designs showing single shelter selection (**top**) and dual choice shelter selection (**bottom**) layouts. EMF (right, magnets powered) and corresponding controls (left, magnets unpowered).

During single and dual shelter trials, the electromagnets were powered under 4 of the tanks with the remaining 4 unpowered acting as a control (Figure 1). Control tanks were randomised to reduce bias. The EMF was mapped for each tank using a gaussmeter (AlphaLab, Inc Gaussmeter Model GM-2) to ensure the correct field strength was obtained (250 μT, 500 μT, 1000 μT).

An individual crab was placed into the centre of each tank and allowed to acclimate for a period of 24 h with the acclimation period being recorded. InfraRed cameras (Sannce 1080p IR surveillance DVR system) were suspended above all tanks and set to automatically record for 24 h acclimation and 24 h experimentation to ensure crab location could be determined. The video files were then analysed from 23:00 p.m.–06:00 a.m., the period during which this species is most active, using Solomon Coder (beta version 17.03.22) to determine the percentage of time spent in the shelters or free roaming within the tank. Time spent within the shelters or free roaming within the tank was calculated as a percentage of the total trial time (420 min) [41].

2.3. Statistical Analysis

Results were expressed as mean ± standard error (SEM). Data were assessed for normality using the Shapiro–Wilk test for normality and Levene's test for equality of error variances. When data met these assumptions, repeated measures multivariate analysis of variance (MANOVA) followed by posthoc analysis by Tukey's test was used. Differences between the treatments were tested by Student's *t*-test and paired samples *t*-test as appropriate. If data did not meet parametric assumptions, Mann–Whitney U-test and Wilcoxon matched pairs signed rank tests were used. All statistics were tested at a probability of 0.05 (IBM SPSS Statistics v.23 SPSS Corp. Chicago, IL, USA).

3. Results

3.1. Physiological Analysis

3.1.1. Haemolymph Analysis

D-Glucose

Significant differences in D-Glucose concentration were observed between sampling times and between treatments ($F(3,316) = 17.51$, $p < 0.001$, $F(3,316) = 4.12$ $p < 0.05$, repeated measures MANOVA). D-Glucose levels followed a similar circadian rhythm in control and EMF exposed crabs, with significant increases towards peak locomotor activity ($F(3,316) = 59.98$, $p < 0.05$, repeated measures ANOVA). D-Glucose concentrations showed significant increases between 0 h and 4 h and 0 h and 8 h in control conditions and during exposure to all three EMF strengths ($p < 0.05$, posthoc Tukey's test) (Figure 2). D-Glucose concentrations had returned to initial levels after 24 h in all samples, resulting in no significant difference from 0 h. There were no significant differences in D-Glucose concentration between control and 250 μT EMF exposed crabs at any sampling point (control 0.46 ± 0.03 mM, 250 μT 0.45 ± 0.05 mM). Crabs exposed to 500 μT and 1000 μT EMF showed significantly higher after D-Glucose concentrations at 4 h (0.91 ± 0.11 mM, 1.06 ± 0.11 mM respectively) and 8 h (0.89 ± 0.11 mM, 0.97 ± 0.11 mM respectively) exposure compared to the control group (0.65 ± 0.08 mM, 0.55 ± 0.07 mM), ($p < 0.05$, posthoc Tukey's test). Haemolymph D-Glucose concentrations after 24 h exposure to 500 μT and 1000 μT EMF returned to baseline levels and did not differ significantly from the control value at 24 h.

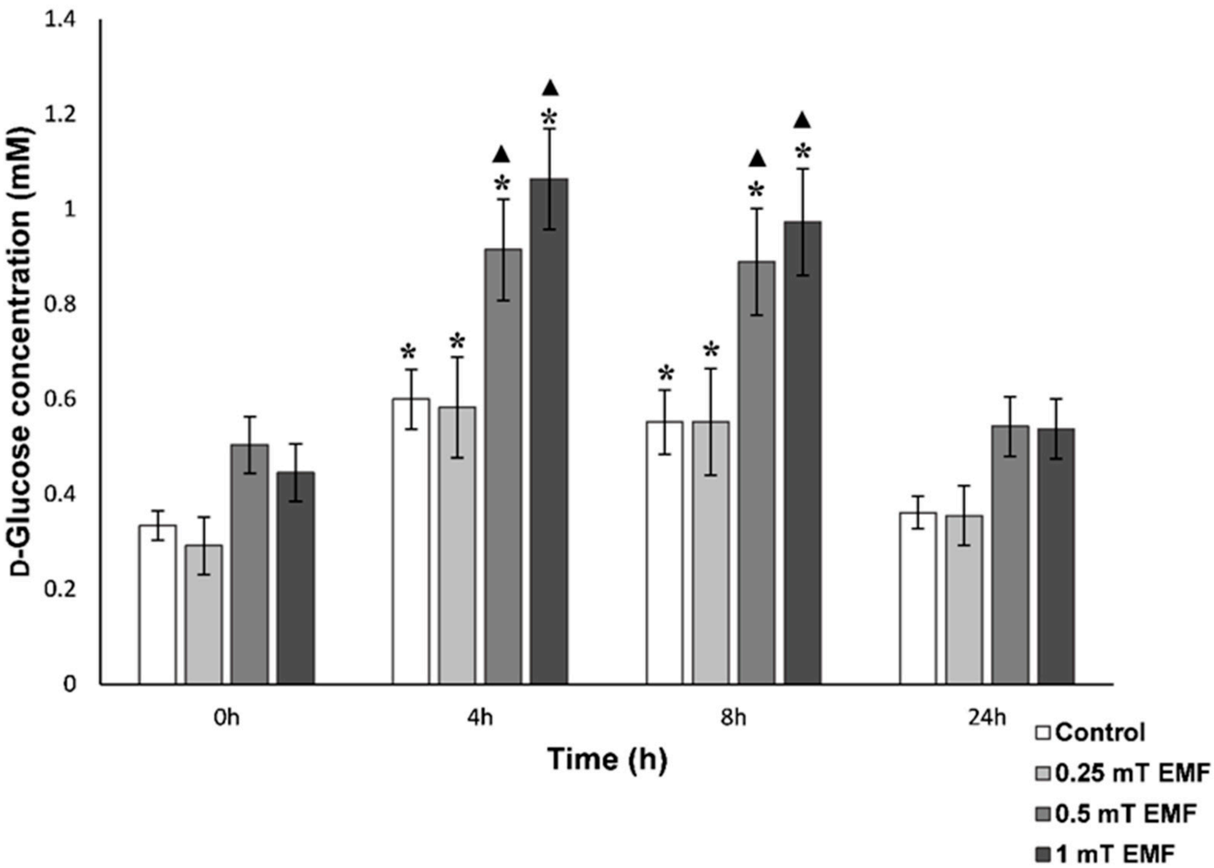

Figure 2. D-Glucose concentration over a 24 h period in control conditions and exposure to EMF at 250 μT, 500 μT, 1000 μT strength. Sample times consisted of 0 h (09:00 a.m.), 4 h (13:00 p.m.), 8 h (17:00 p.m.), 24 h (09:00 a.m.). Values are presented as mean ± SEM, * is the significance from the 0 h within respective treatments, ▲ is the significance from the control group for each treatment at respective sampling times (*, $p < 0.05$), (▲, $p < 0.05$). N = 10 individuals for control and N = 10 individuals for EMF per treatment, total samples of N = 40 control, N = 40 EMF.

L-Lactate

L-Lactate followed a circadian rhythm with increased concentrations coinciding with periods of high activity in control conditions and during exposure to 250 μT EMF (8 h, 0.63 ± 0.12 mM and 0.76 ± 0.22 mM, for control and 250 μT respectively) ($F(3,76) = 3.6$, $p < 0.05$, repeated measures ANOVA). L-Lactate concentrations in 500 μT and 1000 μT exposed crabs lacked a similar increase during periods of increased activity (Figure 3). Significant differences were observed in L-Lactate concentrations among treatments at different sampling times ($F(3,316) = 2.92$, $p < 0.05$, repeated measures ANOVA). Crabs exposed to 1000 μT EMF showed significantly lower L-Lactate concentrations throughout the 24 h period (0.24 ± 0.07 mM, $p < 0.05$, posthoc Tukey's test) when compared to the control values. Crabs exposed to 250 μT EMF had significantly lower L-Lactate concentrations after 4 h exposure (0.19 ± 0.10 mM, $p < 0.05$, posthoc Tukey's test), while 500 μT exposed crabs showed significantly lower concentrations after 24 h exposure (0.23 ± 0.03 mM, $p < 0.05$, posthoc Tukey's test) when compared to the control group (0.51 ± 0.06 mM).

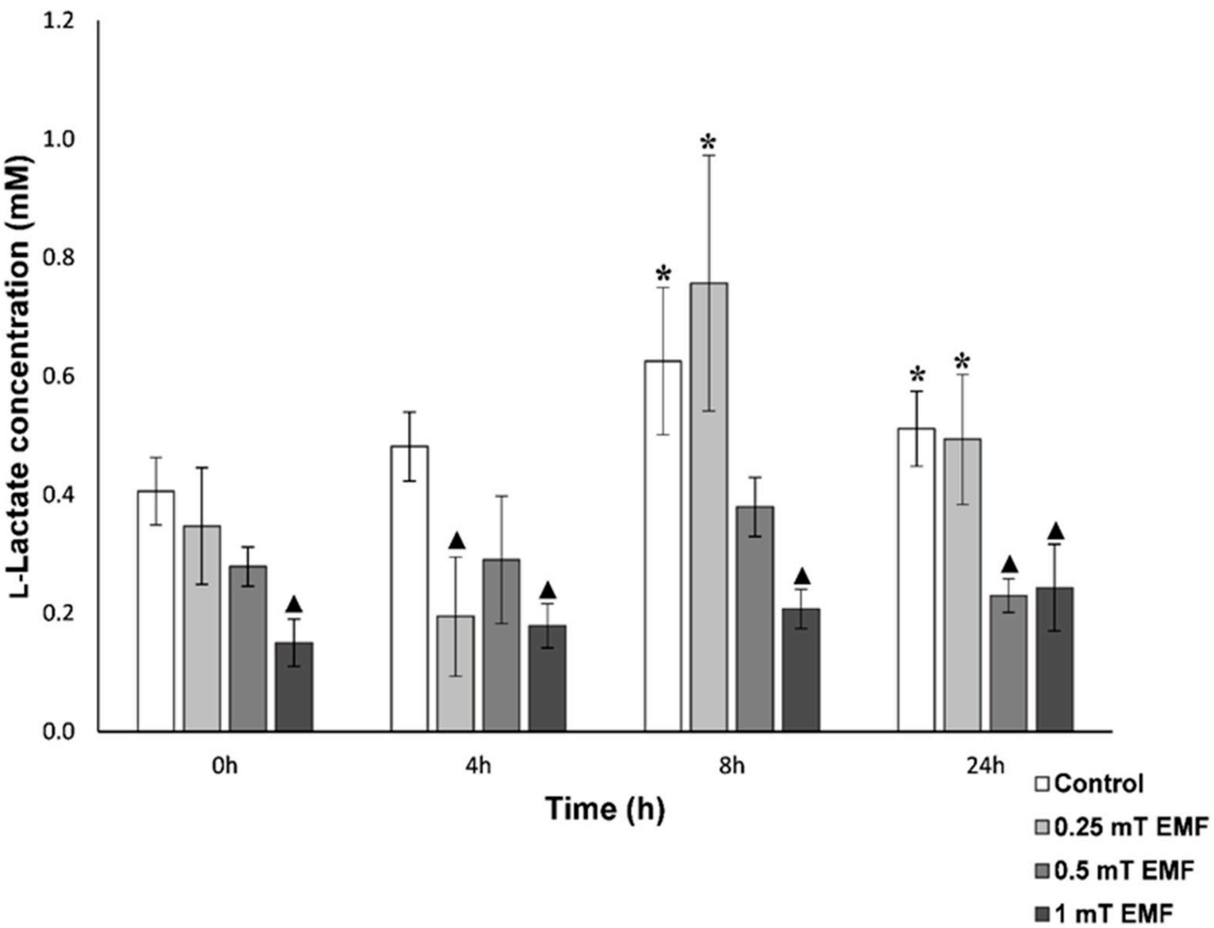

Figure 3. L-Lactate concentration over a 24 h period in control conditions and exposure to EMF at 250 μT, 500 μT, 1000 μT strength. Sample times consisted of 0 h (09:00 a.m.), 4 h (13:00 p.m.), 8 h (17:00 p.m.), 24 h (09:00 a.m.). Values are presented as mean ± SEM, * is the significance from the 0 h within respective treatments, ▲ is the significance from the control group for each treatment at respective sampling times (*, $p < 0.05$), (▲, $p < 0.05$). N = 10 for control and N = 10 for EMF per treatment, total N = 40 control, N = 40 EMF.

THC

Average THC in control crabs was $28.64 \pm 2.14 \times 10^6$ cell mL^{-1}. Short-term rhythmical fluctuations in the control crab's THC over the 24 h sampling period was noted, with significantly lower values after 24 h (Figure 4) ($F(3,156) = 3.82$, $p < 0.05$, repeated measures ANOVA). THC of crabs exposed to 250 μT EMF did not differ significantly from values found in crabs kept in the control condition, with similar fluctuations during the 24 h period. THC of crabs exposed to 500 μT and 1000 μT EMF did not show similar fluctuations with no significant decrease after 24 h of exposure. Crabs exposed to 500 μT and 1000 μT showed slightly elevated values (38.73 ± 6.44 and $36.33 \pm 6.42 \times 10^6$ cell mL^{-1} respectively) after 8 h of exposure when compared to control values ($22.51 \pm 4.55 \times 10^6$ cell mL^{-1}) but was only statistically significant at 500 μT strength ($p < 0.05$, posthoc Tukey's test). THC values after 24 h exposure to 500 μT and 1000 μT EMF returned to basal values and no statistically significant differences were found between experimental and control groups.

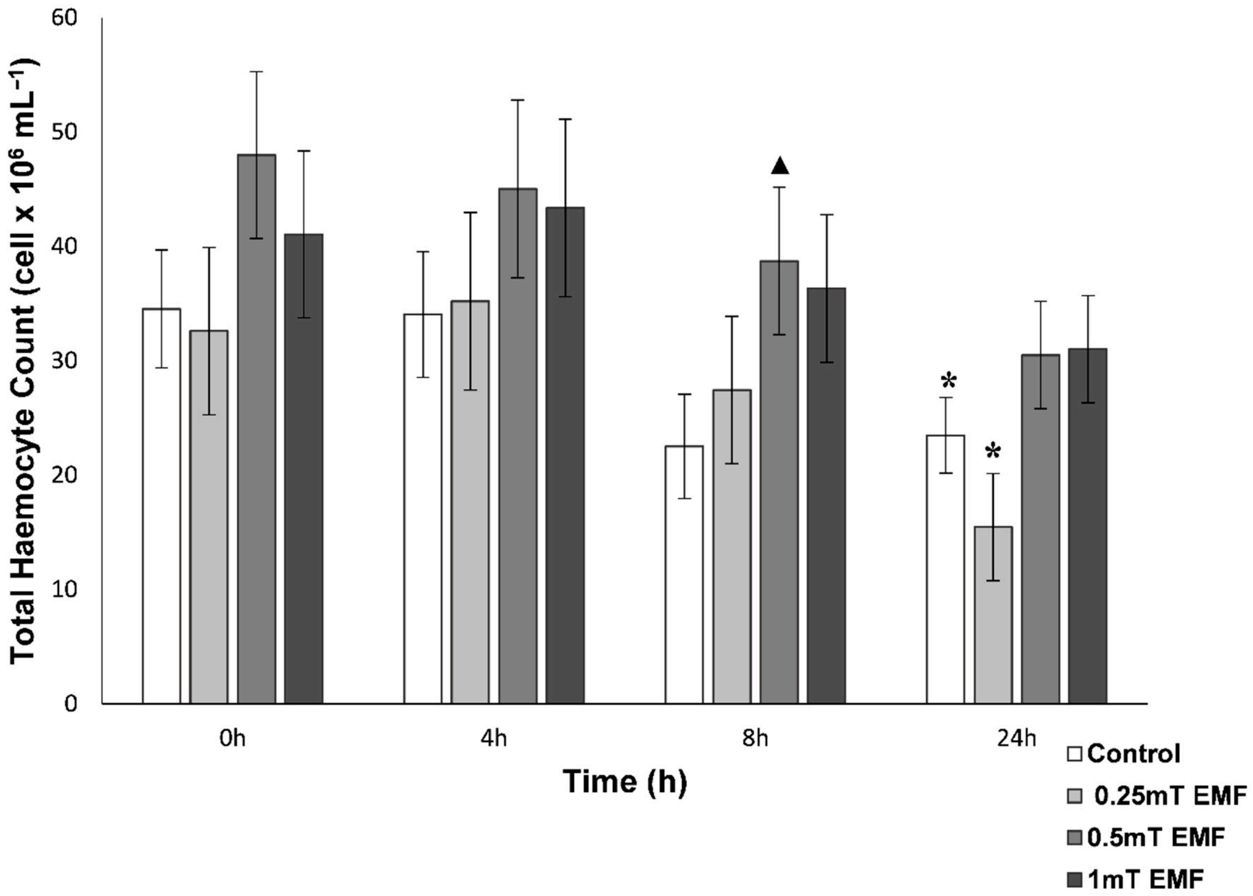

Figure 4. Total Haemocyte Count (THC) over a 24 h period in control conditions and constant exposure to EMF at 250 μT, 500 μT, 1000 μT strength. Sample times consisted of 0 h (09:00 a.m.), 4 h (13:00 p.m.), 8 h (17:00 p.m.), 24 h (09:00 a.m.). Values are presented as mean ± SEM, * is the significance from the 0 h within respective treatments, ▲ is the significance from the control group for each treatment at respective sampling times (*, $p < 0.05$), (▲, $p < 0.05$). N = 10 for control and N = 10 for EMF per treatment, total N = 40 control, N = 40 EMF.

3.2. Behavioural Analysis

3.2.1. Single Shelter Selection

The mean time spent in the shelter (256.20 ± 36.60 min) was slightly higher than time spent roaming the tank (163.80 ± 36.60 min) in control trials (Figure 5). When there was an EMF of 250 μT present, there were no significant differences between the time spent in (273.50 ± 14.88 min) and out (146.50 ± 14.88 min) of the shelter compared to the control. A similar pattern was observed during exposure to 500 μT with no significant differences being found between time spent in (222.63 ± 49.14 min) and out (197.38 ± 49.14 min) of the shelter, despite a slight increase in time spent roaming the tank. Crabs spent significantly more time in the shelter (319.63 ± 25.73 min) during exposure to 1000 μT EMF ($F(1,18) = 36.3$, $p < 0.001$, one-way ANOVA).

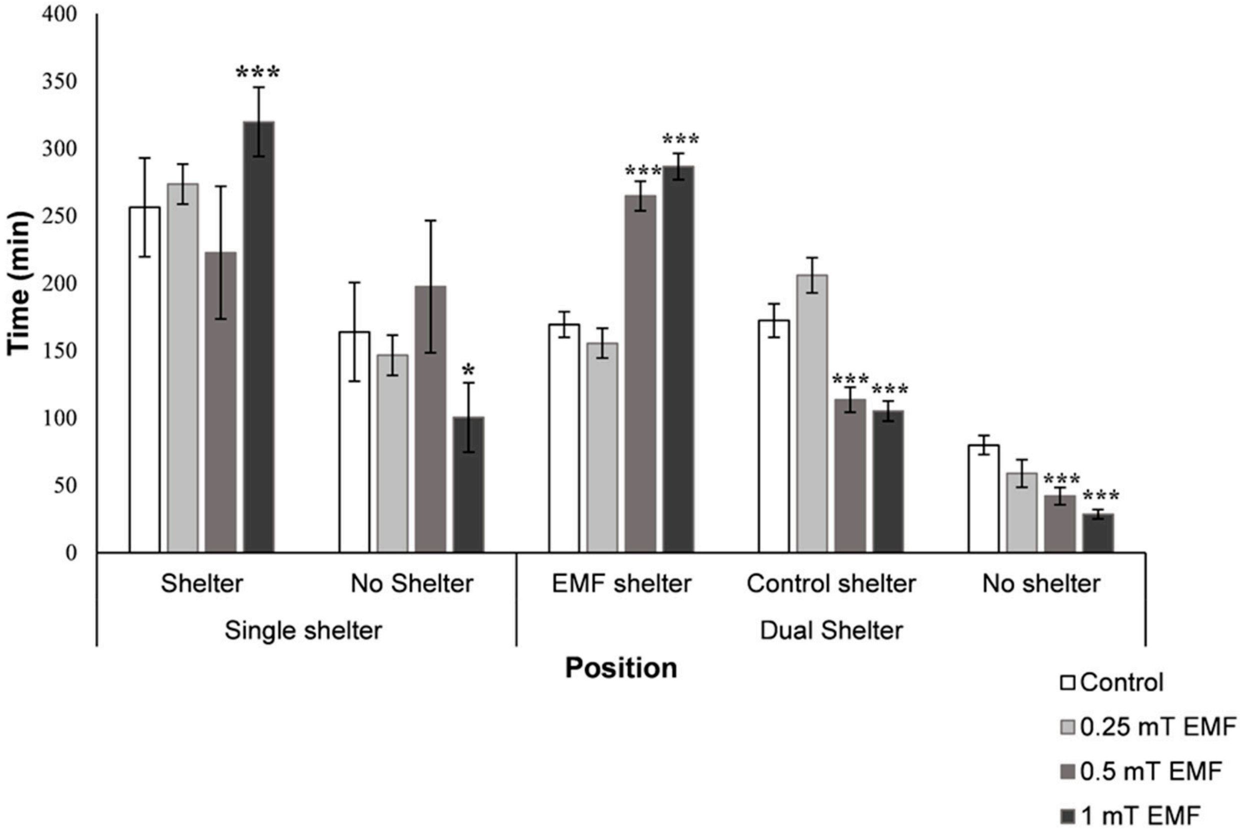

Figure 5. The effects of EMF exposure at various strengths on shelter selection in *C. pagurus*. Mean time spent in the shelter and roaming the tank (no shelter) in control conditions and exposure to 250 µT, 500 µT, and 1000 µT EMF in single shelter trials. Mean time spent within control and EMF exposed (250 µT, 500 µT, and 1000 µT EMF) shelter and roaming the tank (no shelter) in dual shelter trials. Calculated as time spent in each location compared to total trial length. Values are presented as mean ± SEM, * is the significance at $p < 0.05$, *** is the significance at $p < 0.001$. Single shelter $N_{CONTROL} = 10$, $N_{EMF} = 10$, dual shelter $N_{CONTROL} = 10$, $N_{EMF} = 10$.

3.2.2. Dual Shelter Selection

Under control conditions, a near equal split of time was spent between the EMF shelter (169.30 ± 9.56 min) and the control shelter (172.20 ± 12.43 min) with 79.80 ± 7.19 min time spent roaming the tank (Figure 5). Exposure to 250 µT EMF did not highlight any significant changes in the time spent in shelters or roaming the tank (58.80 ± 10.20 min no shelter, 155.40 ± 11.13 min EMF shelter, 205.80 ± 11.04 min control shelter). Exposure to both 500 µT and 1000 µT showed significant differences compared to the control ($F(3,16) = 13.2$, $p < 0.001$, $F(3,16) = 24.3$, $p < 0.001$, MANOVA), with an increased amount of time spent within the EMF shelter (264.60 ± 10.96 min, and 286.50 ± 9.82 min for 500 µT and 1000 µT respectively). There was a drop in the mean time spent roaming the tank from 79.80 ± 7.19 min in control conditions to 42.00 ± 6.41 min and 28.50 ± 3.51 min during exposure to 500 µT and 1000 µT EMF, respectively.

4. Discussion

It has previously been demonstrated that L-Lactate, D-Glucose and haemolymph densities are useful parameters measuring stress in crustaceans as indicators of changes in homeostasis [36,37,42,43]. In crustaceans, L-Lactate and D-Glucose cycle together under normal conditions. L-Lactate levels rise during periods of high locomotor activity, resulting in an increased glucose metabolism [41]. At the same time, D-Glucose levels decrease due to the increased oxidation for ATP production [44]. During the day, the reverse is observed, with a fall in L-Lactate and a subsequent rise in D-Glucose.

At EMF exposure at 250 μT, L-Lactate and D-Glucose concentrations followed a natural circadian rhythm, with rises in D-Glucose throughout the day and an increase in L-Lactate in the evening corresponding with periods of higher activity. This circadian rhythm corresponds well to that found in the literature [13,41,45]. Values obtained for both L-Lactate and D-Glucose correspond to those found in previous studies [13,41,43,44,46–49]. L-Lactate concentrations observed during this study were lower than those values recorded for *C. pagurus* in previous work [13,41,45] but still followed the same diel pattern. This variation in values could be due to the use of a different assay kit during analysis or due to the high individual variances in haemolymph L-Lactate concentrations found within this species [13]. The results obtained throughout this study suggest that exposure to 250 μT EMF does not alter the circadian rhythm of L-Lactate and D-Glucose metabolism.

Exposure to EMF at 500 μT and 1000 μT showed the similar changes in L-Lactate levels as described previously during exposure to 2.8 mT, whereby L-Lactate concentration showed no increase during periods of higher activity [13]. The suppression of L-Lactate impacts the O_2 affinity of haemocyanin, which has been shown to increase during periods of high L-Lactate concentrations to allow more oxygen to be transported around the body to counteract periods of hypoxia [50].

Exposure to 500 μT and 1000 μT EMF elicits the same responses in D-Glucose as has been previously described in this species during exposure to a field strength of 2.8 mT [13]. Despite following the same circadian rhythm, D-Glucose concentrations were significantly higher after 4 h and 8 h before returning to normal levels after 24 h. Haemolymph D-Glucose and L-Lactate should cycle together in normal unstressed conditions but have been shown to be affected by certain environmental stressors [13,48,51,52]. D-Glucose has a negative correlation with vigour, with moribund crabs becoming hyperglycaemic [38]. Evidence suggests that D-Glucose and L-Lactate cycles are controlled by melatonin, a neuropeptide present in crustaceans [49]. Earlier studies have suggested that EMF exposure impacts melatonin levels by decreasing melatonin synthesis [53–55]. This study adds more evidence to this hypothesis by finding similar circadian disruption in D-Glucose and L-Lactate at 500 μT and 1000 μT EMF exposure.

The THC values obtained throughout this study correspond well with those previously recorded for *C. pagurus* in the literature. Vogan and Rowley recorded values of $2.55 \pm 0.14 \times 10^7$ cell mL^{-1} [56], Lorenzon et al. found values of $3.19 \pm 0.92 \times 10^7$ cell mL^{-1} [38], and more recently Parrinello et al. observed values of $4.4 \pm 0.6 \times 10^7$ cell mL^{-1} [57]. In shore crab, *Carcinus maenas* (Linnaeus, 1758), a study conducted in North Wales by Truscott and White found significant differences in THC concentrations between high and low tides with double the concentration recorded at 8 m compared to a 4 m tide [58]. This suggests that there may be natural variations in THC in *C. pagurus* which may explain some of the changes detected during experimentation.

In previous work [45], THC in the European lobster (*Homarus Gammarus,* Linnaeus, 1758) was significantly affected by exposure to an EMF of 2.8 mT resulting in lower mean values after 12 h with significant increases between 6 h and 24 h. However, in this study, a significant rise after 8 h was detected during exposure to 500 μT EMF. During exposure to control and 250 μT, there were significant drops in THC after 24 h, whilst no significant decreases were detected in 500 μT and 1000 μT. Large variations in THC concentration were found in individuals throughout this study which may have masked some of the effects of the treatment. Previous studies have shown that THC levels rise during exposure to increased stress suggesting an immune response [59,60]. However, the reverse has also been confirmed with a decrease in THC resulting from the presence of stressors including bacteria [61], hypoxia [62] and EMF [63]. Significant variations from the normal rhythmic patterns of THC were detected during exposure to 500 μT and 1000 μT suggesting the beginning of an immune response. Exposure to 250 μT showed no significant differences from the control suggesting EMF at these strengths may not result in reduced immune capacity.

During single shelter trials, a higher percentage of time was spent within the shelter than roaming the tank (across all treatments), although this was lower than the results obtained for *C. pagurus* in previous work [13]. This conforms to previous findings that crustaceans show high utilisation of shelters with periods of time spent roaming out with [13,64]. No significant changes were noted when the shelter was subjected to an EMF of 250 µT. This result, combined with those obtained from the physiological analysis, suggests that EMF exposure of 250 µT does not negatively impact *C. pagurus* on a behavioural or physiological level, via tested parameters, as previously found with higher strengths [13]. During exposure to 500 µT EMF, a slight decrease in time spent in the shelter occurred, which also occurred with *H. gammarus* [45]. At 1000 µT there was a clear attraction to the source of the EMF with a significant increase in time spent within the EMF exposed shelter. Results obtained from the dual shelter trials confirm an apparent lack of response during exposure to 250 µT. The remaining dual shelter EMF strengths highlighted an attraction to the EMF source with significant increases in the time spent within the shelter and decreased time roaming the tank.

This increased attraction to the source of the EMF, despite showing signs of physiological stress, has clear implications for *C. pagurus* in areas around MREDs. Many offshore sites have introduced no-take zones around turbine arrays, with speculation that the decrease in fishing pressure, combined with the addition of artificial reefs in the form of scour protection blocks, could enhance the overall crustacean population by providing refuge and breeding areas [27]. However, an attraction to subsea power cables emitting an EMF of >500 µT could come at the cost of time spent foraging for food, seeking mates, and potentially finding shelter, which is a cause for concern. Although the primary underlying mechanism responsible for the effects of EMF on living organisms is unclear changes in cell membrane permeability, gene and protein expression, and developmental changes such as cell growth and proliferation have all been documented during exposure to EMF [65–67]. The impacts of increased EMF exposure can be determined on a number of individuals but determining the impacts on a population level is considerably more difficult. The key link in determining population wide impacts is the development and recruitment of juveniles into the ecological system. The impacts of EMF exposure on brooding females and the subsequent impact on the larvae are currently unknown and needs to be addressed to accurately determine population level impacts. With the addition of scour protection zones aiming to increase biodiversity [26,28], and the plan to co-locate aquaculture around windfarm sites [4,68], there is a clear need to consider the impacts of EMF emissions on benthic species around these sites.

The data presented in this paper can be meaningfully considered alongside previous studies on this species by Scott et al. (Table 1) [13].

Table 1. Summary of the impacts of *C. pagurus* during exposure to multiple EMF strengths from the current study and Scott et al. [13].

EMF Levels	Physiological Analyses			Behavioural Analyses	
	L-Lactate Changes	D-Glucose Changes	THC	Single Shelter Selection	Dual Shelter Selection
250 µT	Followed circadian rhythm, but lower concentrations after 4 h	No significant difference to control	No significant difference to control	No significant difference in time spent inside shelter or roaming compared to control	No significant difference in time spent in either shelter or roaming compared to control
500 µT	Did not follow circadian rhythm, lower concentrations after 24 h	Followed circadian rhythm, but hyperglycaemia seen after 4 h and 8 h	No fluctuations in levels nor significant decrease after 24 h (as seen in control), elevated levels after 8 h	No significant difference in time spent inside shelter or roaming compared to control	Increased time in EMF shelter and reduced time roaming
1000 µT	Did not follow circadian rhythm, lower concentrations throughout 24 h period	Followed circadian rhythm, but hyperglycaemia seen after 4 h and 8 h	No fluctuations in levels nor significant decrease after 24 h (as seen in control)	Significantly more time spent in the shelter	Increased time in EMF shelter and reduced time roaming
2.8 mT	Did not follow circadian rhythm, lower concentrations throughout 24 h period (without usual peaks at dawn)	Followed circadian rhythm, but did not show significant rise in levels after 8 h, as seen in control	Not assessed	Significantly more time spent in the shelter and reduced roaming	Increased time in EMF shelter and reduced time roaming
40 mT	Followed circadian rhythm, but significantly lower concentrations at 4 h and 8 h compared to 0 h (not seen in control)	No significant difference to control	Not assessed	Not assessed	Not assessed

5. Conclusions

The results obtained from this study, combined with the data from previous work [13,41], suggests that increased physiological stress will occur if *C. pagurus* is exposed to EMF of 500 µT or above with data obtained at 1000 µT, 2.8 mT and 40 mT confirming this trend. This is mirrored in the behavioural trends noted, which showed an attraction to EMF sources at the same levels despite the physiological ramifications.

This suggests that a working limit of a maximum of 250 µT could result in minimal physiological and behavioural changes within this species and should be considered during MRED design and implementation. Additional research is required to further identify sensitivities to EMF in different life stages and conditions within this species and benthic crustaceans in general.

Author Contributions: Conceptualisation, Kevin Scott, P.H., A.R.L.; methodology, K.S. and P.H.; validation, K.S. and P.H.; formal analysis, P.H.; investigation, K.S., P.H., B.A.A.E., A.J.R.P., C.M.V.R.; resources, K.S., P.H., B.A.A.E.; data curation, P.H., B.A.A.E., A.J.R.P., C.M.V.R.; writing—original draft preparation, K.S.; writing—review and editing, K.S., P.H., B.A.A.E., A.J.R.P., C.M.V.R.; visualisation, P.H. and A.J.R.P.; supervision, A.R.L.; project administration, K.S.; funding acquisition, K.S. All authors have read and agreed to the published version of the manuscript.

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The Crustacean Fisheries of Inner Galway Bay

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(Fisheries Science Services, Marine Institute)

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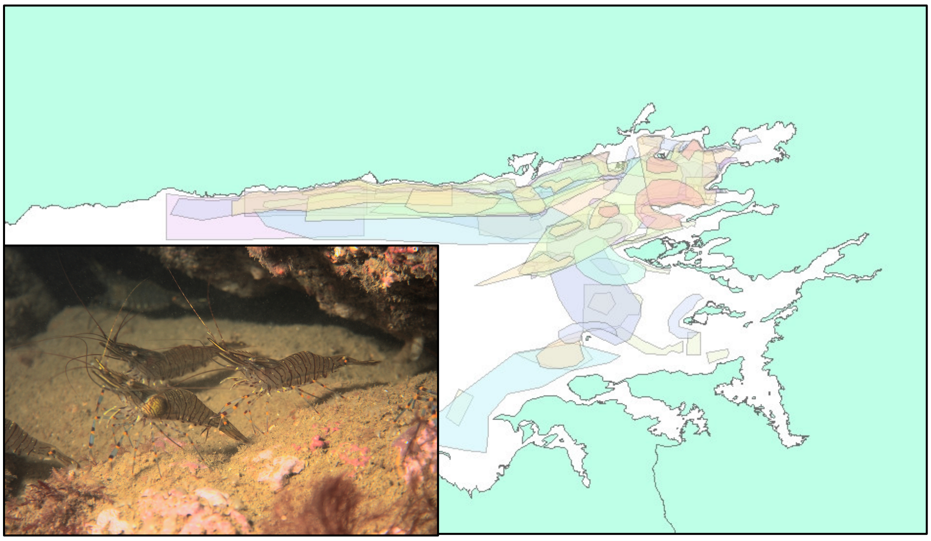
(Fisheries Development Division, BIM)



(Shrimp, Palaemon serratus, in its natural habitat off the north shore of Tawin Island, Galway Bay; the shrimp in the foreground is parasitized by a Bopyrid isopod (picture by Jonathan White) and shrimp fishing 'territories' in Galway Bay in the background)

(A report to the Galway Bay Inshore Fishermen's Association, GBIFA)

May 2010

Contents

Background

Commercial sea fisheries have operated in Galway Bay for over 200 years. Over the past 30 years the profile of fishing activity in the Bay has switched from pelagic, demersal, oyster and salmon fisheries to pot fisheries for crustaceans and a limited fishery for clams and scallops. This switch coincided with a decline in whitefish and oyster stocks in the Bay, closure of the salmon fishery in 2006 and the development of a commercial shrimp fishery in the early 1970s.

Today there are approximately 26 boats fishing in the Bay. They rely almost exclusively on shrimp, lobster and velvet crab stocks. Smaller volumes of spider crab and brown crab are landed and one or two vessels may fish scallops and clams using dredges.

Today the inner Galway Bay crustacean fisheries face a number of pressures, constraints and threats

- A large proportion of the fishing ground has been designated as a Special Area of Conservation (SAC) and a Special Protection area for Birds under the EU Habitats and Birds Directives respectively
- The proposed development of the docks area of Galway City may lead to some loss of shrimp fishing grounds
- Market prices for shrimp and lobster have declined in recent years
- Poor management of the fishery exposes fishermen to
    - Increased competition internally between vessels for fishing grounds
    - Risk of influx of new operators into the fishery
    - The risk of recruitment failure in the shrimp stock. Although there is no evidence of recent recruitment failure uncontrolled fishing effort on this stock is a high risk strategy.

The Galway Bay Inshore Fishermen's Association

The Galway Bay Inshore Fishermen's Association (GBIFA) was founded in early 2010, by the fishermen, with the immediate objective of obtaining the collective view of its members on the pressures and threats that the fisheries were experiencing and to identify how these pressures might best be resolved. Following meetings between the Association and the Marine Institute and BIM terms of reference, describing a workplan for 2010, were drawn up;

1. Issues relevant to the members in 2010 are
   - the docks development
   - designation of the area as an SAC and SPA
   - management of fisheries for the benefits of members
   - improving the market prices for fish landed by the members

2. The Association, with the assistance of BIM and MI, will develop a profile of the fishing activities of its members so that an economic and social value can be put on the fishery that can be used as a basis for developing positions in relation to the issues in 1 above (this is the subject of this report)

3. The Association will work progressively towards development of a fishery plan that will be of benefit to the members and which will assist the Association in complying with Article 6 of the Habitats Directive. The plan will also consider how the balance of fishing costs, catch rate and market price can be optimised for the benefit of the members

4. The Association will seek funding, where available, to strengthen its capacity particularly in the area of marketing

This report quantifies the economic and social value of the fishery, maps the location of each of the fisheries in detail and describes the collective views of all fishermen operating in the Bay on the main issues currently facing the fishery and how these issues can be resolved. The report provides information to the members of GBIFA necessary for the resolution of issues they identify and is also important preparatory work for any fishery management plan(s) that may be developed for the fishery by the Association in the future.

The Inner Galway Bay Area

The Inner Bay, inside the Black Head to Spiddal line is 216km^2 in extent (Figure 1). The area of ground suitable for crustacean pot fisheries is, however, much less than this as these fisheries are confined to shallow water areas (generally less than 20m in depth) along the northern, southern and in particular the eastern shores of the Bay. The seabed in these shallow areas consists of mud, sand, cobble and reefs.

Residual currents in the Bay are westward in direction along the north shore driven by the surface flow of water from the River Corrib and eastwards on the south west area of the Bay. A number of smaller rivers drain into the Bay on its eastern shores. The eastern and southeastern shores have in the past supported major oyster fisheries.

The sub-tidal portion of the inner Galway Bay SAC occupies an area of 81km^2 or 37% of the inner Bay area and the SPA occupies an area of 75 km^2 or 35% of the inner Bay. The SAC and SPA overlap and essentially occupy the same area of the Bay.

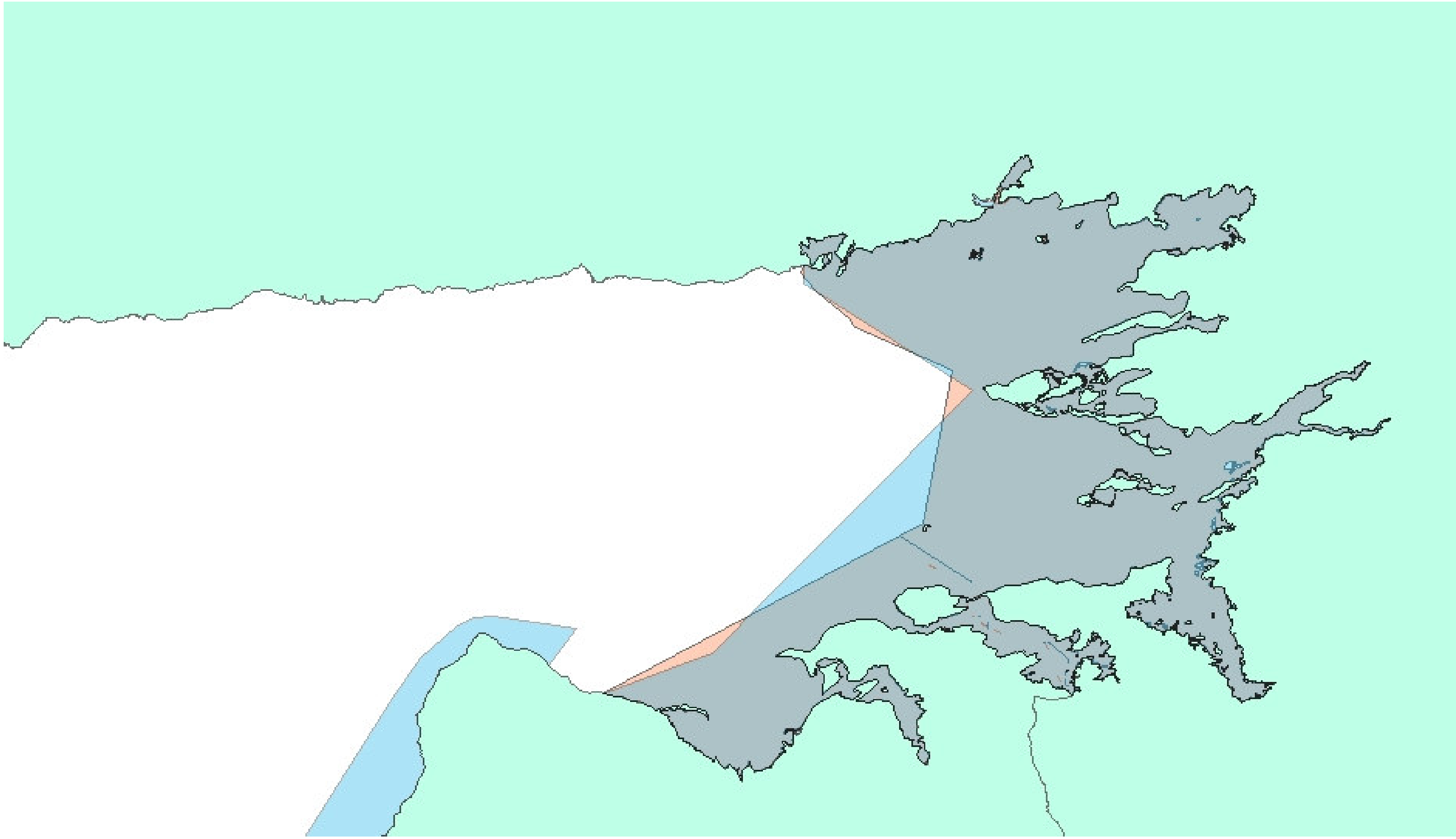


Figure 1. Inner Galway Bay (defined here as the area east of a line connecting Black Head in the south to Spiddal in the north) showing the Special Area of Conservation (blue) and Special Protection Area for birds (brown) and areas where the SAC and SPA overlap (grey).

Legislation governing the lobster, shrimp and velvet crab fishery in Galway Bay

Existing legislation impinging on the crustacean fisheries in the Bay include regulations on minimum landing sizes, a prohibition on landing lobsters with v-notched or damaged tails and a closed season for shrimp (May-August).

All commercial vessels must be licenced in the polyvalent or potting segment of the national fleet.

In addition the EU Habitats and Birds Directives require the fishery does not impact on the long term integrity of the habitats and species, including birds, of the inner part of the Bay which is designated under these directives. SI 346/2009 enables the planning of fisheries within or close to such designated sites with the objective of ensuring these fisheries are compliant with the Directives (Table 1)

Table 1. Legislation impinging on crustacean fisheries in Galway Bay

Legislation	Purpose	Effect
Closed season for shrimp (235/2006)	To prohibit fishing for shrimp during the closed season to allow juvenile shrimp to grow	No fishing during May, June or July
Minimum landing size of lobster (850/98/EC)	Prohibit the landing of small lobsters and to prevent growth overfishing	Lobsters less than 87mm carapace length cannot be landed
V-notched lobsters (234/2006)	Prohibit the landing of lobsters with v-notched or damaged tails	Lobsters with v-notch marks or other damage to the tail fan must not be landed
The Habitats Directive (92/43/EEC) European Union (Natural Habitats) regulations S.I. 94/1997 European Union (Natural Habitats) amendment regulations S.I. 233/1998 European Union (Natural Habitats) amendment regulations S.I. 378/2005	To protect the conservation status of particular habitats and flora and fauna in Special Areas of Conservation (SAC) designated under the Directive	The impact of fisheries on the habitats or species in the SAC must be assessed through appropriate assessment. Fishing activity must not have long term impacts on the habitats or species within the SAC
The Birds Directive (79/409/EEC) S.I. 94/1997	To protect the conservation status of bird species, their critical habitats and their populations in Special Protection Areas (SPAs)	The impact of fisheries on bird populations in the SPA must be assessed through appropriate assessment. Fishing activity must not have long term impacts on bird habitats or species within the SPA
European Union (Habitats and Birds), Sea-Fisheries) Regulations 2009 , S.I. 346/2009	To enable planning and management of fisheries with respect to their impact on the environment where such fisheries occur within SACs or SPAs (collectively Natura sites) designated by the Habitats and Birds Directives.	Fisheries activities where they occur wholly or partially within SACs or SPAs and for the purpose of assessing their impact on the conservation status of those areas may be subject to fishery plans. Vessels operating under such plans may come under additional regulation as outlined in a Natura Declaration and may be required to hold a Natura Permit to operate in such a fishery.

Methods

To obtain information on the fishery a questionnaire was developed (Annex I) and its contents agreed with the fishermen prior to undertaking any data collection. The questionnaires were completed by face to face interviews with fishermen. These interviews, completed during April and May 2010, were therefore partially structured by the questionnaire but in addition it was possible to construct a collective narrative from the conversations with fishermen which provided information on issues relevant to the future management of the fishery. Twenty six interviews were completed which involved all vessel owners fishing crustaceans in the Bay.

Profile of the fishery

Vessels and capital investment

Twenty six potting vessels are or have recently operated in the Bay (Table 2). These are small vessels all below 11 GTs and mostly below 7 GTs. Fourteen are open vessels and 12 are decked or half decked. The total fleet capacity is 97GTs and 865kws. The ratio of kws to GTs is 8.5Kws per GT of vessel (Figure 2). Sixteen of the vessels have GPS and 20 have sounders. The total number of operators (skippers and crew) is 45 and an average of 1.8 operators per vessel.

Capital invested in fishing boats may be in the region of €1million using an average vessel purchase price of €10,000 per GT (based on national statistics from the BIM sentinel vessel data). Capital invested in 6350 shrimp pots and 2400 lobster pots, which is a minimum estimate of the number of pots in the Bay, is at least €290,000. The number of pots in the bay is, however, higher than this.

Capital invested in GTs and KWs, based on 2009 prices and omitting vessels with pot only licences, which are not transferable, did not require investment and have no asset value, is €412,000.

Total investment in capital is, therefore, in the region of €1.7million

Table 2. Profile of vessels in inner Galway Bay

	Quantity
Open vessels	14
Half deck	4
Decked	8
Total GTs	96.8
Total Kws	865.7
Have GPS	16
Do not have GPS	10
Have sounder	20
Do not have sounder	6
Total crew	45.5

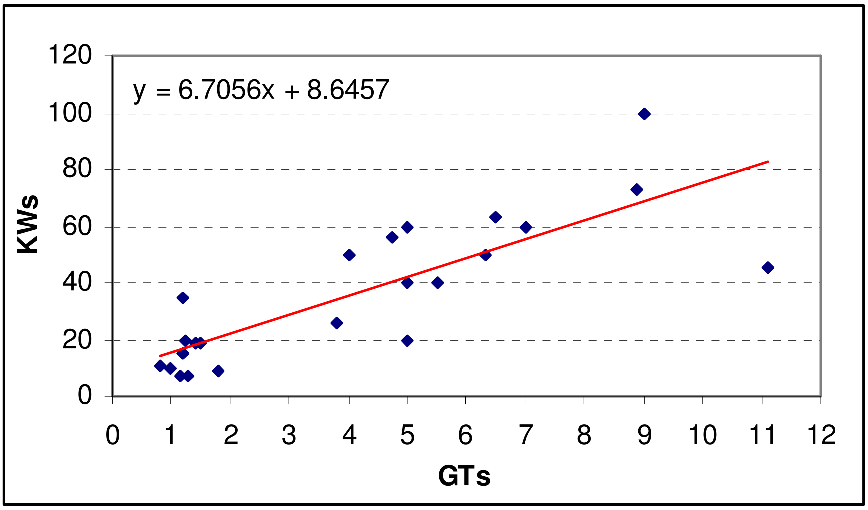


Figure 2. Relationship between GTs and KWs in the inner Galway Bay fleet.

Skippers and crew

The current operators are highly experienced fishermen. They have an average experience of 27 years in fishing. A number of them were responsible for the initial development of the shrimp fishery in the 1970s and still continue in the fishery today.

All recent entrants to the crustacean fishery, of which there are few, come from families who have strong tradition in the fishery or from other fisheries in the outer Bay (Figure 3). Twenty of the 26 fishermen interviewed have been fishing in Galway Bay for over 20 years although they may previously have fished other species such as salmon, oyster and whitefish. Nevertheless, since 1990 there has been a significant increase in the number of vessels targeting shrimp, as shown below, as opportunities in other fisheries declined and as fishermen in the lobster fishery expanded into shrimp.

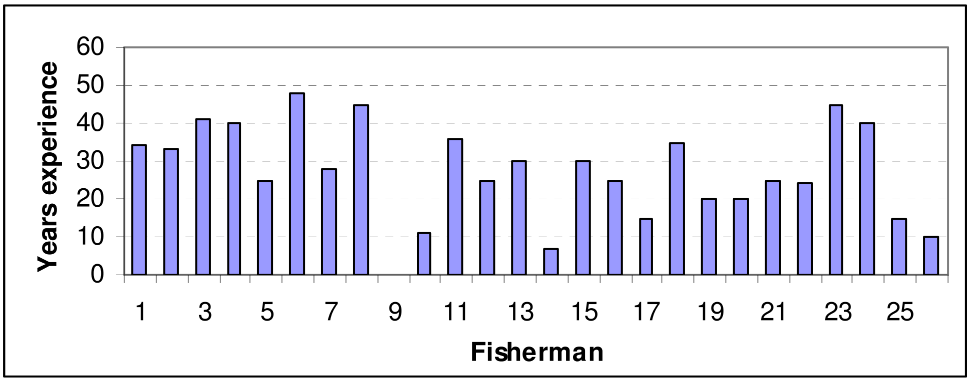


Figure 3. Profile of fishing experience of fishermen in Galway Bay

Landings, value and earnings

Annual landings (tonnes) of shrimp, lobster and velvets in the period 2005-2010 averaged 46, 18 and 42 tonnes respectively (Table 3). These landings had a cumulative value of €0.98million. The annual value of the landings from the inner Galway Bay fishery is, therefore, about €1million when spider, brown crab and prawns are included. These values are based on financial data or volume of landings data obtained during interview and subsequently converted to value, using unit values of €12, €14 and €2.5 per kg for lobster, shrimp and velvet crab respectively.

Official landings statistics for shrimp in county Galway, including Galway Bay, Connemara and smaller shrimp fisheries in Cleggan and Ballinakill in 2008 was 45 tonnes. The data from the questionnaires suggest that the official data underestimate the landings by at least 50%.

Table 3. Annual volume and value of landings of shrimp, lobster and velvet crab from inner Galway Bay.

	Volume (tonnes)	Value
Shrimp	45.8	€540,000
Lobster	18.3	€331,000
Velvets	42.4	€106,000
Total	**106.5**	**€977,000**

Effort and earnings

The annual value of the landings for a vessel is generally positively correlated with the number of days fished by the vessel. Annual value of the landings of vessels fishing around 50 days per year is approximately €20,000. However, earnings by vessels fishing between 100-150 days per annum vary between €15,000 and €80,000. The value of the landings of vessels fishing over 250 days is between €80,000 and €100,000 (Figure 4). The relationship between days at sea and annual value of the landings suggests average gross earnings per vessel per day of €307.

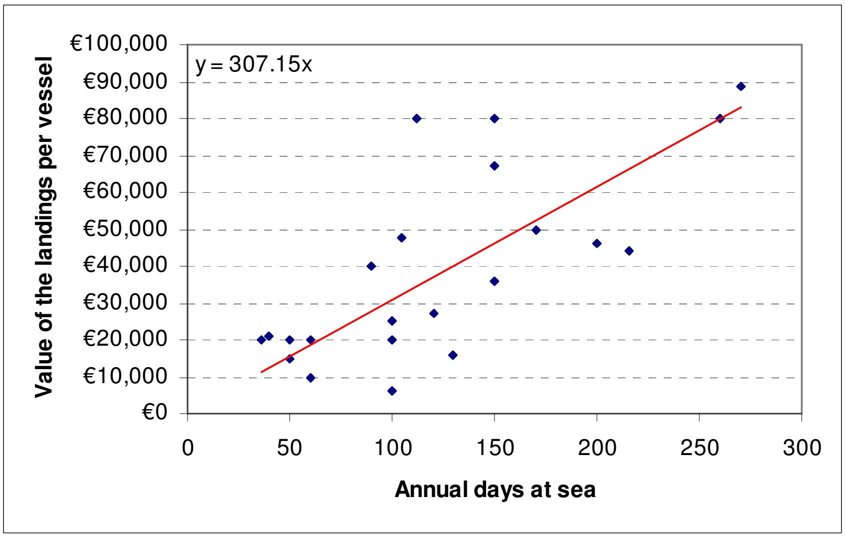


Figure 4. Relationship between the annual value of the landings of a vessel and the annual number of days fished by the vessel.

The number of crew per vessel varies from 1-3. The earnings per fisherman (assuming equal share between crew and skipper/owner) per day, obtained by dividing the annual earnings by the product of the days at sea and the number of crew, ranges from €100-500 but is generally between €100-250 and averages €203 per man per day (Figure 5). Fishermen operating on vessels with high annual effort (and which generally have 2-3 crew) do not earn more per day than fishermen fishing solo and who may fish for less than 100 days. However, annual income per fisherman is related to the number of days the vessel operates (Figure 6).

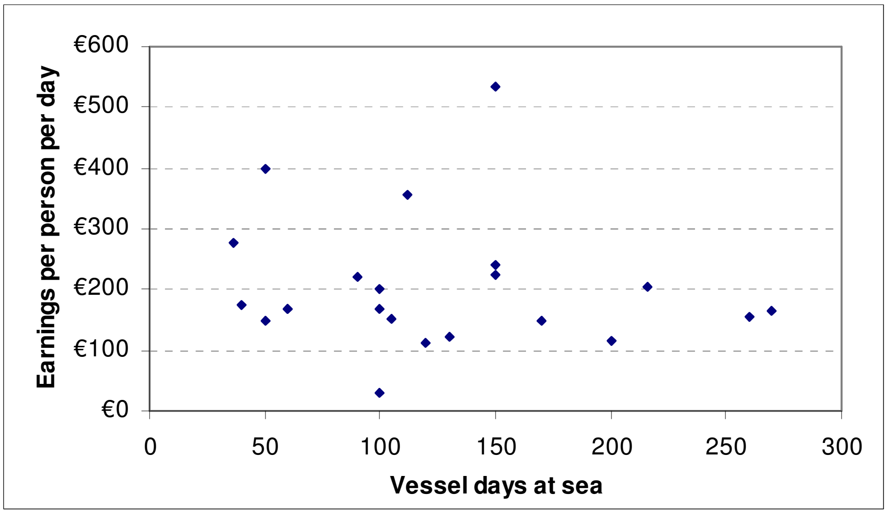


Figure 5. Relationship between the earnings per fisherman per day and the annual number of days fished by the vessel.

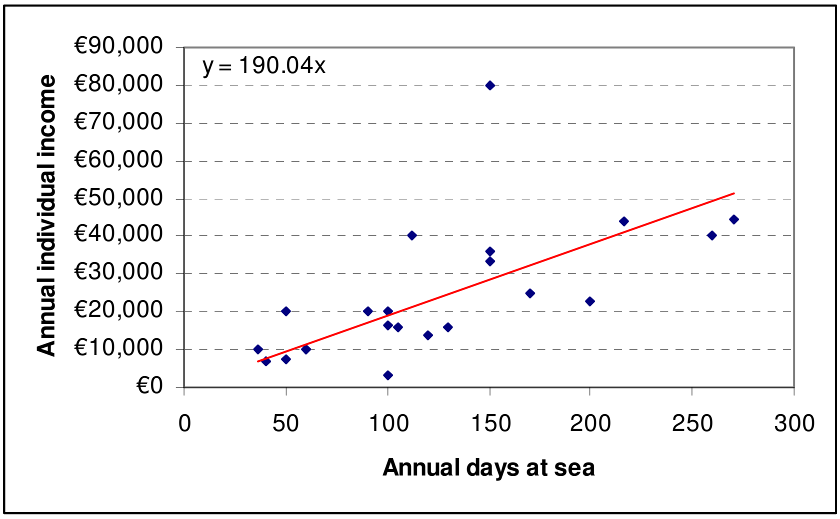


Figure 6. Annual income per fishermen in relation to annual days fished

Fishing activity

Annual activity

The lobster and velvet crab fisheries are open year round. The shrimp fishery is closed during May, June and July.

The fleet is active throughout the year and particularly during the period August to January in the shrimp fishery. The number of days fished per year and the number of months during which a vessel is active has declined consistently since 1990. In recent years (2005-2010), on average, a vessel may operate for 8.5 months and fish for 118 days per year and fish for 8.6 hours per day. In the periods 1990-1995 the number of days fished per year averaged 191 and 11.1 months (Table 4).

Although the shrimp fishing season legally extends from August 1st to May 1st only 2 vessels reported fishing shrimp later than the end of February. Fishing for shrimp ceases towards the end of February for different reasons however; in some areas the abundance of large shrimp is low and the catches are dominated by very small shrimp. In other areas berried females pre-dominate and some fishermen stop fishing when this occurs.

Eight of the vessels fish for 1 species (shrimp) only. Ten vessels target 3 (lobster, shrimp, velvets) species. Some vessels also catch spider crab, brown crab and prawns.

Eighteen of 26 boat owners were previously active in the salmon, whitefish or gillnet fisheries but are now reliant solely on crustaceans.

Table 4. Activity profile of Galway Bay vessels in the period 1990-2010

Time period	Daily hours	Days per year	Months fished per year	Number of crustacean species targeted
1990-1995	9.18	191	11.10	2.55
1995-2000	9.13	158	10.33	2.31
2000-2005	8.75	127	9.21	2.20
2005-2010	8.58	118	8.57	2.33

Fishing effort

Shrimp

The average number of pot hauls per vessel per day in the shrimp fishery in the period 2005-2010 ranged from 120-500 pots per boat per day. The average number of pots hauled per vessel per day has been relatively stable since 1990 increasing from 250 in 1990-1995 to 289 in the period 2005-2010 (Table 5, Figure 7).

The potential total number of pot hauls per day in the shrimp fishery (i.e. if all vessels fished on the same day) has increased significantly during the period 1990-2010 from 2540 pots per day for the fleet in the period 1990-1995 to 6350 in the period 2005-2010.

Average gear set time or soak time has remained stable at between 3.3 and 3.8 days.

The number of pots owned by skippers ranges from 150-1000. A total figure for the number of pots owned by the fleet has not been estimated but it is greater than 6350 (which is the number of pot hauls that can be hauled by the fleet in a day). This figure was estimated directly from the questionnaire data.

Almost all shrimp fishermen use herring to bait shrimp pots.

Lobster

The average number of pot hauls per vessel per day in the lobster fishery in the period 2005-2010 ranged from 60-300 pots per boat per day. The average number of pots hauled per day remained relatively stable at 160-174 pots during the period 1990-2010 (Table 5, Figure 7).

The potential total number of pot hauls in the lobster/velvet crab fishery increased from 1595 during the period 1990-1995 to 2785 during the period 2000-2005 and then declined to 2400 pots during the period 2005-2010 mainly due to a small decline in the number of vessels participating in the fishery in recent years. There has been a significant increase in lobster gear soak time from 3.1 days in 1990-1995 to 4.6 days in 1995-2000.

Most lobster fishermen use fish offal to bait pots. Three of the 26 operators catch their own bait.

Table 5. Average number of pot hauls per vessel per day and total pot hauls of all vessels per day in the shrimp and lobster/velvet fishery between 1990-2010.

Shrimp	1990-1995	1995-2000	2000-2005	2005-2010
Average pots per day	254	260	271	289
Total pots per day	2540	4155	5150	6350
Number of boats	10	16	19	22
Average soak time (days)	3.8	3.3	3.4	3.8
Lobster/Velvets				
Average pots per day	160	170	174	171
Total pots per day	1595	2205	2785	2400
Number of boats	10	13	16	14
Average soak time (days)	3.1	3.2	3.7	4.6

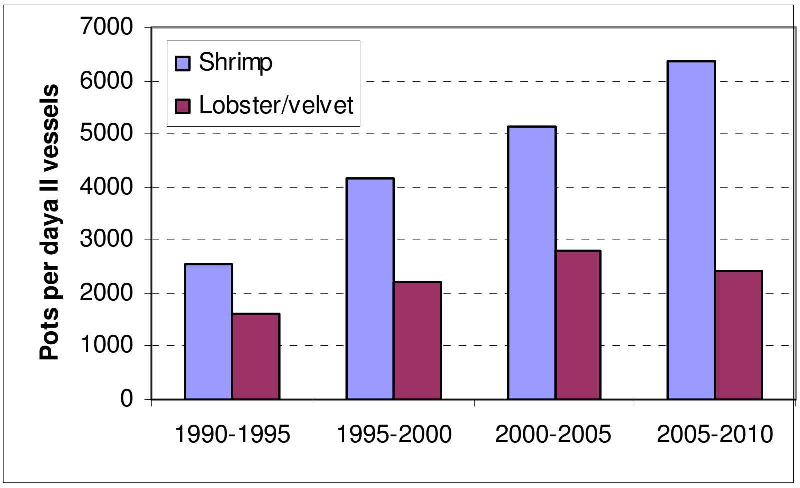


Figure 7. Total number of pots hauls per day in the shrimp and lobster fleet in Galway Bay in the period 1990-2010.

Individual vessel fishing grounds

During interview each fisherman was asked to identify the areas in the Bay where they fish for shrimp, lobster and velvet crab. This was done either by drawing the areas as shape files in a geographic information system (GIS) using the guidance of the fisherman or drawing in the areas on hard copy maps and later transferring these areas to the GIS.

The result of the mapping of fishing locations shows the overall distribution of fishing activity on each species and also the overlap of individual vessel fishing areas.

The total area of the shrimp fishery is 108km^2 and is concentrated on the north and east shores of the Bay with less intensive activity on the south shore (Figure 8). The individual fishing grounds of the vessels overlap in all areas to the extent that the individual areas cannot be said to be ‘territories’ as such. There are few, if any, agreed borders or demarcation lines between vessels on the north and east coasts of the Bay. However, there is limited cross over between vessels on the north, south and east shores although vessels operating out of Galway fish both to the south and to the west and there is generally more ‘crowding’ in the north east corner of the Bay.

Some vessels are precise about where pots are placed and have discrete areas which may be used at different times of year or depending on weather conditions. For others the areas described are larger and less focused on particular sub-sea features or depth contours. Fishing occurs both on soft and weed covered hard ground. Typically larger and older shrimp are found on harder ground.

Not all the areas are used all the time. Gear is moved to relatively deeper water later in the season, as shrimp move into offshore to overwintering grounds or in bad weather.

The total area of the lobster fishery is 99 km^2 and is concentrated on northern, eastern and southern shores. A lot of targeted lobster fishing is concentrated around sub-sea reefs and ledges and on rough ground. There is, however, a lot of overlap with the shrimp fishery.

The intensive overlap in fishing areas between vessels and the high levels of fishing effort (pots) suggests that there is a high level of competition for good fishing ground. However, most fishermen consider that the grounds they fish (and have access to) is good ground for the particular species that they may be targeting i.e. they have not been excluded from good ground (Table 6). Fishermen fishing on poor ground for a particular species do so because that is the nature of the ground they have always fished or it's close to their home pier. For instance the poorest ground for shrimp is on the south shore of the Bay but these fishermen do not fish on the east or north shores. Lobster fishermen fishing poor or limited ground on the north shore do not fish on the south shore.

Table 6. Number of fishermen who consider that the grounds they target for each species is good, average or poor

	Shrimp	Lobster	Velvets
Good	9	8	8
Average	3	3	1
Poor	3	1	2

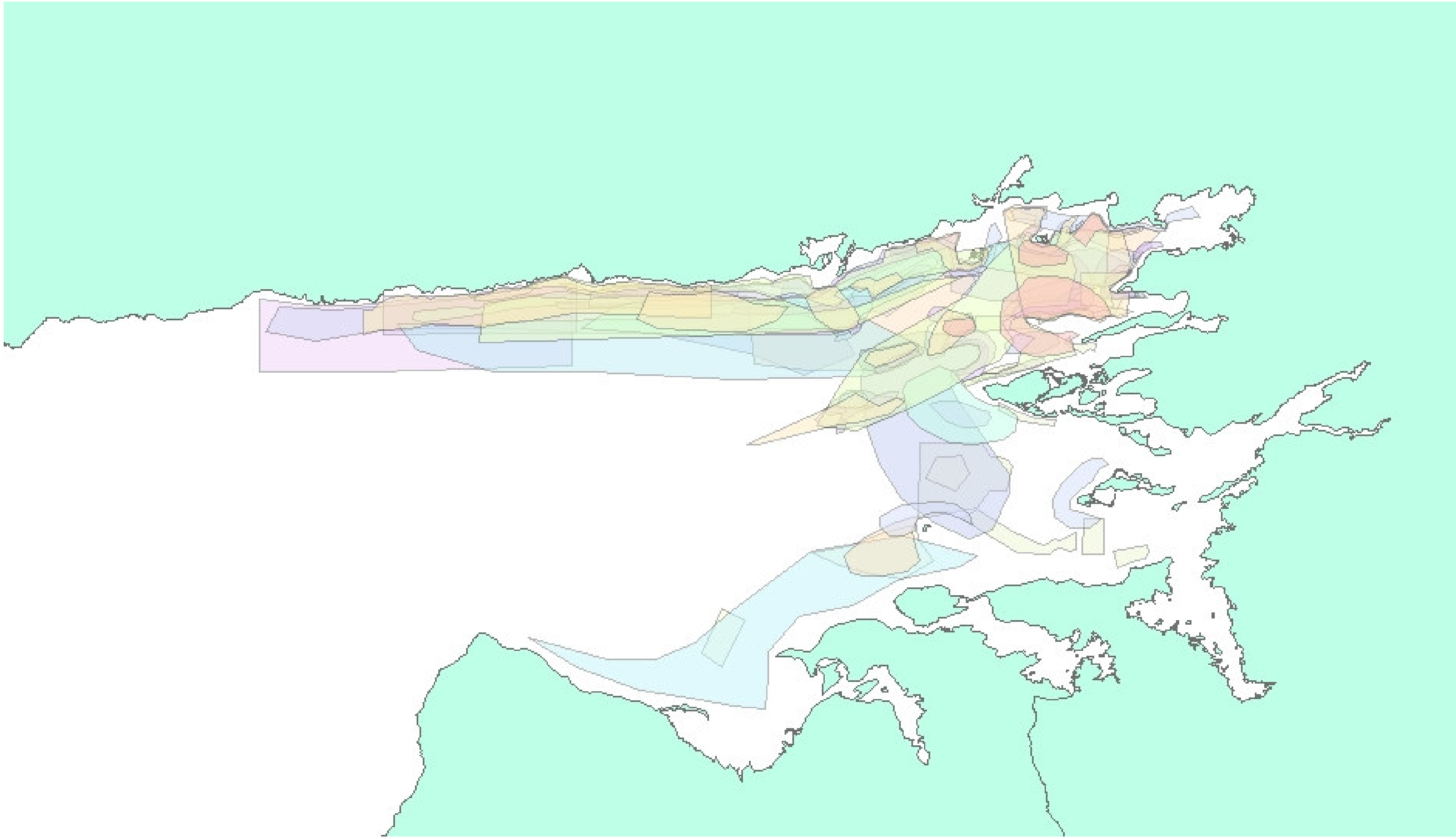


Figure 8. Individual vessel shrimp fishing areas shown as partially transparent superimposed layers.

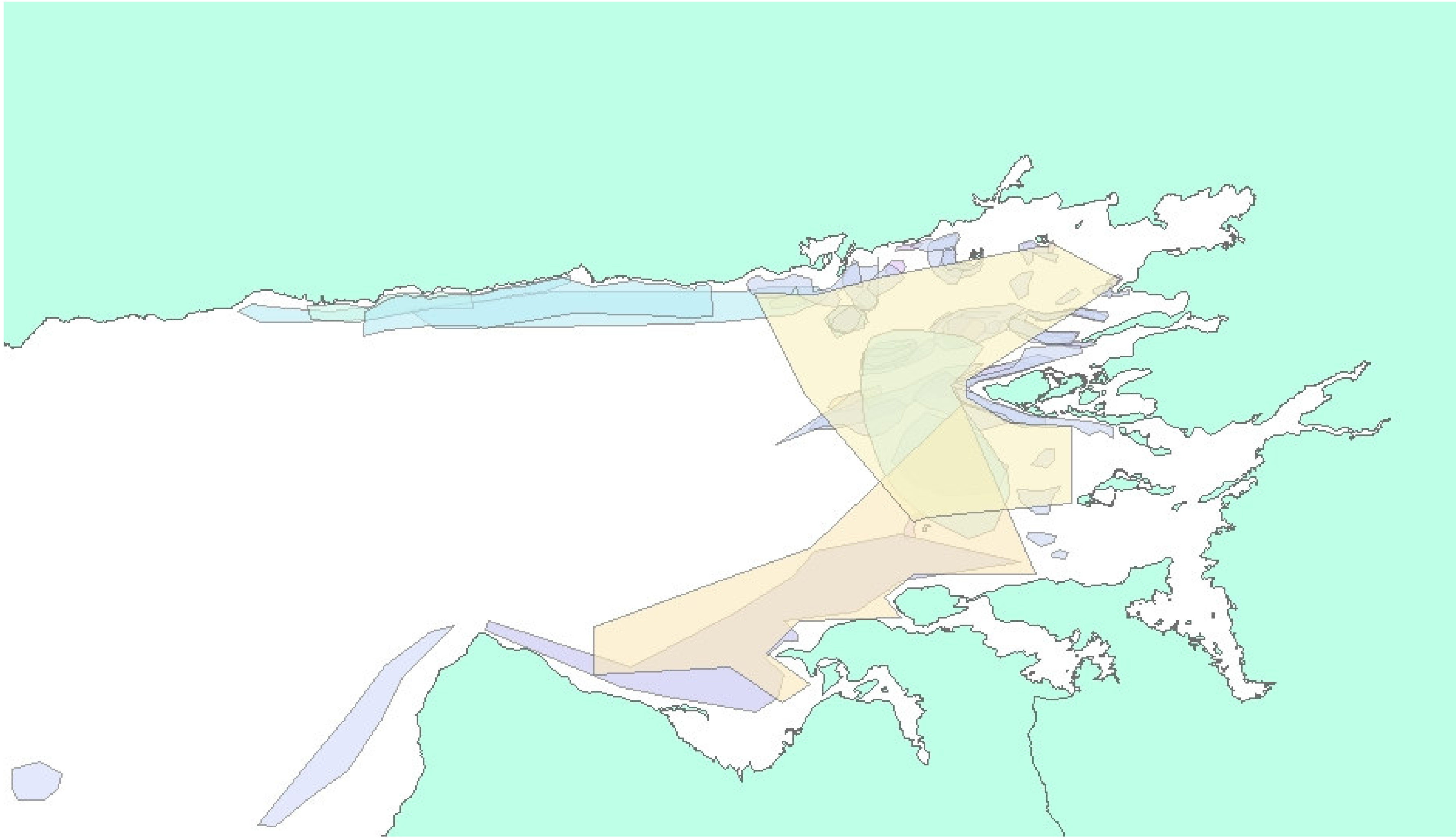


Figure 9 Individual vessel lobster/velvet crab fishing areas shown as partially transparent superimposed layers

Views on the economic performance and management of the shrimp, lobster and velvet crab fisheries

Potential for improvement

Market price, costs and catch per unit of effort determine the net profit per effort. Twenty of 23 fishermen, when asked to rank the potential for improvement in market price, cost reduction or catch rate, indicated the biggest room for improvement was in the market price. No fishermen put cost reduction as the first priority in order to improve net profit. Fifty percent put improvement in catch rate as first or second priority (Table 7).

Table 7. Views expressed by fishermen on the need and potential for improvement in market, fishing costs and catch rate.

Potential for improvement	Market	Costs	Catch rate
First	**20**	0	3
Second	2	**12**	8
Third	1	10	**11**
Total responses	23	22	22

Twelve of 23 fishermen said that fishing was not profitable every day they fished i.e the costs were greater than the value of the fish caught on certain days. These fishermen were all referring to the lobster fishery. Shrimp fishing was regarded as profitable every day. Lobster fishing may not be profitable early in the year in particular.

Issues and solutions identified in the shrimp fishery

<u>The stock</u>

Fifty percent of fishermen interviewed suggested that the shrimp stock was stable. Twenty nine percent suggested it was declining (by about 30% for instance) while 21% said it was increasing (Table 8). These apparently conflicting views probably reflect the experiences of fishermen in different parts of the bay where ground type and shrimp abundance may vary. Some fishermen said there were good and bad years but that the introduction of grading (and live discarding) had stabilised catches and that the last poor year was 2002-2003.

Table 8. Number and percentage of fishermen who regarded the shrimp, lobster and velvet fisheries as stable, increasing or declining.

	Shrimp	Lobster	Velvet
Stable	**12**	**11**	**2**
Decline	**7**	**4**	**11**
Increase	**5**	**3**	**2**
Responses	*24*	*18*	*15*
Stable (%)	**0.50**	**0.61**	0.13
Decline (%)	0.29	0.22	**0.73**
Increase (%)	0.21	0.17	0.13

There was a very positive attitude to grading even though fishermen did not think that they were rewarded for providing graded catch to the buyers. Comments on grading included that it stabilised catches, reduced variation in catch between years, it protected the fishery, it was time consuming, it allowed time for shrimp to grow. Discard rates through the grader, which is mainly on a 9mm bar spacing, were reported as 50-60%.

Some fishermen also suggested that shrimp quality had declined; that there were fewer good quality shrimp available as the season progressed and the quality at the start of the season had fallen. Others said there was no change in shrimp quality and if you fished hard ground there were always good quality shrimp available. Others said there was a lot of small shrimp in Dec and Jan and the run of shrimp at this time was lower in recent years. Others find a lot of berried shrimp late in the season.

One fishermen gave a set of sales invoices for the period 1997-2002 (6 seasons) which showed the percentage of each grade in the landings and the price per grade (Figure 10). These data did not show any change in the percentage of each grade in the monthly catch during that time suggesting that the grade structure of shrimp in the catch was stable both during the season and between seasons in the period 1997-2002. No later data are available for comparison.

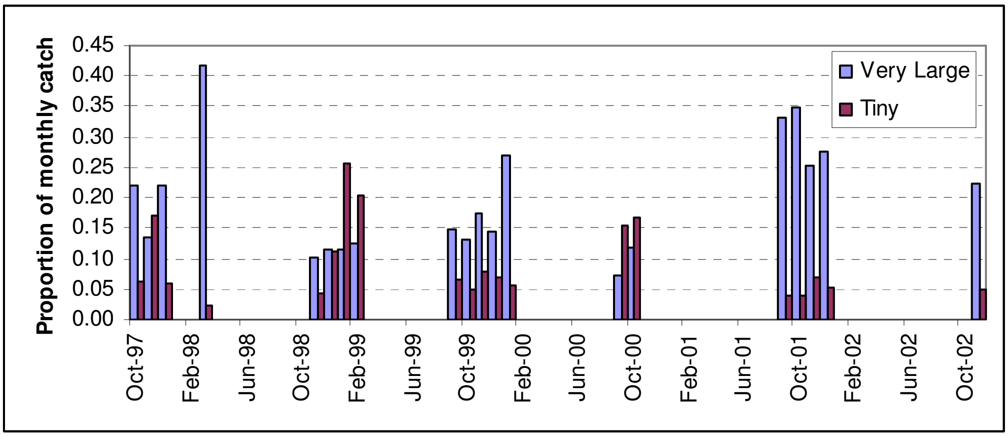


Figure 10. Percentage of 'very large' and 'tiny' commercial grades of shrimp in the monthly landings of 1 fisherman during 6 seasons from 1997-2002.

Fishing effort

Although over 70% of fishermen though that the shrimp stock was stable at least 18 of 26 fishermen indicated that there were too many pots in the Bay (Table 9). This was in response to the question "What are the 3 problems in the fishery at the moment?" or as a proposed solution to low catches rates or high costs. There were some suggestions as to how to limit pot numbers; 500-600 per boat, 500 per boat, 400 per boat, 800 per boat, 500-600 per boat, 800 per boat, 600-700 per boat. Some fishermen with high numbers of pots suggested that a limit per crew member rather than per boat would be more equitable as these vessels had higher pay costs.

The concern about pot numbers is related to access to ground, competition for ground and fishing costs. The competition for ground makes the fishery more difficult than it should be and increases the costs. It was felt by some that the gear was not being used to catch shrimp as such but in the "anticipation of catching shrimp" such that gear was left on the ground waiting for shrimp to arrive.

Seven fishermen said that the number of boats should be limited as a condition of limiting pots.

A number of fishermen thought that the season started too early. In effect few shrimp are being landed in August although gear is set. Most of the shrimp vessels fish from September to February although the open season extends from August 1st to May 1st.

Fishing costs

No quantitative data on fishing costs were requested in the questionnaire. However, bait is regarded as the highest cost for most vessels although some vessels, in the lobster and crab fisheries in particular, have high fuel bills.

Although not included in the questionnaire, information on the quantity of bait used to haul a given number of pots was obtained in conversation. This suggests that bait costs in the shrimp fishery per pot soak are about €0.2 (i.e. 20 cents to bait a pot). If daily potential effort by all boats in the shrimp fishery is 6350 pot hauls then daily bait costs for the entire shrimp fleet may be in the region of €1270 per day and may be €61,000 per season assuming a 6 month season and two hauls of all pots every week. This is about 12% of the value of the shrimp landings.

Market price

Market price was a concern to a lot of fishermen. In particular the lack of price reward for graded shrimp was disappointing to them as the amount of discarding and time required to grade the catch was significant and costly. Higher prices for graded shrimp was given by buyers after grading was first introduced in 2007 (as is evidenced from BIM logbook data at the time). Now that everybody is grading the buyers seem to be giving a flat price to everybody.

Data from 1 fishermen on prices per grade for 6 seasons between 1997-2002 showed that the market, at that time at least, demanded shrimp of different grades and that the price paid by the market was significantly higher for larger shrimps. At that time the buyers bought all shrimp and graded the catch themselves.

During 1997-2002 there were 4 grades and price increased by about €2-3 per grade but were flat during the season. Prices increased annually from 1997-2001 but fell back in the 2002-2003 season (Figure 11)

There were a number of proposed solutions to the low market prices

- collective selling to a fixed price or to the highest bidder
- bring in more buyers to increase competition for the landings
- land high quality shrimp strategically to the market

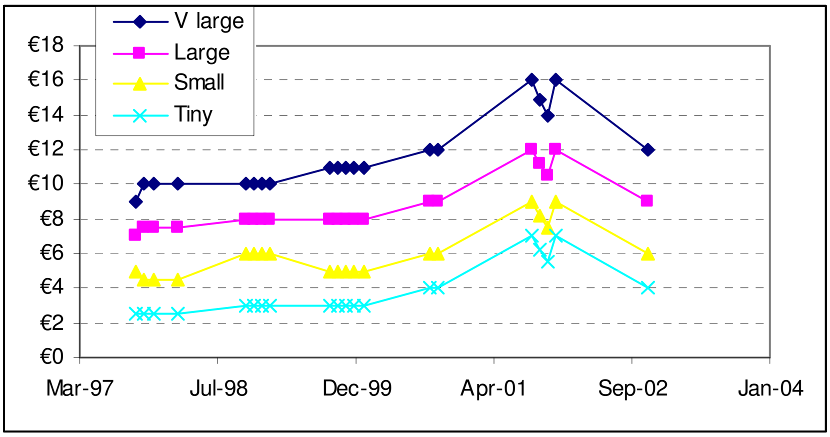


Figure 11. Price of shrimp per grade per month during the 1997-2002 period.

Table 9. Individual fishermen's comments on issues and solutions in the shrimp fishery

Issues	Solutions
Fishery officers	Remove the need for a logbook
Fishing season too long	Delay opening until September
Fishing season too long	Fish from September to January
Fishing season too long	
Fishing season too long	Extend the closed season
High competition for ground	Limit access and gear
High costs	Collective buying, limit gear
High costs	Increase soak time
High costs	Less gear and higher catch rate
Lack of facilities for fishermen	Organise
Low catch rate	Shorter fishing season, limit gear, grade
Low catch rate	Limit gear
Low catch rate	Extend the closed season
Low price for graded shrimp	Price should reflect the grade, agree a max count per grade
Low price for graded shrimp	Price should reflect the grade
Low prices	Sell collectively to a fixed price
Low prices	Grade the catch
Low prices	Sell collectively to a fixed price
Poor market	Collective selling
Poor market	Collective selling
Poor market	Collective selling
Quality of shrimp has declined	Reduce fishing effort, target higher quality shrimp only
Too many pots	
Too many pots	Limit entry and then control pot numbers
Too many pots	
Too many pots	
Too many pots	
Too many pots	Limit entry (full timers only) and pots
Too many pots	Limit entry and then control pot numbers
Too many pots	Limit pots
Too many pots	Limit pots
Too many pots	No extra effort
Too much effort	Limit access and gear
Too much effort	Limit access and gear, closed areas and seasons
Too much gear	

Issues and solutions identified in the lobster fishery

The stock

61% of fishermen thought that the lobster stock was stable and 17% said it was increasing. One fishermen commented on the remarkable consistency in the annual average size of lobsters over the past 10 years (at 1.3lbs) and there were still some large lobsters of 4-5lbs in the catch. On the north shore there are a lot of small lobsters on the ground but this does not necessarily translate into higher catches in the following year or years. One fishermen on the north shore suggested that the catch rate has declined by 40% in the past 10 years. On the south shore there may have been a small decline recently.

V-notching was regarded as a very positive measure. A number of fishermen notch and release lobsters voluntarily. Others notch berried females and do not land berried females at all. Some felt that v-notching should be a mandatory part of the licence.

Some fishermen supported additional technical measures, such as raising the minimum size to 90mm, so that catch rates could be improved.

Fishing effort

Many fishermen also felt that there were too many pots in the lobster fishery and that catch rates were low. Some fishermen fish single pots rather than strings. On the north shore in particular some fishermen said that gear competition was an issue i.e. strings of pots set in deeper water affected catches in shallow water.

Fishing costs

The cost of bait was regarded as high and collective buying of bait proposed as a solution.

Market price

The decline in market price of lobsters was of concern to all fishermen who fished lobsters. The proposed solutions to this were to increase competition among the buyers but also to fish more strategically for the market (suggesting that there would be limited fishing when the market was poor), and to engage in market research and product development (Table 10).

In the lobster fishery, more so than the shrimp fishery, the link between price, fishing costs and fishing effort was more apparent in the questionnaire returns. In the lobster fishery it was thought that fishing costs could be reduced by fishing less and fishing when market conditions were strong. This idea was supported by the responses indicating that the fishery is not profitable all the time. Some suggested that a closed season be introduced.

Table 10 Individual fishermen's comments on issues and solutions in the lobster fishery

Issues	Solutions
Competition for ground	Limit gear
Competition for ground	limit pots,
Decline in price	Fish strategially for the market
Fishing all year round	Fish strategically for the market
High costs	No solution proposed but cutting effort not feasible as income will drop
High costs	Fish strategically for the market, less effort more price
High costs	Limit effort, buy bait in bulk
High costs	collective buying
High costs	Bait: use discards
Low catch rate	More technical measures
Low catch rate	More v-notching no landing of berried lobsters
Low price	sell collectively to an agreed price
Poor access to market	Go for higher volume and lower price if necessary
Poor prices	Product development and market research
Poor prices	get more buyers in, increase market outlets
Poor prices	get in more buyers,
Too many pots	Pot limit (throughout the Bay), mark gear, remove unmarked gear, limit entry
Too many pots	Limit entry (full timers only) and pots
Too many pots	Limit entry and pots per boat, limit part-timers
Too many pots	Limit pots, limit boats but allow transfer to family members
Too much effort	Closed seasons all species, increase minimum size to 90mm
Too much gear reducing catch rate	Limit gear, increase v-notching
Undersized fish being landed	

Issues and solutions identified in the velvet crab fishery

The stock

Although some fishermen target velvet crab most fishermen regard it as a by-catch in the lobster fishery. 73% of fishermen suggested that the fishery had declined in the past 10 years. This decline was in both numbers and size (quality). However, some fishermen in the north and south shores suggested that the size structure of velvets was stable.

Fishing effort

There was some support for a closed season and for introduction of a minimum size. Grading is time consuming especially in areas where quality is poor. The use of escape hatches and a minimum landing size had some support.

Fishing costs

No comments obtained

Market price

No comments obtained

Table 11. Individual fishermen's comments on issues and solutions in the velvet crab fishery

Issues	Solutions
Decline	Minimum size, closed season
Grading is time consuming	Minimum size
Poor quality	Escape hatches
Small velvets killed in the shrimp fishery	

Issues for further discussion by GBIFA

Based on the responses to the questionnaire and issues that arose in conversation with fishermen a number of points of discussion, and potential action can be identified.

1. A significant majority of fishermen feel that there are too many pots in the Bay. Their concern is not primarily that the stocks are depleted but that there is too much competition for ground, too much cost associated with tending gear and generally that it makes fishing more difficult than it should be.

2. The significant effort spent grading the shrimp catch is perceived to be highly beneficial to the stock but the expected increases in price has not materialised

3. The low market prices were seen by many to be due to buyer monopoly and that collective selling to a fixed price or generating a bid from a wider group of buyers would bring benefits in price. Whether such benefits can be obtained is unknown, however, and would require additional market research.

4. Fishing costs, particularly bait costs, are significant and most of the members of GBIFA seem to support the idea of collective buying of bait and perhaps other materials.

5. Fishing for lobster is not profitable at all times of the year due to a combination of low catch rates and low prices. Unfortunately periods of low price corresponds to periods of high catch and the market seems to be highly sensitive to changes in volume. As the lobster stock is 'resident' in Galway Bay and the members of GBIFA have, in effect, sole access to it a more strategic use of this resource could be envisaged which would include strategic fishing of a given quantity of lobsters for the market at certain times of year only.

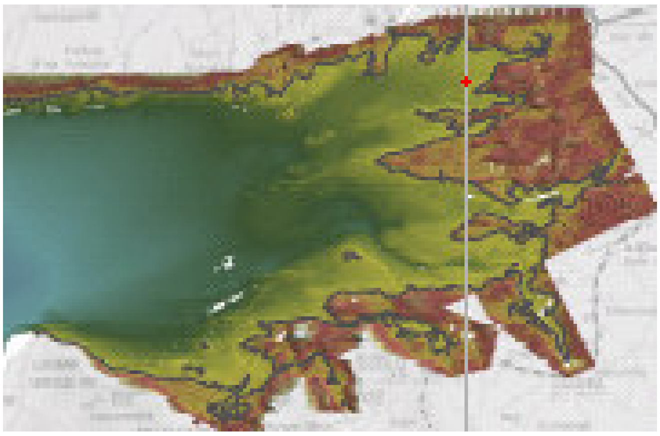
6. The majority of fishermen report that velvet crab stocks have declined. This fishery is totally unregulated with no minimum landing size or other controls. Measures to improve the quality of velvets that are landed and protection of reproductive potential are important for this stock.

7. Although most fishermen regard the shrimp stock as stable the amount of fishing effort has increased significantly in recent years. Although the response of the shrimp stock to this increase is unknown increasing effort may pose a risk to the stock. Measures that protected a proportion of the spawning stock annually would reduce the risk of recruitment variability or failure. This could include an earlier closure to the season for instance. A later start to the season would allow for a better yield early in the season as shrimp grow quickly in August and September when water temperatures are highest.

Annex I: Questionnaire

A profile of the Galway Bay Crustacean Fishery

The information requested in this questionnaire is for and on behalf of the members of the GB Inshore Fishermen's Association. The information will be used to profile and describe how the members of the GBIFA historically and currently fish for species of shrimp, lobster and crab in the bay and seeks to identify the main issues that the members of GBIFA currently see as important in securing the future sustainable development of the fishery. BIM or MI will not publish, otherwise use or distribute to third parties any of the information made available in this questionnaire without first consulting the Committee of the Association. Individuals or vessels will not be identified in any report that may be produced including reports to the Association itself.



Shaded Relief Map of inner Galway Bay (the area fished by members of the GBIFA) : source www.infomar.ie

Descriptions of the crustacean fishery in Galway Bay				
	1990-1995	1995-2000	2000-2005	2005-2010
Vessel type (open, half deck, decked etc)				
Vessel GTs and KWs				
GPS plotter installed ?				
Sounder installed ?				
Crew size				
Daily working hours				
Number of days fished per year				
Months fished				
What crustaceans did you target				
Other (non-crustacean) fisheries in which you and your vessel participated during this time				
SHRIMP pot hauls per day				
LOBSTER pot hauls per day				
VELVET pot hauls per day				
Gear soak times: SHRIMP				
Gear soak times: LOBSTER				
Gear soak times: VELVET				
Bait : shrimp, lobster, velvets				
Annual value of your landings of SHRIMP				
Annual value of your landings of LOBSTER				
Annual value of your landings of VELVETS				
Where do you fish for SHRIMP	NB: draw on the map (provided separately) the areas in which you currently fish for each species. You can also separately draw in areas			
Where do you fish for LOBSTER				

	that you used to fish if these are different to your current fishing area
Where do you fish for VELVET	
Describe the ground you fish for SHRIMP	Very good ground for shrimp Average ground for shrimp Poor ground for shrimp
Describe the ground you fish for LOBSTER	Very good ground for lobster Average ground for lobster Poor ground for lobster
Describe the ground you fish for VELVET	Very good ground for velvet Average ground for velvet Poor ground for velvet

Fisheries Management Issues in the GB Crustacean Fishery		
How many years have you been fishing in Galway Bay?		
How long has your family been fishing in Galway Bay?		
Is the performance of the SHRIMP fishery ? (envisage the trend over the past 10 years)	Stable	
	Increasing	
	Declining	
Is the performance of the LOBSTER fishery ? (envisage the trend over the past 10 years)	Stable	
	Increasing	
	Declining	
Is the performance of the VELVET fishery ? (envisage the trend over the past 10 years)	Stable	
	Increasing	
	Declining	
Describe, how in an ideal world, the crustacean fisheries in the bay would operate. You could consider issues like the market, working conditions, number of boats, catch rate, competition for ground, catch rates, costs etc.		
Describe what you consider are the 3 main problems about how the fishery operates and performs today. You could consider the same issues as above		

Economic status of the GB Crustacean Fishery	
Is fishing profitable every day you fish or are there some days in which the costs outweigh the earnings ?	
If you consider there are 3 elements which determine net profit can you indicate, in order of potential, which elements you think has potential for improvement ? 1. Catch rate , 2. Costs , 3. Market price	
If you consider that these elements can be improved how could this be brought about in each case ? Catch rate: Costs: Market price:	